

NASA BATTERY WORKING GROUP – 2007-2008 BATTERY TASK SUMMARY REPORT

PRESENTATION TO THE IAPG CHEMICAL WORKING GROUP – JULY 11, 2008

This presentation provides a summary of the 2007-2008 NASA Battery Working Group efforts completed in support of the NASA Engineering Safety Center (NESC). The effort covered a series of pro-active tasks that address the following:

Binding Procurements – guidelines related to requirements for the battery system that should be considered at the time of contract award

Wet Life of Ni-H₂ Batteries – issues/strategies for effective storage and impact of long-term storage on performance and life

Generic Guidelines for Lithium-ion Safety, Handling and Qualification – Standardized approaches developed and risk assessments

- Lithium-ion Performance Assessment – survey of manufacturers and capabilities to meet mission needs. Guidelines document generated
- Conditions Required for using Pouch Cells in Aerospace Missions – focus on corrosion, thermal excursions and long-term performance issues. Document defining requirements to maintain performance and life
- High Voltage Risk Assessment – focus on safety and abuse tolerance of battery module assemblies. Recommendations of features required for safe implementation
- Procedure for Determination of Safe Charge Rates – evaluation of various cell chemistries and recommendation of safe operating regimes for specific cell designs

NASA Battery Working Group – 2007-2008 Battery Task Summary Report

Presentation to the IAPG Chemical Working Group – July 11, 2008

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(excerpts from material presented to NESC board on July 10, 2008)

NESC Review Board

Michelle Manzo

July 10, 2008

NASA Battery Working Group – 2007- 2008 Battery Task Summary Report

Michelle A. Manzo, NASA GRC

Part 1

July 10, 2008

NASA Battery Working Group 2007-2008 Proactive Task Report

Michelle Manzo

July 10, 2008

Background

- Summer 2006 NESC call for Proposals for Proactive (also known as Discipline Advancing) work
 - Tasks that address important activities that no single project may be able (or reasonably expected) to fund
 - Areas where something critical (such as fundamental understanding, a specification, basis for risk assessment, etc.) is lacking.
- The NASA Aerospace Flight Battery Systems Steering Committee developed a response to this request.
 - Relevant battery system issues - identified and prioritized.
 - Tasks aimed at solving the most critical of these persistent Agency-wide technical problems were assembled.
- Proposal (PL-07-02/06-069-I NASA Aerospace Flight Battery Systems Working Group Annual Plan) presented to and accepted by the NESC Board.
 - NESC chartered the NASA Aerospace Battery Working Group within the NESC.
 - The Battery Working Group was tasked to complete these tasks and to propose proactive work to address battery related, agency-wide issues on an annual basis.

NASA Battery Working Group 2007-2008 Proactive Task Report

Michelle Manzo

July 10, 2008

Task List

- Binding Procurements
- Wet Life of Nickel-Hydrogen (Ni-H₂) Batteries
- Generic Safety, Handling and Qualification Recommendations and Guidelines for Lithium-Ion (Li-Ion) Batteries
 - Li-Ion Performance Assessment
 - Generation of a Guidelines Document that addresses Safety and Handling and Qualification of Li-Ion Batteries
 - Definition of Conditions Required for using Pouch Cells in Aerospace Missions
 - High Voltage Risk Assessment: Limitations of Internal Protective Devices in High-Voltage/High-Capacity Batteries using Li-ion Cylindrical Commercial Cell
 - Definition of Safe Limits for Charging Li-Ion Cells
- Availability of Source Materials for Li-Ion batteries
- Technical Communications Related to Aerospace Batteries (NASA Battery Workshop)

