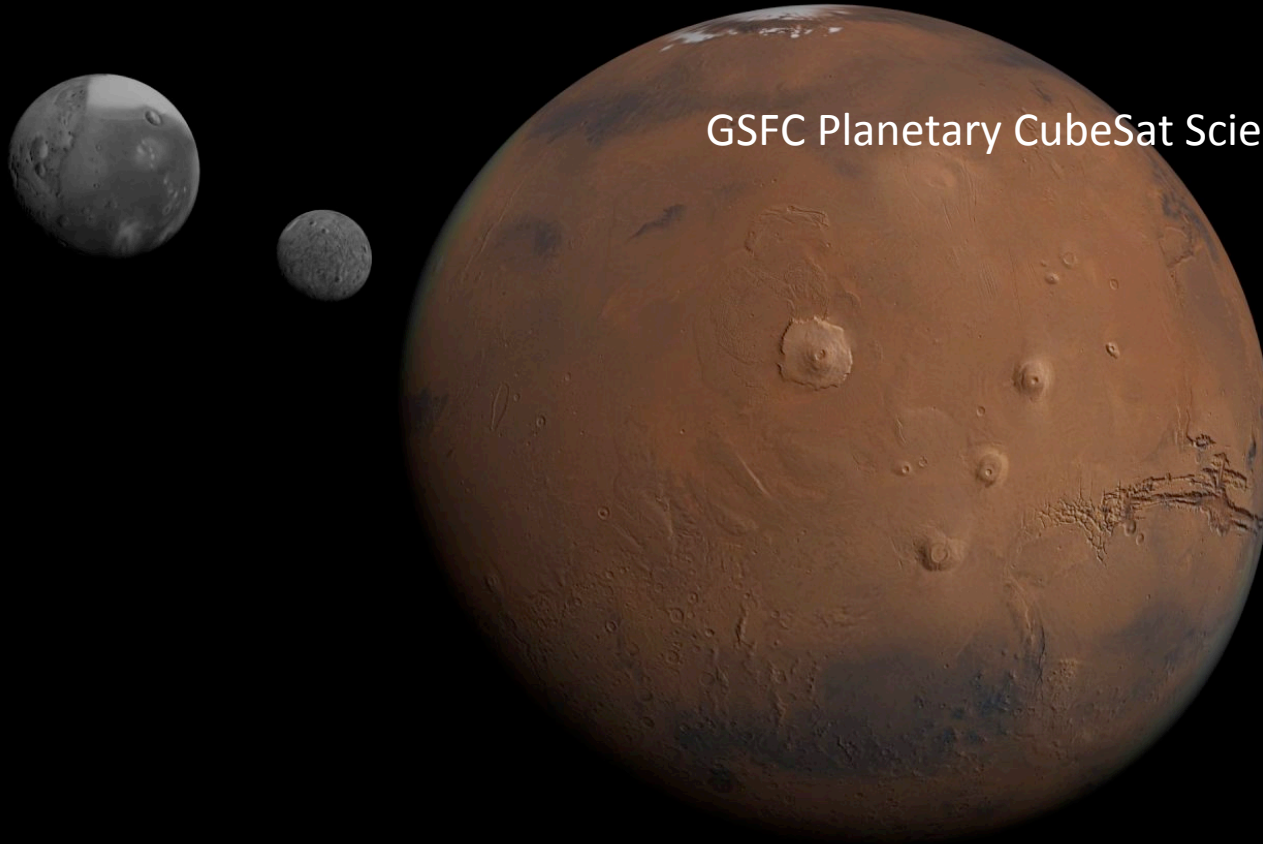


# Dellingr... and Beyond

GSFC Planetary CubeSat Science Symposium

4 August 2016



*Imagination is more important than knowledge.*

Albert Einstein

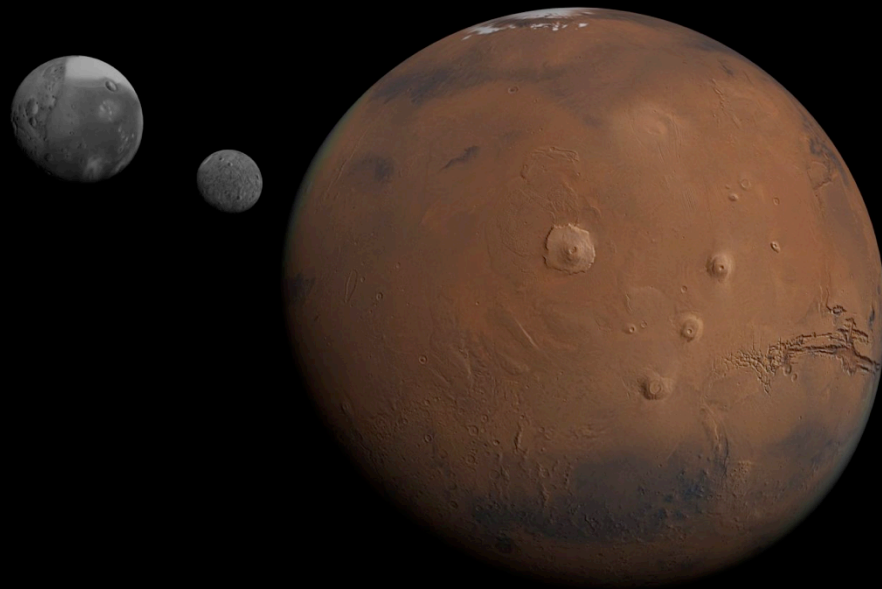
Presented by Michael A. Johnson  
(and enabled by a host of others)  
Chief Technologist

Applied Engineering and Technology Directorate  
NASA Goddard Space Flight Center

# GSFC Planetary CubeSat Science Symposium Agenda



1. The Dellingr Project
2. Planetary CubeSat Challenges
3. Beyond Dellingr: Increasing Science Mission Robustness



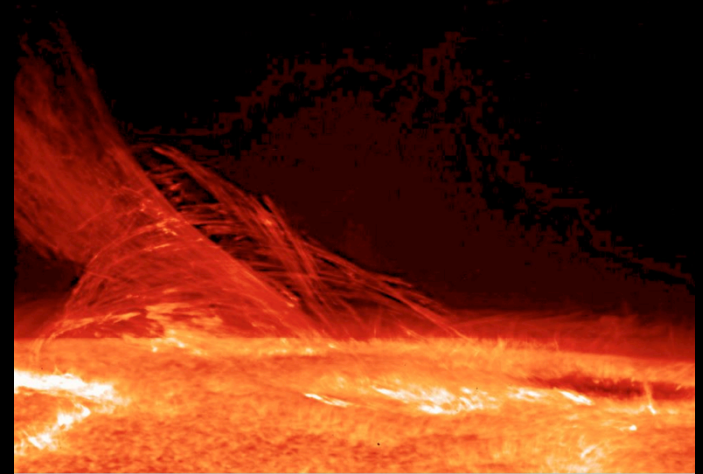
# A Path to Compelling Science: The Dellingr (Not Dellinger) Project



**Challenge:** Develop a flight-ready 2-instrument 6U Heliophysics CubeSat with minimal procurement and workforce funding

## Key Questions:

1. How can GSFC cost-effectively develop and deliver a 6U CubeSat that will achieve compelling science?
2. What are the intelligent “lean” end-to-end systems and processes required to enable lower-cost, scalable risk systems?
3. What key findings should be infused into “beyond Dellingr” activities?



A Collaborative Project:  
Heliophysics Science Division/ Applied Engineering and Technology Directorate/  
Flight Projects Directorate

