THE LUNAR ATMOSPHERE AND DUST ENVIRONMENT EXPLORER (LADEE): INITIAL SCIENCE RESULTS. R. C. Elphic[1], B. Hine[1], G. T. Delory[2], J. S. Salute[3], S. Noble[3], A. Colaprete[1], M. Horanyi[5], P. Mahaffy[4], and the LADEE Science Team, [1]Planetary Systems Branch, NASA Ames Research Center, MS 245-3, Moffett Field, CA, 94035-1000, [2]Space Sciences Laboratory, University of California, Berkeley CA 94720, [3]Planetary Science Division, Science Mission Directorate, NASA, Washington, DC 20546, [4]NASA Goddard Space Flight Center, Greenbelt, MD, 20771, [5]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309

Introduction: On September 6, 2013, a near-perfect launch of the first Minotaur V rocket successfully carried NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) into a high-eccentricity geocentric orbit. The launch, from NASA's Wallops Flight Facility in Virginia, was visible from much of the eastern seaboard. Over the next 30 days, LADEE performed three phasing orbits, with near-perfect maneuvers that placed apogee at ever higher altitudes in preparation for rendezvous with the Moon. LADEE arrived at the Moon on October 6, 2013, during the government shutdown.

Objectives: LADEE's science objectives are twofold: (1) Determine the composition of the lunar atmosphere, investigate processes controlling its distribution and variability, including sources, sinks, and surface interactions; (2) Characterize the lunar exospheric dust environment, measure its spatial and temporal variability, and effects on the lunar atmosphere, if any.

Payload: The LADEE science payload consists of three instruments. A neutral mass spectrometer (NMS) samples lunar exospheric gases *in situ*, covering the 2-150 Dalton mass range. An ultraviolet/visible spectrometer (UVS) acquires spectra of atmospheric emissions and scattered light from tenuous dust, spanning 250-800 nm wavelength, with <1 nm spectral resolution. UVS also performs dust extinction measurements via a separate solar viewer optic. The Lunar Dust Experiment (LDEX) senses dust impacts *in situ*, at LADEE orbital altitudes, with a particle size range of between 100 nm and 5 μm. A fourth instrument is the Lunar Laser Communications Demonstration (LLCD), a test of high-speed optical communications capable of higher bandwidth than conventional radio frequency communications.

Commissioning: Following a nominal Lunar Orbit Insertion-1 burn, LADEE underwent a series of orbit lowering maneuvers until the commissioning orbit was achieved on October 12, with a mean altitude of 240 km. After initial checkout and cover deployment, there followed about 30 days of alternating science instrument checkout and highly successful LLCD operations.

The instrument teams conducted some preliminary science activities while at the high commissioning altitudes. NMS was able to observe atmospheric helium, which can reach high altitudes. LDEX, the first dedicated dust instrument to orbit the Moon, began recording dust impacts as soon as the cover opened. A lunar dust exosphere was expected theoretically, and similar phenomena were seen by Galileo flybys of Jupiter's icy moons. But LDEX made the first measurements of such an exosphere at the Moon. UVS made measurements of atmospheric sodium and potassium at lunar sunset, sunrise and noon.

Science Mission: With commissioning completed, LADEE lowered periapsis over the sunrise terminator on Nov. 10, and on Nov. 20 lowered apoapsis as well. Periapsis and apoapsis are maintained between 20 and 50 km, and 75 and 150 km, respectively.

Everything changed when LADEE swooped down to 50 km above the moon's surface on Nov. 10. At that low vantage point, NMS was able to detect Argon-40 for the first time, and see its distinctive variation across the sunrise terminator. Argon-40, a noble gas, has a lower scale height than that of helium, and can condense on the cold nightside lunar surface. The rate that LDEX was sensing lunar dust at high altitudes (approximately one dust grain every few minutes) suddenly increased several-fold at 50 km.

LDEX has also been observing occasional bursts of dust particles, where rates increase from about one particle per minute to several hundreds of hits in under 30 seconds. These bursts may be due to LADEE flying through the dust plumes thrown up from the lunar surface when a meteoroid impacts the lunar surface near the LADEE orbit.

