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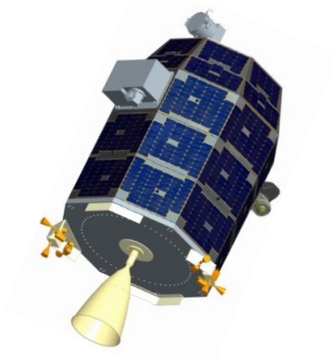

Lunar Atmosphere and Dust Environment Explorer

(LADEE)

LADEE PDS Mission Description

March 21st, 2013

National Aeronautics and Space Administration

Ames Research Center
Moffett Field, California

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REVISION HISTORY			
Rev.	Description of Change	Author(s)	Effective Date
1.0	Initial draft	G. Delory	Nov 1, 2012
1.1	Resolved several TBDs	G. Delory	Nov 29, 2012
1.2	Updated TOC and prepared for conversion to PDF	G. Delory	March 21, 2012

CONFIGURATION MANAGEMENT PLAN

This document is an LADEE Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the LADEE Project Manager. Proposed changes shall be submitted to the LADEE CM office along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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1 MISSION OBJECTIVES

The top-level programmatic and science requirements for the LADEE project are designed to accomplish the following mission objectives:

1. Determine the composition of the lunar atmosphere and investigate the processes that control its distribution and variability, including sources, sinks, and surface interactions.
2. Characterize the lunar exospheric dust environment and measure any spatial and temporal variability and impacts on the lunar atmosphere
3. Demonstrate the Lunar Laser Communications Demonstration (LLCD)
4. Create a low-cost reusable spacecraft architecture that can meet the needs of certain planetary science missions
5. Demonstrate the capability of the Minotaur V as a launch vehicle for planetary missions

Based on the overall science goals outlined in objectives 1 and 2 above, the LADEE mission was designed meet the specific baseline science requirements outlined in Table 1-1.

Table 1-1: LADEE Baseline Science Requirements

	Science Requirement
1	Measure the relevant spatial and temporal variations of Ar, He, Na, and K. The temporal scales covered shall range from 12 hours to 1 month. The spatial scales covered shall be as follows: Ar, within ±20° of the terminator regions of the Moon; He, sufficient coverage to resolve variations from noon to midnight; K, Na, sufficient coverage to resolve variations over the lunar dayside.
2	Detect or establish new limits for selected other species for which previous detections have been attempted. These shall include the following from the family of exogenic/volatile species (CH4, O, OH, H2O, CO, S), and the following from the family of endogenic (regolith-derived refractory) species (Si, Al, Mg, Ca, Ti, Fe).
3	Perform a survey for the presence of other species beyond those listed above, or positive ambient ions of these species and other atoms or compounds, within a mass range of 2-150 Da and a sensitivity of several particles/cc.
4	Detect or set new limits for the spatial and size distribution of atmospheric dust over an altitude range from 3 km up to 50 km, with a height resolution of 3 km, at a minimum detectable density of 10^{-4} grains/cc, for grains from 100 nanometer to at least 1 micrometer in radius. These observations shall be conducted at the temporal and spatial scales for Ar as outlined in the first science requirement above.

2 MISSION DESCRIPTION

2.1 Mission Overview

LADEE was launched on August 12, 2013, from the Wallops Island Flight Facility (WFF) on a Minotaur V launch vehicle (LV). The LV inserted LADEE into an Earth-centered orbit followed by a direct lunar transfer. At lunar arrival, LADEE was inserted into a retrograde equatorial orbit, at which point a commissioning/checkout phase was conducted, followed by the science phase. The total mission duration was 175 days, with 100 days dedicated to nominal science operations.

The mission was decommissioned by impact into the Moon on January 24, 2014. The LADEE science mission was designed to fulfill the science requirements in Table 1-1. The science payload consisted of three instruments: a Neutral Mass Spectrometer (NMS), an Ultraviolet/Visible Spectrometer (UVS), and the Lunar Dust Experiment (LDEX). A separate articulated laser assembly comprised the LLCD. Data from the NMS, UVS, and LDEX instruments was processed and submitted to the Planetary Data System (PDS) for access by the scientific community and the public. The LADEE project and spacecraft were managed by the NASA Ames Research Center (ARC), with the instrument payload and science operations center managed by the NASA Goddard Space Flight Center (GSFC).

