Small Cold Temperature Instrument Packages for Planetary Surfaces. P. E. Clark[1], P.S. Millar[2], W.D. Brigham[2], P.S. Yeh[2], S. Feng[2], B. Beaman[2], R Chalmers[2], M.A. Johnson[2]. [1]Catholic University of America@NASA/GSFC, Greenbelt, MD 20711 (Pamela.E.Clark@nasa.gov), [2]NASA/GSFC.

Introduction: We are currently developing a small instrument package concept analogous to the Apollo Lunar Science Experiment Package (ALSEP) and comparable in size (<150 kg) designed to operate under conditions as extreme as those of lunar night with mass and power requirements comparable to or less than radioisotope based power systems but considerably less costly. In phase 1 of our work, we achieved considerable reduction in an environmental monitoring instrument package mass by applying a) radiation hard, cold temperature (operational to –40^{o}C) electronics and b) innovative thermal balance strategies using unconventional materials and mechanisms. Now, in Phase 2, we are incorporating ULT/ULP electronics, lower voltage power supplies required to support them, and power systems that operate at colder temperatures.

ULT/ULP Electronics: The 0.35μ CMOS RHBD ULP electronics was demonstrated in NASA's ST-5 mission for a chip operating at 0.5 volt logic in space and achieved 100:1 power reduction as compared to its 5 volt part in space. The ULP chip was also tested at cryogenic temperature of near 20K and demonstrated full functionality. A newer generation CMOS RHBD technology was developed for 0.25μ for several ASICs for NASA's missions including LDCM, GOES-R, MMS (Magnetospheric Multi–Scale Mission). This is operating at a core voltage of 2.5 volt. The circuit has already passed 70K low-temperature test and is in the process of being tested to even lower temperature. At this level of CMOS technology, one ASIC can include over several million transistors to support complicated processing logic. A 130nm RHBD test chip with memory elements is being developed. At this CMOS node, core voltage will drop to 1.2 volt or 1.1 volt and will allow system-on-a-chip concept to be implemented. A 90nm RHBD test chip has been submitted for fabrication. At this CMOS node, core voltage will be close to 1 volt and will allow us to realize sub-system as well as system power reduction at relatively large scale, estimated for over 50% for conventional C&DH system. The developed digital core includes several communication channel coders, several high-end data compression coders, reconfigurable base-band modulator, enhanced micro-processor CPU, mass-memory protection circuit, large-scale multi-cross-correlators-on-a-chip and on-chip memory modules. These will be available for any SOC concept in addition to other openly available cores such as the Spacewire, ARM processor, etc.

Colder Temperature Power Systems: Our work will support development of small batteries and power supplies operating efficiently over many diurnal cycles at lower voltages and colder temperatures (down to a minimum of –50^{o}C, with a goal of –80^{o}C). Building on ST–5 technology, our distributed micro-battery-based power supply concept incorporates cold temperature power supplies operating with a 4V or 8V battery. Improvements in operation of Li–based battery systems below –40^{o}C have already been demonstrated in rechargeable Li–ion systems (with low temperature organic electrolyte systems to enhance conductivity and charge transfer (Lithion, SAFT)), as well as lower TRL Li–S and Li–$CuCl_2$ systems (Kolawa et al, 2007). To support the proposed instruments we are testing low temperature battery systems for capability (capacity, power density, recharge) and efficiency of operation below –40^{o}C using available Li–Ion systems at appropriate rates of charge/discharge.

Lower Voltage Power Supplies: Advances in MOSFET technology provide the lower voltage thresholds for power switching circuits incorporated into our low voltage power supply concept. Conventional power conversion has lower efficiency. Our low power conversion circuit concept based on 'synchronous rectification' will produce stable, regulated voltages as low as 0.6V with at least 85% efficiency. Requirements for consumer electronics have produced a variety of low power circuits designed to operate from one or two Li-ion batteries in series. These parts are generally rated for operation down to -40°C with a few rated for -55°C. These and other representative circuits will be tested for reliable operation at temperatures extending into cryogenic regions. If the entire electronic circuit including power supply will operate reliably at cryogenic temperatures, then only the battery itself will need to be heated to its minimum operating temperature, saving a significant amount of battery power. It is also possible to harness thermal discharge of the circuits as a heat source for the batteries. We will explore the potential for the use of cold temperature batteries to provide the power system for our optimized mass spectrometer instrument package. We have obtained representative voltage regulators and several of these highly efficient voltage regulators that use switching technology or synchronous rectification have already been tested successfully to -50°C, confirming minimum performance specifications.

References: [1] Clark et al, *SPESIF-09 Proceedings*, Huntsville, AL, 2009); [2] Clark et al, *SPESIF-10 Proceedings*, Columbia, MD, 2010.