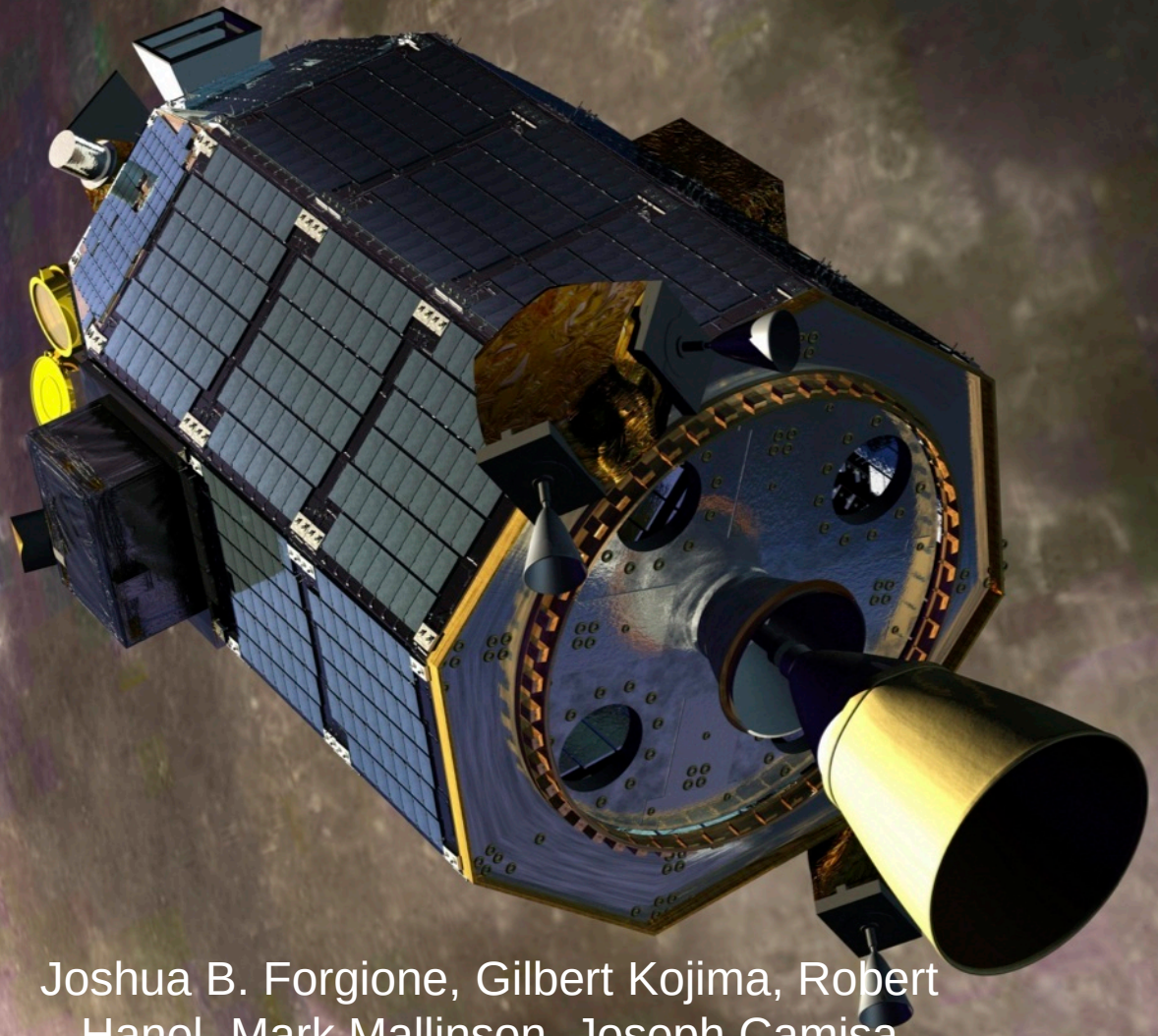
Low-Cost, Risk-Reduction Testing of Class D Spacecraft Photovoltaic Systems

The LADEE Approach



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- LADEE** Background & Power System
- Large Area Pulsed Solar Simulation (LAPSS) & Risk
- The LADEE Solution
- Conclusions

The Bottom Line

A low-cost, short-lifetime, Class D mission eliminated LAPSS testing due to resource constraints. The team instead developed a simple, low-cost, COTS-based method to verified power generation requirements and reduce technical risk.

