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Lunar Atmosphere and Dust Environment Explorer (LADEE) Launch

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For more information, visit:

<http://www.nasa.gov/ladee>

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Video Resources

B-roll for the LADEE mission is available on NASA TV starting Aug. 22. Included is footage of various tests, construction, animations and interview excerpts with key project personnel. For more information, visit:

<http://www.nasa.gov/ladee>

NASA Television Transmission

Live coverage on NASA TV of the LADEE launch will begin at 9:30 p.m. EDT Sept. 6.

In continental North America, Alaska and Hawaii, NASA Television's Public, Education, Media and HD channels are MPEG-2 digital C-band signals carried by QPSK/DVB-S modulation on satellite AMC-3, transponder 15C, at 87 degrees west longitude. Downlink frequency is 4000 MHz, horizontal polarization, with a data rate of 38.86 MHz, symbol rate of 28.1115 Ms/s, and 3/4 FEC. A Digital Video Broadcast (DVB) compliant Integrated Receiver Decoder (IRD) is needed for reception.

For digital downlink information for NASA TV's Media Channel, access to NASA TV's Public Channel on the web and a schedule of programming for LADEE activities, visit: <http://www.nasa.gov/ntv>.

Media Credentialing

News media who are U.S. citizens wish to cover the LADEE launch must send their accreditation request by Aug. 26, to Keith Koehler at NASA's Wallops Flight Facility Public Affairs at 757-824-1579 or keith.a.koehler@nasa.gov. The deadline

has passed for non-U.S. citizens to apply.

News Conferences

Two LADEE pre-launch news conferences will be held at the Wallops Flight Facility's Press Site. The LADEE "mission" news conference will be held on Sept. 5, 2013, at 3 p.m. EDT.

The second, the LADEE "science" news conference, will be held on Sept. 5, 2013 at 4 p.m. EDT.

Approximately two hours after launch: A post-launch news conference will be held.

The news conferences will be televised on NASA TV.

Internet Information

NASA EDGE, the video podcast that takes an inside and outside look at all things NASA, also will webcast a special pre-launch program live from Wallops. They will host a number of Subject Matter Experts discussing the scope of the LADEE mission. During the webcast, viewers can ask questions via Twitter and Facebook by using the hashtag #askNASA. The live webcast is from 9:30 – 11:35 p.m. EDT and can be viewed at:

<http://www.ustream.tv/nasaedge>

More information on the LADEE mission, including an electronic copy of this press kit, news releases, status reports and images, can be found at <http://www.nasa.gov/ladee>.

Quick Facts

Mission Name

LADEE is an acronym for Lunar Atmosphere and Dust Environment Explorer.

Spacecraft

Structure

Main structure: 7.7 feet (2.37 meters) high, 4.74 feet (1.85 meters) wide, 4.74 feet (1.85 meters) deep

Power

Total solar array power at 1 AU: 295 watts

Power: 30 panels of silicon solar cells mounted on the satellite's exterior surfaces

Batteries: 1 Lithium-ion battery providing up to 24 amp-hours of 28-volt power

Instruments

- Lunar Dust Experiment (LDEX)
- Neutral Mass Spectrometer (NMS)
- Ultraviolet and Visible Spectrometer (UVS)
- Lunar Laser Communications Demonstration (LLCD)

Mass

Launch: 844.4 pounds (383 kilograms)
Dry: 547.2 pounds (248.2 kilograms)
Fuel/He: 297.2 pounds (134.8 kilograms)
Payloads: 109.3 pounds (49.6 kilograms)

Launch Vehicle

Type: The U.S. Air Force's Minotaur V launch vehicle provided by Orbital Sciences Corp.

Height with payload: 80.59 feet tall (24.56 meters) and 7.67 feet (2.34 m) in diameter
Mass fully fueled: 197,034 lbs (89,373 kg)

First Through Third Stages:

- The first three stages of the Minotaur V are former Peacekeeper intercontinental ballistic missile (ICBM) solid rocket motors

Fourth Stage:

- Star 48BV solid fuel rocket
- The 48BV solid rocket motor burns 84.8 seconds and produces kN (15,617 lbf) pounds of thrust on average.

Fifth Stage:

- Star 37FM solid fuel rocket
- The 37FM solid rocket motor burns 63.5 seconds and produces kN (10,995 lbf) pounds of thrust on average.

Launch Site

Wallops Flight Facility, Wallops Island, Va.

LADEE Mission Milestones and Distances Traveled

Launch period: Sep. 6 – Oct. 14, 2013 (17 days).

Launch location: Pad 0B, Wallops Flight Facility, Wallops Island, Va.

Moon Arrival Date: As early as Oct. 6, 2013

Science Orbit Altitude: 12.4 – 37.3 miles (20 - 60 kilometers)

The distance travelled to the moon changes as a function of launch date.

Program

The LADEE mission totals approximately \$280 million, which includes spacecraft development and science instruments, launch services, mission operations, science processing and relay support.

Moon Facts

The actual Earth–moon distance ranges from about 223,700 to 251,700 miles (360,000 to 405,000 kilometers), depending on the moon’s position in its orbit.

The mean radius of the moon is 1,080 miles (1,737.4 kilometers); the diameter is 2,159.1 miles (3,474.8 kilometers).

Total mass of the moon is 81 quintillion tons (74 sextillion kilograms). The surface temperature at the equator during the day is as high as 273 degrees Fahrenheit (134 degrees Celsius) and at night is as cold as minus 244 degrees Fahrenheit (minus 153 degrees Celsius).

Gravity at the surface of the moon is 1/6 that of Earth. The moon’s magnetic field is less than 0.01 that of Earth’s.

The orbital speed of the moon is 2,287 mph (3,680 kilometers per hour).

At the closest distance, it would take 135 days to drive by car at 70 mph (113 kilometers per hour) to the moon.

The moon is actually moving away from Earth at a rate of 1.5 inches (3.8 centimeters) per year.

The moon’s widest crater is 1,553 miles (2,500 kilometers) in diameter.

From Earth, we always see the same side of the moon.

If Earth did not have its moon, Earth would spin three times as fast, making a day last only 8 hours instead of 24.

The age of the oldest moon rock collected by astronauts is 4.5 billion years old. The rocks collected during NASA’s Apollo program weigh in at 842 pounds (382 kilograms).

The moon’s highest mountains are 5.6 miles high (9 kilometers).

The lunar day (or the time from sunrise to sunrise) on the moon is approximately 708 hours (29.5 days).

