Electronics/Computers

Qualification of Engineering Camera for Long-Duration Deep Space Missions

NASA's Jet Propulsion Laboratory, Pasadena, California

Qualification and verification of advanced electronic packaging and interconnect technologies, and various other types of hardware elements for the Mars Exploration Rover's Spirit and Opportunity (MER)/Mars Science Laboratory (MSL) flight projects, has been performed to enhance the mission assurance. The qualification of hardware (engineering camera) under extreme cold temperatures has been performed with reference to various Mars-related project requirements. The flight-like packages, sensors, and subassemblies have been selected for the study to survive three times the total number of expected diurnal temperature cycles resulting from all environmental and operational exposures occurring over the life of the flight hardware, including all relevant manufacturing, ground operations, and mission phases.

Qualification has been performed by subjecting above flight-like hardware to the environmental temperature extremes, and assessing any structural failures or degradation in electrical performance due to either overstress or thermal cycle fatigue.

Engineering camera packaging designs, charge-coupled devices (CCDs), and temperature sensors were successfully qualified for MER and MSL per JPL design principles. Package failures were observed during qualification processes and the package redesigns were then made to enhance the reliability and subsequent mission assurance. These results show the technology certainly is promising for MSL, and especially for long-term extreme temperature missions to the extreme temperature conditions.

The engineering camera has been completely qualified for the MSL project, with the proven ability to survive on Mars for 2010 sols, or 670 sols times three. Finally, the camera continued to be functional, even after 2010 thermal cycles.

This work was done by Rajeshuni Ramesham, Justin N. Maki, Ali M. Pourangi, and Steven W. Lee of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47666

Remotely Powered Reconfigurable Receiver for Extreme Environment Sensing Platforms

This receiver also can be used in harsh environments encountered in aerospace and mining.

NASA's Jet Propulsion Laboratory, Pasadena, California

Wireless sensors connected in a local network offer revolutionary exploration capabilities, but the current solutions do not work in extreme environments of low temperatures (200K) and low to moderate radiation levels (<50 krad). These sensors (temperature, radiation, infrared, etc.) would need to operate outside the spacecraft/lander and be totally independent of power from the spacecraft/lander. Flash memory field-programmable gate arrays (FPGAs) are being used as the main signal processing and protocol generation platform in a new receiver. Flash-based FPGAs have been shown to have at least 100× reduced standby power and 10× reduction operating power when compared to normal SRAM-based FPGA technology.

Supercapacitors are nanotechnology-based electrochemical capacitors that can be cycled millions of times, compared to tens to hundreds of times for batteries. This allows supercapacitors to be used in conjunction with batteries by acting as a charge conditioner, storing energy for load-balancing purposes and then using any excess energy to charge the batteries at a suitable time. Supercapacitors are insensitive to radiation past 1 Mrad. JPL has demonstrated supercapacitor electrolytes that function to 189K.

This technology uses the ultra-low-power flash-based FPGA as the communication protocol (physical and medium layers) generator that is powered by a hybrid combination of lithium-based batteries and supercapacitors. A SiGe based RF front end can be used to provide transmitter/receiver capability for the 2.45-GHz and 858-MHz ISM frequency bands at low temperatures. The low power is critical because it defines how long the system can operate. The cold temperatures will reduce the performance of the batteries. Instead of lasting a year at room temperature, a lithium battery may only last a few weeks at cold temperatures. Even at cold temperatures, the battery output will be reduced. This means only a very-low-power circuit can be considered for use. The supercapacitors provide additional direct power capability for short-burst communication, and they provide the ability to extend the life of the battery by maintaining the voltage longer than the battery could alone. The FPGA can implement load-balancing and control logic to enable the battery to either operate completely alone, in combination with the supercapacitors, or have the supercapacitors alone power the FPGA in standby mode and/or be the startup power source if the FPGA is completely powered off.

This powering-off capability exists due to the use of the non-volatile flash memory cell-based FPGAs. This allows the supercapacitor to act also in countdown circuit mode, where the discharge time constant of the circuit is used as the time to keep the FPGA power off in order to save power. Once the supercapacitor-based circuit reaches a given level, this voltage is sensed and the wake-up sequence to the FPGA begins.

The supercapacitors also provide the ability to store and harvest recharge energy for the battery. RF energy can be beamed into the system and then fed back into the battery/supercapacitor network. Alternatively, mechanical energy from a MEMs device can be used to re-charge the supercapacitor. The capacitors can be quickly charged up and then act as a power reservoir for the battery. The completely described system above is currently in development.

This work was done by Douglas J. Sheldon of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-47718, volume and number of this NASA Tech Briefs *issue, and the page number.*

Bump Bonding Using Metal-Coated Carbon Nanotubes

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Bump bonding hybridization techniques use arrays of indium bumps to electrically and mechanically join two chips together. Surface-tension issues limit bump sizes to roughly as wide as they are high. Pitches are limited to 50 microns with bumps only 8–14 microns high on each wafer. A new process uses oriented carbon nanotubes (CNTs) with a metal (indium) in a wicking process using capillary actions to increase the aspect ratio and pitch density of the connections for bump bonding hybridizations. It merges the properties of the CNTs and the metal bumps, providing enhanced material performance parameters.

By merging the bumps with narrow and long CNTs oriented in the vertical direction, higher aspect ratios can be obtained if the metal can be made to wick. Possible aspect ratios increase from 1:1 to 20:1 for most applications, and to 100:1 for some applications. Possible pitch density increases of a factor of 10 are possible.

Standard capillary theory would not normally allow indium or most other metals to be drawn into the oriented CNTs, because they are non-wetting. However, capillary action can be induced through the ability to fabricate oriented CNT bundles to desired spacings, and the use of deposition techniques and temperature to control the size and mobility of the liquid metal streams and associated reservoirs.

This hybridization of two technologies (indium bumps and CNTs) may also provide for some additional benefits such as improved thermal management and possible current density increases.

This work was done by James L. Lamb, Matthew R. Dickie, Robert S. Kowalczyk, and Anna Liao of Caltech; and Michael J. Bronikowski of Atomate Corporation for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46592