**LADEE – Lunar Atmospheric and Dust Environment Explorer

Background – LADEE Mission

Objective
- Measure Lunar Dust
- Examine the Lunar atmosphere

Key parameters
- Launched Sept 6, 2013
- Science Data Acquisition: 100 days
- 1 Month Mission Extension (Impact ~4/21/14)

Spacecraft
- Type: Small Orbiter - Category II, Enhanced Class D
- Provider: ARC/GSFC

Instruments
- Science Instruments: NMS, UVS, and LDEX
- Technology Payload: Lunar Laser Communications Demo

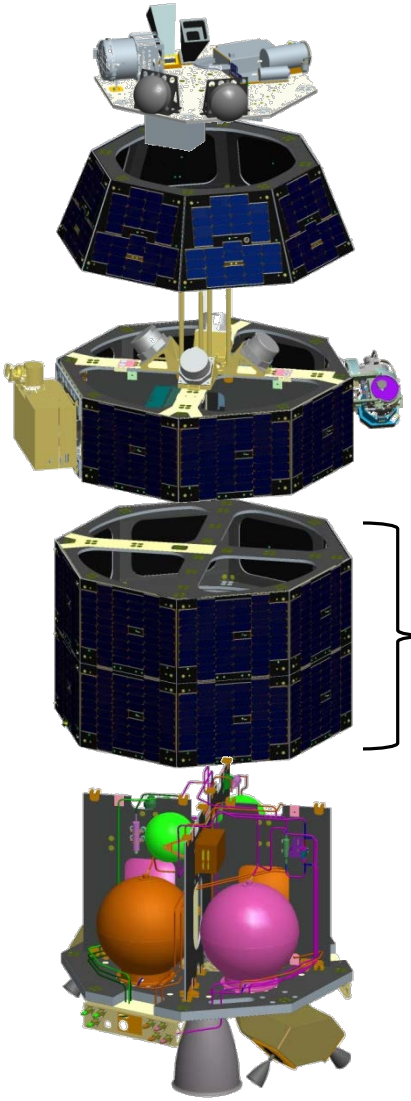
Launch Vehicle: Minotaur V

Launch Site: Wallops Flight Facility (WFF)

Class D: Low complexity, high-risk, short lifetime (NPR 8704.5)

