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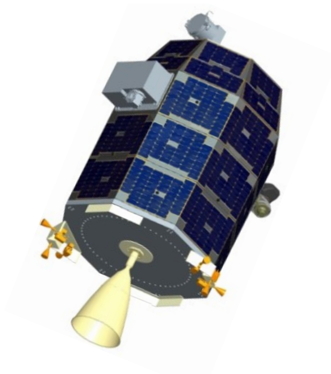

Lunar Atmosphere and Dust Environment Explorer

(LADEE)

LADEE PDS Spacecraft Description

March 14th , 2013

Ames Research Center
Moffett Field, California

National Aeronautics and
Space Administration

This document is approved in accordance with LADEE Configuration Management Plan, C04.LADEE.CM, paragraph 3.6.1.1 Document Release Routing Approval Process.

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REVISION HISTORY			
Rev.	**Description of Change**	**Author(s)**	**Effective Date**
1.0	Initial draft	G. Delory	Feb 15, 2013
1.1	Updated thermal, GNC, and FSW system description	G. Delory	Mar 5, 2013
1.2	Incorporated inputs from GNC and FSW leads	G. Delory	Mar 14, 2013
NC	Baseline	G. Delory	

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 LADEE SPACECRAFT OVERVIEW

The LADEE spacecraft is a lunar orbiter designed to study the lunar atmosphere and dust. These measurements are conducted with the goal of determining how future explorers and the lunar environment will interact, and as an example small body exospheres throughout the solar system. The LADEE spacecraft is designed to meet the following primary objectives:

- Determine the composition of the lunar atmosphere and investigate the processes that control its distribution and variability, including sources, sinks, and surface interactions.
- Characterize the lunar exospheric dust environment and measure any spatial and temporal variability and impacts on the lunar atmosphere.
- Carry out the Lunar Laser Communication Demonstration.
- Demonstrate the use of the Minotaur V as launch vehicle for planetary missions.

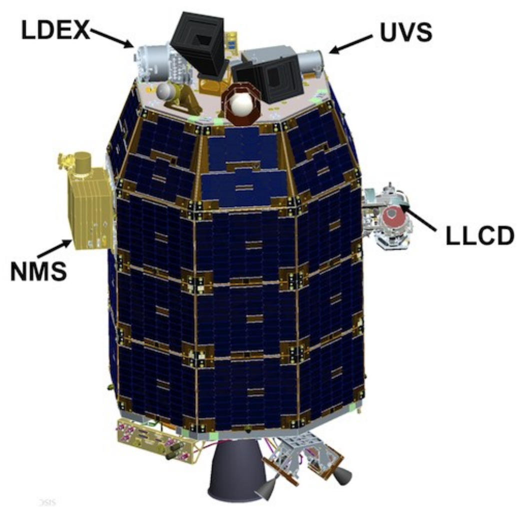


Figure 1-1: The LADEE Spacecraft and Instrument Locations

LADEE carries three science instruments: a Neutral Mass Spectrometer (NMS), Ultra-Violet/Visible Spectrometer (UVS), and the Lunar Dust Experiment (LDEX). The Lunar Laser Communications Demonstration (LLCD) will study the feasibility of high data rate communications from the Moon. The spacecraft is 3-axis stabilized, and points the science instruments into different viewing directions as desired. The remaining major spacecraft systems include a bi-propellant propulsion section, body-mounted solar arrays, 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 1-1. Total spacecraft wet mass is 375 kg, with a total instrument payload of 53 kg.

2 LAUNCH CONFIGURATION

LADEE is scheduled for launch from WFF on a Minotaur V five-stage rocket consisting of Minotaur IV+ with a Star 37FM or FMV upper stage during a launch window that opens Aug 12, 2013 (Figure 2-1).