NASA Battery Working Group 2007-2008 Proactive Task Report

Michelle Manzo

July 10, 2008

- **Report Split into Three Parts – Today’s report is on Part 1**
 - **Part 1 - Lithium Battery Related & NASA Battery Workshop**
 - Generic Safety, Handling and Qualification Recommendations and Guidelines for Lithium-Ion (Li-Ion) Batteries
 - Li-Ion Performance Assessment
 - Generation of a Guidelines Document that addresses Safety and Handling and Qualification of Li-Ion Batteries
 - *Definition of Conditions Required for using Pouch Cells in Aerospace Missions*
 - *High Voltage Risk Assessment: Limitations of Internal Protective Devices in High-Voltage/High-Capacity Batteries using Li-ion Cylindrical Commercial Cell*
 - *Definition of Safe Limits for Charging Li-Ion Cells*
 - Availability of Source Materials for Li-Ion batteries
 - Technical Communications Related to Aerospace Batteries (NASA Battery Workshop)
 - **Part 2 - Binding Procurements**
 - **Part 3 - Wet Life of Nickel-Hydrogen (Ni-H₂) Batteries**

Li-Ion Performance Assessment

Paul Schmitz

July 10, 2008

Li-Ion Performance Assessment Paul C. Schmitz (PCS/GRC)

Li-Ion Performance Assessment

Paul Schmitz

July 10, 2008

Problem Description

- Perform a survey of existing Li-Ion battery manufacturers and their capability to meet future NASA mission needs. Multiple NASA mission needs will be addressed including: LEO, GEO, Constellation requirements and the use of commercial-off-the-shelf technology for portable applications

Proposed Solution

- Develop a database (MS Excel) which contains information about Lithium-Ion cells and batteries which have either flown in space or are appropriate for space use (cells > 1 A-hr Capacity)

Li-Ion Performance Assessment

Paul Schmitz

July 10, 2008

Assessment Plan

- Create a survey questionnaire which asks participants to provide their cell and battery data.
 - The survey will describe the cells/batteries performance and the testing they have undergone (either at the manufacturer or by other government agencies) to help the mission planner/hardware developer in the battery/cell selection
 - Contact relevant cell and battery vendors and customers to populate the database

Li-Ion Performance Assessment

Paul Schmitz

July 10, 2008

Participants in the database include both Govt. and Industry

- Naval Research Lab
- NASA Johnson Space Center
- NASA Glenn Space Center
- NASA Ames
- Lockheed Martin
- Quallion
- Yardney
- Sanyo
- ABSL

Li-Ion Performance Assessment

Paul Schmitz

July 10, 2008

- Created a database of lithium-ion cells and batteries appropriate for aerospace applications with capacities greater than 1 A-hrs
 - This database is not a comprehensive of all lithium-ion cells and batteries, rather a compilation of data that was either found or shared from various industry and government partners
- There is a significant diversity in both cell/battery capacity and manufactures for aerospace applications
 - A majority of the batteries found in space applications using Li-Ion batteries were based on the 18650 HC cells and made by ABSL. It is unknown if this reflects accurately the space battery experience with Li-Ion batteries or those that used other cells were unwilling to share their data
- Data base is currently a Microsoft Excel spreadsheet
 - Architectural limitations - difficult to keep up to date and shared with many parties.
 - Limited database functionality to link photographs and other documents with the associated cell and or battery
- Explore options for alternate architects – web-based approach

Li-Ion Guidelines Document

Barbara McKissock

July 10, 2008

Li-Ion Guidelines Document Barbara I. McKissock (GRC)

Li-Ion Guidelines Document

Barbara McKissock

July 10, 2008

Problem Description

- Li-Ion technology evolving rapidly, need continuous monitoring and assessment

Proposed Solution

- Standardized approaches needed for defining, determining, & addressing safety, handling and qualification standards for Li-Ion batteries
- Generate a general guidelines for project managers, payload managers, technologists document defining specific parameters that must be addressed for the safe implementation of Li-Ion battery technology

Li-Ion Guidelines Document

Barbara McKissock

July 10, 2008

- Surveyed existing documents relating to safety, use, issues, qualification, and testing of aerospace Li-Ion batteries
- Sources included documents from NASA, The Aerospace Corporation, Air Force, Army, Naval Research Laboratory, and European Cooperation for Space Standardization
- Pertinent guidelines and recommendations compiled into one document, revised and expanded upon to address safe implementation of the technology
- Li-ion is dynamic technology – document will require periodic reviews and updates