Integrated LADEE @ WFF

LADEE Modular Spacecraft Bus



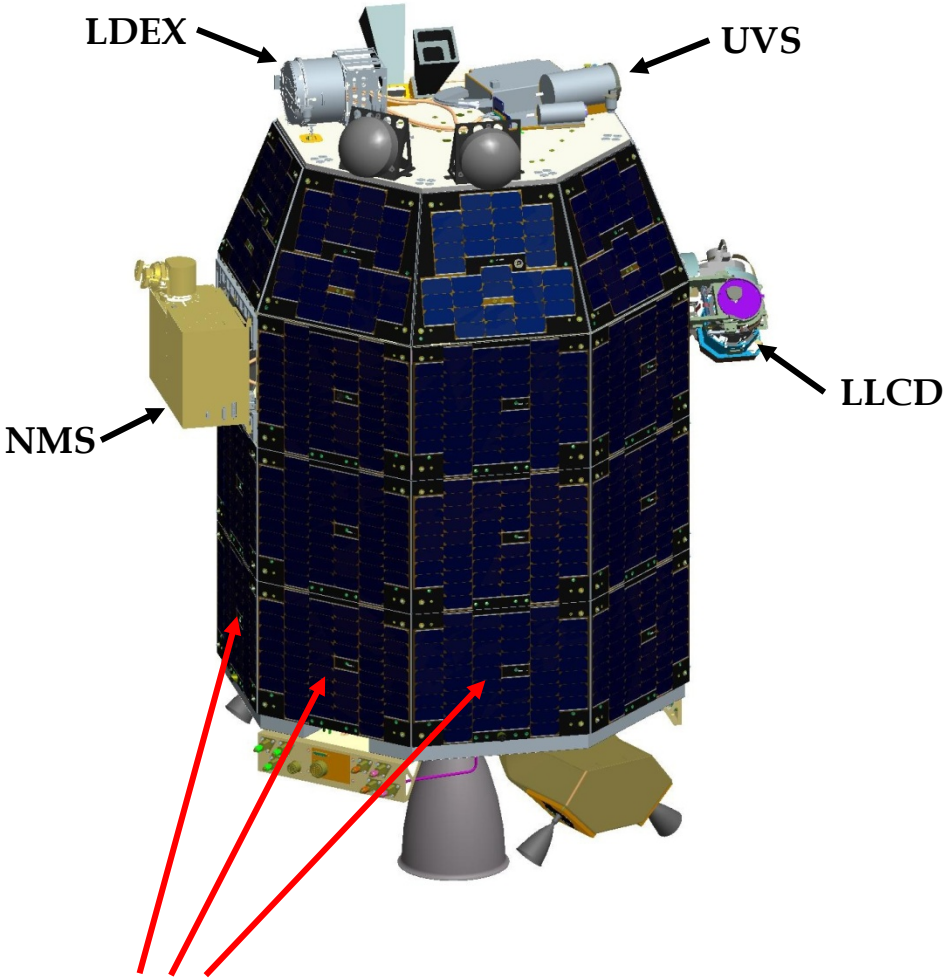
Radiator Assembly

Bus Module

Payload Module

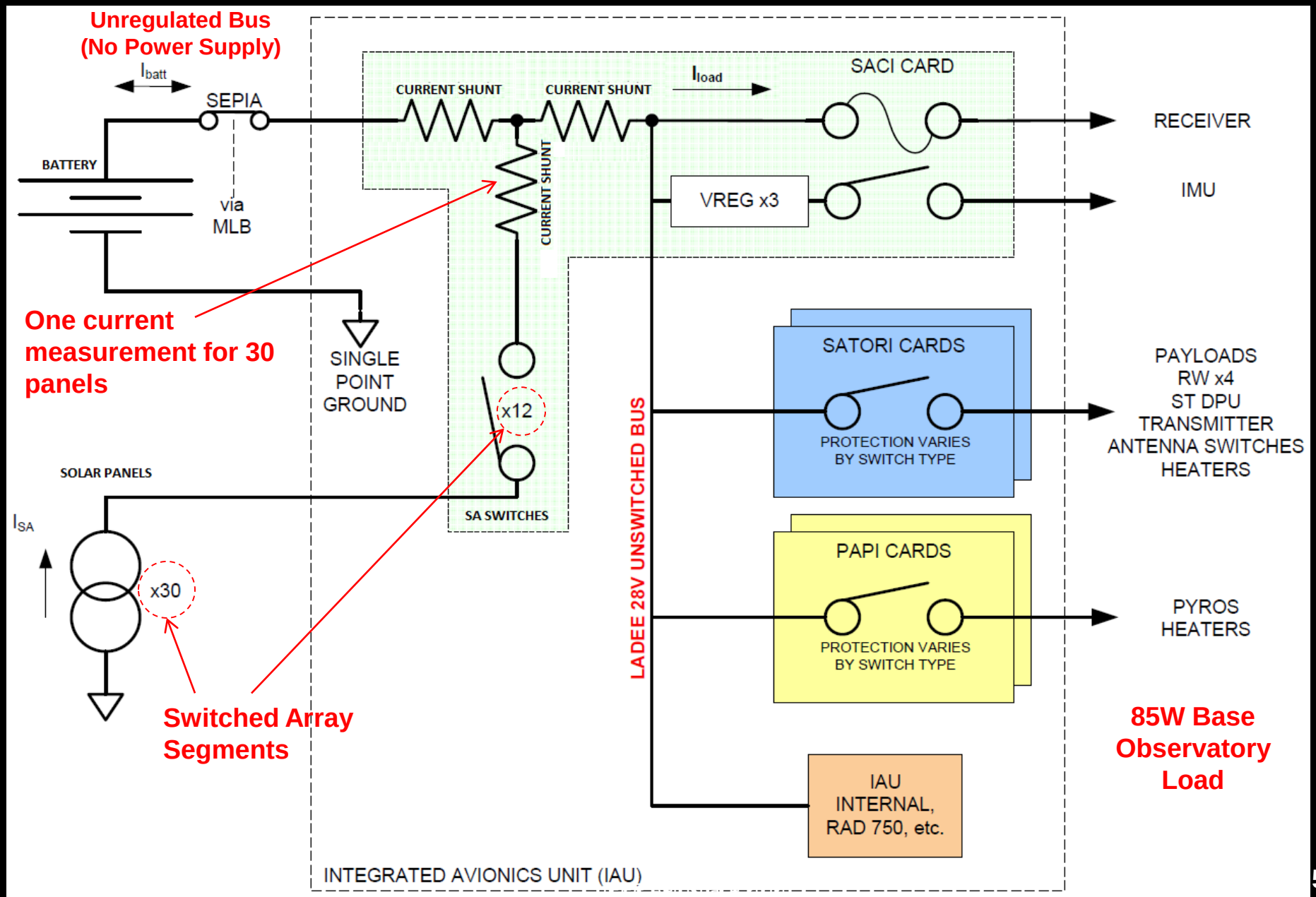
Extension Modules

Propulsion Module



Power Generation: 30 Body-Mounted Panels (295W)

LADEE Electrical Power System (EPS)



Large Area Pulsed Solar Simulation

LAPSS is the 'Gold Standard' for aerospace array testing

Does it make sense for LADEE?

