The ISS currently uses Ni-H2 batteries in the main power system. Although Ni-H2 is a robust and reliable system, recent advances in battery technology have paved the way for future replacement batteries to be constructed using Li-ion technology. This technology will provide lower launch weight as well as increase ISS electric power system (EPS) efficiency. The result of incorporating this technology in future re-supply hardware will be greater power availability and reduced program cost. The presentation will outline some of the major benefits and safety considerations of incorporating the new technology.
Li-Ion Battery for ISS

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Why Use Li-Ion Batteries for ISS

Significant Program Cost Savings
- Reduced cost of battery re-supply procurement
- Reduced weight and volume will provide significant launch cost benefits to NASA

- Technical benefits of Li-Ion Battery Technology are Real
  - Increased EPS performance
  - Decreased launch weight or increased life
  - Higher operational thermal limits

- New battery subsystem integration can be performed with minimal vehicle impact

- Operation with any Ni-H2 / Li-Ion Battery combination on Integrated Equipment Assembly (IEA) allows greater logistics flexibility
**Why Li-Ion Battery For ISS?**

**Overall Design Performance Parameter Battery Level Comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Li-Ion</th>
<th>Ni-H2</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell energy density @ 100% DOD, W.hr/l</td>
<td>250</td>
<td>50</td>
<td>One Li-Ion ORU can replace multiple Ni-H2 ORUs</td>
</tr>
<tr>
<td>Battery specific energy @ 100% DOD, W.hr/kg</td>
<td>~80</td>
<td>29</td>
<td>Lower equivalent launch weight</td>
</tr>
<tr>
<td>Nameplate capacity, kW-hr / Battery</td>
<td>&gt;10</td>
<td>8.4</td>
<td>Will result in higher reserve capacity for contingencies</td>
</tr>
<tr>
<td>Operating voltage range, V</td>
<td>81 to 123</td>
<td>76 to 125</td>
<td>Voltage range is compatible with in situ hardware</td>
</tr>
<tr>
<td>Normal operating DOD, %</td>
<td>15 to 25</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Roundtrip efficiency @ BOL, %</td>
<td>≥95</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Roundtrip efficiency @ EOL, %</td>
<td>&gt;85</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Operating temperature range, deg. C</td>
<td>0 to 40*</td>
<td>0 to 10</td>
<td></td>
</tr>
<tr>
<td>Non-operating temperature range, deg. C</td>
<td>-40 to +40</td>
<td>-10 to +20</td>
<td></td>
</tr>
<tr>
<td>Design life, years</td>
<td>6.5</td>
<td>6.5</td>
<td>Reduced logistics and launch costs (fewer launches)</td>
</tr>
</tbody>
</table>

* Manufacturer/chemistry dependent

- **Higher nameplate capacity will result in more power reserve for contingencies**
- Higher roundtrip efficiency will result in greater continuous power to the users
- Initially: Two Ni-H₂ battery Orbital Replacement Units (ORU) can be replaced with a single Li-Ion battery ORU, resulting in a weight saving of ~45% per battery.
- Considerable ISS life cycle cost savings due to fewer Battery ORUs
- Reduced on-orbit start-up time resulting from launch of charged Li-ion versus discharged Ni-H₂ batteries (present plan)
Li-ion Battery Replacement Concept

Spare Li-ion Battery ORU launch on FSE for On-Orbit Use

Only one ORU necessary for Li-ion
System Objectives / Targets

Li-Ion battery shall be designed to meet or exceed existing battery performance/life requirements.

- Any power channel will be able to support a combination of batteries - one or more Ni-H2 battery(s) and one or more Li-Ion battery(s) on the same power channel.

- Goal is for replacement hardware to be “plug and play” to minimize impacts to the present ISS hardware and software.
Current Battery Design Requirements

- Nameplate Capacity ≥ 81 A.hr
- Satisfy following power requirements:
  - Peak power at 6000 W for 5 minutes during eclipse or insolation period
  - Continuous power at 4600 W
  - Contingency discharge power at 1300 W for 92 minutes following a normal orbit
  - Offloaded configuration, continuous power at 7220 W
- Voltage range, during charge and discharge, not to exceed 76 to 125 V
- Capable of full charge in 4 orbits or less
- Roundtrip energy efficiency ≥ 80%
- Provide fault protection to the main power cables
- Each battery ORU shall weigh <375 lb (two ORUs make a battery)
- Design life of the battery 6.5 years with a storage life of 4 years
- Safety:
  - No fault propagation
  - Single fault tolerant to critical hazards
  - Two fault tolerant to catastrophic hazards
- Withstand specified thermal environments and MMOD exposure
- Withstand launch loads

Li-ion battery expected to meet or exceed these requirements
Li-ion will replace Ni-H$_2$ battery technology.

- ORU box design will be similar to the current Ni-H2 ORU box
  - Identical baseplate fins to interface with finned coldplate
  - Identical box and cover with its thermal protection
  - Identical power, data and control connectors

- An interface unit will be provided for connection to the BCDU. It will, in conjunction with BCDU perform charge control, heater, and dead-face (for safe ORU handling) functions.

- Heaters will be provided for low load operations and to thermally balance all battery ORUs within a power channel
Simplified ISS EPS Block Diagram
(One Channel)
Charge/Thermal Control

• Charge control
  – Would be (primarily) based on voltage data from cells.
  – Several charge control algorithms may be incorporated.
  – Multiple safety monitoring and mitigation methods will be employed

• Existing TCS has more than adequate capacity for new battery system

• Heater control
  – Will have series redundant switching.
  – Thermal control system will utilize multiple sensors
System Summary & Conclusions

- Change to Li-ion would be transparent to ISS except for changes to the Portable Computer System (PCS) and Mission Control Center (MCC) displays

- Higher efficiency and higher capacity of Li-ion batteries will enhance power channel power capabilities - continuous power and contingency power

- Safety aspects of the Li-ion batteries are understood and the proposed design will incorporate fault protection circuitry.

- Change from Ni-H2 to Li-ion battery can save launch weight and cost