Compact Ultra Low Temperature Instrumentation for the Lunar Surface: P.E. Clark[1], S. Whitaker[2], K. Brown[3], R. Cox[4], A. Vasant[4] [1]Catholic University of America@NASA/GSFC, Greenbelt, MD 20771, [2]ICs LLC, Albuquerque, NM, [3]Morehead State University, Morehead, KY, [2]Flexure Engineering Inc. (Correspondence email: Pamela.E.Clark@NASA.gov).

Context: The single most important discovery in lunar science in the last decade is the confirmation of icy volatiles at the lunar poles. This discovery implies that volatiles are far more ubiquitous on most of the surfaces in the solar system, for which the lunar polar regions are an analogue, than previously assumed. Apparently, the solar system still has far more to reveal about its origin, history, and current state. This not only makes the Moon an exciting destination in its own right, but the Lunar polar regions a Rosetta Stone for cryogenic chemistry and physics throughout the solar system and beyond, and a testbed for technologies needed to support exploration of the entire solar system.

Purpose: Here, we discuss technologies needed to support such exploration of the lunar polar regions, their current state of and ongoing activities related to their development, particularly in regard to cold temperature electronics. A particular concern is operation under the extremely cold conditions at or near the lunar poles, particularly in the always or nearly always shadowed regions that can act as efficient cold traps for such volatiles.

Technology Challenges, Power, Avionics, Thermal/Mechanical Systems: Designing power systems to operate at cold temperatures is especially challenging. Hibernation has been proposed to provide limited duty cycle operation on the lunar surface [1]. Work done primarily at JPL indicates that Li-based battery technology will allow operation down to -100 degrees C within the next few years [2]. For operating at the extremely cold temperatures in the permanently shadowed areas, down to 25K, we will need high temperature superconductor systems now under development by Selvamanickam, Masson, Beno, Meinke, and others [2,3,4,5]. High Temperature Superconductor based systems for cooling, power generation, wire for transmission, energy storage and regulation (superconducting magnetic energy storage or flywheel) are currently being developed tested for the large-scale applications for efficient power generation, but we will require the same scales that are normally used in the laboratory. HTS-based technologies, although currently relatively low TRL, would provide optimal solutions for operating at cold temperatures.

Thermal and mechanical design must provide a shield from extreme environmental conditions as well as deep space radiation on the lunar surface. Clark and coworkers developed a concept for a passively temperature controlled instrument package operating on a limited duty cycle [6]. Ramsey has described a passive cryocooler angled as a function of latitude, and particularly efficient at high latitudes [7]. Flexure Engineering has also proposed a concept for a cryovac test chamber that could operate at three lunar surface temperature regimes that exist near the lunar poles. Such a system could be used to simulate and observe surface processes and to test equipment for use at the lunar poles. High temperature superconductors could also provide the basis for efficient mechanisms for applications where 'moving parts' are required to operate under cryogenic conditions where minimal power is available, as well as for magnetic shields to protect equipment or crew in deep space radiation environments. Such HTS-based concepts have been designed and tested [2,3,4].

Current Design Challenge in Avionics for Essential Science Activities: Cold temperature analogue (Si Ge) [8] and digital (ULT, ULP) [9,10,11] electronics that will currently operate at these 'cryo' temperatures far more efficiently and with lower noise than conventional electronics are available now, and awaiting an opportunity to be employed in the design of an entire package, which may need to be designed to operate at a lower voltage.

We are currently identifying and exploring design solutions for essential radiation-hard, low temperature operation on the lunar surface. Part of this work involves developing and testing the use of ICs ULT cold temperature electronics [9,10,11] for cold temperature radiation-hard avionics systems, including instrument electronics, in CubeSat payload packages leveraging the Morehead State CXBN mission 3U bus [12], each with single guest instruments, to be self- or human-deployed on the lunar surface.

The most challenging surface activities which we will ultimately address include measurement and curation of cryogenic samples [13], robotic rover operation at or near cold traps [14], combined in situ measurement techniques in lieu of sample handling techniques [15,16], and distributed, self-deploying astrophysical observatory networks, such as ROLSS[14].

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