PRO	CON
Very accurate (<2%)	ARC has no LAPSS – either build one or test off-site
End-to-End Calibration	Expensive (>$100k)
Safe – pulsed light does not heat array	Lengthy (test or build)
Can detect minor defects	Complex
Facilities exist within NASA	Heavy – 900kg (~1 ton)

Want to know more about LAPSS?

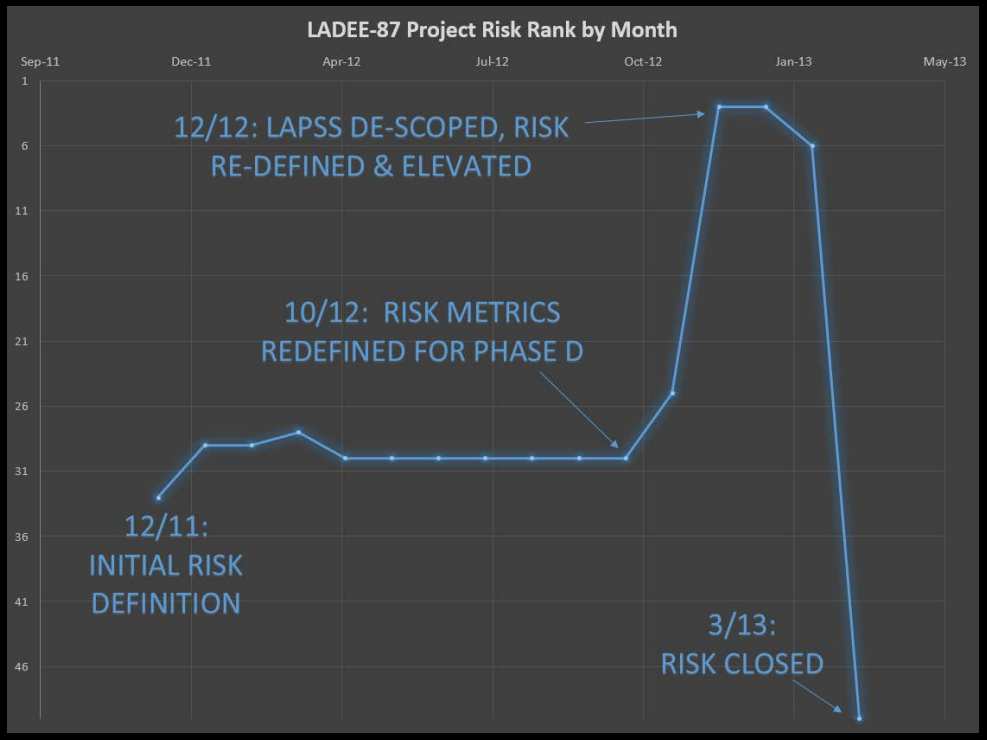
- Mueller, R.L. *The Large Area Pulsed Solar Simulator.* NASA Technical Report #NASA-CR-194507, Aug 15. 1993
- http://www.spectrolab.com/simulators.htm

LAPSS and Risk

- Enter Phase D, LADEE faced substantial schedule challenges and redefined its risk metrics.
- The original risk (LADEE-87), related to scheduling of the LAPSS test
- In Phase D, LAPSS testing was cancelled – the risk morphed & elevated

Given that: LAPSS testing was only performed for each individual solar panel by the vendor.

There is a possibility that: Without Observatory level LAPSS system performance testing for the interconnected solar panels, which are combined through the Primary cable harness panel interconnections, the requirements verification of the 295 Watts solar panel output power will not be verified by testing.