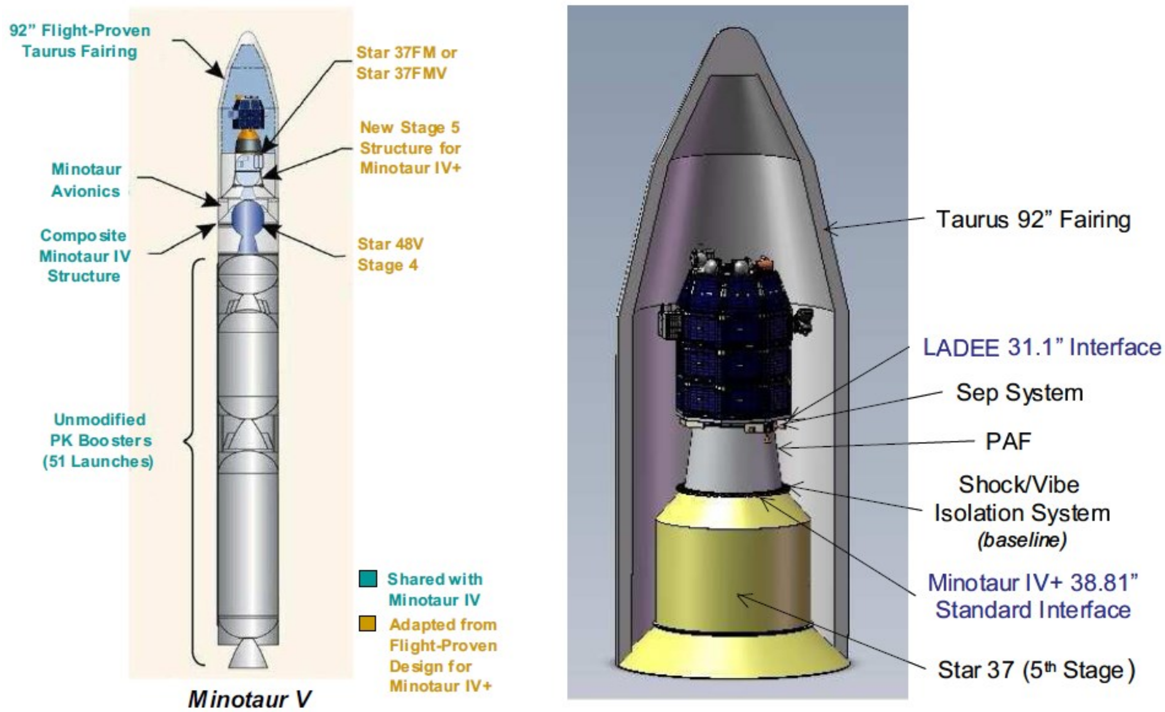


Figure 2-1: LADEE launch vehicle and configuration

3 STRUCTURES AND LAYOUT

LADEE's spacecraft bus design was derived from the Modular Common Spacecraft Bus (MCSB), also known as the "Common Bus" architecture developed at NASA ARC. The MCSB is a small, low-cost spacecraft designed to deliver scientifically and technically useful payloads to a variety of locations, including low earth orbit (LEO), lunar orbit and lunar surface, Earth-Moon Lagrange points, and near earth objects (NEOs). It consists of a lightweight carbon composite structure designed for ease of manufacturing and assembly. The modular design also allows parallel development, assembly, and test of modules. The spacecraft bus modules consist of: (1) the Radiator Module, which carries the avionics, electrical system, and attitude sensors, (2) the Bus Module, (3) the Payload Module, which carries the two largest instruments, and (4) the Extension Modules, which house the propulsion system (Figure 3-1).

