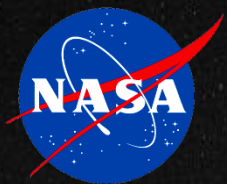




# Wilkinson Microwave Anisotropy Probe (WMAP) Nickel-Hydrogen ( $\text{NiH}_2$ ) Battery Anomaly Investigation

Denney Keys – NASA Engineering and Safety Center (NESC) Albert Zimmerman – The Aerospace Corporation

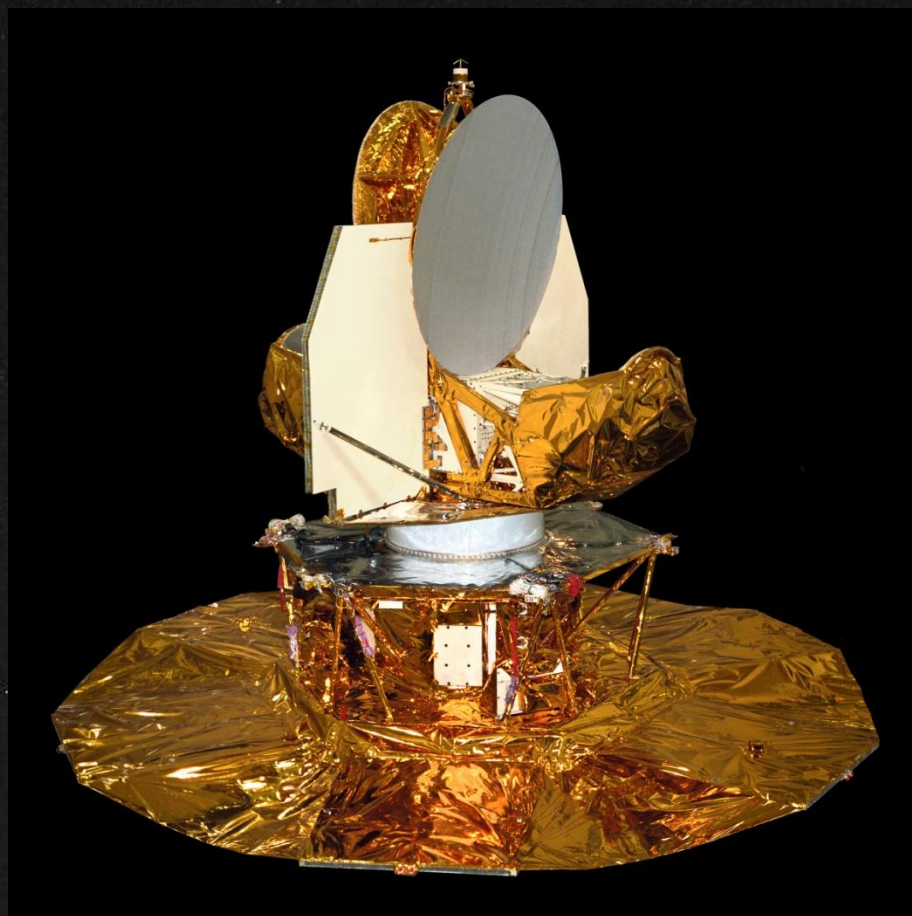
Space Power Workshop – Los Angeles, CA  
April 19, 2011

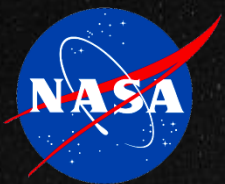


# Mission Background



- WMAP was launched June 30, 2001 to map the Cosmic Microwave Background radiation and produce a fine-resolution full-sky microwave map of the universe
- Originally designed for a mission duration of 2 years, operating on mission extensions for science operations through August 2010