Technical Summary

Barbara McKissock

July 10, 2008

Guidelines Document Table of Contents

- Introduction
- Basic Chemical Information
- Factors Affecting Battery Performance
- Battery Design
- Hazards and Controls
- Battery Requirements
- Cell/Battery Handling and Procedures
- Testing
- References
- Definitions

Pouch Cell Corrosion

Eric Darcy

July 10, 2008

Pouch Cell Corrosion Eric C. Darcy (JSC)

Pouch Cell Corrosion Investigation

Eric Darcy

July 10, 2008

Problem Description

- Li-ion pouch cell design are susceptible to life limiting corrosion due to internal root causes

Proposed Solution

- Determine the pervasiveness of the corrosion phenomena
- Attempt to replicate and accelerate the corrosion in laboratory conditions to determine root cause
- Establish findings and recommendations to obviate/mitigate corrosion

Risk Assessment

- 4 of 6 cell designs evaluated were found susceptible to limiting pouch corrosion



Pouch Cell Corrosion Investigation

Eric Darcy

July 10, 2008

Assessment Plan

- Determine the pervasiveness of the corrosion by inspection and DPA - pouch cells from ElectroVaya, Kokam, LG, Saehan, SKC, and Quallion
 - Establish commonalities between corrosion sites
 - All were found in stressed areas of the pouch laminate
- Measure pouch isolation resistances of affected cells and compare them to healthy cells
- Examine the isolation of cell stack components from the aluminum layer of the pouch laminate
- Attempt to replicate and accelerate the corrosion in laboratory conditions to determine root cause
 - Compare the corrosion spots in lab to those found in field cells
 - Determine why certain cell designs are more resistant to corrosion
- Compare various manufacturer's pouch cell designs
 - Measure electrolyte leak rate with PA-IR leak detection method
 - Determine cell design features (commonalities and differences) via DPA



Pouch Corrosion Investigation - Findings

Eric Darcy

July 10, 2008

- Corrosion spots in pouch were successfully replicated in all but 2 cell designs by shorting pouch to negative potential in certain pouch cell designs
 - LG and SKC cells did not corrode when pouch was negatively polarized
- Electrical isolation of the aluminum layer of the pouch laminate from the negative terminal of the pouch cell degrades in the days and hours prior to the initial appearance of corrosion spots, which suggests weaken isolation
 - Failed to replicate hypothesized Li-Al alloy “corrosion” in pouch material even after 90 days of testing
 - Even with folded, aggressively sealed, and butter-cupped pouched material
 - Adding to or substituting Cu for Li did not produce corrosion
 - Either electrode material or both must be present
- Pouch corrosion only found in stretched, butter cupped sections of pouch
- The cell pouch design with the lowest leak rate per Ah is LG’s with Kokam, Quallion, and SKC also performing well
 - Large and thick tab seal material is most distinguishing feature not found in Saehan and ElectroVaya designs and only one pouch layer (side) is butter-cupped, not both
- Estimation of calendar life is possible with knowledge of the amount of free electrolyte and its PA-IR determined leak rate
 - Calendar live estimates ranged from 3 to 63 months on the designs tested
- Leak rate of all cell designs increase with exposure to thermal cycling vs only ambient temperature exposure.

Pouch Corrosion Investigation - Recommendations

Eric Darcy

July 10, 2008

For Buyers of Li-ion Pouch Cell Designs, it's recommended that the following design feature examinations and tests be performed...

- Look for uniformity in the placement of the pouch perimeter seals relative to the cell stack
- Polarize the pouch to the negative terminal for several weeks to determine susceptibility to corrosion
- Obtain a cross-cut examination of the pouch laminate in the flat, butter cupped, and seal areas to determine uniformity of thickness of all laminate layers
Measure isolation resistance of each tab seal from the pouch as an indication of poor symmetry within the tab to pouch seals
- Select a design that butter cups only one pouch cell side, not both
- Leak test the cell design using PA-IR or other suitable technique after exposure to mission conditions to establish leak rate of the most volatile components of the electrolyte, determine the quantity of free electrolyte, mass fraction of the most volatile component, and estimate calendar life