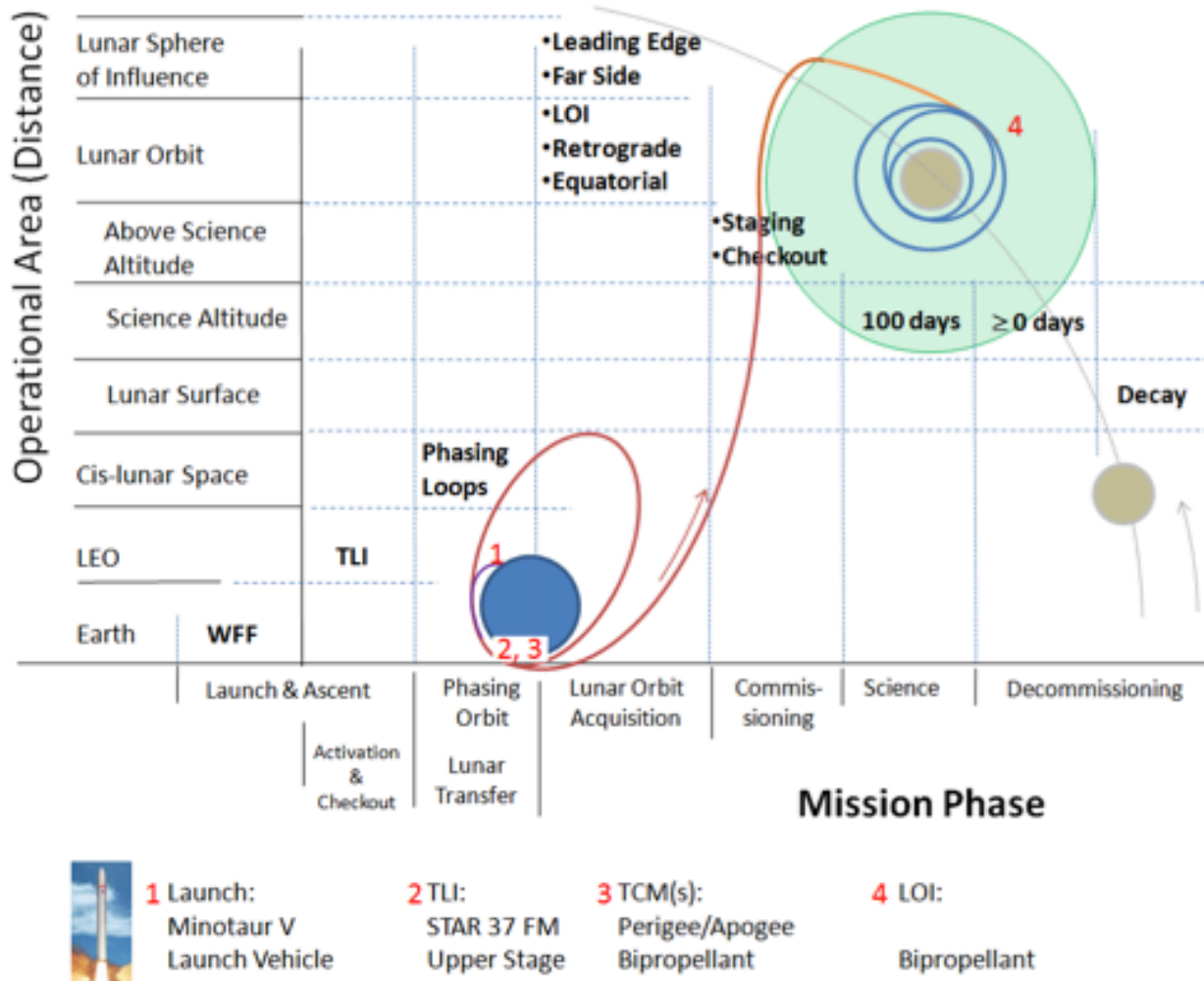
The surface area of the moon is 23,559,000 square miles (37,914,000 square kilometers). It has almost the same surface area as the continent of Africa.

If you weighed 120 pounds, you would weigh only 20 pounds on the moon.

The moon has no known active volcanoes.

There are two high tides and two low tides every day on every beach on Earth because of the moon’s gravitational pull.

Mission Overview



This figure shows a timeline of the LADEE mission phases from launch through the various mission phases. Since the relative position of Earth and the moon change over this entire period, it is simplest to illustrate the events relative to the sun, or heliocentric view.

The LADEE spacecraft will be launched on a Minotaur V vehicle during a five-day launch period that opens on Sept. 6, 2013.

The LADEE mission is divided into mission phases: Launch, Ascent, Activation and Checkout, Phasing Orbits, Lunar Orbit Insertion, Commissioning, Science, and Decommissioning.

Once launched, LADEE will enter a series

of phasing orbits, which allows the spacecraft to arrive at the moon at the proper time and phase. This approach accommodates any dispersion in the Minotaur V launch injection.

LADEE's arrival at the moon depends on the launch date. The spacecraft will approach the moon from its leading edge, travel behind the moon out of sight of the Earth, and then re-emerge and execute a

three-minute Lunar Orbit Insertion maneuver. This will place LADEE in an elliptical retrograde equatorial orbit with an orbital period of approximately 24 hours.

A series of maneuvers is then performed to reduce the orbit to become nearly circular with a 156-mile (250-kilometer) altitude.

The 100-day Science Phase is performed at an orbit that will vary between 20–60

kilometers due to the moon’s “lumpy” gravity field. During the Science Phase, the moon will rotate more than three times underneath the LADEE orbit.

Following the Science Phase, a decommissioning period is planned, during which the altitude will be managed down to lower altitudes, after which the spacecraft will impact the lunar surface.