2.2 Spacecraft

The LADEE spacecraft bus design was derived from the Modular Common Spacecraft Bus (MCSB or "common bus") architecture developed by ARC from 2006-2008. The spacecraft is 3-axis stabilized, and points the instruments into ram direction (in the direction of the spacecraft velocity) or for limb or occultation viewing as needed. The remaining major spacecraft systems include a bi-propellant propulsion section, body-mounted solar arrays, several medium-gain and omni-directional antennas, and star trackers. The LLCD system utilizes a laser mounted on an articulated boom. The NMS is mounted to the spacecraft body while UVS and LDEX reside on the upper deck. The basic spacecraft and instrument configuration is shown in Figure 1.

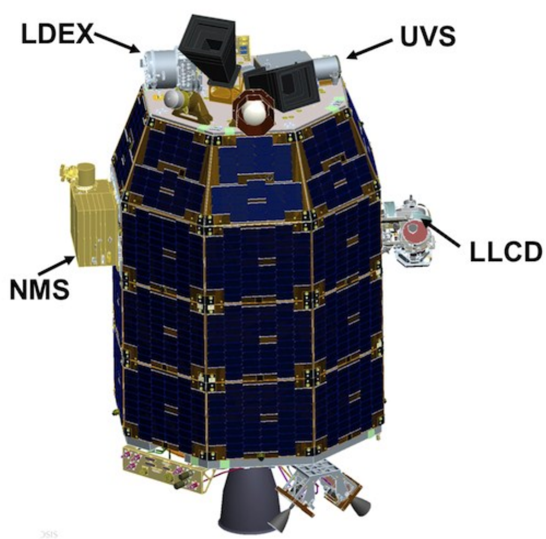

Figure 2-1: The LADEE Spacecraft and Instrument Locations

2.3 Instrument Payload

2.3.1 Neutral Mass Spectrometer

The LADEE NMS measures the mass distribution of neutral species over a mass-to-charge (*m/z*) range between 2-150. NMS draws its design from similar mass spectrometers developed at GSFC for the MSL/SAM, Cassini Orbiter, CONTOUR, and MAVEN missions. At low altitudes, NMS is be capable of measuring the abundance of gases such as Ar and CH_4, which may indicate internal geophysical processes at the Moon. Measurements of He are used to understand the importance of the solar wind in the generation and dynamics of the helium exosphere. NMS was also designed to detect refractory elements in the exosphere (Si, Al, Mg, Ca, Ti, Fe), as well as Na and K, which may be indicative of more energetic processes acting on the lunar surface such as sputtering and impact vaporization. In terms of volatiles, NMS can detect OH and CO. There is also an ion-detection mode. Ultimate sensitivity for detection of most species is in the few/cc range.

2.3.2 Ultraviolet/Visible Spectometer

The UVS instrument is a next-generation, high-reliability version of the LCROSS UV-Vis spectrometer, spanning 250-800 nm wavelength, with high (<1 nm) spectral resolution. UVS was designed to be used in both limb and occultation mode. In limb mode, UVS will search for resonant scattering emissions from exospheric species as well as scattering of sunlight from lunar dust. In occultation mode, UVS will search for scattering of sunlight by dust using a separate solar viewing optic. UVS can detect volatiles such as OH, K, Li, Ba, and Na, as well as more refractory elements such as Al, Ca, Si, Ti, and Mg. UVS can also detect water (H_2O) in several of its positively ionized states

2.3.3 Lunar Dust Experiment

LDEX senses dust impacts in situ, using an impact vaporization and charge detection assembly. Dust particle impacts on a large hemi-spherical target create electron and ion pairs. The latter are focused and accelerated in an electric field and detected at a micro-channel plate. The LDEX design heritage includes instruments aboard HEOS 2, Ulysses, Galileo and Cassini. It was designed to operate at the relatively low LADEE orbital speed of 1.6 km/s and altitudes of 50 km and below, and is sensitive to a particle size range of between 100 nm and 5 µm.

