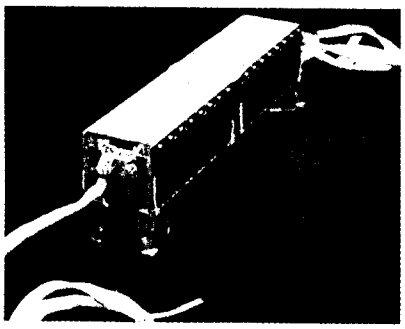
Powering the Mars Rover

In late April, **NASA** announced that both of its Mars Exploration Rovers (MERs) had completed their originally planned mission and were "tackling extra-credit assignments." They met all goals for numbers of locations examined in detail, distances traveled, and scientific measurements with all instruments. In its three-month primary mission, Opportunity sent home 15.2 gigabits of data about Mars, including 12,429 images and evidence of a body of salty water blanketing its coverage area from long ago. In early April, NASA approved funding for extending operation of Spirit and Opportunity through September.

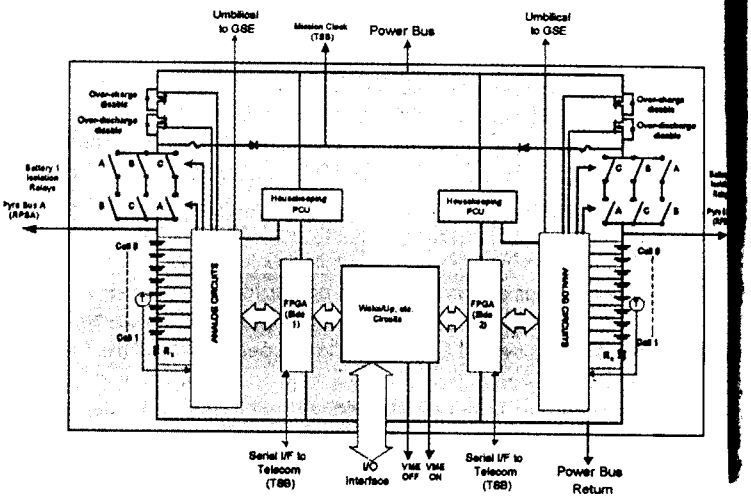
Much of the MERs success would not have been possible without power supplied by their onboard batteries. In 2001, **Lithion/Yardney** was awarded a contract from NASA's Jet Propulsion Laboratory to deliver the main Li-ion batteries for the mission. The contract required the completion of all qualification testing by December 2001 and delivery of flight units by October 2002. Spirit and Opportunity each contain two of Lithion/Yardney's Li-ion batteries packaged in housings called Rover Battery Assembly Units (RBAUs).

The RBAUs were designed to provide power during the launch sequence, and if called upon, they could have supplied power during cruise anomalies, such as if the spacecraft orientation to the sun was lost during the seven-month flight. The RBAUs supported the dedicated pyro bus and are currently providing power to Spirit and Opportunity on Mars, during the day when several scientific instruments are being used simultaneously and for maintaining loads at night.

The overall responsibility for the RBAU design was shared between JPL and Lithion/Yardney, with the latter responsible for the cell design and fabrication, battery assembly, and acceptance as well as qualification testing. Jim Rickmond, Program Manager, and Frank Puglia, Chief Engineer, led the Lithion/Yardney team. JPL and Lithion/Yardney worked together to complete the battery design,



The advanced RBAU for the Mars Rovers has two Li-ion batteries connected in parallel and is located in the MERs' warm electronic box.



Cell balancing (circuit shown) enabled the Spirit MER's battery to deliver 95.6% of its pre-storage capacity, providing more power than was necessary as NASA engineers resolved initial mission software issues.

and structural/thermal analysis. JPL was responsible for designing and delivering the cell-balancing electronics.

To eliminate concerns about weld strength, RBAU cases were milled from solid blocks of aluminum. The cover was bolted to the case to form a structurally sound assembly. Heater blankets are used to keep the temperature of the Li-ion batteries within the warm electronics box from falling below -20°C during the night. Boron-epoxy struts were used to thermally and electrically isolate the batteries from the spacecraft. Lithion/Yardney says that both RBAUs are functioning as designed.

According to Lithion/Yardney, factors that made it possible to meet or exceed NASA requirements were the company's previous experience designing and fabricating large Li-ion cells and its ability to control the manufacturing and assembly processes, which aided in keeping between-cell variability very small. This ensures that the battery's capacity is not limited by one weak cell. The cell-balancing electronics provided further assurance that the battery would be able to deliver the maximum amount of energy. The battery with cell balancing was able to deliver 95.6% of its pre-storage capacity, while a battery without cell balancing is able to deliver only 82.1%.

The RBAUs' performance enabled the batteries on Spirit to provide more energy than planned while NASA engineers resolved the software problems that occurred shortly after the rover landed on Mars. Presently it appears that the batteries' ability to support MER energy requirements will be limited only by the amount of electricity that the solar panels can generate, claims Lithion/Yardney. A combination of dust accumulation on the solar panels and shorter days due to the oncoming Martian winter will reduce the amount of energy available to fully charge the batteries.

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