Final Report Submitted to the
Earth Science Technology Office (ESTO)
for the

Li-Ion Technology Infusion for Low Earth Orbit (LEO) Study

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This study was a partnership between ESTO and the GPM project.

Annual Report for the
Earth Science Technology Office (ESTO)
Li-Ion Technology Infusion for Low Earth Orbit (LEO) Study

Introduction

Sony first introduced commercial Lithium-Ion (Li-Ion) batteries in 1991. Li-Ion cells consist of a lithiated carbon or graphite negative plate, a lithium mixed-metal oxide positive plate, a separator, and an organic electrolyte containing a lithium salt. This technology is widely used now for portable devices such as cellular and mobile phones, PDA's, notebook computers, MP3 players, and other products requiring a reliable, high-energy power source. Also, military organizations throughout the world rely on Li-Ion to provide both primary and back-up power for a wide range of communications equipment, imaging devices and weapons systems. This technology provides long storage life with virtually instant power when needed and exceeds strict military performance requirements.

For space applications, Li-Ion battery technology offers the potential for a ~ 50% decrease in weight and >60% decrease in volume relative to existing Nickel-Hydrogen batteries (space-flight batteries). Moreover, Li-Ion chemistry may be capable of reliable operation at temperatures as high as 40° C (and does not present hazards to the environment that require special handling or disposal procedures). An additional benefit is that Li-Ion batteries do not exhibit "memory" problems, that is, they can be recharged at any state of charge without first having to be completely discharged.

Because of its relatively smaller mass and volume, and more relaxed thermal and mechanical requirements, successful qualification of Li-Ion batteries for LEO would provide significant benefits for a wide range of Earth Science (ES) Enterprise flight missions. This technology promises superior energy-storage performance and reduced power-system mass allocations for ES space systems.

Qualification testing must be performed before we can be certain that Li-Ion technology will be reliable in space applications. More specifically, Li-Ion cells must be tested for tolerance to the space environment, with emphasis on life-cycle performance for charge/discharge profiles typical of Low-Earth-Orbit (LEO) applications. It is anticipated that similar benefits can be realized for Geosynchronous-Earth-Orbit (GEO) orbits.

Study Approach

Four qualified vendors were selected in late 2002. They are Atomic Energy Authority (AEA) Technology, Japan Storage Battery (JSB), Societe Accumulateur Fixe Traction (Saft), and Yardney Technical Products (YTP) – Lithion.

AEA 60 Ah battery has 384 commercial SONY 18650 1.5 Ah cylindrical cells in series /parallel configuration (8s- 48p). Cell balancing and cell bypass circuitries were not incorporated in the design. The test start date was December 2002.

JSB pseudo prismatic 100 Ah cells were used to fabricate 8-cell battery (8s) by GSFC. Cell balancing and cell bypass circuitries were not incorporated in the current battery pack but will be needed for the flight hardware. We are planning to incorporate cell balancing circuitry at a later stage for our current test battery. The test start date was June 2003.

Saft 80 Ah battery has 16 40 Ah cylindrical cells in series/parallel configuration (8s-2p). Cell balancing and cell bypass circuitries were incorporated in the design. The test start date was December 2003.

Lithium Ion 50 Ah prismatic cells were used to fabricate a 100 Ah battery (2s-2p) by GSFC. Cell balancing and cell bypass circuitries were not incorporated in the current battery pack but will be needed for the flight hardware. We are planning to incorporate cell balancing circuit at a later stage for our current test battery. The test start date was January 2004.

LEO Test Condition

- Temperature: 20 ± 2°C
- Depth of Discharge (DoD): 33% (AEA 30%)
- Discharge: 0.55C A rate for 36 minutes
- Charge: GPM orbit profile with a selected battery voltage clamp with taper

Data

Test start date depended on the availability of the battery hardware. The AEA battery was already built and the first one to start. The test status as of to date is given in the table (see below).

Vendor	Battery Size (Ah)	Start Date	Clamp Voltage (V)	End of Discharge Voltage (V)	Cycle #
AEA	60	2/03	33.6	30.3	4800*
JSB	100	5/03	31.2	28.8	3900**
Saft	80	11/03	31.2	28.3	1300
Lithion	100	1/04	7.8***	7.18****	350

*First 1800 cycles at 40% DoD, **12 cycles at 27 %, and 32 cycles at 13% DoD, *** 31.2 V at battery level, **** 28.7 V at battery level

Deliverables

Three attachments are the reports on AEA battery, JSB battery and SAFT battery performance.
Bi-monthly technical reporting into the ESTO E-books system.
Monthly financial reporting, also into E-books.

Conclusions

Results of testing funded by ESTO and NASA HQ through GRC (in particular for the AEA and SAFT batteries build) indicate that Li-Ion technology is a viable candidate for space application and may be appropriate for missions in LEO orbit including the upcoming Global Precipitation Mission (GPM). Data from this study demonstrates that Li-Ion Battery technology could support a benign LEO mission for one year at about 20 to 25% DOD. However additional funding is required for continued testing to mitigate the cycle and calendar life issues of an extended mission like GPM. Cell Balancing, Over Charge and Over Discharge Protection Circuits must be included as part of any battery design. The TRL level of Li-Ion batteries for an extended LEO mission is currently considered to be 6.

Presented/Published papers detailing the test configuration, conditions, and data can be found in the website below.
https://webdrive.gsfc.nasa.gov/longauth/500/Leonine.S.Lee.1/QStWXYC39KUAAFpcKC0

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