# Dellinger Spacecraft: GSFC-Developed Flagship Quality Instruments

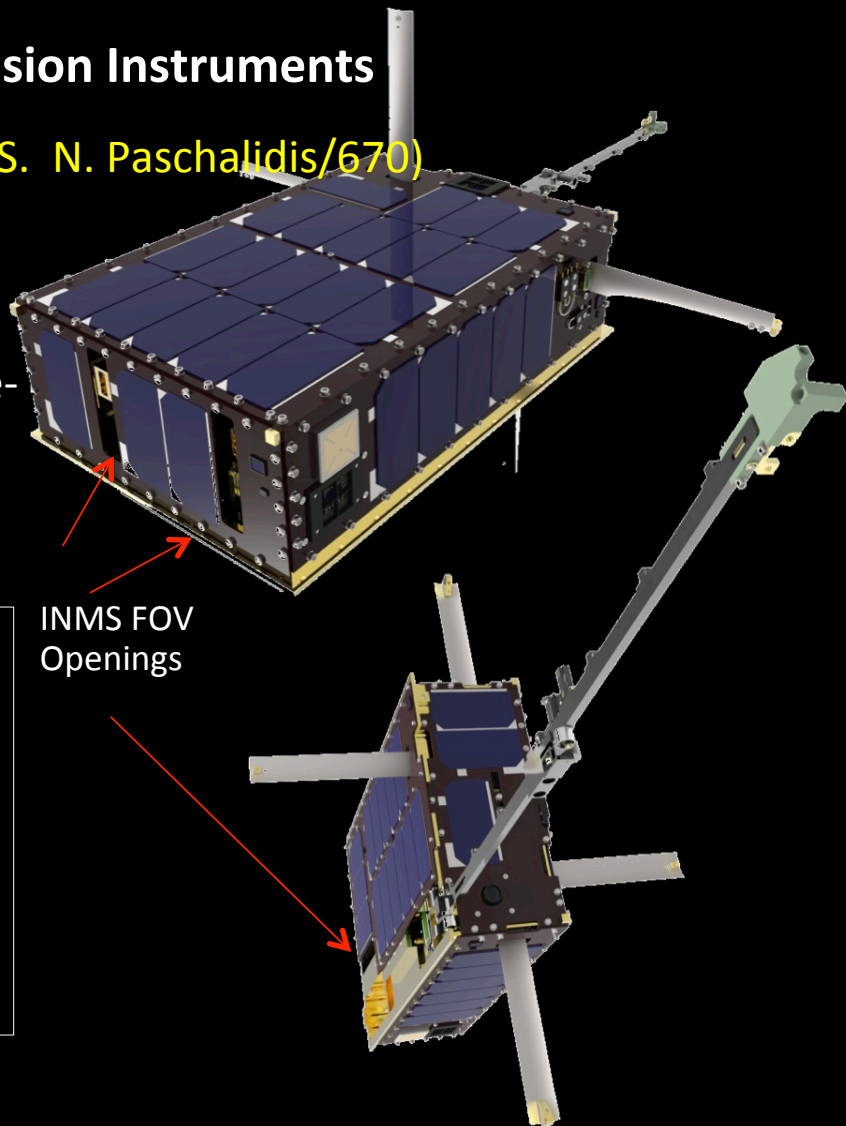
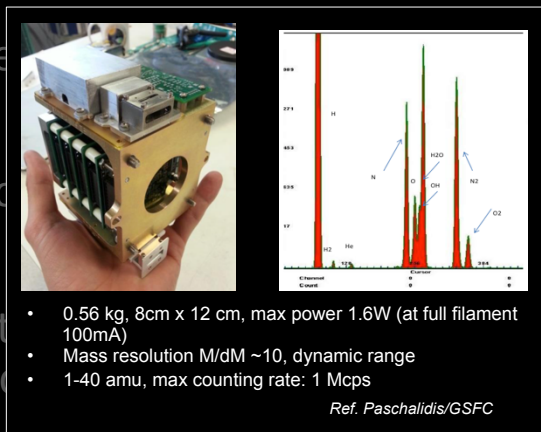
## Operate successfully 2 GSFC Heliophysics Division Instruments

### Compact Ion and Neutral Mass Spectrometer (INMS. N. Paschalidis/670)

- Measure ion and neutral composition and densities
- Study of the dynamic ionosphere-thermosphere-mesosphere system and coupling to the steady state background atmospheric conditions

### CubeSat Science Magnetometer (E. Zesta/673)

- Miniaturized fluxgate resolution at 3.5 Hz
- Boom (50 cm) and boom magnetometers
- Measurement algorithm generated disturbance



