NEXT GENERATION LUNAR SCIENCE EXPERIMENT PACKAGES. P.E. Clark[1], R. Lewis[2], P. S. Millar[2], P.S. Yeh[2], J. Lorenz[3], and L. Leshin[2] [1]Catholic University of America (Physics Department), [2]NASA/GSFC, [3]Northrop Grumman; all at NASA/GSFC, Greenbelt, MD 20771, Pamela.E.Clark@NASA.gov.

Introduction: In order to support the development of lunar surface architecture that will meet the published goals and objectives of the scientific community [1], we have been part of several interdisciplinary teams of scientists and engineers that have been formulating how to implement these goals and evaluating surface operational strategies in terms of their impact on surface science activities [2]. Implementation of these goals will involve: 1) delivering a lunar environmental monitoring package as early as possible, 2) delivering site analysis and sampling tools along with rover with tens of kilometers mobility capability in the first human crewed mission, with resupply kits on each human crewed mission, 3) delivering a series of global scale interior monitoring stations and deploying them at sites separated by hundreds of kilometers, and 4) providing laboratory analysis capability correlated to the length of the stay on the surface. The efforts described in detail here involve conceptualizing and investigating state-of-the-art design and components for generic state-of-the-art science packages for the ultra cold and dark conditions of the lunar surface [3], with particular emphasis on instruments which have the highest priority for early deployment.

Our study demonstrated that when conventional approaches are used in designing instrument packages, performance suffers and mass and cost parameters grow significantly as a result of increased thermal protection and battery power requirements necessary to withstand lunar environmental conditions within needed operational constraints.

Instrument packages under consideration: Three packages underwent preliminary system and subsystem design using a conventional instrument package design approach at the GSFC ISAL (Instrument Systems Analysis Laboratory) facility. These included an environmental monitoring station (LEMS) (Figure 1), an unpressurized carrier, and a small Earth Observing telescope package. We assumed the need for stand alone power, because the need to deploy in an area free from contamination brought by human presence would mean deploying kilometers away from a human habitat. We also assumed we would need to depend on solar panels and backup batteries, because of the uncertainty over the future availability of Pu238-based batteries that were used on Apollo missions.

LEMS is designed to provide detailed measurements and comprehensive understanding of the interactions between radiation, plasma, solar wind, magnetic and electrical fields, exosphere, dust and regolith.

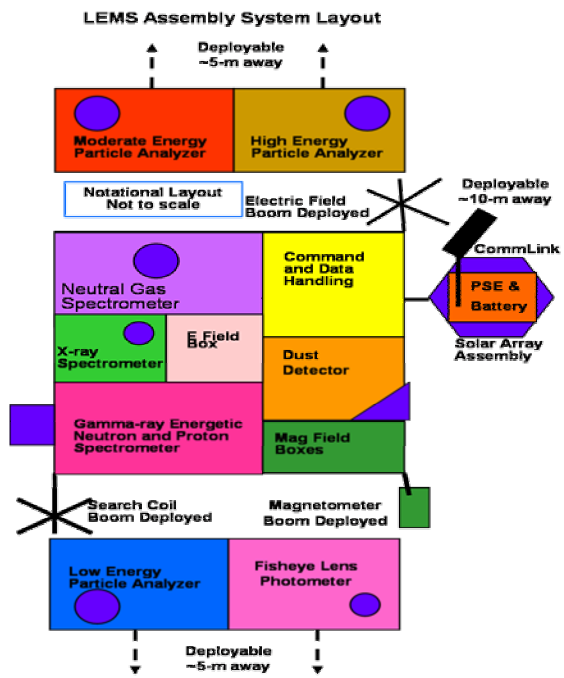

Figure 1: Schematic of one of Lunar Environmental Monitoring Station (LEMS).

It is not only representative of automated lunar science stations which would provide a much needed context for in depth understanding of the Moon, and is a primary candidate for early deployment before contamination of the lunar exosphere. Thus LEMS would provide critical data on space weather and medium- to long-term trends in the lunar surface environment. The comprehensive instrument package consists of spectrometers to measure neutral gas species of the exosphere, X- and Gamma-radiation, energetic neutrons and protons from the solar and galactic radiation environment; particle analyzers to measure the spatial and energetic distribution of electrons and ions; a dust experiment to measure diurnal variations in the size, spatial, and velocity of lunar and micrometeorite dust; and electric and magnetic field instruments to indicate changes resulting from variations in solar activity, and terrestrial magnetic field interactions.