3 MISSION PHASES

The LADEE mission profile consists of the following major phases: pre-launch, launch, ascent, activation & checkout, phasing orbits, lunar transfer/orbit acquisition, commissioning, nominal science operations, and decommissioning. These phases, along with dates and durations for each, are summarized in Table 3-1

Table 3-1: LADEE Mission Phases

Mission Phase	Entry	Exit	Date & Duration	Description
Launch & Ascent	LV lift-off	LADEE separation from 5th stage	Aug 12, 2013 20 min	Launch from Wallops Flight Facility Achieve phasing orbit insertion De-spin 5th stage
Activation & Checkout	LADEE separation from 5th stage	Transition to fine pointing mode	Aug 12, 2013 1 day	Transition from safe to fine-pointing mode Ground station acquisition & initial orbit determination
Phasing Orbit	Transition to fine pointing mode	Start 3rd of perigee burn sequence	Aug 13, 2013 23.5 days	Execute 3 phasing loops Spacecraft commissioning and bake-out Instrument aliveness checks
Lunar Transfer	Start of 3rd perigee burn sequence	LOI-1 Sequence	Sep 6, 2013 5.25 days	Final perigee burn, orbit determination, and timing corrections maneuvers (TCMs) as needed
LOI	LOI-1 sequence	Lunar staging orbit	Sep 12, 2013 1 – 3 days	Series of LOI maneuvers. Achieve 250 km staging orbit.
Commissioning	Lunar staging orbit	Science orbit	Sep 15, 2013 40 days + 20 days contingency	Instrument checkout & commencement of LLCD operations. Instrument science checkout during last 10 days
Science	Science orbit	End of nominal science operations / propellant at critical level	Oct 26, 2013 100 days	Nominal operation of UVS, NMS, and LDEX instruments on a duty-cycled basis.
Decommissioning	End of nominal science operations / propellant at critical level	Impact on lunar surface	Feb 3, 2014 30 days	Impact site TBD; science measurements obtained until lowest possible altitude

3.1 Launch

Launch occurred on August12th, 2013, from WFF on a Minotaur V launch vehicle. The ascent phase lasted 20 minutes at which point LADEE separated from the last (5th) stage of the vehicle. This was followed by a day of spacecraft activation and checkout in a low-Earth orbit, culminating in a maneuver to increase the LADEE apogee into the phasing loop orbits.

3.2 Phasing Loops

After ascent, LADEE was inserted into Earth-centric phasing loop orbits on August 13th, 2013, ranging in period from 6 to 10 days each. LADEE executed a total of three phasing orbits over a period of 23.5 days prior to a maneuver placing LADEE into a trans-lunar trajectory. The geometry and basic trajectory information (apogee, perigee, and period) for each orbit is shown in Figure 3-1.

