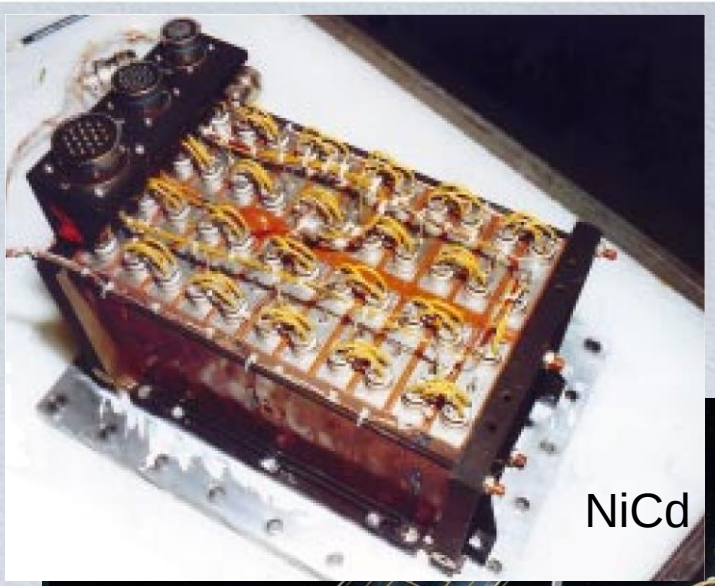
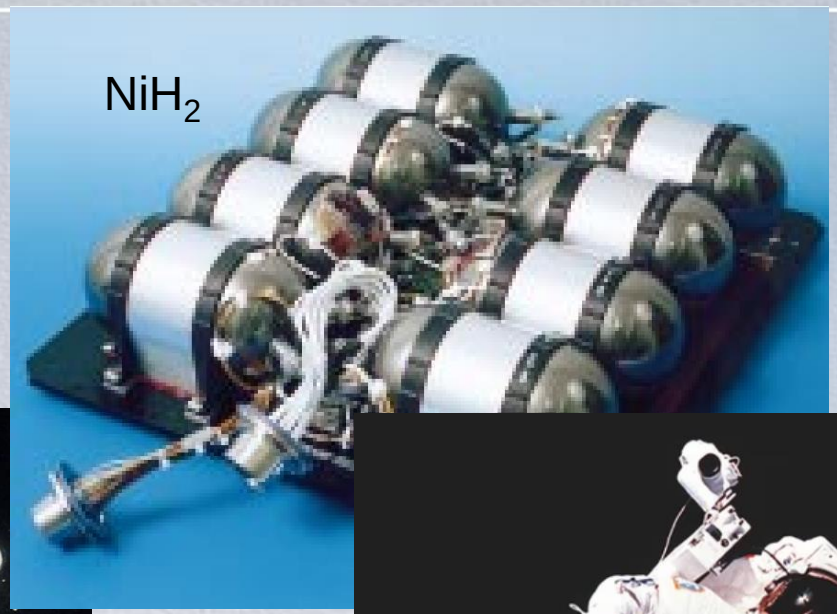
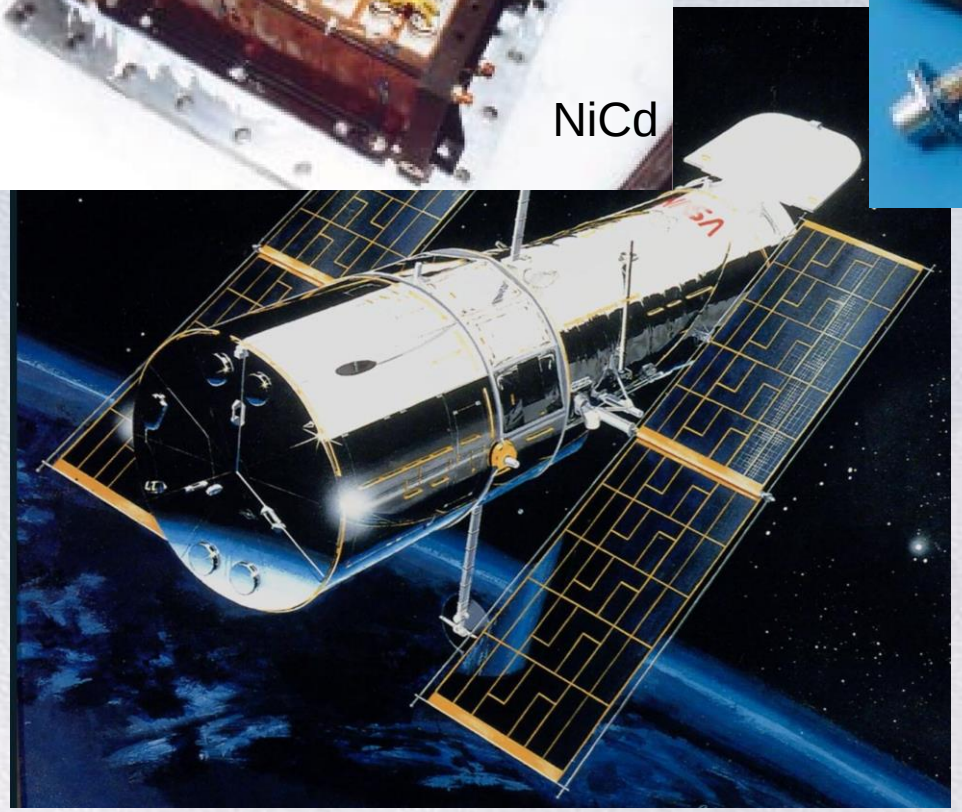
1980s