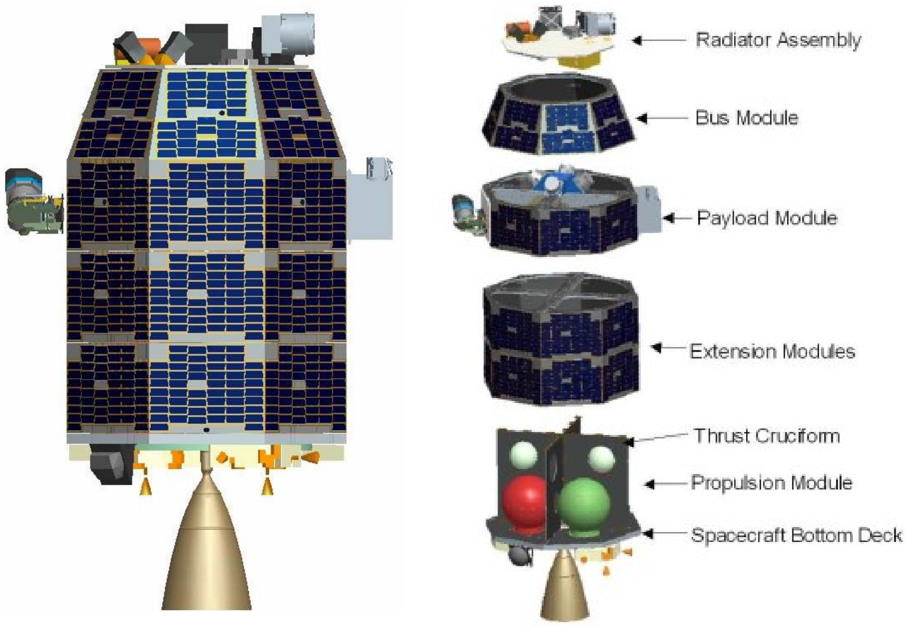


Figure 3-1: LADEE major structural components and layout

4 SUBSYSTEMS

4.1 Propulsion

The spacecraft's propulsion subsystem consists of titanium tanks, platinum-rhenium thrusters, and stainless steel components and lines. There is a pressurized bipropellant system using monomethyl hydrazine fuel and mixed oxides of nitrogen oxidizer. Four propellant tanks and two helium tanks provide storage for fuel, oxidizer, and pressurant. The propellant and pressurant tanks are all of a standard, flight-proven design. In flight, helium is stored at a maximum pressure of 3600 psia and propellant at 250 psia. The propellant tanks are hazardous leak-before-burst, while the helium tanks are not a leak-before-burst design. The propellant tanks use surface tension devices to maintain liquid flow at the tank outlets. The propulsion subsystem has one large 460N orbital control system (OCS) thruster for orbit control maneuvers and four small 22N reaction control (RCS) thrusters for stabilization during orbit control maneuvers, and for desaturation of the reaction wheels which normally control the spacecraft attitude. Both the OCS and RCS thrusters are flight-proven types commonly used on geosynchronous communications satellites.

4.2 Power

The power system consists of an array of body-fixed solar panels, in a design that minimizes articulation requirements on the spacecraft bus. The solar arrays are connected to an Electrical

Power System (EPS) in the spacecraft avionics, which controls switching, power distribution, and charging services to the Li-ion batteries

4.3 Thermal

At the sub-system level, thermal limits are achieved using combinations of appropriate isolation, multi-layer insulation, and where necessary active heaters for critical elements. The LADEE top deck acts as a thermal radiator, which contains heaters should internal temperatures become too cold for any reason. Active heaters are used on each instrument, the LLCD optics, the propulsion system and associated lines, batteries, transponder, and the upper radiator panel. Heaters are controlled by the spacecraft avionics. The mission profile yields a hot case during telemetry orbits when one side of the spacecraft faces the Sun/Earth for extended periods. During regular operations, lunar noon represents the hottest period, and there are no cold cases of concern. Prior to lunar orbit insertion (LOI), LADEE can withstand up to a 1 hour eclipse before low temperature limits are exceeded.

4.4 Avionics

The Integrated Avionics Unit (IAU) consists of a commercially available BroadReach 8-slot 3U cPCI integrated avionics system providing the following functions:

- Command & Data Handling (C&DH)
- Power Distribution
- Solar Array and Battery Charge Management
- Pyrotechnic Actuation

A separate electronics box in the Propulsion Module handles the valve driver actuation.

4.5 Flight Software

The LADEE flight software (FSW) uses VxWorks as a real time operating system and runs on the Rad750 processer in the IAU. The FSW is responsible for C&DH, and guidance, navigation, and control (GN&C) functions. LADEE utilizes a model-based development approach layered on hand-code, Government- off-the-shelf (GOTS) and Commercial-off-the-shelf (COTS) software elements. The core of the spacecraft control and simulation software is modeled in MathWorks Simulink software.

For C&DH tasks, the FSW manages analog and digital interfaces to the instruments and subsystems, memory allocation and scrubbing, instrument commanding via relative sequence (RTS) loads, and the telecommunications system. Data is stored using a file-based system prior to transmission to the ground via the CCSDS File Delivery Protocol (CFDP). The FSW manages the thermal, actuation/pyro, and power control systems.

For GN&C, the FSW controls the attitude control system (ACS) and performs state estimation. The FSW is responsible for managing the spacecraft mode, including startup, safe, fine-pointing, and nominal science modes.

4.6 Guidance, Navigation, and Control

LADEE uses a bi-propellant propulsion system, reaction wheels, star tracker, sun sensors, and an inertial measurement system to provide three-axis attitude control. The GN&C system can achieve 0.50 mrad of pointing accuracy during science operations by using an attitude estimator and Kalman filter along with four reaction wheels arranged in a pyramid configuration. Four small RCS thrusters are used for attitude control during main engine burns and for reaction wheel momentum desaturation activities. The sun sensors are evenly distributed around the surface of the spacecraft and are used along with the reaction wheels to orient the spacecraft into a power positive attitude relative to the sun while the spacecraft is in Safe Mode.