Mission Phase	Entry	Exit	Duration	Summary and Objectives
Pre-Launch	Start of LV Count-down Sequence (TBR)	LV Lift-off	TBD	<ul style="list-style-type: none"> Configure LADEE for launch, then power-off.
Launch & Ascent	LV Lift-off	LADEE Separation from 5 th Stage	~20 minutes	<ul style="list-style-type: none"> Achieve phasing orbit trajectory (POI) De-spin of 5th Stage LADEE launches powered OFF
Activation and Checkout	LADEE Separation from 5 th Stage	Transition to Fine Pointing Mode	~1 day	<ul style="list-style-type: none"> Transition from safe-mode to fine pointing mode Ground station acquisition Initial orbit determination
Phasing Orbit	Transition to Fine Pointing Mode	Start of 3 rd Perigee Burn Sequence	~23.5 days	<ul style="list-style-type: none"> Execution of 3 Phasing Loops and up to 3 Perigee burns. 1st burn L+6 days (approx.) Utilization of TDRSS for perigee burns Spacecraft commissioning and bake out Instrument aliveness checks Check-out of LLCD (time permitting)
Lunar Transfer	Start of 3 rd Perigee Burn (P _{final})	Start of LOI-1 Sequence	~5.25 days	<ul style="list-style-type: none"> Final perigee burn (PM-3) Orbit determination following PM-3 ½ Phasing Orbit Coast with execution of TCMs as necessary Prepare for Lunar orbit insertion
Lunar Orbit Acquisition	Start of LOI-1 Sequence	Lunar Staging Orbit	~3 days	<ul style="list-style-type: none"> Perform series of lunar orbit insertion (LOI) maneuvers. Achieve 250 km circular staging orbit
Commissioning	Lunar Staging Orbit	Science Orbit	40 days (nominal) 60 days (contingency)	<ul style="list-style-type: none"> Check-out of power, thermal, earth-pointing and science attitudes Instrument checkout Lens cover deployment Demonstration of LLCD
Science	Science Orbit	End of Nominal Science Operations / Propellant at critical level	100 days	<ul style="list-style-type: none"> 50 km circular reference orbit Science, communications and power operational modes Orbit determination and maintenance Housekeeping and tracking
Decommissioning	End of Nominal Science Operations / Propellant at critical level	Impact on Lunar Surface	3 – 7 days	<ul style="list-style-type: none"> Plan optimal post-depletion trajectory & ops Natural decay from gravitation Continue science and bus attitude control Continue data collection and transmission High value science opportunities
Post-Flight	Impact on Lunar Surface	Completion of Closeout Activities	< 6 months	<ul style="list-style-type: none"> Archival of mission data products Science data archival in PDS Capture of lessons learned

This figure shows the various LADEE mission phases.

Mission Phases

Launch Phase

The Launch Phase begins with liftoff and ends about 20 minutes later. This phase culminates with separation of LADEE from the launch vehicle, when the spacecraft powers up and transitions to safe mode.

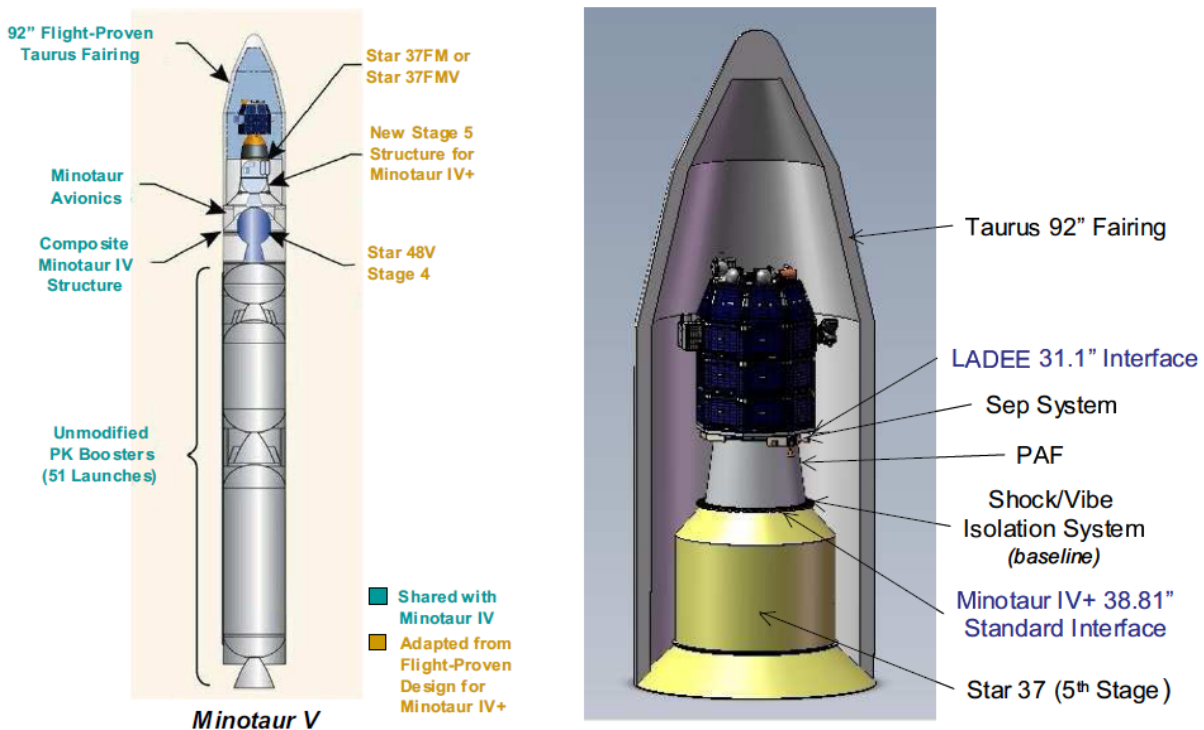
Launch Strategy

To reach the moon with the Minotaur V, the LADEE launch is limited to a handful of days each month. On each day within the launch opportunity, there is a launch window of up to 15 minutes. On Sept. 6, the launch opportunity is at 11:27 p.m. EDT.

LADEE's Ride Into Space

The launch vehicle selected for the LADEE mission is the U.S. Air Force's Minotaur V launch vehicle. LADEE will be the first mission to launch on the Minotaur V. This is a five-stage (solid propellant) launch vehicle with a 7.67-foot-diameter (2.34-meter) payload fairing. The launch vehicle is slightly more than 80.59 feet tall (24.56 meters) tall.

The Minotaur family of launch vehicles are provided via the Orbital/Suborbital Program and managed by the U.S. Air Force Space and Missile Systems Center, Space Development and Test Directorate Launch Systems Division located at Kirtland Air Force Base, N.M.



LADEE's Minotaur V launch vehicle and configuration. Image credit: NASA

First Three Stages

The first three stages of the Minotaur V use former Peacekeeper solid rocket motors with more than 50 flights of each stage. The first three stages of the Minotaur V engine will burn for approximately 208 seconds, and will then be jettisoned into the Atlantic Ocean.

Fourth Stage

The fourth stage of the Minotaur V is powered by a Star 48BV engine, burning 84.8 seconds. The burn of the fourth stage occurs during the final portion of the boost phase and is used to insert the vehicle into low Earth orbit.

Fifth Stage

The fifth stage of the Minotaur V is powered by a Star 37FM engine, burning 63.5 seconds.

Payload Interface and Fairing

The LADEE observatory is housed within a payload fairing that is 7.67 feet (2.34 meters) in diameter and 20.67 feet (6.3 meters) tall. The fairing is used to protect the observatory during the early portion of the boost phase when the aerodynamic forces are great. The fairing will be jettisoned shortly after the ignition of Stage 3, at about 163 seconds into flight and an altitude of approximately 77 miles (124 kilometers).