NiCd



NiH_2

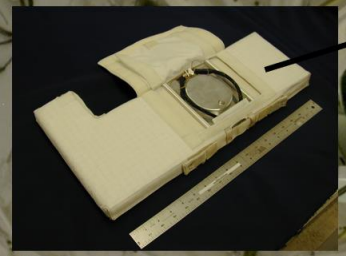


In 1980's, this workshop debated the performance and safety pros and cons of replacing NiCd batteries with NiH2 (Nickel/Hydrogen) for the benefit of Hubble, ISS, and numerous other LEO and GEO satellites.
And worked Ag/Zn battery challenges for the EMU and MMU.

1990s Space Walking Batteries

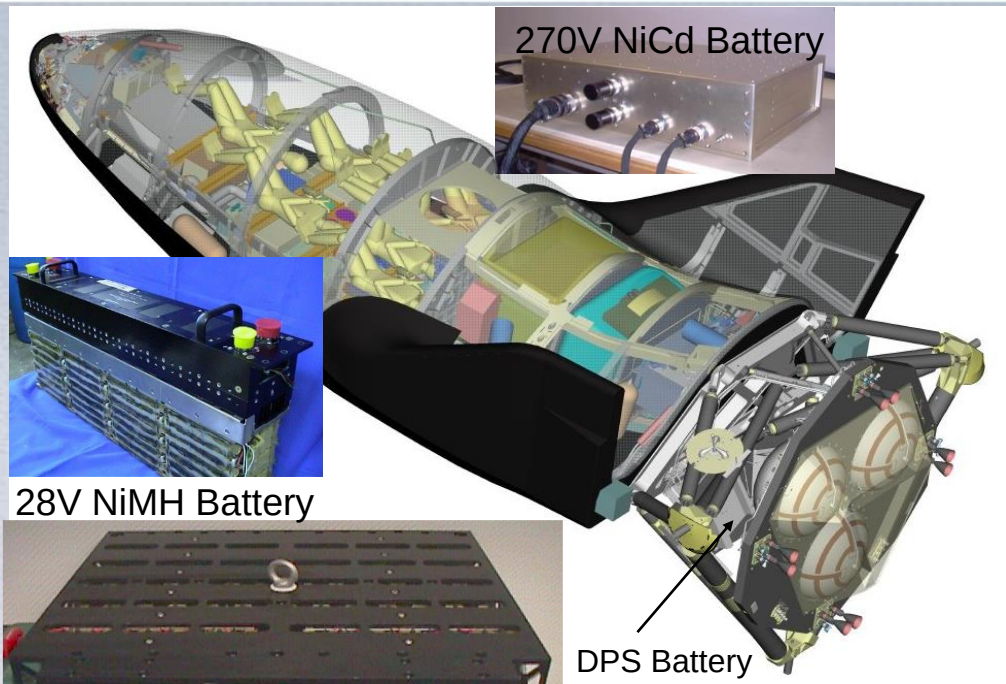
Pistol Grip Tool (PGT) Battery
Nickel Metal Hydride (NiMH)

