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

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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)
- **Long Life Battery (LLB) for EMU**
  - Lithium ion (Li-ion)
- **Simplified Aid For EVA Rescue (SAFER) Battery**
  - Lithium Manganese Dioxide (Li-MnO₂)

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>
</tr>
<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>
<tr>
<td>Total GRMS</td>
<td>34.73</td>
<td>49.12</td>
<td>69.46</td>
</tr>
</tbody>
</table>
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
Acknowlegements

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