# Dellingr Spacecraft: GSFC-Developed Flagship Quality Instruments



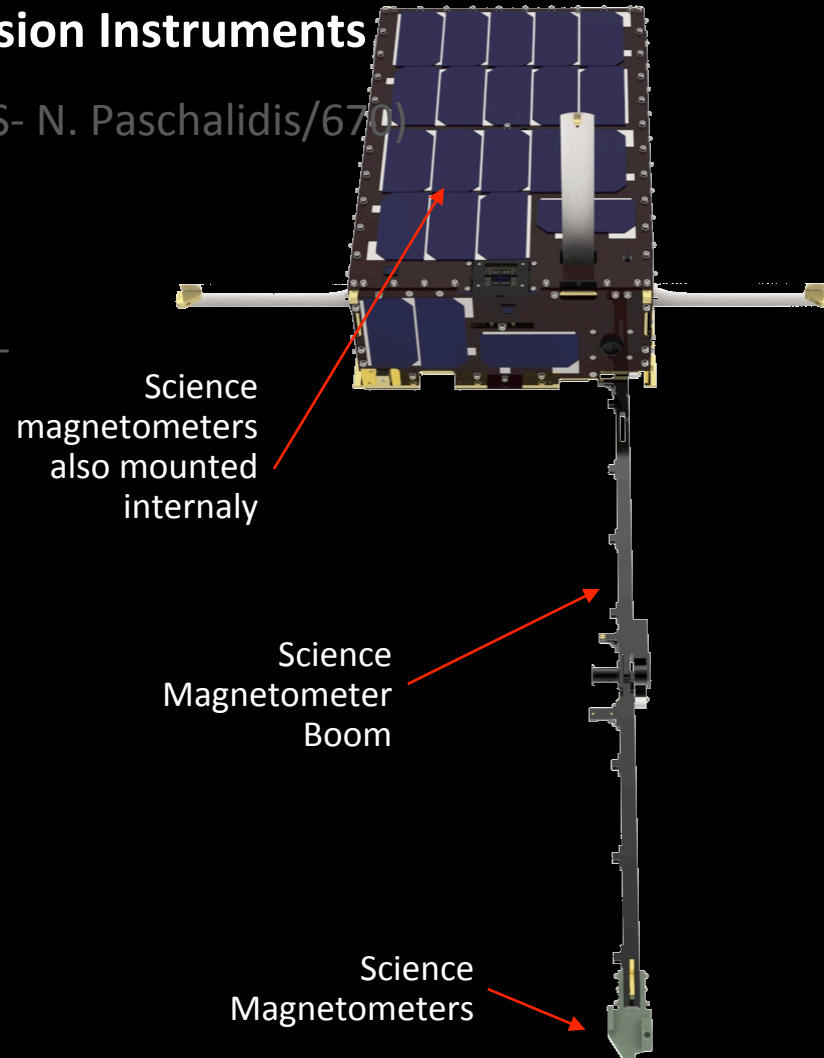
## Operate successfully 2 GSFC Heliophysics Division Instruments

Compact Ion and Neutral Mass Spectrometer (INMS- N. Paschalidis/6770)

- Measure ion and neutral composition and densities
- Study of the dynamic ionosphere-thermosphere-mesosphere system and coupling to the steady state background atmospheric conditions

### CubeSat Science Magnetometer (E. Zesta/673)

- Miniaturized fluxgate with better than 0.1nT resolution at 3.5 Hz
- Boom (50 cm) and body mounted magnetometers
- Measurement algorithms null spacecraft-generated disturbance fields





# Dellinger Bus: Key Requirements

- Assume ISS-like orbit
- Satellite shall manage power operationally
- In addition to Science pointing, guidance navigation and control shall provide a sun pointing / charging and survival pointing mode  $\pm 30^\circ$  of the Sun line
- Satellite software shall be capable of updates from ground
- $\sim 10\text{W}$  available average worst case average orbit power