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



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

Simplified Aid For EVA Rescue (SAFER) Battery
Lithium Manganese Dioxide (Li-MnO_2)

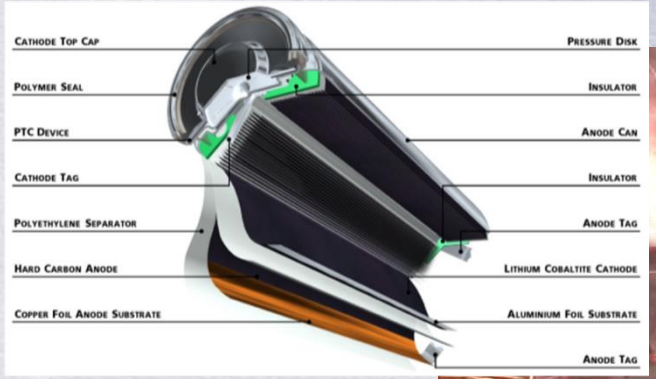


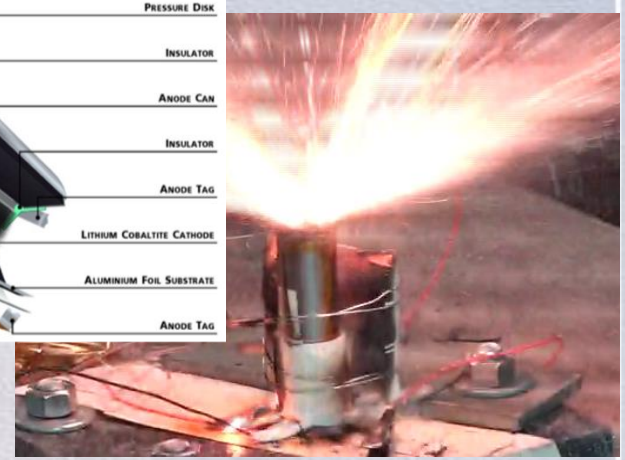
270V NiCd Battery

28V NiMH Battery

DPS Battery

Deorbit Propulsion Stage
Li/MnO_2 Battery





The benefits and drawbacks of NiMH (Nickel/Metal Hydride) were flushed out for the benefits of EVA batteries for helmet lights, pistol grip tool, and video camera/glove heater battery. Three battery designs were developed for the X-38. We also explored the promising but very hazardous Li-ion chemistry.

2000s

EMU LLB

Causes of Li-ion Internal Cell Faults

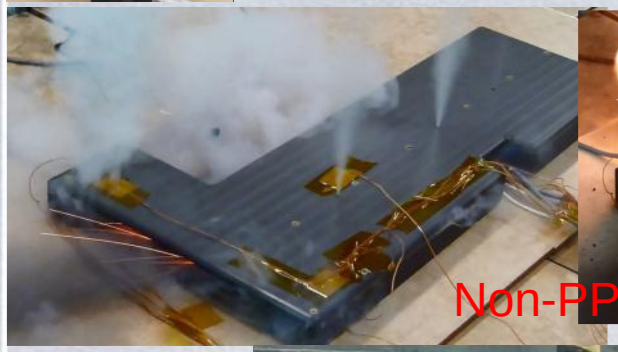
- **Manufacturing errors**
  - Lead problems
  - Winding edge problems
  - Localized damage to separator
- **Electrode degradation due to cell design or use/abuse**
  - Overcharge related
  - Over-discharge related (copper dissolution)
  - Localized lithium plating

In 2000's, Li-ion commercial industry had matured enough to offer compelling advantages over NiH2 and NiMH to force us to address its very challenging safety issues for space applications. In 2008, this forum dedicated an entire day about how to assess the risk of spontaneous internal short circuit in cells and best ways to prevent them. What we learned contributed to successfully converting the Ag/Zn (Silver/Zinc) battery for the spacesuit into Li-ion.