NMS has continued to monitor helium and argon, and has now observed neon as well. New UVS measurements of potassium and sodium promise to tell us the origins of these exotic species. And the day after Thanksgiving, Nov. 29, three distinct meteoroid impacts on the moon were recorded by the Meteoroid Environment Office's Lunar Impact Monitoring Program, based at NASA's Marshall Space Flight Center. Knowing the location and time of these impacts, LADEE's measurements of their effects can help us understand how atmospheric species can be produced by such events, and provide measurements of dust plumes they create.

LADEE Watches for Chang'e 3: The Chinese lunar mission Chang'e 3 landed in northern Mare Imbrium at 13:10 UTC Dec. 14, 2013. LADEE was watching too. Earlier, LADEE controllers had uploaded a command sequence that scheduled the science instruments for operations prior to and during the Chang'e 3 landing period.

The Neutral Mass Spectrometer (NMS) was running in a mode that would allow it to monitor native lunar atmospheric species, as well as those resulting from Chang'e 3's propulsion system. These combustion products were known to include diatomic nitrogen, water, diatomic hydrogen and several other species. LDEX and UVS ran in their normal configurations and were capable of detecting ejected dust and gas species from the landing, provided these products could make the long trek to LADEE's position, far from the landing site.

LADEE's retrograde, near-equatorial orbit never strays beyond approximately 22.5 degrees north and south latitude. Chang'e 3's landing site was far to the north of LADEE's path, at 44.12N and 19.51W. At the time of landing, LADEE was orbiting over a different part of the moon east of the Chang'e 3 path, at 21.77 degrees south latitude and 82.17 degrees east longitude - more than 3,400 km away.

At 13:41 UTC, about 30 minutes after the Chang'e 3 landing, LADEE flew over 19.51W longitude. At this time, LADEE was still more than 1,300 km south of the landing site. The NMS had started exosphere observations at 13:22 UTC and would continue for 55 minutes as LADEE sped across the lunar sunrise terminator and into lunar night. The UVS had performed atmospheric scans one orbit previous (LADEE's orbit period is about 2 hours), around 12:15 UTC, and would do so again later. The LDEX was operating normally, recording dust impacts prior to, during and after the Chang'e 3 descent.

Surprisingly, the LADEE science teams' initial evaluation of the data did not reveal any large effects attributable to Chang'e 3. An increase in dust was observed by LDEX, but this increase had started one day earlier and was evidently linked to the Geminid meteoroid shower. No dramatic change was seen by UVS. Evidently, the native lunar atmospheric species normally seen by UVS and NMS were unaffected as well. Evidently, exhaust products from a large robotic lander do not overwhelm the native lunar exosphere. As the descent video shows, the interval of time that dust was launched by the lander is very short, perhaps less than 15 seconds. LADEE would probably have had to be in just the right place at the right time to intercept it. However, more careful examination of the LADEE data is needed. We can compare these results to theoretical predictions of gas and exhaust plume particle ejecta, and update our understanding of the interaction of lander propulsion systems with surface materials.

Early LADEE Science: The talks presented in this special session will highlight LADEE's preliminary science results. These include initial observations of argon, neon and helium exospheres, and their diurnal variations; the lunar micrometeoroid impact ejecta cloud and its variations; spatial and temporal variations of the sodium exosphere; and observations of sunlight extinction caused by dust, as well as other topics.

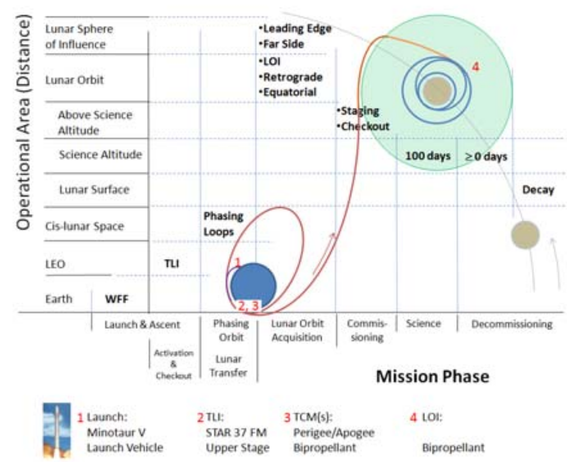

Fig. 1. LADEE's journey to the Moon.