Pouch Cells

Kumar Bugga

July 10, 2008

Operational Requirements for Pouch Cells in Aerospace Applications Ratnakumar V. Bugga (JPL)

Operational Requirements for Applications of Li-ion Pouch Cells

Kumar Bugga

July 10, 2008

Problem

- Pouch cells have several advantages over conventional cells with metallic containers
 - Enhanced specific energy and energy densities .
 - Better form factor and packing efficiency.
 - Attractive option for short-life missions.
- Pouch cells have an inability to maintain hermeticity through their lifetime and exhibit shorter cyclic lifetimes due to a rupture of pouch seal
- Attributed to the high vapor pressure of (organic) liquid electrolytes

Limitations

- High temperature operations
- Pressure build up on extended cycling
- Lack of reliability under hard vacuum.

Proposed Solution, Risk Assessment

- A systematic study was carried out to categorizing safe charge conditions, by identifying the charge conditions conducive to and permitting lithium plating, which are to be precluded to ensure the performance, reliability and safety.

Operational Requirements for Applications of Li-ion Pouch Cells

Kumar Bugga

July 10, 2008

Assessment Plan

Determine the viability of using pouch cells under conditions relevant to space applications, (hard vacuum and thermal cycling)

- To evaluate lithium-ion pouch cells, with different electrolytes and from different manufacturers for their ability to maintain hermeticity.
- The test articles utilized in this study include
 - Quallion - baseline electrolyte, Quallion and JPL low temperature electrolytes SKC cells - gel polymer electrolyte,
 - Compact Power - gel polymer electrolyte, JPL low temperature electrolytes as plasticizers and
 - LTC Li-ion cells.
- Testing
 - Characterization testing (capacities and impedance), as a function of charge and discharge rates and at different temperatures.
 - Cycling (at 100% and partial DOD) of LTC and Compact power cells.
 - High temperature cycling, as a means of accelerating the failure that would occur over longer cycles at ambient temperature.
 - Exposure to thermal vacuum cycling in the non-operating mode followed by a detailed characterization to quantify their effects on the performance.

Operational Requirements for Applications of Li-ion Pouch Cells

Kumar Bugga

July 10, 2008

Findings

- Pouch cell configuration provide specific energy, energy density and packing efficiency advantages over conventional Li-ion cells with metallic containers
 - Some of the prototype cells of different types have shown impressive specific energies of 160-200 Wh/kg, at least 20% improvement over their counterparts.
- Limitation - lack adequate robustness in the hermeticity and integrity of the cells, especially upon electrical and thermal cycling and possibly under hard vacuum environments.
 - Function of electrolyte, type of cathode material (which dictates the charge voltage and hence the extent of electrolyte oxidation) and the pouch seal design
- Failure is accelerated at high temperatures

Operational Requirements for Applications of Li-ion Pouch Cells

Kumar Bugga

July 10, 2008

Recommendations

- Selected cells should be tested in the anticipated thermal and vacuum environments putting them for use.
 - Subject cells to an accelerated cycling test at a high temperature, after establishing a correlation between such acceleration and the expected cycle life at room temperature.
- It is recommended that they are subjected to thermal vac cycling test before use.

Internal Safety Device Limitations for High Voltage Systems	Judy Jeevarajan
	July 10, 2008

**Limitations of Internal Protective Devices in
High Capacity, High Voltage Batteries
Judith A. Jeevarajan (JSC)**

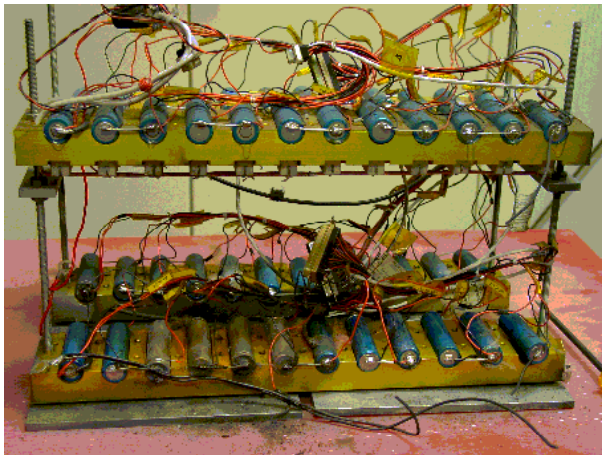
Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules

Judy Jeevarajan

July 10, 2008

Problem Description:

Internal protective devices in small cylindrical COTS (commercial-off-the-shelf) Li-ion cells failed to protect when the battery module designs included multi-cell series and/or parallel configurations. Issue identified with overcharge and external shorts, the two major hazard causes.