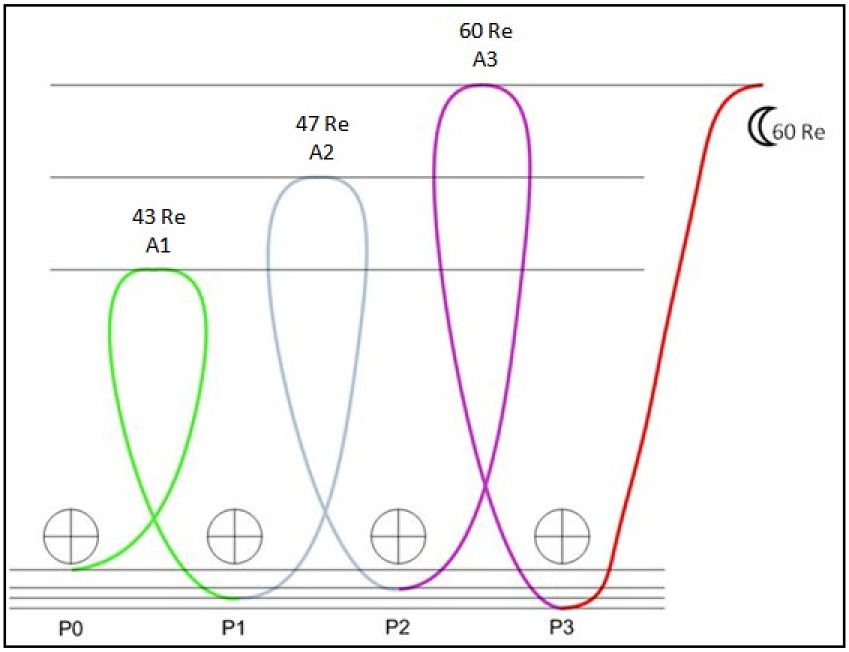

Figure 3-1: LADEE phasing loops (approximate periods of 6, 8, and 10 days, respectively)

3.3 Lunar Transfer

Initiation of the trans-lunar trajectory began on September 6, 2013. The trans-lunar trajectory phase ended with the first lunar orbit insertion (LOI-1) burn that captured LADEE into lunar orbit. Two subsequent LOI maneuvers sequentially lowered the lunar orbit from the arrival hyperbola to a 250 km circular orbit as shown in Figure 3-2. LADEE approached the Moon from the right in the figure shown, and was captured into a 24 hour orbit (612 km × 15596 km in lunar altitude) where the spacecraft remained for 2 revolutions lasting 2 days. LOI-2 lowered the orbit down to a 4 hour orbit (253 km x 2183 km altitude), shown in blue where LADEE remained for 12 revolutions (2 days). Finally, LOI-3 lowered the orbit down to al 250 km x 250 km lunar commissioning orbit on September 26th, 2013.

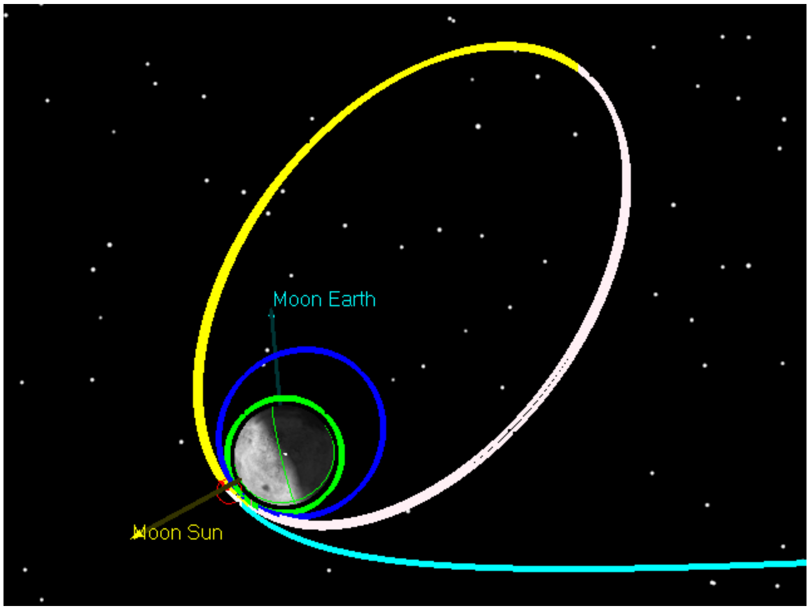

Figure 3-2: LOI phase of the LADEE mission

3.4 Commissioning Phase

During the commissioning phase the LLCD technology demonstration and basic checkout of the science payload was completed. The prime operational phase of the LLCD was conducted during the first 30 days while LADEE was in the 250 km circular orbit at 10° inclination. During this time, science payload activation and initial checkout was also initiated. During the last 10 days of the commissioning period, the LADEE periapsis was lowered to 75 km while science payload checkout activities continued, and the first measurements of the lunar exosphere and dust properties were performed. The commissioning phase ended on October 25th, 2013, when LADEE was maneuvered into the science orbit.

