Lithium Batteries on Mars

In the "Spirit" of a successful landing on Mars on January 4, and with this "Opportunity" doubling in the following two weeks, there will be an astounding scientific exploration of Mars in the next few months. This TechWatch takes a look at the power behind these successful twin rovers that come "with batteries included."

Batteries are vital components on these Mars Exploration Rovers (MERs) and perform key operations during launch, cruise, entry, descent, landing, and surface operations. Both the twin rovers have three types of lithium batteries: (1) thermal batteries located on the back shell, (2) primary or non-rechargeable batteries on the Lander petals, and (3) rechargeable batteries in the warm electronics box of the rover, which empower the rovers during their 90-day-long surface exploration.

Exciting as it was to have such a wonderful landing, it is equally exciting, from a battery standpoint, to have Li-ion batteries on these rovers. Lithium-ion batteries are relative newcomers to the aerospace arena, and this is the first NASA mission (or of any agency) of this magnitude, to incorporate this new battery technology. It has been the dream of Jet Propulsion Laboratory (JPL), NASA, and U.S. Air Force battery researchers for the last two decades to replace the conventional massive and bulky aqueous nickel rechargeable batteries with lightweight and compact Li-ion batteries. Aided by detailed and broad research efforts spreading over two decades at JPL and elsewhere, and propelled largely by the commercial developments at overseas battery industries specific to portable electronics applications, Li-ion batteries have finally broken through and made their debut in a planetary exploration mission.

The MER Li-ion batteries are similar to the Li-ion batteries we use on our laptops, camcorders, and cell phones, in terms of the type of electrode. Yet they are considerably superior in their capability to function well down to -20°C at moderate rates and with high specific energies, without any compromise in their high temperature (up to 40°C) resilience. These technological advances are born out of detailed electrochemical studies at JPL, with the cooperation of the Mars Exploration Technology program, on novel solvent mixtures with good ionic mobility, electrochemical stability, and favorable interfacial (*i.e.*, charge transfer) characteristics of the selected electrode materials.

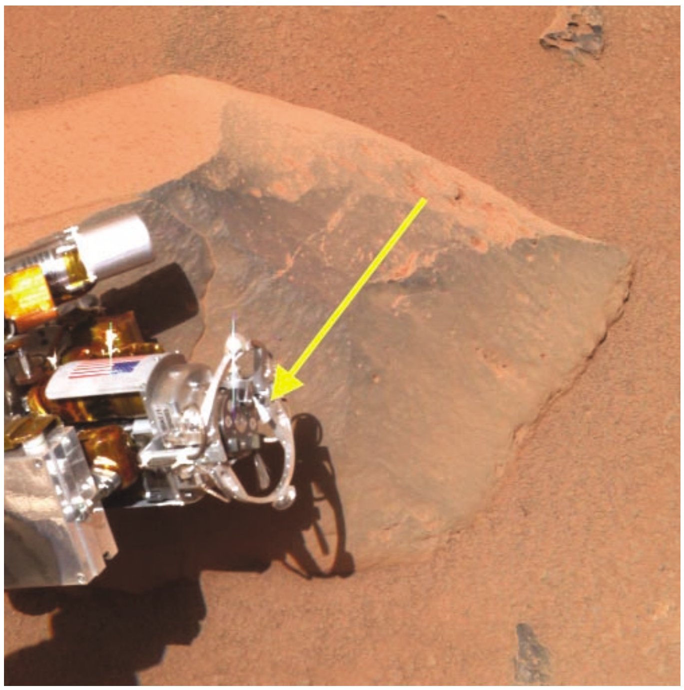

Image courtesy of NASA/JPL/Cornell.

This image shows the Mars Exploration Rover Spirit's "hand," or the tip of the instrument deployment device, poised in front of the rock nicknamed Adirondack. In preparation for grinding into Adirondack, Spirit cleaned off a portion of the rock's surface with a stainless steel brush located on its rock abrasion tool and seen here at the end of the yellow arrow. The image was taken by the rover's panoramic camera.

It would not be possible to translate these laboratory findings, at low technology readiness levels, to flight prototype cells, without the leadership of the U.S. Air Force in forming the NASA-DoD consortium and developing a manufacturing base with its industrial partners, Yardney Technical Products (Pawcatuck, Connecticut) and SAFT America (Cockeysville, Maryland). The Advanced Battery Technology Program from NASA/GRC paved the way for generating an extensive and convincing performance database on these improved Li-ion cells for a flight insertion. Finally, Yardney Technical Products, currently Lithion, successfully fabricated the battery using improved chemistry. The battery housings were designed and fabricated at JPL with sound structural and thermal engineering principles.

Apart from the launch, cruise, and post-entry/descent/landing (EDL) needs, which they have already fulfilled, these batteries provide power for nighttime experimentation and augment solar array during the daytime. The critical charge and discharge limits and a regular cell balance during charge are being achieved via a battery control board, designed and fabricated at JPL. The laboratory tests on these improved Li-ion cells and batteries point to their excellent calendar and cycle life characteristics, such that missions may well extend beyond the extended mode to the extent permitted by the solar array.

The Lander primary batteries are based on lithium-sulfur dioxide chemistry, which had a good track record in space missions, including Galileo, Cassini, Stardust, and Genesis. The MER batteries, however, consist of low rate cells, as opposed to the high rate cells used thus far. SAFT America (Valdez, North Carolina) fabricated the cells; and the batteries were built by SAFT America (Cockeysville, Maryland), using the housings designed and fabricated by JPL engineers. One novel feature in the use of these batteries relates to a preconditioning of these batteries, by constant voltage discharge, to alleviate their voltage delay. Several laboratory tests were performed to identify the optimum pre-conditioning protocol, which was successfully implemented on the Spirit, with the Opportunity to follow. The entire EDL operations were powered by these batteries, thus saving the rechargeable batteries for immediate surface operations.

The thermal batteries are activated by a current squib and are capable of supporting several high currents required for several pyros over a short duration of 5 minutes. These batteries consist of lithium-ion disulfide cells, are used routinely for defense applications, and also have been used in the past for Mars Pathfinder and DS1 NASA missions. These batteries were fabricated by Eagle Picher Technologies (Joplin, Missouri) to JPL specifications and guidelines. Once again, the thermal batteries worked well on the Spirit and repeated their success on the Opportunity.

In summary, all these different battery technologies have withstood the rigors of the launch, the longevity of the cruise, and have performed well in an unfamiliar, low-gravity planetary environment. New explorations provide newer challenges, and thanks to the pioneers and technology forecasters, we will have new (lithium) battery technologies as well. ■

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