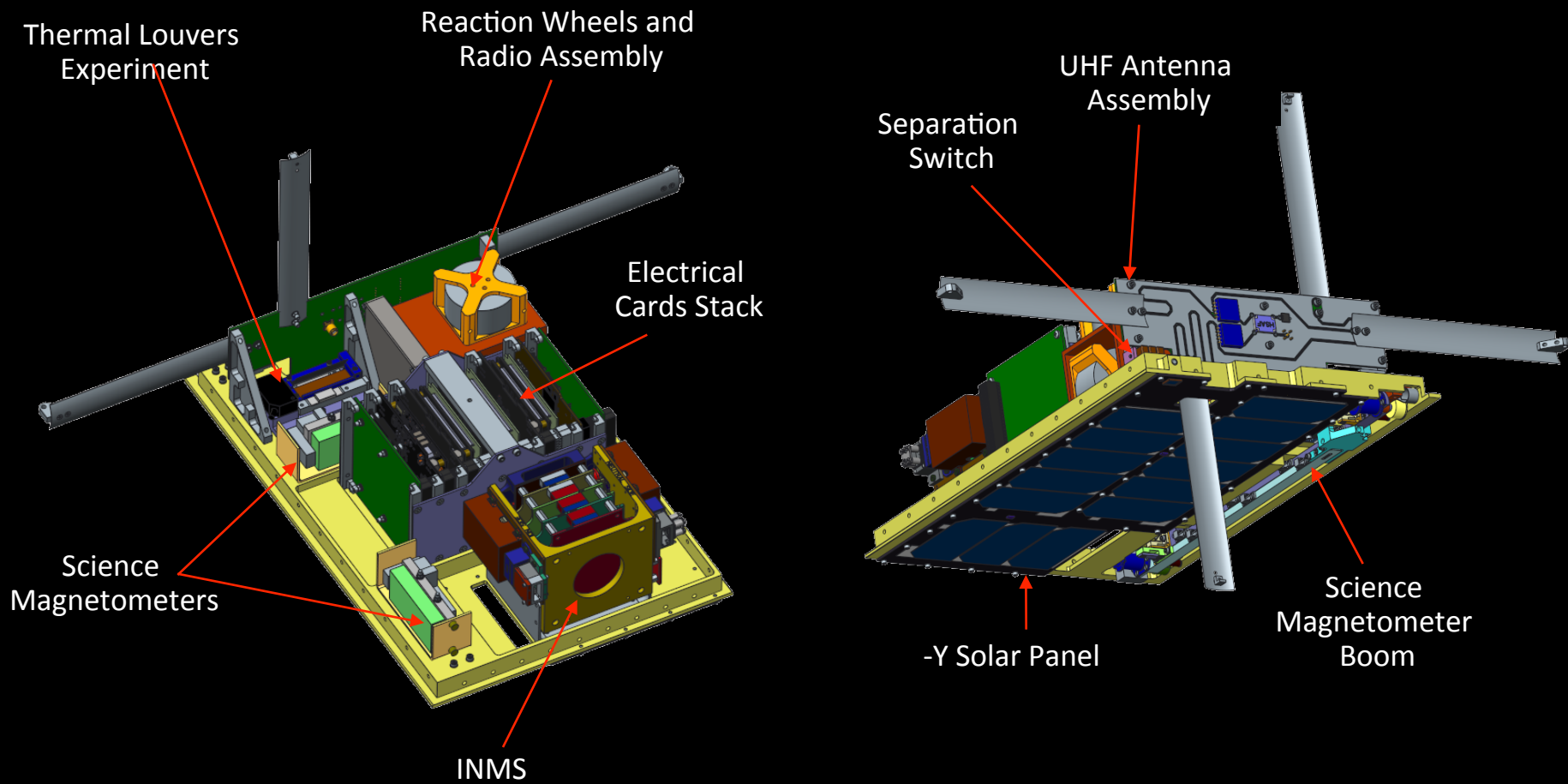
## Instrument Derived Requirements

- Provide pointing ( $\pm 1^\circ$ ) and knowledge ( $\pm 0.1^\circ$ ) for magnetometer and INMS Science modes
- Provide instrument thermal stability
- Store and transmit science data ( $\sim 20$  kbps)





# Dellinger Spacecraft: Internal Systems





# The Mission is More than the Spacecraft: Integrated Test and Operations System (ITOS)

- ITOS is the core element of a spacecraft or space instrument Ground Data System for flight operations, integration and test, and development
- It is highly user-configurable, and provides a scalable, cost-effective platform for small-budget projects to billion-dollar observatories

History: MMS, LRO, Fermi (GLAST), THEMIS/ARTEMIS, Swift, ICESAT-2, LADEE, CYGNSS, ICON, SAMPEX, FAST, SWAS, TRACE, WIRE, RHESSI, NuSTAR, IRIS, and others