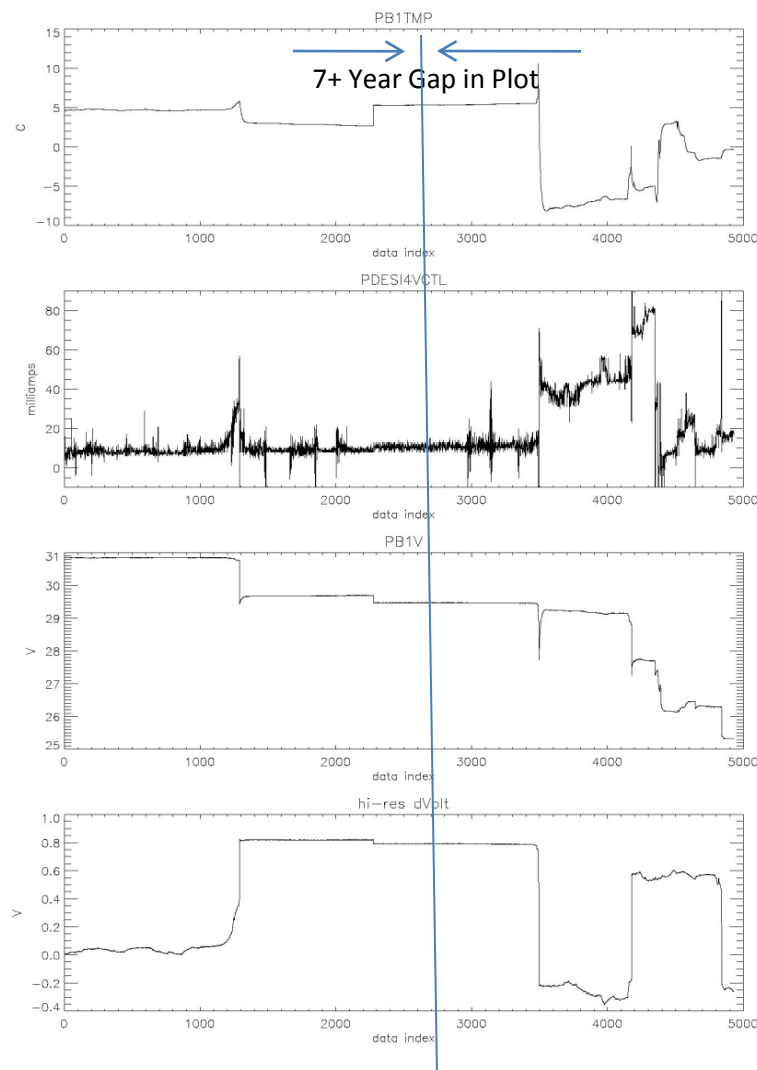


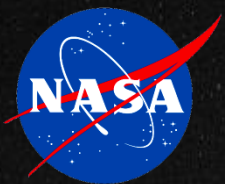


# Battery Anomaly Identified



- Identified in daily telemetry, the WMAP Common Pressure Vessel (CPV) based  $\text{NiH}_2$  battery suffered a series of individual cell voltage drops
- The first cell voltage drop occurred in February 2002 with four more cells experiencing similar voltage

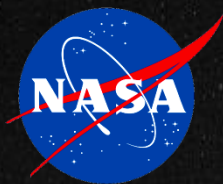




# Plan Developed to Address Battery Anomalous

## Performance Issues

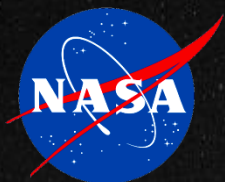
- Review of historical data related to WMAP mission issue, including battery parameters, battery performance, and current status
- Identification of any additional data, information, tests, or modeling needed to more effectively evaluate current battery status
- Performance of comparable electrical stress test on a WMAP spare flight battery cell and subsequent destructive physical analysis to evaluate possible internal chemistry effects
- Implementation of any additional identified on-orbit tests as a result of assessment investigation/modeling/and testing performed, to be coordinated through W-MAP Flight Operations
- Identify all potential candidates associated with battery performance degradation experienced