The LADEE Risk Management process is not novel, and typical of NASA programs

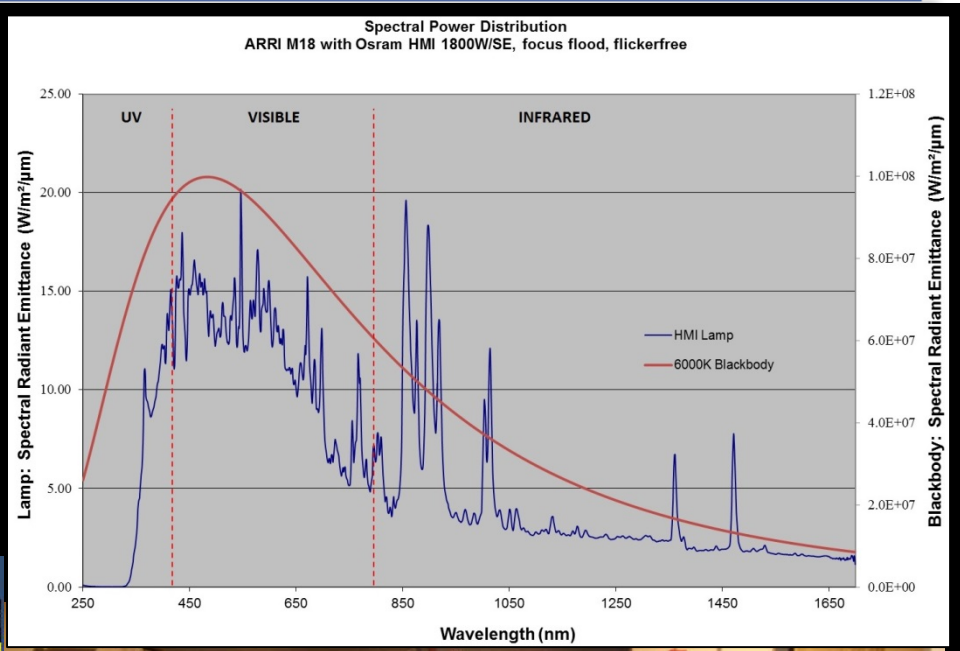
Class D resource constraints forced the project to take a risk & innovate

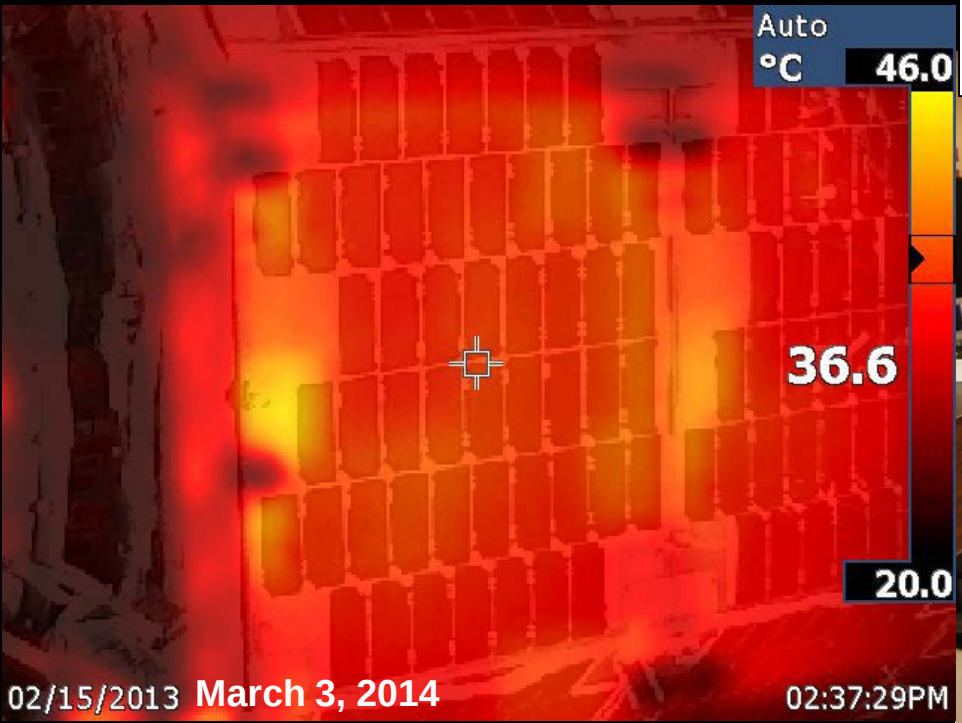
Developing the Solution

Key Requirements:

- Generate rated power (295W req.)
- Hardware safety (temperature)
- Personnel safety (UV)
- Quick test (<1 day)
- Low Cost