Orbiter-Launch Vehicle Separation

Payload separation occurs at 23.45 minutes after launch; that is 5.44 minutes after Stage 5 burnout.

Activation and Checkout

Spacecraft activation and checkout occurs immediately after launch vehicle separation - approximately 23 minutes after launch.

Phasing Orbits

All of LADEE's mission events - except the lunar gravitational capture - are made using the propulsion system to maneuver the spacecraft. The Minotaur V launch vehicle will execute a Phasing Orbit Insertion burn to place LADEE on the first phasing loop, however all maneuvers after that will be done using LADEE's onboard bi-propellant propulsion system.

The first phasing orbit maneuver is scheduled to occur approximately six days after launch. The LADEE spacecraft will orbit Earth three times in a highly elliptical orbit, making trajectory corrections on each pass if necessary.

On the final phasing loop orbit, LADEE's onboard propulsion subsystem will add enough energy to the orbit until the moon's gravity can take over, and LADEE begins its approach trajectory to the moon.

Lunar Orbit Insertion Phase

The primary focus for this phase is the critical lunar orbit insertion maneuver. This phase begins with LADEE's arrival at the moon.

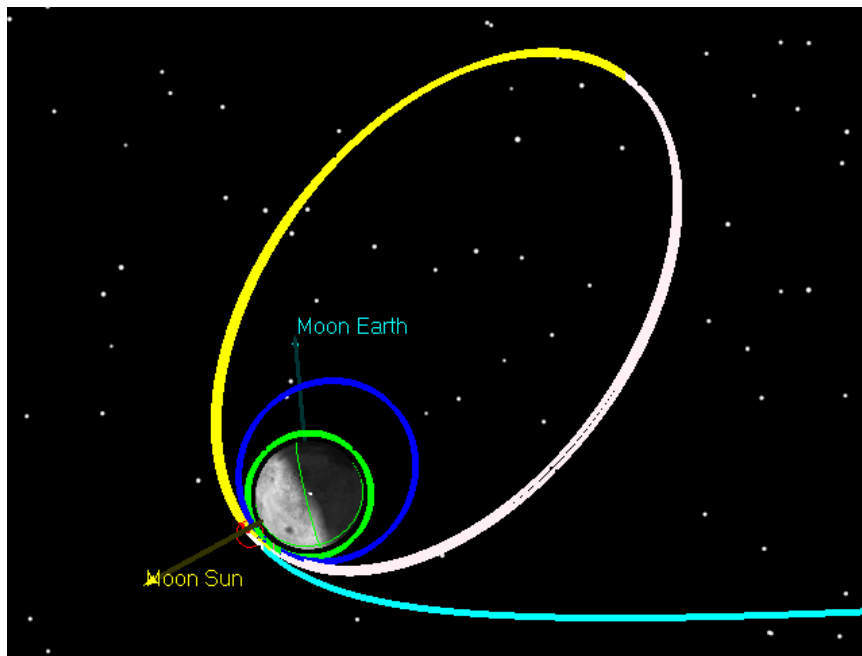
LADEE will coast to the moon rotating slowly about its longitudinal axis, which

will be oriented toward ecliptic-North (nearly perpendicular to both the sun and Earth).

As LADEE approaches the moon it will fire its onboard propellant and be captured into lunar orbit. If this burn does not occur, LADEE will continue on a “swing-by” trajectory and escape the moon’s gravity field. The lunar orbit insertion burn for the spacecraft lasts approximately three minutes and changes the orbiter velocity enough to capture the spacecraft around

the moon.

The first maneuver will establish LADEE's initial orbit at the moon. Subsequent firings of LADEE's onboard propellant will place LADEE into a 250 km circular orbit with an orbital period of approximately 24 hours. The altitude of 250 km was selected to allow communications visibility to Earth during burn, and to minimize the need for orbit maneuvers during the commissioning phase.



LADEE's incoming trajectory and Lunar Orbit Insertion (LOI) burn. Blue line marks the moon's terminator at time of insertion. Image credit: NASA Ames

Commissioning

Approximately 30 days after launch, LADEE will begin the 40-day Commissioning Phase. LADEE's initial circular 250 km circular staging orbit will become approximately 200 x 300 km due to the moon's gravity. During the first 30 days, high altitude commissioning activities, such as the LLCD technology demonstration prime operational phase

and activation and basic checkout of the science payloads will be completed.

LADEE's orbital period during the Commissioning Phase will be approximately two hours (between 122 - 132 minutes).

LLCD requires LADEE to very precisely maintain its pointing at the Lunar Laser Ground Terminal. In between successive orbits of Lunar Laser Space Terminal observations, the spacecraft will be

oriented for best power production and thermal stability.

During the last 10 days of the commissioning period, LADEE's onboard propulsion subsystem will lower the observatory's altitude to 46.6 miles (75 km) while science payload checkout activities continue, and the first measurements of the lunar exosphere and dust properties will be performed. The commissioning phase will end when LADEE is maneuvered into a science orbit.

Science Phase

The Science Phase will last 100 days and consists of the collection of science data. At the start of the Science Phase, the LADEE spacecraft will be in a near-circular orbit with an altitude of about 12 – 93 miles (20 - 150 kilometers).

During the Science Phase, LADEE will orbit between 111.5 and 116.5 minutes.

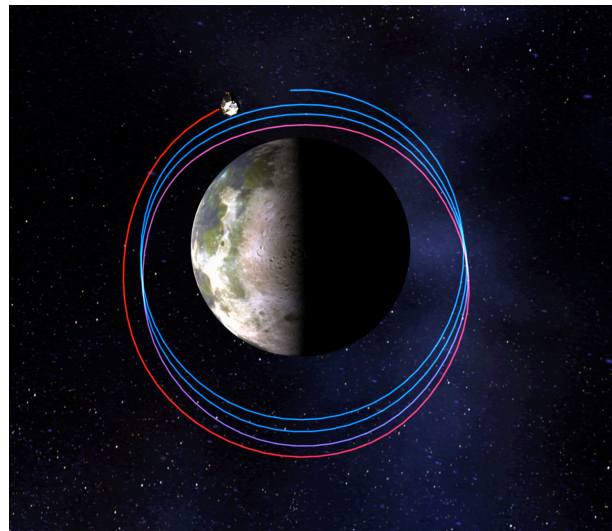
Due to the unevenness of the moon's gravitational field, the 50 x 50 km orbit requires significant orbit maintenance activity with maneuvers taking place as often as every 3-5 days or as infrequently as once every two weeks. Orbit Maintenance Maneuvers will be used to keep LADEE's lowest altitude above 31 miles (50 kilometers) and highest altitude below 93 miles (150 kilometers) to the extent possible. Orbital Maintenance Maneuvers are designed to maintain the altitude over the lunar sunrise terminator whenever possible.

