

TECHNOLOGICALLY OPTIMIZED INSTRUMENT PACKAGES FOR LUNAR SURFACE SCIENCE.

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Introduction: Development of selectable, competitive science payloads requires optimization of instrument and subsystem design, packaging and integration for planetary surface environments to support solar system exploration fully. This process must be supported by incorporation of components and design strategies which radically minimize power, mass, and cost while maximizing the performance under extreme surface conditions that are in many cases more demanding than those routinely experienced by spacecraft in deep space.

Phase 1: Previously, we launched a multi-year effort to develop strategies and design concepts for ALSEP-like stand-alone lunar surface instrument packages with minimized mass/power requirements and without dependence on radioisotope-based batteries [1,2,3,4]. An initial conventional attempt to design an environmental monitoring package with a solar/battery based power system led to a package with an unacceptably large mass (500 kg) of which over half was battery mass. Our Phase 1 work led to considerable reduction (5x to 100 kg) in the initial mass of such a concept deployable near the poles (up to a few days of darkness once a year) by incorporating a) radiation hard, cold temperature electronics readily available but not routinely considered for deep space missions and b) innovative thermal balance strategies through use of multi-layer thin materials and gravity-assisted heat pipes.

Phase 2: We are investigating strategies and leveraging ongoing work in the universal incorporation of Ultra Low Temperature/Ultra Low Power (ULT/ULP) digital and analog electronics, lower voltage power supplies, and distributed or non-conventionally packaged power systems. These strategies will be required to meet the more challenging thermal requirements of operating through a normal 28 day diurnal cycle while maintaining a mass of under 150 kg. ULT/ULP radiation hard digital components, developed at GSFC and through partnerships with the U. Idaho and the DOD National Reconnaissance Office, have successfully been demonstrated to offer orders of magnitude savings in power consumption and thermal tolerance. CULPRiT (CMOS Ultralow Power Radiation Tolerant) technology has successfully flown on NASA's ST5 90 day mission. Similar high end channel coder and compression chips have been requested for use in MMS, and GOES-R missions. Design and testing of the first custom designed radiation hard, low power analog components for ASICS in for extreme environments is

also being harnessed. The ultimate goal is the development of ULT/ULP analog and digital logic chips for use in system on a chip which includes CPU as well as other components. Similarly, we leveraging existing conceptual studies of microbatteries for use as distributed power supplies or converters.

Application and Future: Having already facilitated incorporation of Phase 1 findings into ongoing instrument integration efforts, we plan to incorporate the full range of technologies into science instrument package and payload accommodation concepts currently under study and considered near-term contenders for implementation and to provide guidelines for applying these approaches generically to the widest range of lunar surface instrument packages, leveraging existing and projected unique capabilities to create and implement these technologies that are critically in-demand to serve needs for exploration of the Moon and other solar system bodies.

References: [1] Clark, P.E., P.S. Millar, P.S. Yeh, J. Lorenz, S. Feng, W. Powell, B. Beaman, K. Brown, and L. Leshin (2009) 'Enabling Technology for Lunar Surface Science', in proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-09)*, edited by Glen A. Robertson, AIP Conference Proceedings, Melville, New York (2009); [2] Clark, P.E., Millar, P.S., Beaman, B., Yeh, P.S., Cooper, L., Feng, S., Young, E., 'Ultra Low Temperature Ultra Low Power Instrument Packages for Planetary Surfaces,' in proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-10)*, edited by Glen A. Robertson, AIP Conference Proceedings, Melville, New York, (2010).