Research & Experimentation yielded a COTS solution that exceeds requirements

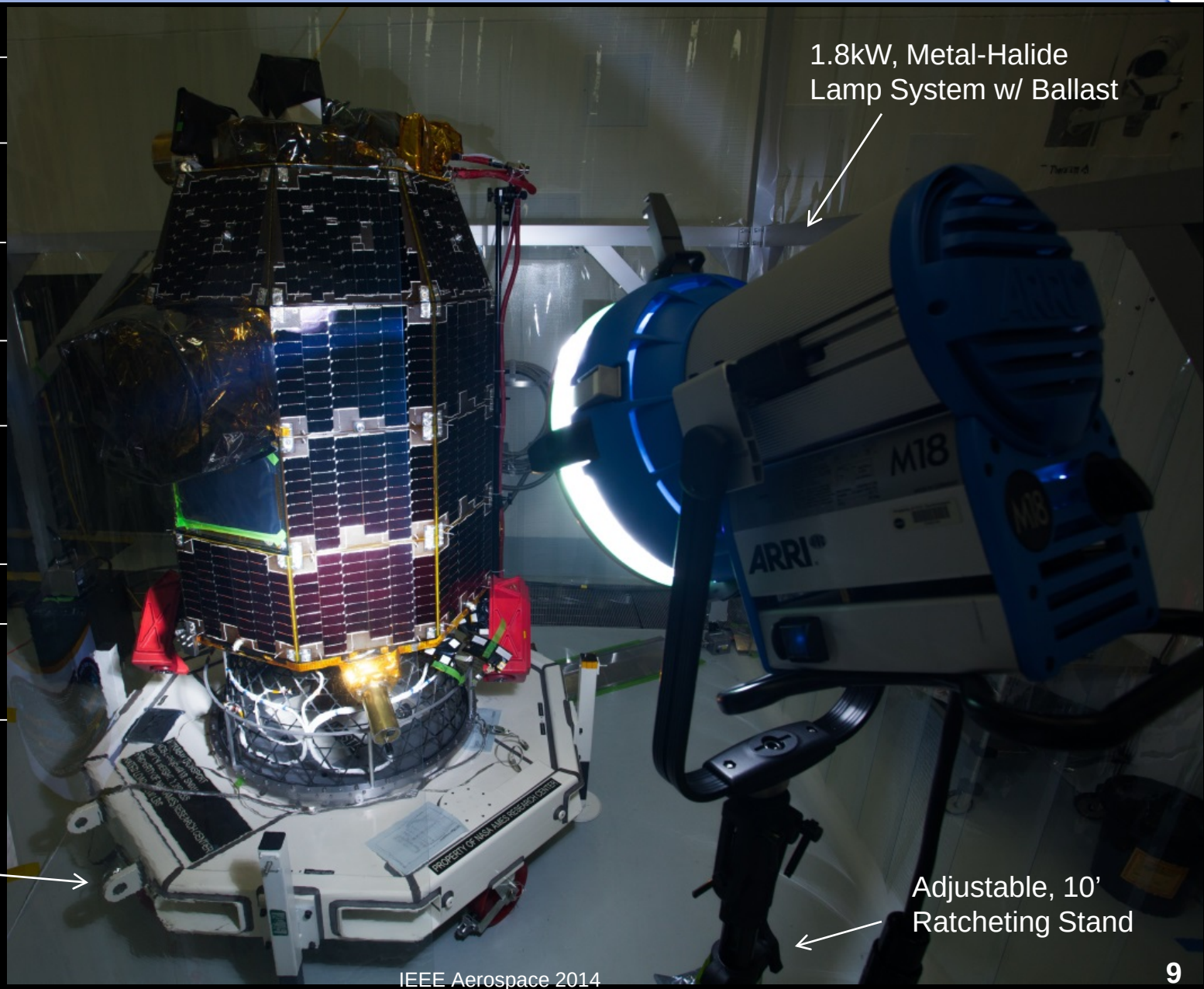




March 3, 2014

Observatory Test

- 295W req. verified!
- Thermal imagers monitor temperature
- ANSI z87.1 glasses protect from UV
- Test repeated 3 times before launch
- Easy to perform inside 10k clean tent
- Lamp System Cost:
  $10k Buy
  $750/wk Rent
- Test Time: 4 Hours
- System weight:
  ~45kg (~100lb)
- ‘Corn-Cob’ Test :
  Test Panels Individually, then Rotate Spacecraft

