Electronic technologies that are to be used in near-term exploration activities must be capable of operating on the lunar and/or Martian surfaces. Systems will need to operate across a wide temperature range and must survive frequent (and often rapid) thermal-cycling. For example, the Moon's equatorial regions experience temperature swings from -180°C to +130°C during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230°C. Likewise, the diurnal temperature on Mars spans from about -120°C to +20°C. While many types of devices can operate down to very low temperatures (e.g., SiGE HBT's), there are significant circuit design challenges that need to be addressed.

Thermal cycling present in lunar and Martian environments introduces reliability concerns associated with mechanical stress and fatigue of components and integrated circuits. For example, thermal cycling may result in mechanical or packaging related fractures. The selection of appropriate materials is therefore critical to developing suitable electronic products.

In addition, electronic systems and/or components must be radiation tolerant, operating reliably after receiving a total ionizing dose (TID) greater than but not equal to 50 krads (Si) and providing single-event latchup immunity (SEL) greater than but not equal to 100 MeV cm²/mg.

Proposals are sought in the following specific areas:

- Wide temperature (-180°C to +130°C) and low-temperature (-230°C), radiation-tolerant, low-power circuits including analog-to-digital converters, digital-to-analog converters, low-noise pre-amplifiers, voltage and current references, multiplexers, power switches, microcontrollers, and integrated command, control, and drive electronics for sensors, actuators, and communications transponders.

- Packaging capable of surviving numerous thermal cycles and tolerant of the extreme temperatures on the Moon and Mars. This includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.
Tightly-integrated electronic sensor and actuator modules that include power, command and control, and processing. Such modules should be capable of operating at the lunar and/or Martian temperature extremes.

Radiation-tolerant, SEL immune, wide temperature (-180°C to +130°C), and low-temperature (-230°C) RF electronics for short-range and long-range communication systems.


Physics-based device models valid at temperature ranging from -230°C to +130°C to enable design, verification and fabrication of custom mixed-signal and analog circuits.

Circuit design and layout methodologies/techniques that facilitate improved low-temperature (-230°C) analog and mixed-signal circuit performance.

Radiation-tolerant processors with significantly improved throughput and processing efficiencies. Chip-level (not board-level) technologies optimized for numerically intensive algorithms and applications with the following minimum performance metrics are sought:

- Sustained throughput - 2 GMACS (16-bit operations);
- Power efficiency - 1 GMACS/W (16-bit operations);
- Total ionizing dose - 100 krads;
- Single event upset rate - 10-10 errors / bit-day;
- Single event latchup - greater than 75 MeV/cm²/mg;
- Operational temperature range - -55°C to +125°C.

Proposals should demonstrate a working knowledge of temperature concerns, whether they be mechanical (material transition points, thermal stress, fatigue, fracture, etc.) or electrical (carrier freezeout, base-emitter injection efficiency, leakage, threshold voltage dependency, Johnson noise, charge trapping, kink effect, etc.).

Research should be conducted in two phases. During Phase 1, research should demonstrate the technical feasibility and show a path towards a hardware/software demonstration. During Phase 2, emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into space-worthy systems. When applicable, researchers should deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.