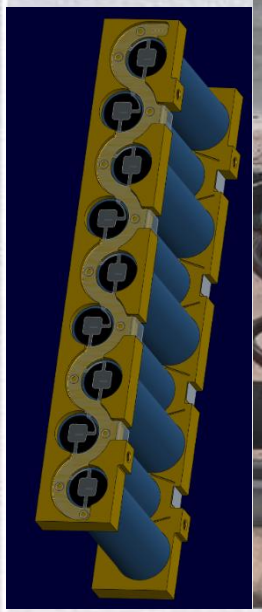
2010s

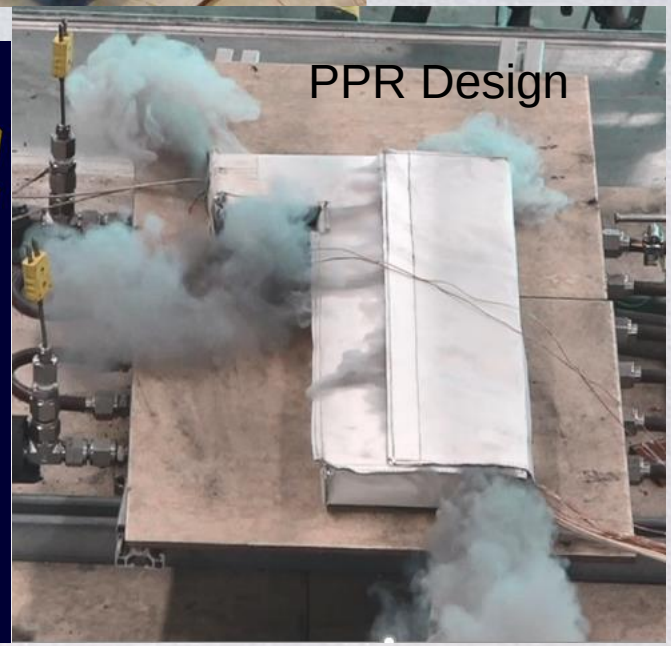
2 Battery TR events grounds fleet

Steel box for battery



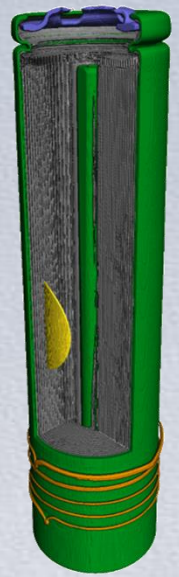
Non-PPR Design



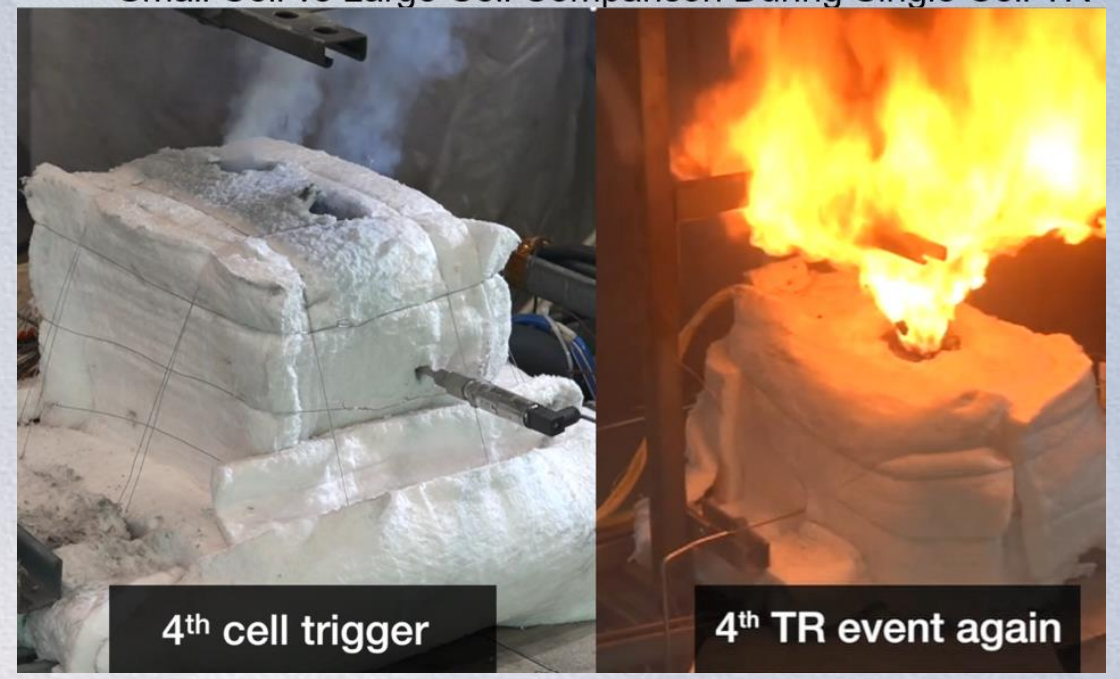


PPR Design

Internal Short Circuit Device Trigger Cell



Small Cell vs Large Cell Comparison During Single Cell TR



The grounding of the Boeing 787 Dreamliner due to spontaneous battery fires led our aerospace community to develop passively propagation resistant (PPR) battery designs that were still compelling vs older chemistries. Numerous talks were dedicated to understanding, detecting, and mitigating cell internal shorts and how to trigger them in a relevant