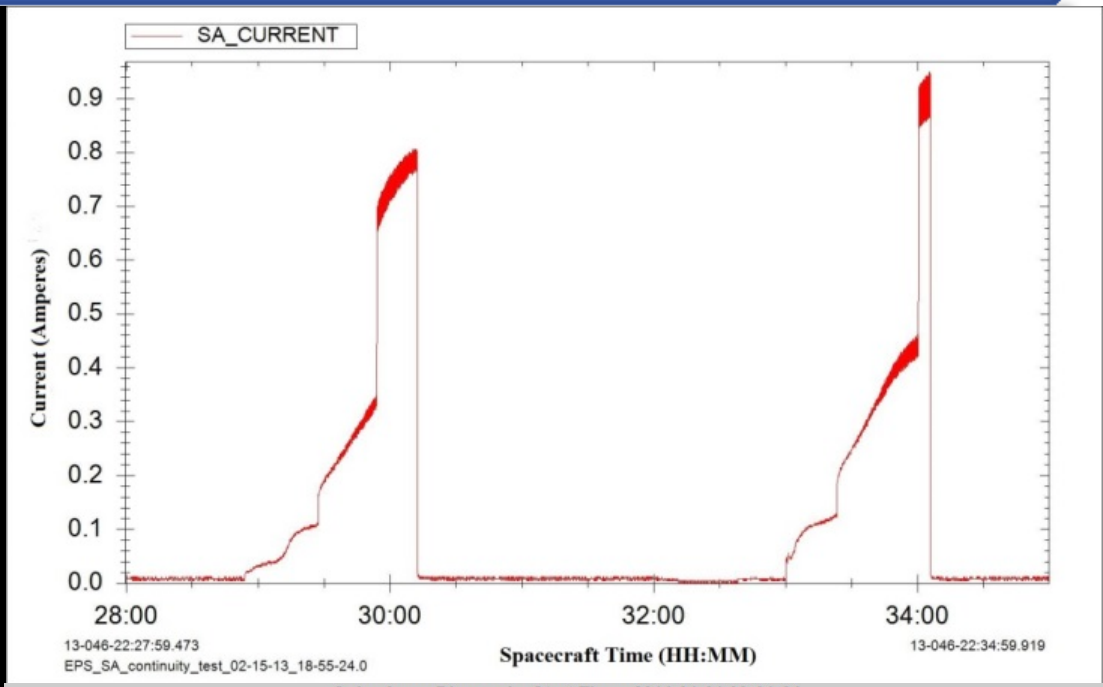


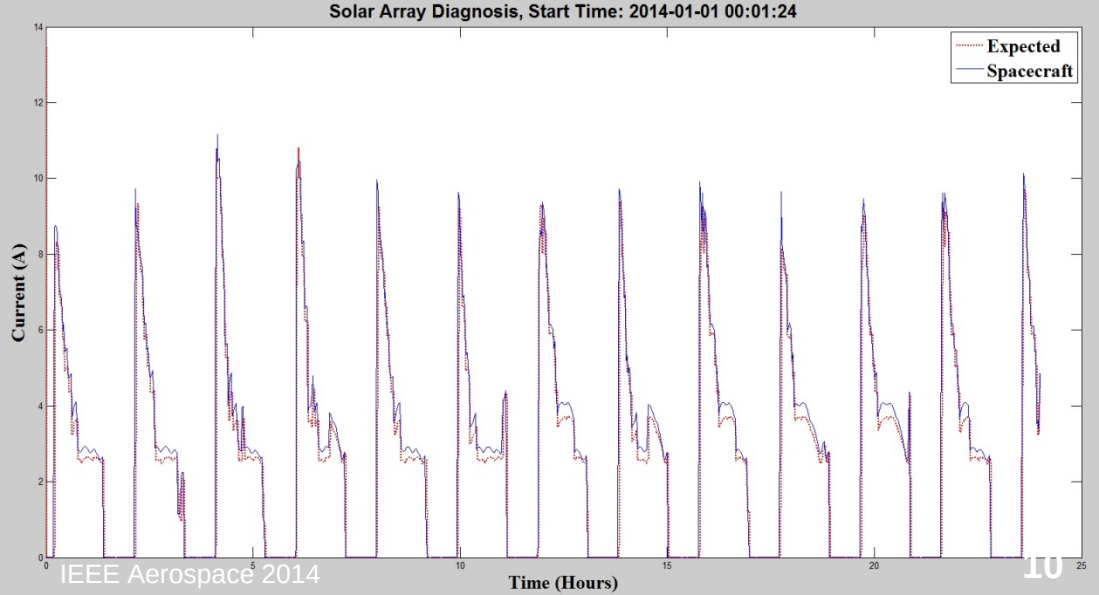
Maintaining System Health

Avionics data capture demonstrates end-to-end functionality & current levels

Avionics measures only one current for entire array – based on spacecraft attitude, can track each panel's degradation during ops

Launch-site panel inspection yielded 5 cracked cells – repair & retest at launch site!