ITA # 06-069-1

Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules	Judy Jeevarajan
	July 10, 2008

Assessment Plan:

- **Single component and cell testing**
 - Determine the breakdown voltage limits of cell PTC devices
 - Determine the arcing limits of the CID
 - These tests were performed at Symmetry Resources, Inc. (SRI), in Arab, AL and at NASA-JSC.
- **High voltage and high capacity battery bundle tests**
 - Electrical abuse test to determine the abuse tolerance differences between single cell and multiple cell batteries.
 - These tests were conducted at Mobile Power Solutions (MPS), in Beaverton, OR.
- **Generation of a design guideline for a diode protection scheme for high voltage battery applications using cells with PTC devices.**

Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules	Judy Jeevarajan
	July 10, 2008

The PTC characteristics varied from manufacturer to manufacturer in their trip currents as well as withstanding voltages. The withstanding voltage of the PTCs implies that they have a voltage limitation.

- Determine the PTC withstanding voltage and trip current for the cell to be used in battery design by test.
- Cells from different manufacturer will have different PTC ratings and this information is not provided in a cell specification.

Diodes placed across series substrings could help shorten string lengths and reduce the voltages seen by the cell PTCs during fault conditions.

- In batteries where other design features cannot be used to limit voltage, substring diodes can be used to prevent PTC exposure to high voltages, under fault conditions.

Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules	Judy Jeevarajan
	July 10, 2008

Seals in cells with tripped PTCs are stressed by the heat generation which holds them in their tripped state. Tripping cell PTCs irreversibly increases electrical resistance by up to a factor of two. Compromised or high-resistance PTCs cause catastrophic failures under overcharge conditions.

- PTC should not be compromised if needed as safety control
- Cell screening for battery build should not cause inadvertent activation of the PTC.
- Any cells in which the PTC may have been inadvertently tripped should not be used in the fabrication of flight batteries.

The heat generated in a tripped cell PTC was 3.2 to 3.5 W (irrespective of cell manufacturer and load used for trip) which could have been one of the causes for the thermal runaway in a multi-cell battery configuration under unsafe conditions.

- Heat generated in a tripped cell PTC device must be properly dissipated
- Analyze and validate thermal dissipation paths heat to ensure preservation of the cell PTC device's safety feature.

Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules	Judy Jeevarajan
	July 10, 2008

The CID did not protect or underwent incomplete opening and reset under some overcharge conditions.

- The CID cannot always be depended upon as safety control in multicell series/parallel battery designs.
- Voltage monitoring is required to allow reliable, accurate detection and prevention of an overcharge condition

Charge current and voltage limit of the charger or power supply dictated the reaction of the cells to overcharge conditions.

- Confirm that the CID safely activates and protects the battery from overcharge catastrophes in the actual flight battery configuration,
- Tests should be run at the module size that the CID is being used as a safety control.

Catastrophic results were found when the charge current and the power supply voltage are set at high values parallel bank of cells

- Charge current used to charge a string or a bank should be as low as possible.
- For charging of cell banks, the total charge current should be limited to a value that would not cause PTC activation in any single cell in the event that the CIDs of all the other cells have opened.

Limitations of Internal Protective Devices in Cylindrical Li-ion COTS Cells in High-Voltage, High-Capacity Cell Modules	Judy Jeevarajan
	July 10, 2008

Excessive charger power supply voltage can cause catastrophic failures if batteries get into an overcharge condition. The difference between the end-of-charge voltage of the module and the charger power supply voltage limit could result in CID arcing if that difference was too large (≥ 50 V for the cells studied).

