COTS Li-ion Cells; How rugged are new designs?

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For the
NASA Aerospace Battery Conference
6-8 Nov 2012
Huntsville, AL

Preliminary Draft
Outline

• Introduction and purpose
• COTS cell designs tested
• Test Plan
• Cell Quality Assessment
  – Capacity cycling pre & post vibration
  – Cell DPA
• Summary Conclusions
Current Batteries Supporting Space Walks

- **Rechargeable EVA Battery Assembly (REBA)**
  - Nickel Metal Hydride (NiMH)

- **Pistol Grip Tool (PGT) Battery**
  - Nickel Metal Hydride (NiMH)

- **Helmet Light (EHIP) Battery**
  - Nickel Metal Hydride (NiMH)

- **Simplified Aid For EVA Rescue (SAFER) Battery**
  - Lithium Manganese Dioxide (Li-MnO₂)

- **Long Life Battery (LLB) for EMU**
  - Lithium ion (Li-ion)

All made with commercial cylindrical cell designs, none are pouch construction.
Objective & Rationale

• **Introduction**
  – Orion LAS found shock & vibration limitations with a COTS 18650 cell design from Sanyo
  – Several new NASA applications have very high vibration requirements

• **Objective**
  – Can current high energy COTS Li-ion cell designs tolerate rigorous random vibration levels?

• **Rationale**
  – COTS Li-ion cell designs offer high performance, reliability, and consistency at a low cost
  – The Aerospace battery community will benefit from knowing the mechanical environment limitations of COTS Li-ion cell designs
## New COTS Cell Designs Evaluated

<table>
<thead>
<tr>
<th>Cell Manufacturer</th>
<th>Cell Model</th>
<th>Cell Capacity (mAh)</th>
<th>Virtual Cell Capacity (Ah)</th>
<th>Heritage &amp; Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>LG Chem</td>
<td>ICR18650 B4</td>
<td>2600</td>
<td>39</td>
<td>Highest Wh/L with SS can</td>
</tr>
<tr>
<td>E-One Moli Energy</td>
<td>ICR18650J</td>
<td>2400</td>
<td>36</td>
<td>LLB cell</td>
</tr>
<tr>
<td>Panasonic</td>
<td>NCR-18650A</td>
<td>3100</td>
<td>46.5</td>
<td>SpaceX cell, Highest Wh/L of all</td>
</tr>
<tr>
<td>Samsung</td>
<td>ICR-18650-26F</td>
<td>2600</td>
<td>39</td>
<td>Very high Wh</td>
</tr>
<tr>
<td>Sony</td>
<td>18650V3</td>
<td>2250</td>
<td>33.75</td>
<td>Good mix of power/energy, no PTC</td>
</tr>
<tr>
<td>Boston Power</td>
<td>Swing 5300</td>
<td>5300</td>
<td>39.75</td>
<td>Larger format, good mix of Wh/W, no PTC</td>
</tr>
</tbody>
</table>
Test Plan

• Procure lots of 20 cells for each cell design
• Use existing, proven 18650 vibration fixture
• Design & fabricate BP vibration fixture
• Receiving Inspection of all cells (120 in total), 20 per design
• Perform capacity cycling on all 120
• Vibrate 3 cells per design at each level
  – Level 1: Baseline Level
  – Level 2: Repeat with 3 fresh cells per design to Baseline + 3 dB
  – Level 3: Repeat with 3 fresh cell per design to Level 2 + 3 dB
• Perform post vibration capacity cycling
• Perform fully DPA on one cell from each design
• Perform abbreviated DPA on every cell
  – Cut open the tops and bottoms only to verify electrical connectivity of jellyroll to Enclosure
• Document results in Task History
# Level 2 Vibration Spectrum

Taken from Orion Abort Reqs

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Baseline PSD (g²/Hz)</th>
<th>Level 2 (g²/Hz)</th>
<th>Level 3 (g²/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.05</td>
<td>0.1</td>
<td>0.2</td>
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<tr>
<td>80</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>150</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>240</td>
<td>1.5</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>500</td>
<td>1.5</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2000</td>
<td>0.15</td>
<td>0.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Total GRMS | 34.73 | 49.12 | 69.46 |
Post Vibration Cell DPA showing positive and negative tab connections

Panasonic NCR-18650A (3.1Ah)

LG ICR18650B4 (2.6Ah)
Summary

• All cells (54) passed the intensive vibration levels
  – Level 3 exposed cells to 69 grms over 20-20,000 Hz
  – OCV pre and post vibration did not vary > ± 5 mV
  – Capacity performance pre and post vibration did not vary > 1 %
  – Abbreviated cell DPA after vibration indicated that all internal tab connections from the electrode jellyroll to the top/bottom of cell enclosure show no signs of fatigue

• Full cell DPA revealed unique features of each cell design and overall quality of manufacturing
Acknowledgements

• Propulsion & Power Division at JSC for funding the effort
• Energy Systems Test Area at JSC for conducting the test
  – Laura Baldwin, Frank Zambrano
• John Weintritt and Nick Kidd (Jacobs Engineering) for enabling high quality cell DPAs