Conclusions

Notes on Class D & Risk:

- Unlikely to have enough resources to guarantee elimination of a risk
- Sometimes it will not be possible to quantify the risk
- Analyze, disposition, accept, and document the risk
- Educated risk taking vs. ignorance

- Sometimes the ‘conservative’ spaceflight approach is easier – just take the ‘high road’ because the resources are there

In Conclusion,

- The LADEE risk management process is standard & not novel
- The LADEE EPS team was forced by resources to develop a cost-effective risk solution appropriate for a short-duration mission:
  - Inexpensive (project savings >$100k)
  - Portable (<100lb)
  - Re-usable – system was brought to & used at the launch site
  - Safe – ‘daylight’ lamps keep panels cool, $15 glasses protect eyes

Conclusions

Thank you for your time!

Questions?

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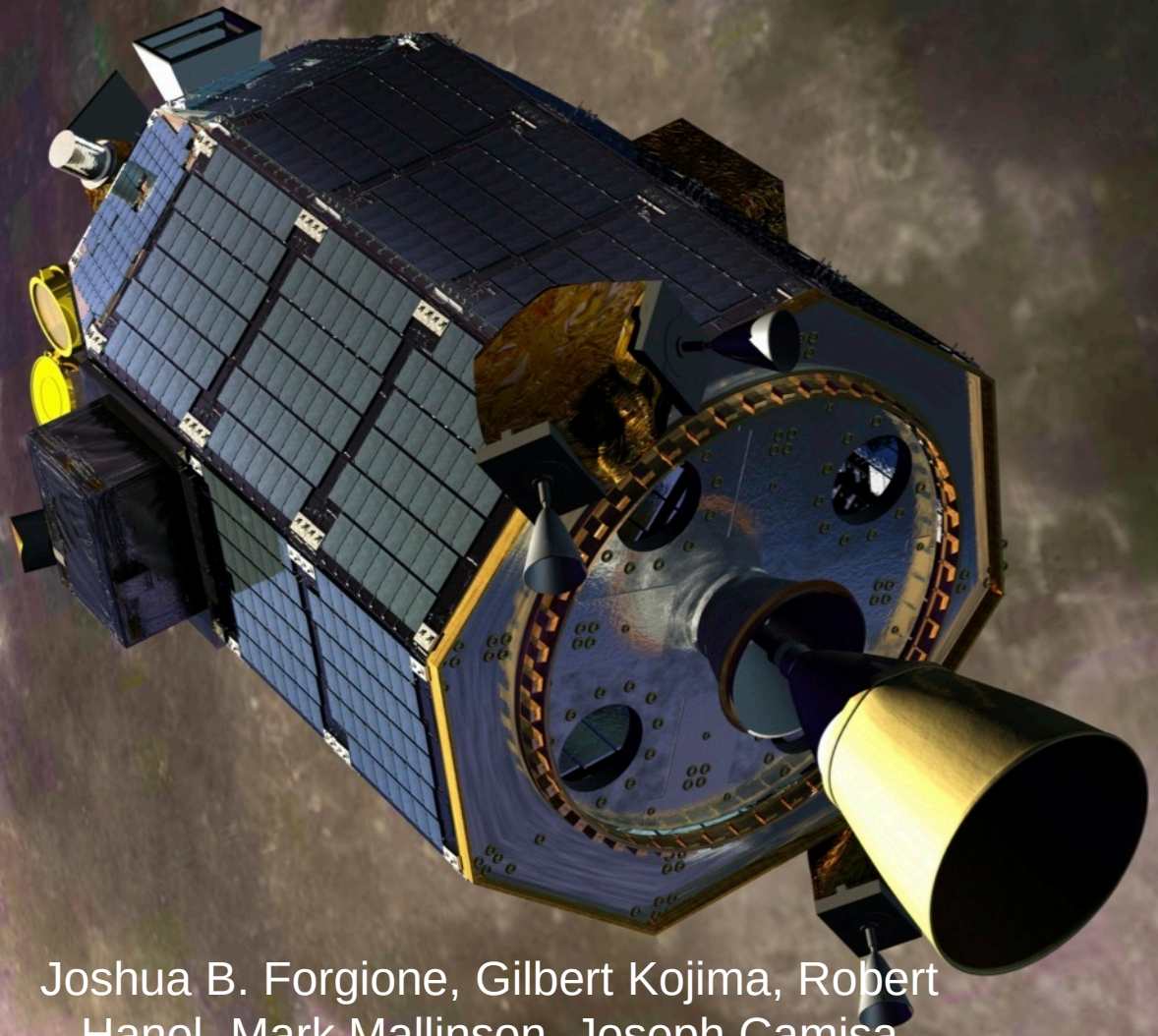

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Backup Slides

BACKUP SLIDES!

UV vs. Metal-Halide vs. Sunlight