# Potential Causes for Observed Behavior

- NESC Investigation Team initially identified the following potential causes for the observed anomalous performance of defect \*
  - Foreign object/debris \*
  - External short \*
  - Overcharge \*
  - Age based capacity depletion \*
  - Undercharge
  - Items subsequently eliminated from consideration during investigation

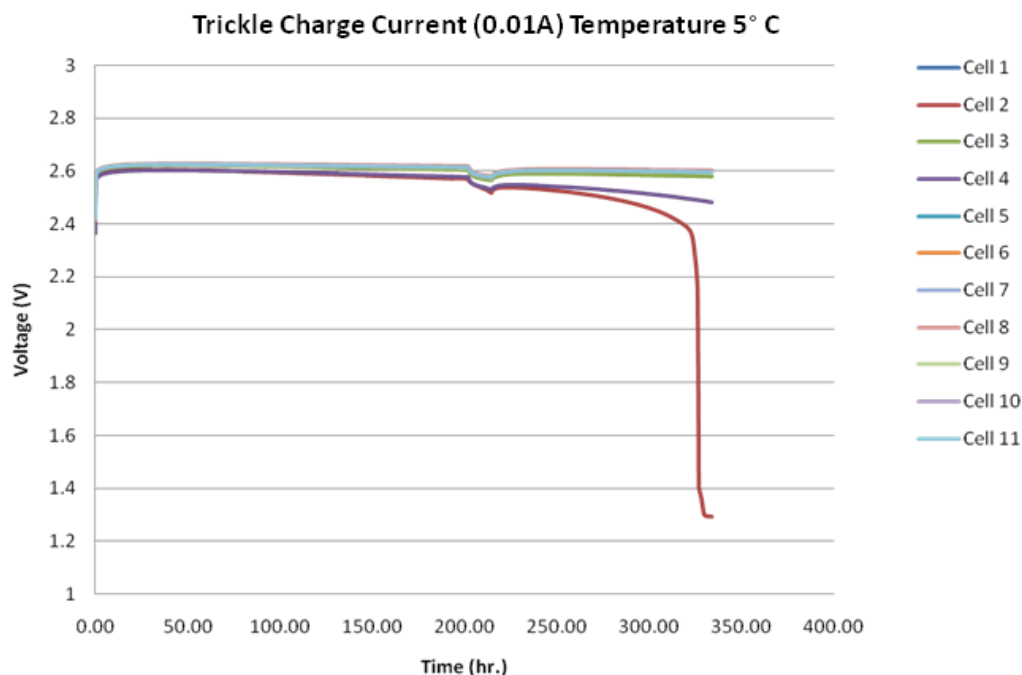




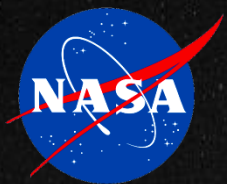
# Spare Battery Lab Testing Overview

Orbit simulated laboratory testing of the WMAP mission conditions using the flight spare battery identified the likely

**WMAP Flight Spare (Test) Battery Voltage Under Simulated On-Orbit  
Low Trickle Charge (C/2300) at Low SOC (at 5°C)**



Simulated on-orbit conditions successfully duplicated a cell voltage collapse while using low trickle charge conditions similar to that experienced on-orbit.



# Summary – On-Orbit Performance with Charge

## Maintenance

- Long term inadequate trickle charge mission operations precipitated cell voltage collapse events and likely initiation of electrolyte bridging within cells
- Application of recommended periodic charge pulses temporarily restored all but one of the collapsed cells, battery temperature limited recharge amount and was a concern during charging events (limited heat dissipation capability/thermal runaway concern)
- Nearly all cells experienced re-collapsing voltage over time after recharge activities
- WMAP was ultimately able to successfully complete science operations and was finally decommissioned in late 2010
- Follow up lab testing performed on a synthesized