Overview Summary/ Abstract

- 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

Space Power Workshop

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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

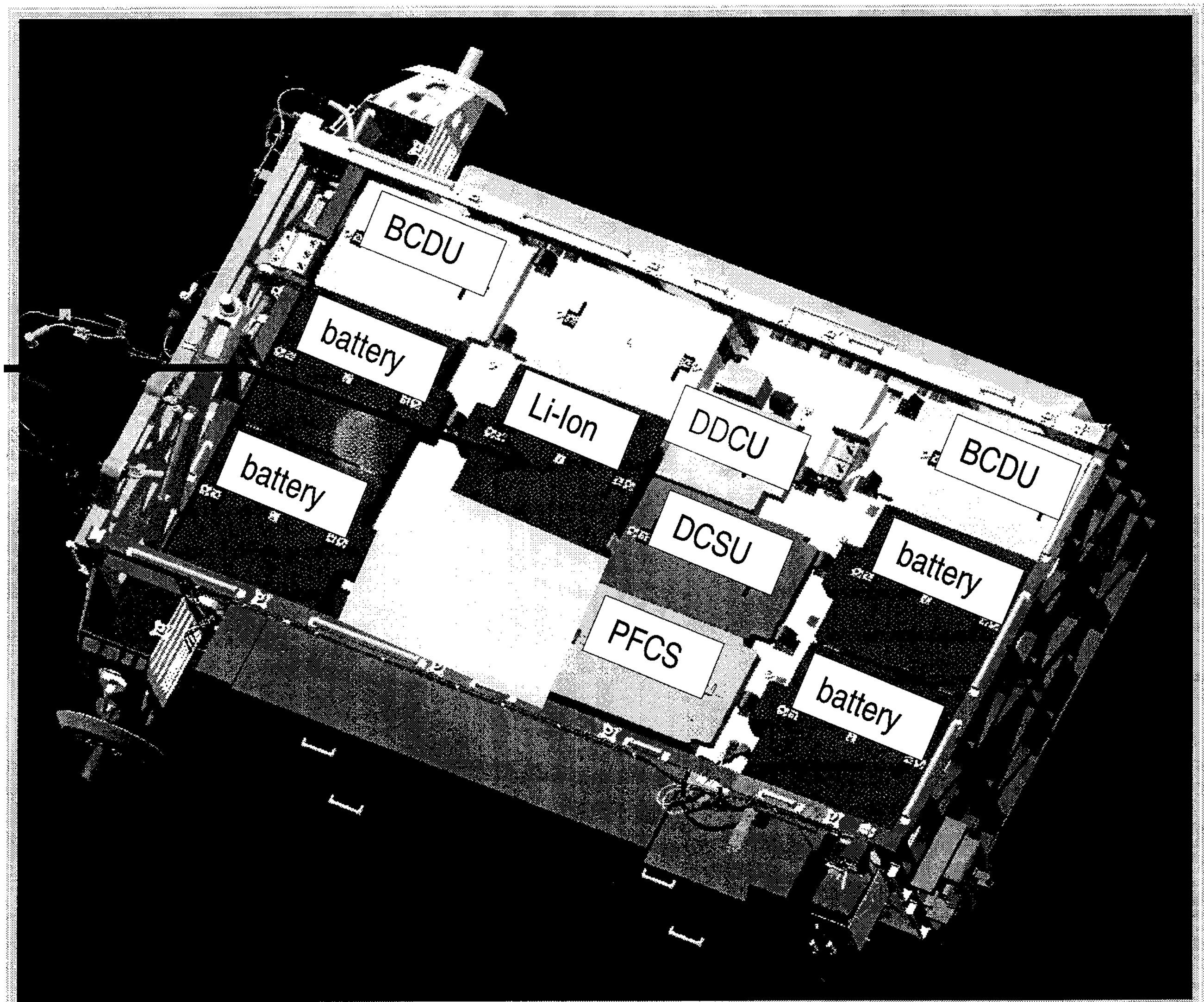
Parameter	Li-Ion	Ni-H2	Comment
Cell energy density @ 100% DOD, W.hr/l	250	50	One Li-Ion ORU can replace multiple Ni-H2 ORUs
Battery specific energy @ 100% DOD, W.hr/kg	~80	29	Lower equivalent launch weight
Nameplate capacity, kW-hr / Battery	>10	8.4	Will result in higher reserve capacity for contingencies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

* 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-H_2 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-H_2 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 $\geq$ 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 $\geq$ 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 Battery ORU Description

- Li-Ion will replace $Ni\text{-}H_2$ battery technology.