- Set charger/power supply voltage limit as close as possible to the end of charge voltage for the battery
- At any point during the charging process, including failure modes that result in overcharging, no single cell CID should see a voltage high enough to cause arcing during CID opening.

In cell header tests, CID arcing, in the absence of excess liquid electrolyte was observed in some cases; in actual cell tests, this arcing was not observed (electrolyte could have reduced the incidence of arcing).

- Recommend all new cell designs be verified for arcing limits.

Charge Limits

Kumar Bugga

July 10, 2008

Determination of Safe Charge Conditions for Li-Ion Cells/Batteries

Ratnakumar V. Bugga (JPL)

Safe Charge Rates for Li-Ion Cells

Effects of Lithium Plating

Kumar Bugga

July 10, 2008

Problem Description

- Lithium-ion batteries may exhibit a tendency to have metallic lithium deposited on the graphite anode during strenuous charge conditions; i.e., a combination of high charge rate and low temperature.
 - May reversibly oxidize during subsequent discharge giving a high voltage plateau.
 - Depends on the Nature of electrolyte, Nature anode composite electrode, extent of anode reserve
 - May result in accelerated degradation of the electrolytes, reduced cycle life, reliability and safety.

Proposed Solution, Risk Assessment

- A systematic study was carried out to categorizing safe charge conditions, by identifying the charge conditions conducive to and permitting lithium plating, which are to be precluded to ensure the performance, reliability and safety.

Safe Charge Rates for Li-Ion Cells

Effects of Lithium Plating

Kumar Bugga

July 10, 2008

Assessment Plan

- Develop adequate screening methods were developed to identify the lithium plating phenomenon, e.g., high voltage plateau.
- Fabricate laboratory glass cells with carbon anodes and nickel cobalt oxide cathodes and Li reference with different electrolytes to assess their impact
- Evaluate lithium-ion cells, with different electrolytes, electrode capacity ratios and configurations from different manufacturers,
 - SAFT DD cells with a low temperature electrolyte
 - Yardney 7 Ah cells, with chemistry similar to the MER batteries
 - Quallion 18650 cells,
 - Quallion pouch cells of 4 Ah with three different electrolytes,
 - SKC polymer cells
 - A123 26650 cells of 2.3 Ah.
- Charge at different charge rates (up to C rate) and temperatures (down to -40°C) followed by discharge at the same temperatures, at constant current corresponding to C/10.
 - The discharge profiles were examined to determine the on-set of Li plating in the preceding charge

Safe Charge Rates for Li-Ion Cells

Summary Findings

Kumar Bugga

July 10, 2008

- **Li-ion cells upon charge at high rates and/or low temperatures can exhibit a tendency to have metallic lithium deposited on the carbon anode – a deviation from the intercalation process that the Li-ion chemistry was designed to accomplish (in contrast to Li metal systems). Such Li plating will have deleterious impact on the performance, reliability and even safety.**
- **This characteristic is dictated by several parameters including the nature of electrode and electrolyte materials and the cell design parameters, especially the relative electrode capacities.**

Safe Charge Rates for Li-Ion Cells Recommendations

Kumar Bugga

July 10, 2008

- **It is recommended that Li-ion cells and batteries be tested in the expected charge regime and temperature range before putting them for use.**
- **Charge cells at the relevant charge rate and temperature and look for the evidence for Li plating in a subsequent discharge, which will be in the form of a voltage plateau about 100 mV higher than normal in the early stages of discharge.**
- **It is recommended that some margin is allowed in the charge rates, since the relative electrode capacity ratios may get worse upon cycling, due to a relative faster degradation from the anode.**
- **The plated lithium may partly be intercalated, either during the tapered charge mode or in the open-circuit stand, which we need to study further. Likewise, the long-term impact of such Li plating, though known to be harmful, needs to be understood.**

Availability of Source Material for Li-Ion Cells	Michelle Manzo
	July 10, 2008

Availability of Source Material for Li-Ion Cells

Michelle A. Manzo (GRC)

Availability of Source Material for Li-Ion Cells

Michelle Manzo

July 10, 2008

- Li-ion batteries - beginning to demonstrate the long cycle life required by low-earth and geosynchronous-orbiting missions.
- Li-ion production dominated by commercial marketplace
 - Optimized for weight, volume, cost and run time at the expense of cycle life.
 - Materials change from the validated electrode materials that demonstrated necessary performance for aerospace mission applications
 - Source materials that produce the life required by NASA missions are becoming unavailable.

