CALIBRATION OF THE NEUTRAL MASS SPECTROMETER FOR THE LUNAR ATMOSPHERE AND DUST ENVIRONMENT EXPLORER (LADEE) MISSION. P. R. Mahaffy[1], R. R. Hodges[2], D. N. Harpold[1], T. T. King[1], F. Jaeger[1], E. Raaen[1], E. Lyness[1], M. Collier[1], and M. Benna[1]. NASA Goddard Space Flight Center, Code 699, Greenbelt, MD 20771 (Paul.R.Mahaffy@NASA.gov), [2]U. Colorado, Laboratory for Atmospheric and Space Physics, 1234 Innovation Drive, Boulder, CO 80303.

Introduction: Science objectives of the LADEE Mission are to (1) determine the composition, and time **variability of the tenuous lunar atmosphere** and (2) to characterize the **dust environment and its variability.** These studies will extend the insitu characterization of the environment that were carried out decades ago with the Apollo missions and a variety of ground based studies. The focused LADEE measurements will enable a more complete understanding of dust and gas sources and sinks. Sources of gas include UV photo-

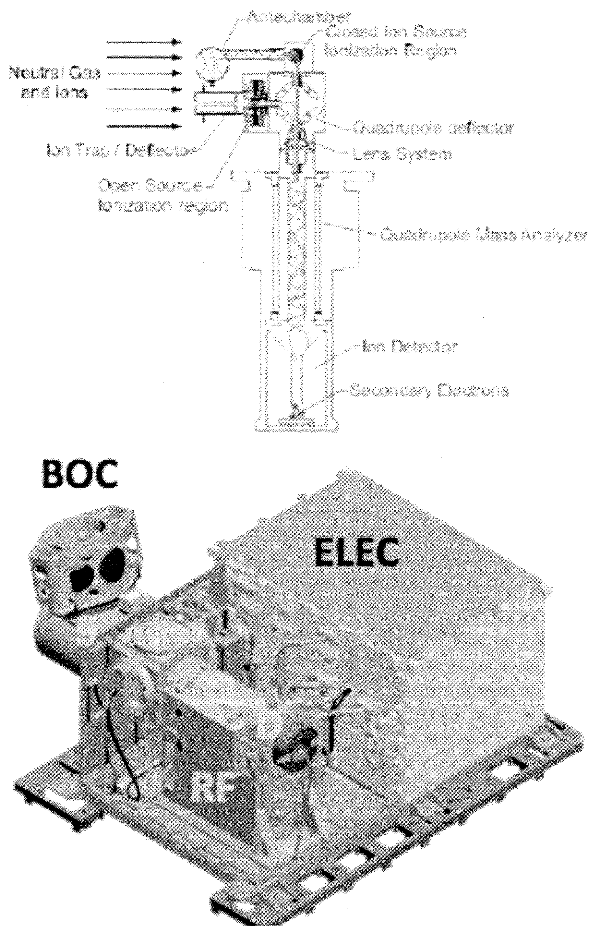

Figure 1. *Top - NMS elements; bottom model shows (BOC=break-off cap, ELEC=electronics, S=ion source region, Q=quadrupole region, D=detector, RF=radio frequency.*

stimulated desorption, sputtering by plasma and micrometeorites, as well as thermal release of species such argon from the cold surface or venting from the lunar interior. Sinks include recondensation on the surface and escape through a variety of mechanisms. The LADEE science payload consists of an Ultraviolet Spectrometer, a Neutral Mass Spectrometer, and a Dust Detector. The LADEE orbit will include multiple passes at or below 50 km altitude and will target repeated sampling at the sunrise terminator where exospheric density will be highest for some thermally released species. The science mission will be implemented in approximately three months to allow meas urements to be made over a period of one or more lunations In addition to the science mission NASA will use this mission to demonstrate optical communication technology away from low Earth orbit.

The Neutral Mass Spectrometer and its measurement objectives: The elements of the LADEE NMS are shown in Figure 1. Its ion dual ion source, hyperbolic quadrupole rod assembly, and vacuum housing consist of refurbished elements of the engineering unit Neutral Gas and Ion Mass Spectrometer (NGIMS) developed for the CONTOUR mission. This mass spectrometer (Figure 1) 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 to the moons of Saturn. With a new ion/electron optical design the sensitivity of the NMS has been improved over the INMS by more than an order of magnitude to optimize measurements in the low density lunar exosphere. The NMS closed source is suitable for species that do not adsorb on ion source surfaces such as 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. The NGIMS field of view of ~6 degrees will be increased several fold for the LADEE NMS to increase measurement sensitivity in this mode and its look direction can be commanded by rotation of the spacecraft. The NMS quadrupole analyzer will transmit a selected m/z value in the 1-150 Da range of the mass spectrometer in either "open" or "closed"modes within the integration period of the detector which can be set to as low