way to enable effective battery PPR test campaigns. This benefited Orion/Artemis, ISS, CCP, EVA, and numerous other human spacecraft batteries.

2020s

Li metal

Si anodes

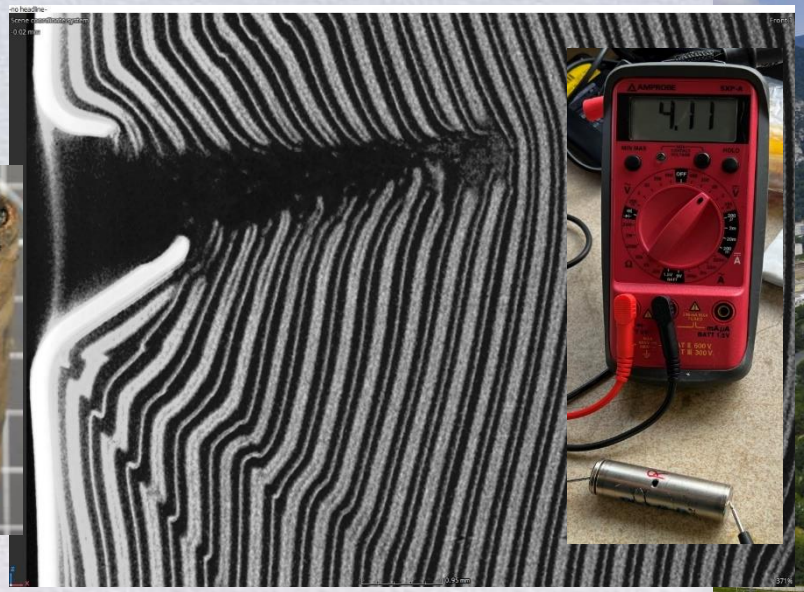
Pressurize gas electrolyte

Li-S

Fractional TR Calorimeter

Blast Plate Tester

Sidewall Rupture



Nail Tolerance with Plastic Current Collectors

This forum brought to light the performance and safety pros/cons of new Li-ion chemistries such as Li metal and Si anodes, Ni rich and Sulfur cathodes, pressurize gas electrolytes, thermally stable separators, plastic current collectors, solid-state electrolytes, and new tools for evaluating them. This stands to benefit our HLS and Artemis programs.