ENABLING MINIMAL MASS SCIENCE PACKAGES FOR LUNAR SURFACE STUDIES. P.E. Clark[1], R. Lewis[2], P. S. Millar[2], P.S. Yeh[2], J. Lorenz[3], S. Feng[2], W. Powell[2], B. Beaman[2], M. Choi[2], L. Cooper[2], 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: Lunar surface science packages must survive ultra cold (during extended dark periods) and extreme variations in thermal conditions, operating autonomously with stand-alone power systems whether delivered robotically or by a human crew. From the time of the Apollo era, radioisotope (Pu238) based power systems (RPS) have met the need to supply both power and heat in the coldest and darkest environments like those experienced periodically on the lunar surface, but, despite the recent announcement of several advanced stirling radiothermal generators, the systematic availability of radioisotope based power systems over the next decade and a half is uncertain. Our preliminary study demonstrated that when conventional (non-RPS) 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. The efforts described in detail here demonstrate that alternative state-of-the-art design and components for generic state-of-the-art science packages can at least meet the power and mass constraints of earlier packages without requiring the use of Pu238. We also identify strategies required to exceed them to produce min-payloads.

Instrument package considered in initial study: LEMS, a lunar environmental monitoring station, is a stand-alone automated package concept powered by solar panels with batteries with a suite of instrument and instrument capable of providing comprehensive measurements critical to understanding the interactions between radiation, plasma, solar wind, magnetic and electrical fields, exosphere, dust and regolith. Some version of LEMS would be a primary candidate for early deployment before contamination of the lunar exosphere. Instruments include 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 distribution 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: The LEMS faced the challenges typical of autonomous lunar surface science packages. 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. On the lunar surface, battery mass was driven by the need for power for survival heaters during periods of prolonged darkness and became the overwhelming driver of the total mass to 500 kg 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, 60W for thermal heaters alone at night with the instruments turned off, even though measurements made during periods of darkness are essential.

Table 1: Reduction in Mass and Power for LEMS

Design Regime	Conventional Electronics	Cold Electronics	New Pack-Concept	ALSEP approx
Performance	-10oC Op -20oC Surv	-40oC Op -50oC Surv	-40oC Op -50oC Surv	9 instruments
Battery Mass	240	120	60	30
Remaining Mass	260	260	184	70
Total Mass	500	380	244	100
Min Power	60	30	15	10

High Performance Electronics and Alternative Thermal Design: Just by introducing more robust electronics capable of operating over a wider temperature range, and particularly at colder temperatures, we reduced the required battery power by a factor of 2, as indicated in Table 1. We have introduced 2 thin insulating fiberglas layers (multi thin layer or MLT), a material used on JWST, as external packaging, along with heat pipes attached to radiators in each package, packaging instruments together when possible. These strategies combined with operating instruments on reduced duty cycles, reduce thermal loss, mitigate the need for active survival heaters, and reduce the thermal and power system masses. The preliminary results (Table 1) indicate that we can reduce the total package mass of the package by at least of factor of 2. We estimate that if we reduced the number of instruments slightly and used sold state versions of the instruments when possible, we would be operating in the ALSEP regime without the use of Pu238.