NEUTRAL MASS SPECTROMETER UNDER DEVELOPMENT FOR THE LUNAR ATMOSPHERE AND DUST ENVIRONMENT EXPLORER (LADEE) MISSION.

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Introduction: The objectives of the LADEE Mission given in the March 21, 2008 Request for Information (RFI) from the Lunar Science Program of NASA's Science Mission Directorate [1] were:

- Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity;
- Determine if the Apollo astronaut sightings of diffuse emission at 10s of km above the surface were Na glow or dust and;
- Document the dust impactor environment (size-frequency) to help guide design engineering for the outpost and also future robotic missions.

These objectives were derived most immediately from the report of the LADEE Science Definition Team [2] and are consistent with the National Research Council's report, "Scientific Context for the Exploration of the Moon" [3].

NASA selected for the LADEE payload an Ultraviolet Spectrometer, a Neutral Mass Spectrometer, and a Dust Detector. The core science mission to be implemented in the 2012 time frame is 90 days to allow measurements to be made over a period of one or more lunations and examine the lunar exosphere in different space environments from an orbital altitude of 50 km or lower. In addition to the science mission NASA plans to use this mission to demonstrate optical communication technology away from low Earth orbit.

Species in Lunar Exosphere: To date, the four constituents He, Ar, K, and Na have been firmly identified [4, 5] in the lunar exosphere by mass spectrometers accommodated by the Apollo program and by ground based spectroscopy. The source of the species in the lunar exosphere can be from (1) the solar wind, (2) from the lunar regolith, and (3) from the lunar interior. He, both K and Na, and ^{40}Ar are expected to be predominantly from these three sources respectively. Nevertheless, upper limits have been set for a large number of other atomic and molecular species. These upper limits vary widely [5] from greater than 1,000 particles/cc predicted at 50 km above the surface for Mg, Al, Kr, Xe, CO, H_4, H_2, and OH to tens to hundreds of particles/cc for Si, Al, Fe, CO_2, H, N, C, N_2, O, and S. The LADEE measurements are designed to measure the abundance of several of these species and substantially lower the upper limits for others.

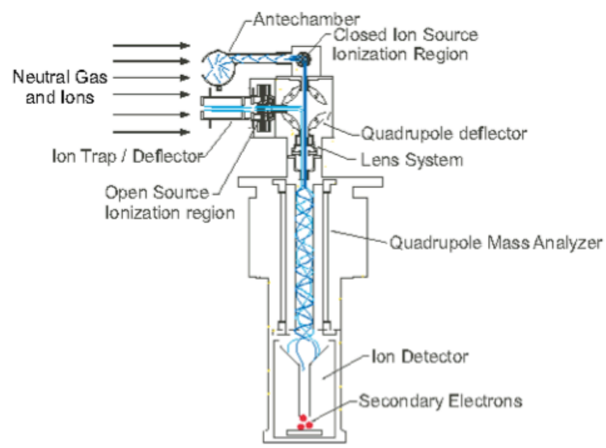

Figure 1. *A schematic of the various elements of the NMS.*

Spatial/temporal variability of lunar species: The Apollo in situ measurements and remote sensing observations of the lunar exosphere have provided a general understanding of the spatial distribution and temporal variability of the detected species. In the collisionless environment away from the surface, released particles follow ballistic trajectories and either return to the surface after hops of tens to hundreds of km or escape. Species such as Ar that condense at nighttime on the dark side of the moon show peak concentrations at the dawn terminator as the sun warms the regolith. The limited day/night variations measured by Apollo have been satisfactorily modeled but the reported [6] longer-term variability due to possible episodic release from the lunar interior is not well characterized. The minimum 90-day LADEE science mission that would secure measurements over multiple lunations could search for such episodic release and also characterize the variability in the abundance of those species released directly from the regolith by sputtering or photon simulated desoption in the changing surface space environment.

The LADEE Neutral Mass Spectrometer (NMS): The LADEE NMS consists of the engineering unit (EU) Neutral Gas and Ion Mass Spectrometer (NGIMS) developed for the CONTOUR mission. This mass spectrometer (Figures 1-3) is a similar design to the Cassini Ion and Neutral Gas Mass Spectrometer (INMS) designed and developed at NASA Goddard as a facility instrument for this mission. However, while the NGIMS ion mass analyzer and ion optics design is similar to the INMS the mass spectrometer sensitivity has been increased by more than a factor of ten (to > $5x10^{-3}$ (counts/sec)/(part/cc) for a compound with the same ionization cross section as molecular nitrogen) by modifications to the electron gun and ion focusing optics. The attention to instrument sensitivity that was motivated by the low gas densities expected during the CONTOUR comet nucleus flyby should serve the LADEE mission well to search for trace species in the tenuous lunar exosphere.