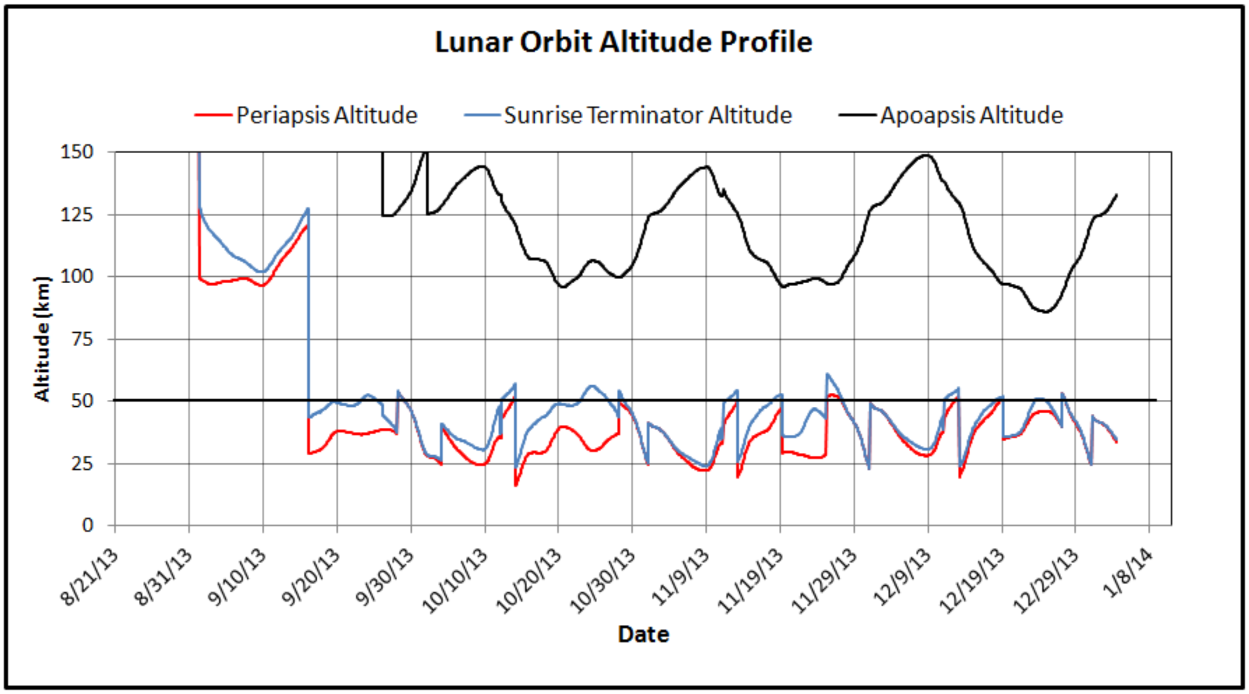

Figure 3-3: LADEE orbit altitude profile throughout the commissioning and science mission phases.

3.5 Science Phase

The science phase began on October 25th, 2013 and lasted 100 days. Orbit Maintenance Maneuvers (OMMs) were used during this period to keep the periapsis altitude below 50 km and the apoapsis altitude below 150 km to the extent possible. The orbit design with OMMs during the science phase is shown in Figure 3-3. OMMs were designed to maintain the periapsis over the lunar sunrise terminator whenever possible.

3.6 Decommissioning

After a 100 day science phase, decommissioning was initiated on February 3rd, 2014 in a controlled trajectory designed to impact LADEE into the lunar surface. Lunar impact was achieved on March 5th, 2014 in the TBD region of the Moon.

Appendix A Acronyms

ARC	Ames Research Center
GSFC	Goddard Space Flight Center
LADEE	Lunar Atmosphere and Dust Environment Explorer
LDEX	Lunar Dust Experiment
LLCD	Lunar Laser Communications Demonstration
LOI	Lunar Orbit Insertion
LV	Launch Vehicle

MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
NMS	Neutral Mass Spectrometer
OMM	Orbital Maintenance Maneuver
PDS	Planetary Data System
TBD	To Be Determined
TCM	Timing Correction Maneuver
UVS	Ultraviolet/Visible Spectrometer
WFF	Wallops Flight Facility