The science orbit is designed to satisfy the basic science requirements of the LADEE mission, which are for a low-altitude, near-circular, equatorial orbit. The primary design parameter from a science

perspective is the orbit altitude, since sensitivity to the lunar atmosphere is driven by orbit altitude (i.e. the lower the altitude, the more sensitive the science measurements). Limits on the minimum orbit altitude are driven primarily by orbit lifetime considerations.

During the 100-day Science Phase, the moon will rotate more than three times underneath the LADEE orbit.

The LADEE spacecraft and payload instruments are designed to orbit the moon in an upright posture; that is, with the longitudinal spin axis pointing north. This upright cruise attitude is intended to place the antenna in the best location for communication with Earth, and will allow exposure to the sun similar to power and thermal conditions in lunar orbit. Depending on antenna placement and signal strength, LADEE's rotation may need to be halted to perform communications with Earth stations.



Artist's concept of the LADEE science orbital path.
Image credit: NASA Ames / Dana Berry

Decommissioning Phase

The final phase of the LADEE mission is the Decommissioning Phase. During this phase, the LADEE observatory will perform a final Ka-band calibration and will continue to acquire science data, as power and thermal resources allow. The Decommissioning Phase ends at the end of the Science Phase and 100 days after commissioning.

The design of the LADEE science orbit is such that, when the onboard propellant is almost gone at the end of the Science

Phase, LADEE's orbit will be managed down to lower altitudes until it impacts the lunar surface. LADEE will continue to acquire data until impact.

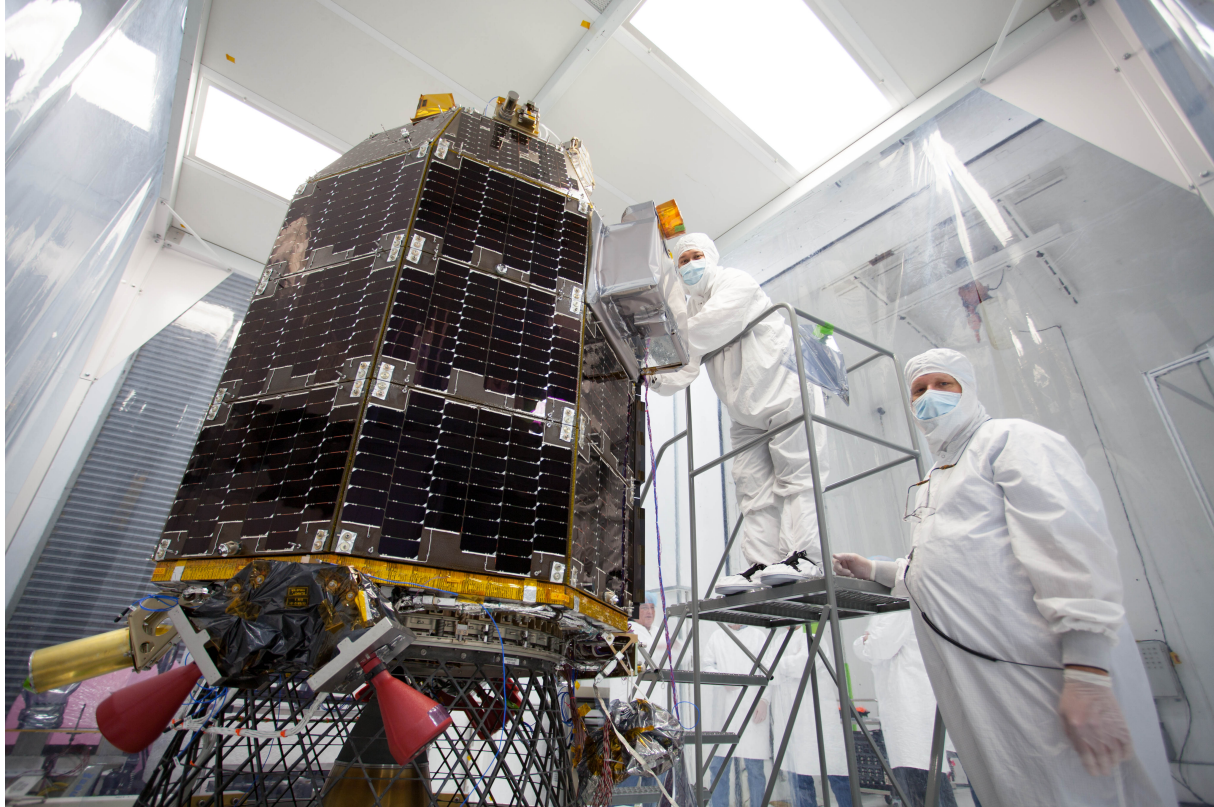
It is unlikely there will be any attitude requirements during decommissioning, except perhaps keeping the antenna pointed at the Earth for telemetry and tracking until the last orbit.

There are no plans to target the impact points on the lunar surface. If LADEE's propellant is depleted and orbital decay occurs naturally, the point of impact may not be in sight of Earth.



Artist's concept of the LADEE end-of-mission lunar impact. Image credit: NASA Ames/ Dana Berry

Spacecraft



Engineers at NASA's Ames Research Center, Moffett Field, Calif., prepare NASA's LADEE Observatory for acoustic environmental testing. Image credit: NASA Ames

The spacecraft was developed, designed, integrated and tested at NASA's Ames Research Center, Moffett Field, Calif.

Structure

LADEE comprises a spacecraft bus built using the Modular Common Spacecraft Bus architecture. The Modular Common Spacecraft Bus – also known as the "common bus" - is an innovative way to ease the manufacturing and assembly process; away from custom designs and toward multi-use designs and assembly line production, which could drastically reduce the cost of spacecraft development. The modular design also allows parallel

development, assembly, and testing of modules.

The LADEE spacecraft bus modules consist of a the Radiator Module, that carries the avionics, electrical system, and attitude sensors; the Bus Module; the Payload Module that carries the two largest instruments, and the Extension Modules, which house the propulsion system.

The current common bus design has the ability to perform on various kinds of missions – including voyages to orbit and land on the moon, low Earth orbit, and Near Earth Objects – with different

modules, or applicable plug-and-play systems.

For example, a common bus used for a mission to land on a planetary body could add a module for "legs" and other associated components. For an orbiter, engineers could insert a body extension. And for a more compact mission, they could take out the extension to make the spacecraft lighter and decrease launch costs.