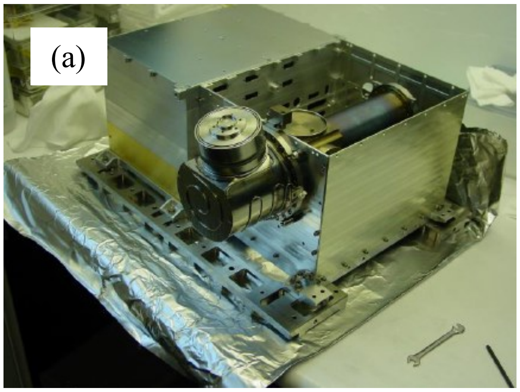
4.7 Telecommunications

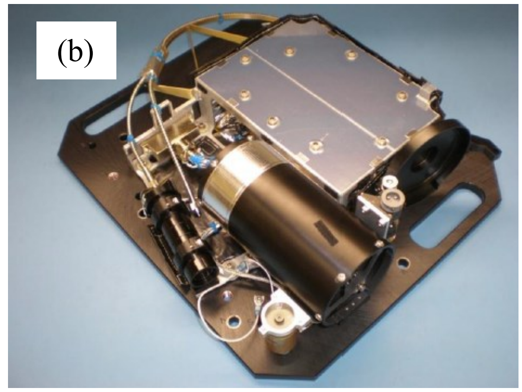
The LADEE Communications Sub-system consists of a NASA Standard S-Band transponder, two Omnidirectional antennas (Omni), a medium gain antenna (MGA), and other RF components. The spacecraft uses "evolved" Omni/MGA antenna designs, developed at NASA ARC, to achieve omni-directional coverage with a smaller area of medium gain response The uplink is received on only the Omnis. The downlink is transmitted on either the Omni antennas or on the MGA, selection of which is via a radio-frequency transfer switch. The S-band transponder supports simultaneous telemetry, command and ranging. The transponder can be configured for either coherent or non-coherent mode to support two-way Doppler measurements required for orbit determination. Maximum transmitter power is 5W. Downlink data rates are at least 4 kbps with the Omni antennas, and range between 50-128 kbps using the MGA. Uplink rates can be either 1 or 2 kbps.

5 INSTRUMENT PAYLOAD

5.1 Neutral Mass Spectrometer

The LADEE NMS measures the mass distribution of neutral species over a mass-to-charge ratio (*m/z*) 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 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.





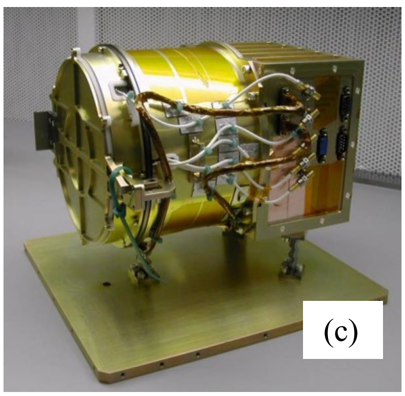


Figure 5-1: (a) Neutral Mass Spectrometer. (b) Ultraviolet/Visible Spectrometer. (c) Lunar Dust Experiment

5.2 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

5.3 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 microchannel 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.

Appendix A Acronyms

ACS	Attitude Control System
ARC	Ames Research Center
C&DH	Command and Data Handling
CFPD	CCSDS File Delivery Protocol
FSW	Flight Software
GN&C	Guidance Navigation and Control
GSFC	Goddard Space Flight Center
IAU	Integrated Avionics Unit
IMU	Inertial Measurement Unit
kbps	kilobits per second
LADEE	Lunar Atmosphere and Dust Environment Explorer
LDEX	Lunar Dust Experiment
LEO	Low Earth Orbit
LLCD	Lunar Laser Communications Demonstration
LOI	Lunar Orbit Insertion
LV	Launch Vehicle
MGA	Medium Gain Antenna
MOC	Mission Operations Center
MCSB	Modular Common Spacecraft Bus
NASA	National Aeronautics and Space Administration
NEO	Near Earth Object
NMS	Neutral Mass Spectrometer
OCS	Orbital Control System
OMM	Orbital Maintenance Maneuver
PDS	Planetary Data System
PSIA	Pounds per Square Inch Absolute
RCS	Reaction Control System

RTS	Relative Time Sequence
TBD	To Be Determined
UVS	Ultraviolet/Visible Spectrometer
WFF	Wallops Flight Facility