



### **2 On a Formal Tool for Reasoning About Flight Software Cost Analysis**

A report focuses on the development of flight software (FSW) cost estimates for 16 Discovery-class missions at JPL. The techniques and procedures developed enabled streamlining of the FSW analysis process, and provided instantaneous confirmation that the data and processes used for these estimates were consistent across all missions. The research provides direction as to how to build a prototype rule-based system for FSW cost estimation that would provide (1) FSW cost estimates, (2) explanation of how the estimates were arrived at, (3) mapping of costs, (4) mathematical trend charts with explanations of why the trends are what they are, (5) tables with ancillary FSW data of interest to analysts, (6) a facility for expert modification/enhancement of the rules, and (7) a basis for conceptually convenient expansion into more complex, useful, and general rule-based systems.

*This work was done by John N. Spagnuolo, Jr. and Sherry A. Stukes of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Dan Broderick at [Daniel.F.Broderick@jpl.nasa.gov](mailto:Daniel.F.Broderick@jpl.nasa.gov). Refer to NPO-48487.*

### **3 A Nanostructured Composites Thermal Switch Controls Internal and External Short Circuit in Lithium Ion Batteries**

A document discusses a thin layer of composite material, made from nanoscale particles of nickel and Teflon, placed within a battery cell as a layer within the anode and/or the cathode. There it conducts electrons at room temperature, then switches to an insulator at an elevated temperature to prevent thermal runaway caused by internal short circuits.

The material layer controls excess currents from metal-to-metal or metal-to-carbon shorts that might result from cell crush or a manufacturing defect.

The use of recently available nanoscale particles of nickel and Teflon permits an improved, homogenous material with the potential to be fine-tuned to a unique switch temperature, sufficiently below the onset of a catastrophic chemical reaction. The smaller particles also permit the formation of a thinner control film layer (<40  $\mu\text{m}$ ), which can be incorporated into commercial high-rate lithium primary and secondary cells. This innovation increases safety for high-rate batteries, thus preventing injury to nearby personnel and equipment.

*This work was done by Robert C. McDonald, Shelly L. Van Blarcom, and Katherine E. Kwasnik of Giner, Inc. for Johnson Space Center. 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 MSC-24398-1, volume and number of this NASA Tech Briefs issue, and the page number.*

### **4 Spacecraft Crew Cabin Condensation Control**

A report discusses a new technique to prevent condensation on the cabin walls of manned spacecraft exposed to the cold environment of space, as such condensation could lead to free water in the cabin. This could facilitate the growth of mold and bacteria, and could lead to oxidation and weakening of the cabin wall.

This condensation control technique employs a passive method that uses

spacecraft waste heat as the primary wall-heating mechanism. A network of heat pipes is bonded to the crew cabin pressure vessel, as well as the pipes to each other, in order to provide for efficient heat transfer to the cabin walls and from one heat pipe to another. When properly sized, the heat-pipe network can maintain the crew cabin walls at a nearly uniform temperature. It can also accept and distribute spacecraft waste heat to maintain the pressure vessel above dew point.

The warmest portion of the spacecraft active thermal control system (ATCS) is connected to the heat-pipe network to allow the spacecraft waste heat to warm the pressure vessel walls. A backup electrical heater is attached to the ATCS loop/heat pipe interface to allow for heating in the event that the ATCS has insufficient energy to maintain the pressure-vessel walls above the dew point. A bypass control system sends ATCS fluid to the ATCS/heat pipe interface when there is sufficient energy for this purpose, and bypasses the heat-pipe network when there is not. This allows the backup electric heaters to efficiently heat the pressure vessel (without having to heat the flowing ATCS fluid). It also allows the flow to the ATCS/heat pipe interface to be modulated, thereby controlling the cabin wall temperature. The ATCS/heat pipe interface conductance is designed so that the energy input per unit length along the interface is roughly uniform. This allows the heat pipes to remain within their operational range.

A limited number of backup heaters provide a secondary source of energy to heat the cabin walls. This technique decreases control complexity, parts count, and heater power requirements. It also does not use long, massive lengths of coolant loop tubing to carry energy to the spacecraft walls.

*This work was done by Laurie Y. Carrillo, Steven L. Rickman, and Eugene K. Ungar of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24526-1*