The LADEE bus is a lightweight carbon composite structure with a dry mass of 547.2 pounds (248.2 kilograms), and fully fueled mass of 844.4 pounds (383 kilograms).



Artist's concept of LADEE's major structural components and layout. Image credit: NASA Ames

Attitude Control Subsystem

The Attitude Control subsystem is used to provide three-axis stabilized control throughout the mission. The subsystem is used to point the science instruments into different viewing directions as desired. This subsystem consists of a sun sensor,

two star trackers, reaction wheels, and an inertial measurement unit.

Propulsion System

The propulsion subsystem, built by Space Systems/Loral (SSL), Palo Alto, Calif., provides the thrust required to transfer the LADEE spacecraft into a low lunar orbit once it has separated from the launch vehicle. It also has the capability to provide three-axis attitude control and it is used as part of LADEE's momentum control strategy.

The propulsion subsystem is a module, designed to be easily integrated with the small spacecraft bus architecture developed by NASA's Ames Research Center, Moffett Field, Calif. It is a bi-propellant system that shares extensive heritage with SSL's fleet of commercial spacecraft. The propulsion module consists of a composite structure, a 455 Newton (N) orbit control thruster, four attitude control 22N thrusters, propellant tanks, pressurant tanks, valve control electronics, valves, regulators, and filters.

The main engine is a 455N High Performance Apogee Thruster (HiPAT). The thruster features high-temperature materials and a large exit ratio to maximize performance.

The high efficiency 22N attitude control thrusters are manufactured using high temperature materials and similar to the HiPAT, the attitude control thrusters share extensive heritage with SSL's large fleet of orbiting spacecraft.

The main engine provides the majority of the thrust for spacecraft trajectory correction maneuvers. The control system thrusters will be used for the small

maneuvers planned for the Science Phase of the mission.

The attitude control thrusters are canted to provide coupled thrust during main engine maneuvers. The warm gas thruster locations have been designed to minimize plume impingement on the main body and solar arrays.

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.

Command & Data Handling

LADEE's Command and Data Handling subsystem is used for telemetry and command processing.

Power

The electrical power subsystem is responsible for generating and storing energy for the spacecraft and its systems. This power subsystem includes an array of external, body-fixed solar panels and a Lithium-ion battery.

The solar array generates the energy to operate the spacecraft. The solar array has 30 panels and is capable of producing 295 watts at 1 AU.

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 battery.

The lithium-ion battery has a capacity of 24 amp-hours of 28-volt power, and is used to provide energy to the spacecraft during periods when the solar arrays are not able to generate enough power for the spacecraft systems.

Telecommunications

The telecom subsystem is responsible for sending telemetry and radiometric data from the spacecraft and receiving commands from the ground during the mission. The telecom subsystem for LADEE consists of a medium-gain and # omni-directional antennas. These antennas are the mission controllers' primary means of communicating with the spacecraft.

The Lunar Laser Communications Demonstration payload system utilizes a laser mounted on an articulated boom.

Facilities across several NASA centers will support LADEE including, the Multi-

Mission Operations Center (MMOC) located at NASA's Ames Research Center in Silicon Valley, Calif., which will serve as a base for mission operations and real-time control of the observatory. LADEE also will have a Science Operations Center at NASA's Goddard Space Flight Center in Greenbelt, Md., that will catalogue and distribute instrument data to the science team located in instrument operations centers.

The Ground Segment relies on several radio communication facilities to communicate with the spacecraft. The primary ground station will be an 18-meter antenna located at the White Sands Complex near Las Cruces, N.M. Other facilities include the Deep Space Network's 34-meter antennas located in Madrid, Spain and Canberra, Australia.

Science Instruments

Onboard, LADEE will include three science instruments and a technology demonstration.

Ultraviolet and Visible Light Spectrometer

The Ultraviolet and Visible Light Spectrometer (UVS) is located on the upper deck of the spacecraft and will determine the composition of the lunar atmosphere and remotely sense any lofted dust. The Principal Investigator is Anthony Colaprete at NASA's Ames Research Center, Moffett Field, Calif.

The UVS instrument is a spectrometer, an instrument that measures different colors of light, and will measure light between 230 and 810 nanometers, or the ultraviolet to just past visible wavelengths. UVS has two means of observing including the limb telescope and solar viewer.

The UVS limb telescope will point just above the moon's surface, at its "limb," and look for light emissions by exosphere gasses and the dimming or scattering of sunlight from lunar dust grains.

For a typical orbit, the limb telescope will be focused on the boundary between lunar day and night as well as the lunar "noon." During these activities LADEE will keep the limb telescope pointed lower than 12.42 miles (20 km) above the lunar surface. Each limb "stare" is accompanied by a "nod" during which the telescope field of view is nodded down to below the lunar limb, so that the moon is entirely in the telescope's field of view.

The UVS solar viewer will stare at the sun to monitor the setting of the set as it passes from high above the lunar surface to below the lunar limb. If there is dust present above the lunar surface, the total solar light entering the instrument will be partially blocked. The UVS is sensitive to very small concentrations of dust near the lunar surface.

UVS can only detect water molecules in the lunar atmosphere if they are negatively or positively charged, or if the water has been disassociated – or broken apart – by solar ultraviolet light to produce hydroxyl. Scientists are very interested in water on the moon, because it may migrate from lower latitudes to the poles where it is cold-trapped. NASA's Lunar CRater Observation and Sensing Satellite (LCROSS) discovered water ice when it impacted in 2009.

Neutral Mass Spectrometer

The Neutral Mass Spectrometer is mounted to the spacecraft body and will measure chemical variations in the lunar atmosphere over multiple lunar orbits with the moon in different space environments. The Principal Investigator is Paul Mahaffy at NASA's Goddard Space Flight Center, Greenbelt, Md.

At low altitudes, the NMS is capable of measuring the abundance of gases such as argon, which may indicate internal geophysical processes at the moon. Scientists will use helium measurements to understand the importance of the solar wind in the generation and dynamics of the moon's helium exosphere. NMS also was designed to detect metallic elements in the exosphere that may indicate more energetic processes acting on the lunar surface such as sputtering from solar wind particles and vaporization of materials from meteoroid impacts. Helium and argon are important targets for NMS and their abundance variability followed over the course of the mission and at different times and altitudes will help scientists understand the response of this tenuous space environment to energy inputs and how these atoms move from the surface into space. NMS can detect any chemical with a molecular or atomic mass between 2 and 150 atomic mass units if present in sufficient abundance. NMS will target trace levels of other atoms or compounds such as methane, sulfur, magnesium, carbon monoxide, hydrogen, and water or its fragment hydroxyl.