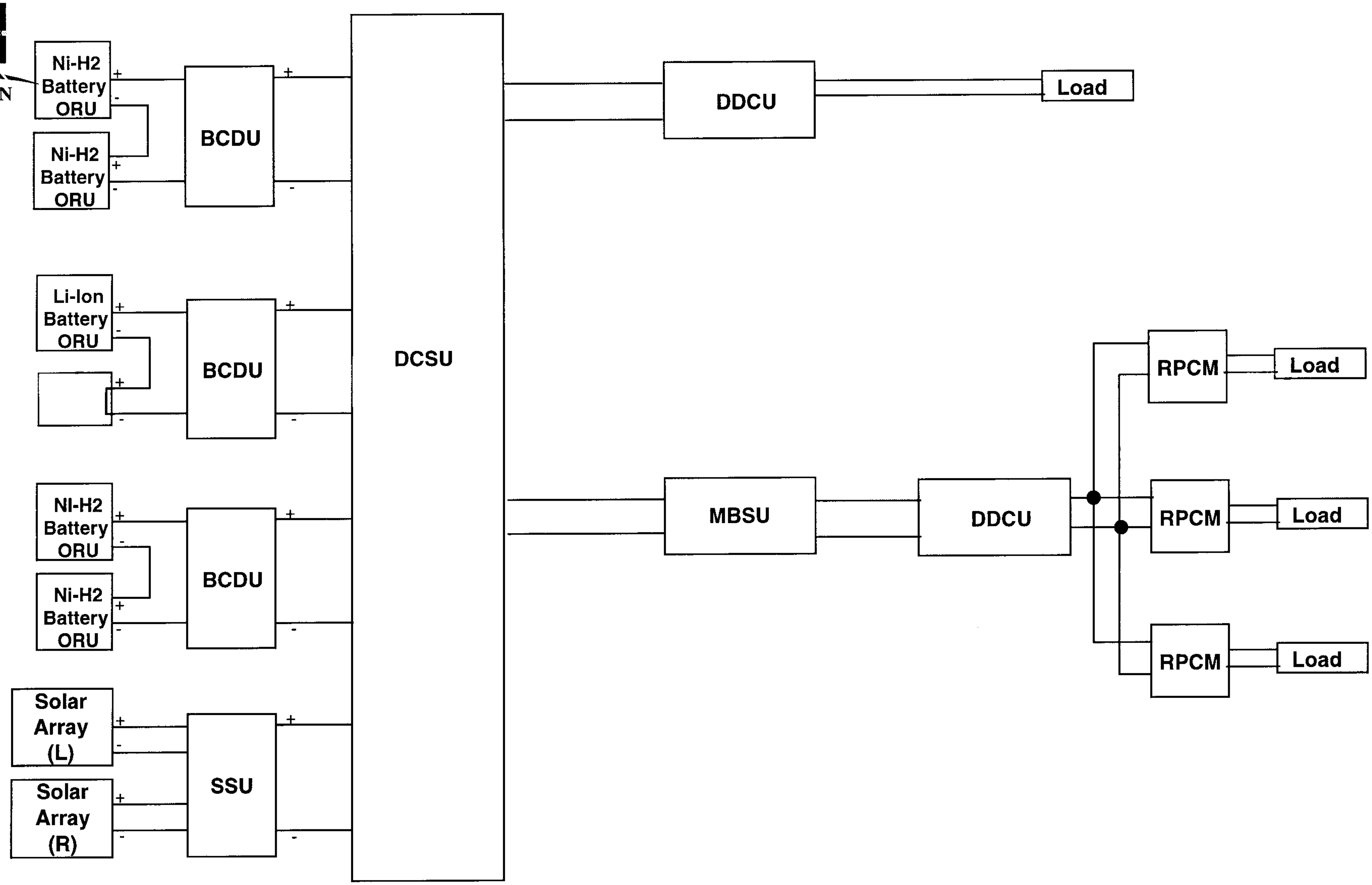
- ORU box design will be similar to the current Ni-H2 ORU box
  - Identical baseplate fins to interface with finned coldplate
  - Identical box and cover with its thermal protection
  - Identical power, data and control connectors

- 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