Using a Conventional Design Approach: LEMS is designed to be an automated stations powered by solar panels with batteries, and operational for up to five years. The station must survive the extreme cold (<100K), as well as days (5 to 14) of loss of solar power and thermal cycling at the poles due to umbral shadowing in otherwise 'permanently' illuminated locations or elsewhere due to diurnal variations. These lunar surface conditions are quite different from conventional deep space conditions where one side of the spacecraft is almost always illuminated and heat dissipation is the thermal issue. In fact, when conventional approaches were used to design the LEMS package, for example, battery mass driven by the need for power for survival heaters during periods of prolonged darkness became the overwhelming driver of the total mass with only 19% allocated for the instrument payload and 53% for the power system. The power allocation was 180W (85W for the instruments) during the day, 90W (60W for thermal heaters alone) at night with the instruments turned off, even though measurements made during periods of darkness are essential.

Alternative Thermal Design: Clearly, strategies which reduce the need for battery mass required for thermal survival, an issue particularly in minimal atmosphere surface environments with long periods of low to no illumination, are needed. The use of thermal design and innovative thermal balance strategies are crucial to design a package with mass, power, and volume significantly reduced to create opportunities for more science packages. We are modeling the use of multi-layer insulating packaging and heat pipe technology to reduce thermal loss, the need for survival heaters, and thus the need for battery mass. Similar design concepts are being tested in Antarctica and the Arctic as of this writing. Preliminary results indicate that we can reduce the total package mass by at least of factor of 2.

Incorporation of Ultra-low power, ultra-cold operating (ULP/ULT) components: Strategies which allow operation during periods of prolonged darkness, and resulting cold, are also essential to meet science requirements. Ultra-low power and low temperature (ULP, ULT) strategies, developed at GSFC and through partnerships with the University of Idaho and the Department of Defense (DoD) National Reconnaissance Office (NRO), are being used successfully and have demonstrated orders of magnitude savings in power consumption and thermal tolerance [3]. These systems include the use of CULPRiT (CMOS Ultra-low Power Radiation Tolerant) technology successfully flown on NASA's ST5 90 day mission in March 2006.

Based on preliminary information, we should be able to incorporate ULT/ULP components extensively in shared or unshared digital electronics of individual instruments, plus communication, control and data handling, power and thermal subsystems. ULP/ULT electronics cannot be applied analog portions of instruments, the electronics associated directly with sensor heads. We are in the process of testing this approach by applying it to a Goddard Space Flight Center (GSFC) science instruments package concept under development for LSSO.

Attempt to develop a new design strategy: Our strategy incorporates components and design concepts which radically minimize power, mass, and cost while maximizing the performance under extreme cold and dark conditions even more demanding than those routinely experienced by spacecraft in deep space. In this way, instrument system and subsystem design, packaging, and integration will significantly enhance the opportunities for the science community to develop selectable, competitive science payloads.

Our ultimate goals include the development of a plan for advancing recommended technologies in application to lunar surface instruments, payloads, and associated systems to minimize mass, volume, and power requirements as a precursor to design guideline generation. This approach will leverage NASA's existing and projected unique capabilities within the creation and implementation of these technologies that are critically in demand to serve NASA's Vision for Exploration.

References: [1] Committee on the Scientific Exploration of the Moon (2007) National Academy of Science, Final Report, http://www.nap.edu/catalog/11954.html; [2] Clark, P.E. et al (2007) *LEAG Workshop, http://www.lpi.usra.edu/meetings/leag2007/pdf/3033.pdf*. [3] Maki and Yeh (2003) ESTO Conference, http://esto.nasa.gov/oldsite/conferences/estc2003/papers/A3P4(Yeh).pdf.

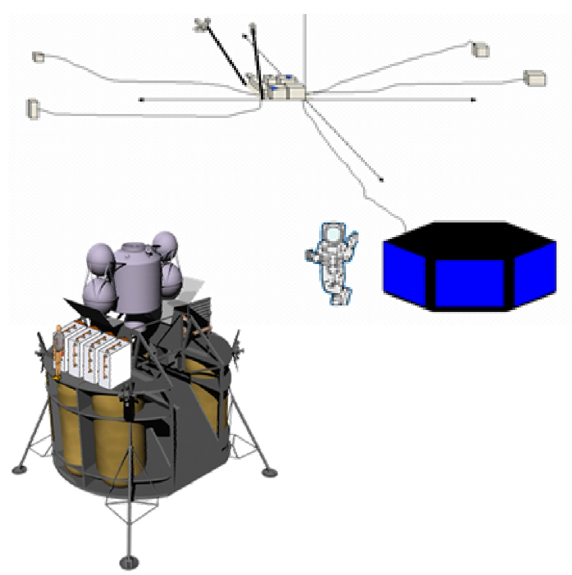

Figure 2: Schematic of deployed Lunar Environmental Monitoring Station (LEMS).