High Specific Energy Primary Batteries for NASA Missions

Erik J. Brandon (erik.j.brandon@jpl.nasa.gov)
Jet Propulsion Laboratory, California Institute of Technology

To enable the Europa Lander mission concept, high specific energy primary Li/CF_x battery cells have been developed over the last several years. JPL worked with the battery vendors Rayovac and EaglePicher Technologies to develop cells that exceed a specific energy of 700 Wh/kg, surpassing the performance of traditional space rated primary battery cells based on the Li/SO_2 or Li/$SOCl_2$ chemistries. A unique feature of this cell chemistry is the significant amount of heat generated during discharge, with approximately 1 W of thermal power generated for every 1 W of electrical power delivered to the external load. This generated heat can he used to keep the cells and battery modules warm, preserving electrical power that would typically be used for heaters and thereby making it available for achieving science objectives.

JPL has performed extensive testing of these cells over a wide range of temperatures and rates, and developed electrical and thermal models for this technology. Power models using the JPL Multi-Mission Power Analysis Tool (MMPAT) have been developed, to allow prediction of performance over a variety of loads and temperatures. Initial multi-cell pack designs were developed at JPL, to support a high cell packing efficiency and effective of use of the generated heat for keeping the cells at a suitable operating temperature. JPL also performed extensive safety and radiation testing with Sandia National Laboratory, to guide the development of safe, reliable module designs. The cells were determined to have a high radiation tolerance up to 10 Mrad total ionizing doses.

Extensive storage testing and micro-calorimetry measurements have also been performed at JPL, to establish self-discharge rates at various storage temperatures. Arrhenius models have been established, to allow prediction of self-discharge at storage temperatures outside of the current test conditions. This information is critical when long cruise times to the outer planets are involved, to predict and minimize loss of cell capacity over time. The testing also allows the development of more realistic, data-driven battery deratings. Finally, JPL has worked with the vendors to increase specific energy at low discharge rates, developing novel electrolytes and cell designs. The technology development and testing enabled the Europa Lander mission concept to close from a power perspective, allowing primary science objectives to be met. Options for mission lifetime extension were also developed.

This cell technology and the initial module level designs can now be applied to mission concepts such as the Small Next-Generation Atmospheric Probe (SNAP) For Ice Giant Mission, the Saturn Probe, the Uranus Orbiter Probe and to low cost Mars missions such as small hard and soft landers. Any probe or mission requiring the use of primary batteries can potentially benefit from this technology. Use of the Li/CF_x cell technology can reduce by a factor of 2X the mass of battery modules, relative to heritage $LiSO_2$ batteries used on the Galileo and Huygens Probes. In addition, those missions required the use of radioisotope heating units or RHUs to keep the batteries sufficiently warm, whereas with proper thermal design of the battery module these cells could be used with no RHUs due to the heat generated during discharge. The technology is currently at TRL 4, and can be elevated to TRL 6 with the design and environmental testing of modules designed for specific mission requirements. The design work and testing performed during the Europa Lander battery development, along with the subsequent lessons learned, can be applied for infusion of this technology into future NASA missions.