Mitigation:

- Title 3 Effort – Sponsored by US Government
 - Ensure a constant supply of the source materials that have demonstrated the long life performance required for long-life aerospace missions.
 - 5-year, cost share Technology Investment Agreement (TIA) was awarded to Quallion, LLC, Sylmar, California on September 5, 2006.
 - The agreement is managed by the US Air Force Research Laboratory (AFRL/RXM)Data Analysis

Availability of Source Material for Li-Ion Cells - Background	Michelle Manzo
	July 10, 2008

Quallion Title III Li-Ion Battery Program Quarterly Management Review – June 24, 2008

- **Tasks Progressing toward the following goals:**
 - full cell production capability in the 4th Quarter of 2009
 - full cathode production capability by the 2nd Quarter 2010
 - full anode production capability by the 3rd Quarter of 2010
- **Materials produced under this contract will be available to any domestic manufacturer of Li-Ion cells for government space programs.**

Li-ion Source Material Availability Observations

Michelle Manzo

July 10, 2008

O-1. NASA has contributed to the support of the Defense Production Act Title III effort via this NESC supported task. Under this project, a cost share Technology Investment Agreement (TIA) was awarded to Quallion, LLC, Sylmar, California on September 5, 2006. The agreement is managed by the US Air Force Research Laboratory (AFRL/RXM). It will serve to do the following:

- Strengthen the US-owned domestic industrial base for true prismatic, extremely long life cells and batteries for USG satellite use of at least one MWhr/year (approximately 3600 nominal 50 Ahr cells). This will be produced in a clean/dry room at a semi-automated rate of 70 per week.
- Establish US-owned domestic source of LCO cathode materials (200kg/month) for USG satellite use, through a technology transfer agreement with a foreign company.
- Establish US-owned domestic source of anode material MCMB (200kg/month) for USG satellite use, through a technology transfer agreements with Ube Chemical.
- Stockpile the LCO precursor material for future USG satellite cell production use.

Battery Workshop

Jeff Brewer

July 10, 2008

NASA Aerospace Battery Workshop Jeffrey C. Brewer (MSFC)

NASA Aerospace Battery Workshop

Jeff Brewer

July 10, 2008

Problem Description

- Quality venues are lacking to discuss aerospace battery technology issues/concerns.
- Existing venues are generally broad in their focus.
- Dissemination / discussion of aerospace battery issues are hindered.

Proposed Solution

- The NESC will jointly sponsor the NASA Aerospace Battery Workshop with the Exploration Technology Development Project to maintain a consistent, quality venue.

NASA Aerospace Battery Workshop

Jeff Brewer

July 10, 2008

Risk Assessment

- Without an appropriate venue wherein issues that directly affect the aerospace battery industry can be discussed, increased risk to the development of safe, reliable, and efficient battery systems for future NASA missions will be present.

Assessment Plan

- An annual aerospace battery workshop is convened, coordinated by Electrical Power Branch personnel at MSFC.
- Facilities, materials, and proceedings costs are all contracted efforts, while labor is provided by civil service personnel at MSFC.
- Technical focus each year is dictated by current issues that face the aerospace battery community. The focused topic for the 2007 workshop was the NESC proactive battery work conducted under this assessment.

NASA Aerospace Battery Workshop - Findings

Jeff Brewer

July 10, 2008

- The 2007 NASA Aerospace Battery Workshop convened in November 2007.
 - Attended by scientists and engineers from around the world, representing both private industry and government entities.
 - 123 attendees - 10 percent increase over the previous year's attendance.
- Topics covered
 - Ground test and flight results, charge control, and safety for the Li-Ion battery chemistry, flight results for the nickel-hydrogen battery chemistry
 - The focused topic for the 2007 workshop was the NESC proactive battery work conducted under this assessment.