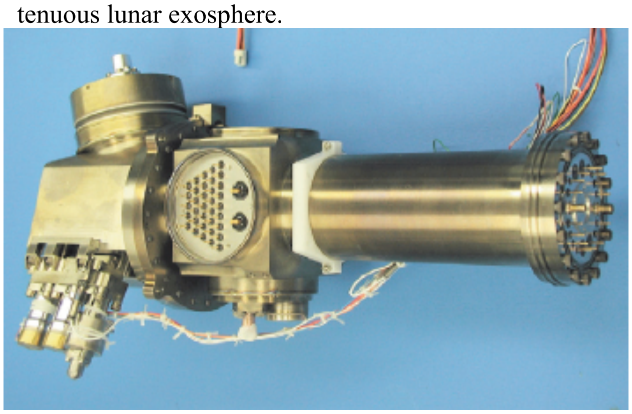

Figure 2. *The NMS sensor housing showing the detector flange on the right and the ion source cover and pyrotechnic break-off cap on the left. The cylindrical section of the mass spectrometer housing is 2 inches in diameter. The NMS electronics will be adapted from those of the Mars Science Laboratory Sample Analysis at Mars suite.*

The NMS employs a quadrupole mass filter and redundant detectors. The flexible gas sampling system consists of two ion sources, designated "open" and "closed", each optimized for a specific mode of measurement of lunar exosphere neutral gases. In a third sampling mode, thermal or suprathermal ambient ions in the lunar atmosphere are sampled by NMS. The mass range of the instrument is 1 to 150 Da and rapid mass selection allows for a high spatial resolution tracking of the density profile of selected species over the course of a lunar orbit.

The NMS closed source is most suitable for measurements of He and Ar. A RAM density enhancement is realized in this source and the measurement of these inert noble gas species is not impacted by the multiple wall collisions in this source prior to ionization. On the other hand, the open source is required for a search for species such as metal atoms that are surface reactive. In this source the atomic or molecular species are ionized and focused into the quadrupole analyzer without wall collisions. A LADEE rotisserie mode is planned to scan the field of view of the open source across the lunar surface for a subset of the orbits to optimize its sampling. The NGIMS field of view of ~6 degrees will be increased several fold for the LADEE NMS to increase measurement sensitivity in this mode. Ambient ions are also measured through the open source with the ionizing electron beam suppressed or turned off.

The NMS can switch to any arbitrary m/z value in the 1-150 Da range of the mass spectrometer in either "open", "closed", or "ion" modes within the 30 milli second integration period of the detector. This allows much of the integration time to be spent on mass channels of interest. A NMS "adaptive" scan mode allows selected bands of mass values to be selected to search for unexpected species. If the signal in any band is above a threshold increased integration time can then be allocated by the scan algorithm to unit scans in this region.

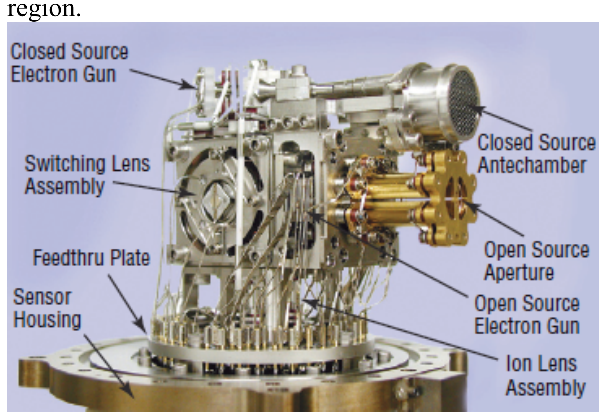

Figure 3. *The NMS dual ion source is shown with the ion source cover removed. The mounting block that contains the switching lens assembly is ~ 1 in on each side.*

References: [1] http://nspires.nasaprs.com, Solicitation number NNH08ZDA006L, March 21, 2008. [2] Leshin, L. A. et al., Proceedings of the Lunar Science Conference, 2163 (2008). [3] Space Studies Board, NRC, (2007) National Academies Press, http://www.nap.edu/catalog.php?record_id=11954. [4] Hodges, R. R., et al., Icarus 21, 415 (1974). [5] Stern, S. A., Rev. Geophys., 37, 453 (1999). [6] Hodges, R.R., Proc. 6th Lunar Sci. Conf., 3039 (1975)