NMS usually measures neutral gases and then makes them either positively or negatively charged using an electron beam to be sorted by mass in a mass spectrometer. However, NMS will occasionally use another mode to directly

search for ions that are already present in this space environment.

Lunar Dust Experiment

The Lunar Dust Experiment is located on the upper deck of the spacecraft and will detect lunar dust particles in the tenuous atmosphere. These measurements will help scientists address longstanding mysteries, including: was lunar dust, electrically charged by solar ultraviolet light, responsible for the pre-sunrise horizon glow that the Apollo astronauts saw? The Principal Investigator is Mihaly Horanyi, at the Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder.

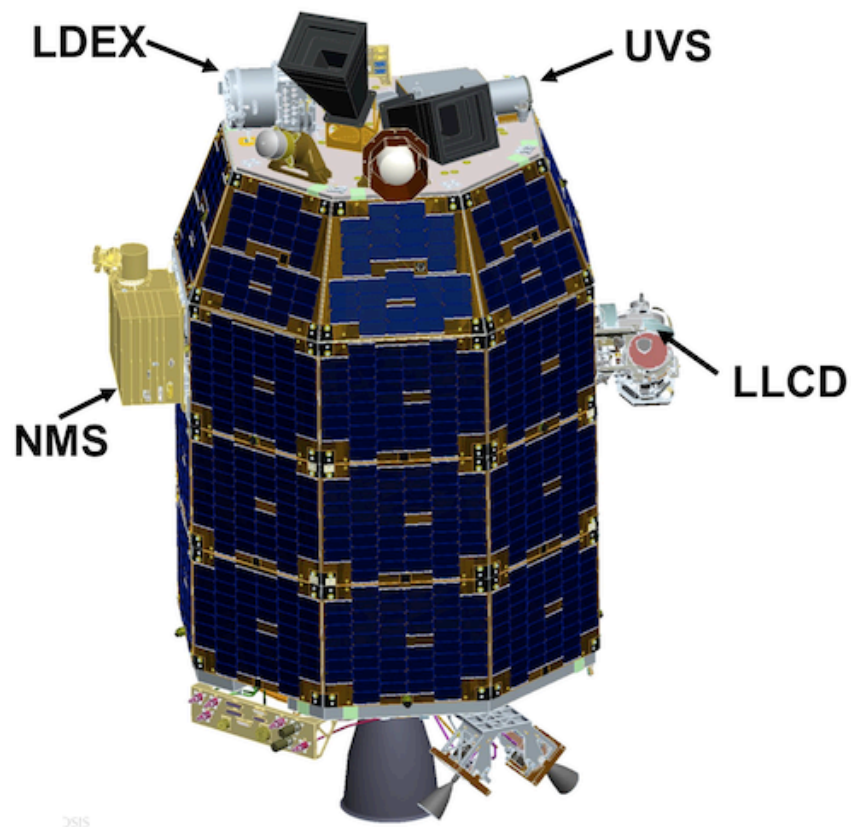
LDEX senses dust impacts using the impact-generated plasma in a charge detection assembly. Dust particles impact a large hemi-spherical target and create clouds of electron and ion pairs. The latter are focused and accelerated in an electric field and detected at a micro-channel plate. LDEX is designed to operate even at the relatively low LADEE orbital speed of 1.6 km/s, and will detect single impacts of individual particles with radii approximately 1 micrometer (The diameter, or thickness of the average human hair is 100 micrometers). In addition, LDEX can also identify the collective signal of the simultaneous hits of particles with radii bigger than 0.1 micrometer. If present at the predicted levels, these tiny grains will be measured through their impact generated current in LDEX.

LADEE Bloodline

LADEE's UVS instrument is a next-generation, high-reliability version of the UV-Visible spectrometer that flew onboard NASA's LCROSS mission.

LADEE's NMS will build on the heritage of similar mass spectrometers in predecessor NASA missions including the Science Analysis at Mars Instrument onboard the Curiosity rover; the Cassini Orbiter; Comet Nucleus Tour; and the Mars Atmosphere and Volatile Evolution missions.

Finally, the LDEX design heritage includes instruments aboard HEOS 2, Ulysses, Galileo and Cassini.



*LADEE spacecraft and instrument locations.
Image credit: NASA Ames*

Why Study the Moon's Exosphere?

Earth's atmosphere is critically important to all of us. In addition to providing us with air to breathe, it protects us from temperature extremes, harmful space radiation, and vast numbers of incoming meteoroids. The atmosphere is a very complex system that we are only beginning to understand. Gaining a better understanding of the atmosphere, how it protects us, and how we can protect it is in all of our interests.

In order to understand Earth's atmosphere and how it works, it is essential to study atmospheres under a wide range of conditions beyond Earth. Examining atmospheres on other planets allows this. For example, by studying the atmosphere of Venus, we learned about the role of carbon dioxide as a greenhouse gas, and saw how it drives the temperature on Venus as high as 860 degrees Fahrenheit (460 degrees Celsius).

The moon has a type of atmosphere scientists call a surface boundary exosphere. This very thin atmosphere may actually be the most common type of atmosphere in our solar system. Yet despite occurring so frequently, surface boundary exospheres largely remain a mystery. The moon, Mercury, larger asteroids, many moons orbiting the solar system's giant planets and even some of the distant Kuiper Belt Objects beyond Neptune, all have surface boundary exospheres.

To fully understand atmospheres and how they work, we also need to understand the most common type. Fortunately, the moon is in our own celestial "backyard," and NASA's Lunar Atmosphere and Dust Environment Explorer's (LADEE) observations of the lunar atmosphere and surface conditions will provide us with insights we can apply to many worlds.



This image shows the moon, Earth's only natural satellite, at center with the limb of Earth near the bottom transitioning into the orange-colored troposphere, the lowest and most dense portion of the Earth's atmosphere. The troposphere ends abruptly at the tropopause, which appears in the image as the sharp boundary between the orange- and blue-colored atmosphere. The silvery-blue noctilucent clouds extend far above the Earth's troposphere. Image Credit: NASA

Science Overview

LADEE Science Overview

NASA's LADEE mission will extend the knowledge it will gain about the moon to inform our understanding of the development of the other planetary bodies in the inner solar system: Mercury, Venus, Earth and Mars. As the most accessible planetary body besides Earth, and as one that is thought to have changed little since its initial development (unlike Earth, Mars, and Venus), the moon offers a unique look into the distant past of planetary evolution.

A surprising discovery was made in the 1960s, when Apollo astronauts saw diffuse emissions above the moon's surface. LADEE will determine whether what they saw is Na glow or dust and document the dust impactor environment (size-frequency) to help guide design engineering for outpost and future robotic missions.

