Low-Cost Distributed Networks for Lunar Geophysical or Environmental Monitoring. Pamela E. Clark[1], David Bugby[1], Keith Chin[1], [1]Jet Propulsion Laboratory, California Institute of Technology (pamela.e.clark@jpl.nasa.gov).

Overview: Credible opportunities for delivery of small payloads to the lunar surface via commercial landers are emerging in the coming decade. Characterization of the highly interactive environment of the lunar surface and subsurface, requires continuous operation. Due to the uniquely extreme lunar surface conditions (high radiation, 2-week <150K night, 2-week 150-400 K day), radioisotopes have been required for either full day and night operation: the Apollo Lunar Surface Experiment Package required deployment of a large RTG package. All others, including Lunakhod, Yutu, and proposed commercial designs using RHUs, were limited to daytime operation only and survival or 'hibernation' during lunar night. Despite the need for day and night operation to understand the dynamic nature of the lunar environment, and the availability of compact in situ instruments, RTG packages are expensive and not necessarily readily available.

Radioisotope Power: Pu238, by far the most desirable isotope for use in radio isotope based power supplies (RPS), is no longer readily available and, although development of future power Pu238-based power supplies has been planned for well over a decade, such RPS are relatively inefficient, require additional volume and mass for containment, and will be costly due to the complex multi-step process in the production, monitoring, and control of this strategic material.

Alternative approach: Successfully demonstrating the feasibility of a concept that would enable such measurements without the need for radioisotopes would represent a major breakthrough by enabling studies of the dynamic activities in extreme solar system surface environments via distributed, low cost platforms.

Preliminary studies have indicated that we could build comparable size packages with several instruments that could operate on at least a limited duty cycle during lunar night without radioisotopes [1,2]. Early indications are that payloads as small as 25 kg, the equivalent of a 12U cubesat, should be possible with current technology.

Overcoming the challenges: The most challenging problem is creating a thermal and power system designs to allow at least limited duty cycle night operation for a cubesat-scale package without radioisotopes. Recent developments in compact instruments and other technologies may now provide the basis for compact instrument packages with: 1) to a large extent, advanced far more efficient thermal switches, high performance insulators, heat pipe embedded material [3]; 2) greater survival and operational temperature range battery technology including state-of-the-art Li/electrolyte batteries demonstrated in CSUNSat1 [4]; 3) deployable systems for small/cubesats including stowable solar panels, thermal shields, antennas; 4) compact electronics that operate over greater temperature range, utilizing components more tolerant to total ionizing dose and NEPP-identified architectures less susceptible to latch-up [5].

We are in the process of developing and testing prototypes for compact, low-cost in situ lunar surface measurement packages with a highly efficient reverse thermal switch component as well as state of the art rechargeable Li/electrolyte batteries.

Distributed Network Concepts: We envision in situ measurement packages (deployed on or from lander decks or legs, not requiring mobility) as part of a Lunar Geophysical Network (prioritized in the latest decadal survey) or Environmental (including volatiles) Monitoring network (addressing Strategic Knowledge Gaps. Compact instruments could include two to three of the following: surface magnetometers, from which subsurface conductivity and temperature profiles, electromagnetic activity during terminator and Earth's magnetotail crossings, as well as buried resources can be inferred; 3-axis seismometers, to characterized internal and impact activity; laser retroreflectors, to provide Earth-Moon system dynamics; electric field instruments; mass spectrometer to provide ;particle analyzers and ULF E-field Instrument to determine electron and ion density range and variations and wave generation indicating field boundary crossings, and interactions of solar wind and SME particles with lunar surface.

References: [1] Clark et al, 2011, http://digitalcommons.unl.edu/nasapub/47; [2] Elliott and Alkalai, 2014, IAC-10-B4.8.5; [3] Bugby et al, 2010, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100011380.pdf; [4] Chin et al, 2014, AIAA/USU Conference on Small Satellites, SSC14-VII-9; [5] Peltz et al, 2016, https://solarsystem.nasa.gov/docs/ 4_Peltz_SiGe_Technology_for_Europa.pdf