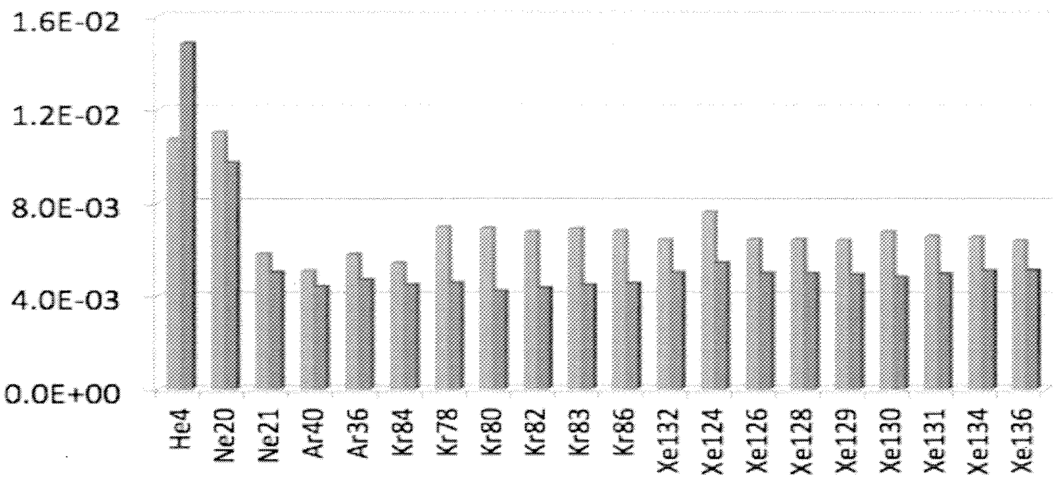

Figure 2. *Sensitivity values established with one of the calibration runs for the closed source for each of the redundant detectors are shows for the noble gas isotopes. The sensitivity plotted on the vertical axis is in units of (counts/second)/(particle/cc) after normalization using ionization cross-sections to that of N_2 to illustrate the differences between the low (^{21}Ne thru ^{136}Xe) and high frequency (^{4}He thru ^{20}Ne) FR regions.*

as 7 msec. A table driven mass scan 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. Four constituents He, Ar, K, and Na have been firmly identified [1,2] in the lunar exosphere by mass spectrometers accommodated by the Apollo program and by ground based spectroscopy. The NMS will secure measurements of He and Ar while the UVS will measure K and Na. Upper limits for a large number of other atomic and molecular species vary widely [2] 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 combined NMS and UVS LADEE measurements are expected to determine the abundance of several of these species and substantially lower the upper limits for others.

NMS calibration approach on the vacuum chamber: The NMS calibration will enable the response of the NMS to lunar gas to be established so that the detector counts measured in lunar orbit can be converted into ion source densities for the open source and into neutral flux into the closed source. The NMS was calibrated on a thermal gas ultra-high vacuum chamber pumped by magnetically levitated turbomolecular pumps. Both the chamber and the mass spectrometer were baked for several days prior to calibration. High purity N_2 and the noble gases He, Ne, Ar, Kr, and Xe were utilized either as single gases or as mixtures. The flow out of the vacuum chamber was limited by an iris valve to minimize density gradients within the vacuum chamber. A NIST tracable Bayard Alpert gauge measured pressure. The mass spectrometer was operated with first with ground support equipment (GSE) electronics to optimize lens focusing and to establish the response of the detector signal to variations in lens voltages and then moved to the NMS flight electronics.

NMS calibration after separation from the vacuum chamber: The NMS sensor incorporates a passive chemical getter that can remove the active gases. After the chamber calibration described in the preceeding paragraph had been completed a mixture of noble gases He, Ar, Kr, and Xe was prepared and several static mode mass spectrometer scans carried out where the only pump utilized was the the getter. The sensitiveity of the closed source established for various noble gas isotopes from one of these runs is shown in Figure 2. When the density of noble gasses in the mass spectrometer was judged to be appropriate for testing in the next set of environmental tests planned (thermal, vibration, electromagnetic, etc.) the NMS sensor was totally isolated from the pumping system by a cold weld pinch off operation. This residual noble gas will remain in the mass spectrometer and can be utilized to establish instrument tuning and sensitivity until the break-off cap is removed prior to science operations at the moon.

References: [1] Hodges, R. R., et al., Icarus 21, 415 (1974). [2] Stern, S. A., Rev. Geophys., 37, 453 (1999).