The primary LADEE science objectives are to

- determine the global density, composition, and measure any spatial and temporal variability of the moon's fragile atmosphere
- investigate the processes that control its distribution and variability, including sources, sinks, and surface interactions
- characterize the lunar exospheric dust environment and variability and impacts on the lunar atmosphere
- Determine the size, charge, and spatial distribution of electrostatically transported dust grains and assess their likely effects on lunar exploration and lunar-based astronomy.

A secondary science objective is to extend knowledge gained from the moon to other terrestrial planets. These objectives will be achieved during a 100-day Science Phase.

Science Team

LADEE Science Team

Sarah Noble, program scientist,
NASA Headquarters, Washington

Richard Elphic, project scientist,
NASA's Ames Research Center, Moffett
Field, Calif.

Greg Delory, deputy project scientist,
NASA's Ames Research Center, Moffett
Field, Calif.

Ultraviolet and Visible Light Spectrometer

Anthony Colaprete, principal investigator,
NASA's Ames Research Center, Moffett
Field, Calif. Other members of the UVS
science team, include Diane Wooden and
John Karcz at Ames.

Neutral Mass Spectrometer

Paul Mahaffy, principal investigator,
NASA's Goddard Space Flight Center,
Greenbelt, Md. Other members of the
NMS science team, include Mehdi Benna
at Goddard, and Richard Hodges at the
University of Colorado.

Lunar Dust Experiment

Mihaly Horanyi, principal investigator
Laboratory for Atmospheric and Space
Physics (LASP), University of Colorado at
Boulder. Other members of the LDEX
science team, include Zoltan Sternovsky
at LASP CU Boulder, Eberhard Gruen at
the University of Colorado/Max Planck
Institut fur Kernphysik, and Ralf Srama at

the University of Stuttgart.

Guest Investigators

Jasper Halekas at the University of
California, Berkeley.
"Quantifying the links between the space
plasma environment and the lunar dusty
atmosphere: A virtual plasma instrument
for LADEE"

Dana Hurley at the Johns Hopkins
University Applied Physics Laboratory,
Laurel, Md.
"Exospheric modeling for interpretation of
LADEE data"

Sascha Kempf at the University of
Colorado
"Investigating Dust Exospheres by
LADEE"

Menelaos Sarantos at the University of
Maryland, Baltimore County
"A toolbox of exospheric models and
visualization methods for LADEE data
acquisition and interpretation"

Tim Stubbs at Goddard
"Exploring the Lunar Exospheric Dust
Environment with LADEE"

Program / Policy Management

NASA's Ames Research Center, Moffett Field, Calif., is responsible for managing the LADEE mission, building the spacecraft and performing mission operations for NASA's Science Mission Directorate, Washington. The LADEE mission is part of the Lunar Quest Program managed at NASA's Marshall Space Flight Center in Huntsville, Ala. NASA's Goddard Space Flight Center, Greenbelt, Md., is responsible for managing the science instruments and technology demonstration payload, and the science operations center. NASA Wallops Flight Facility will be responsible for launch vehicle integration, launch services, and launch range operations.

At NASA Headquarters, John Grunsfeld is associate administrator for the Science Mission Directorate.

James Green is director of the Planetary Division.

Joan Salute is LADEE program executive, and Sarah Noble is the program scientist.

At Ames, Butler Hine is LADEE project manager. Dawn McIntosh is deputy project manager.

At Marshall, Danny Harris is the Lunar Quest program mission manager.

At Goddard, Robert Caffrey is the LADEE payloads manager.

At Wallops, Doug Voss is launch manager.

Orbital Sciences Corp., of Dulles, Va., will operate the U.S. Air Force Minotaur V rocket, an excess ballistic missile converted in to a space launch vehicle.

Missions to the Moon

Historical Exploration of the Moon

1609

Hans Lippershey invented the telescope.

1610

Italian astronomer Galileo Galilei made the first telescopic observation of the moon.

1610

Thomas Harriot and Galileo Galilei drew the first telescopic representation of the moon.

1645

Michael Florent van Langren made the first map of the moon.

1647

Johannes Hevelius published the first treatise devoted to the moon.

1651

Giovanni Battista Riccioli named craters after philosophers and astronomers.

1753

Roger Joseph Boscovich proved the moon has no atmosphere.

1824

Franz von Gruithuisen thought craters were formed by meteor strikes.

1920

Robert Goddard suggested sending rockets to the moon.

1959

Soviet spacecraft Luna 2 reached the moon, impacting near the crater Autolycus.

1961

President John F. Kennedy proposed a manned lunar program.

1964

NASA's Ranger 7 produced the first close-up TV pictures of the lunar surface

1966

Soviet spacecraft Luna 9 made the first soft landing on the moon.

1967

NASA's Lunar Orbiter missions completed photographic mapping of the moon.

1968

NASA's Apollo 8 made the first manned flight to the moon, circling it 10 times before returning to Earth.

1969

Apollo 11 mission made the first landing on the moon and returned samples.

1969

(Nov.) Apollo 12 made first precision landing on the moon.

1972

Apollo 17 made the last manned landing of the Apollo Program.

1976

Soviet Luna 24 returned the last sample to be returned from the moon (to date).

1990

NASA's Galileo spacecraft obtained multispectral images of the western limb and part of the far side of the moon.

1994

NASA's Clementine mission conducted multispectral mapping of the moon.

1998

NASA's Lunar Prospector launched.

2007

Japanese SELENE (Kaguya) launched. Chinese Chang'e 1 launched.

2008

Indian Chandrayaan 1 launched.

2009

NASA's Lunar Reconnaissance Orbiter and Lunar CRater and Observation and Sensing Satellite (LCROSS) launched; LCROSS impact

2011

NASA's Gravity Recovery And Interior Laboratory (GRAIL) satellites launched.

NASA's Lunar Quest Program

NASA's Lunar Quest Program is a multi-element program consisting of flight missions, instruments for lunar missions of opportunity, as well as research and analysis efforts. NASA's Marshall Space Flight Center in Huntsville, Ala., has program management responsibility for the Lunar Quest Program, providing overall mission management oversight.

In addition to LADEE, Lunar Quest also oversees NASA's Lunar Reconnaissance Orbiter (LRO), which was launched on an Atlas V rocket on June 18, 2009 with a mission of mapping the moon's surface. The observations of LRO have enabled numerous groundbreaking discoveries, and the mission is still collecting invaluable data about the moon.

As a complement to NASA's larger "flagship" planetary science explorations, the Lunar Quest Program goal is to engage the science community to prioritize mission objectives and robotic lunar exploration of the moon.

For more information about NASA's Lunar Quest program, visit:

<http://www.nasa.gov/lunarquest>