The screenshot displays the Delingr ITOS interface, which is divided into several sections:

- Command Line Page:** Shows the current command being executed: `codet:radio`. It includes fields for the command name, version, and status.
- Status Page:** Displays various system metrics such as "Codet: Radio Status", "Codet Configuration Payload", and "Codet: Data Status". It includes sub-sections for "Codet: Radio Data" and "Codet: Data Status".
- Packet Status Page:** Shows a table of packet statistics, including "Delingr Speed/Freq Packet Status" and "Delingr Ground System Packet Status".
- Events Page:** Displays a list of system events, such as "Multiple slots processed: slot = 0, count = 2" and "Relative Law Sequence 002 Execution Completed".
- Command Log Page:** Shows a list of commands and their execution status, including "graph\_process", "statistic", "interference", "system", and "page codet:radio".

Supports "Test as You Fly"

Delingr ITOS page. Virtual Mission Operations Center (vMMOC) will be used for Delingr test as well as Command and control.





# Dellingr Spacecraft: Status



- Spacecraft integration complete
- Magnetics characterization complete
- Environmental test: Q3 CY2016
- Flight readiness: Q1 CY2017
- May/June 2017 flight manifest to International Space Station

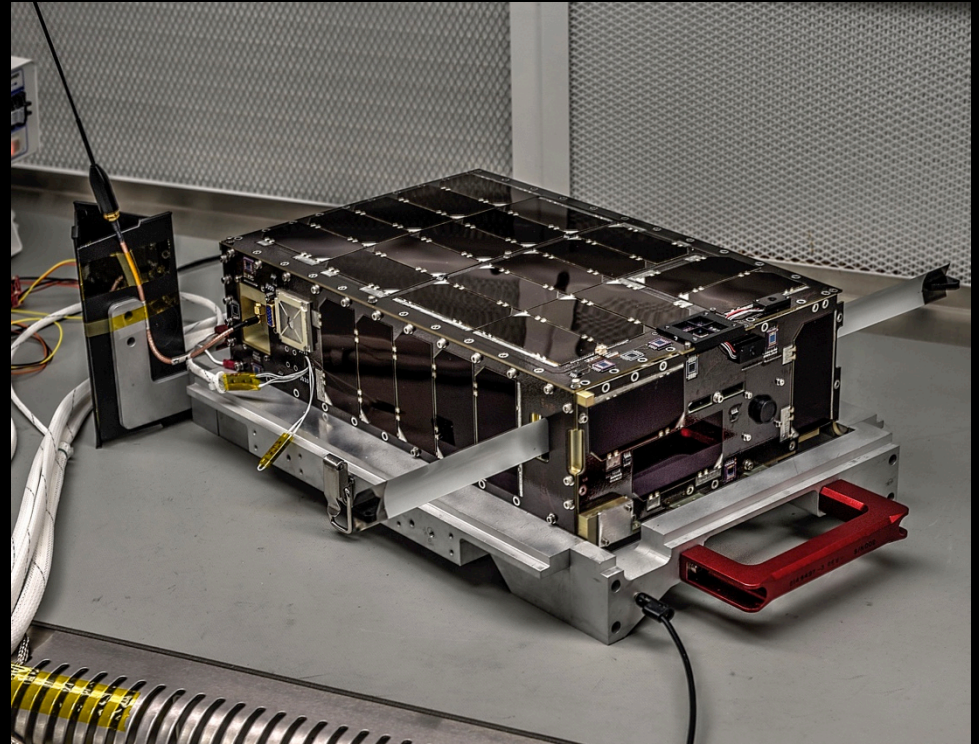


Dellingr spacecraft in B21 lab.

Chuck Clagett- Project Manager  
Luis Santos- Deputy Project Manager  
Larry Kepko- Science Lead

# Dellingr: Key Findings

1. It is a system, not just a spacecraft.
2. The quality of most commercial components is inconsistent with planetary mission requirements. Remedial actions are essential.
3. GSFC spaceflight systems acumen is mitigating potential failure modes.



Dellingr spacecraft in B21 lab.



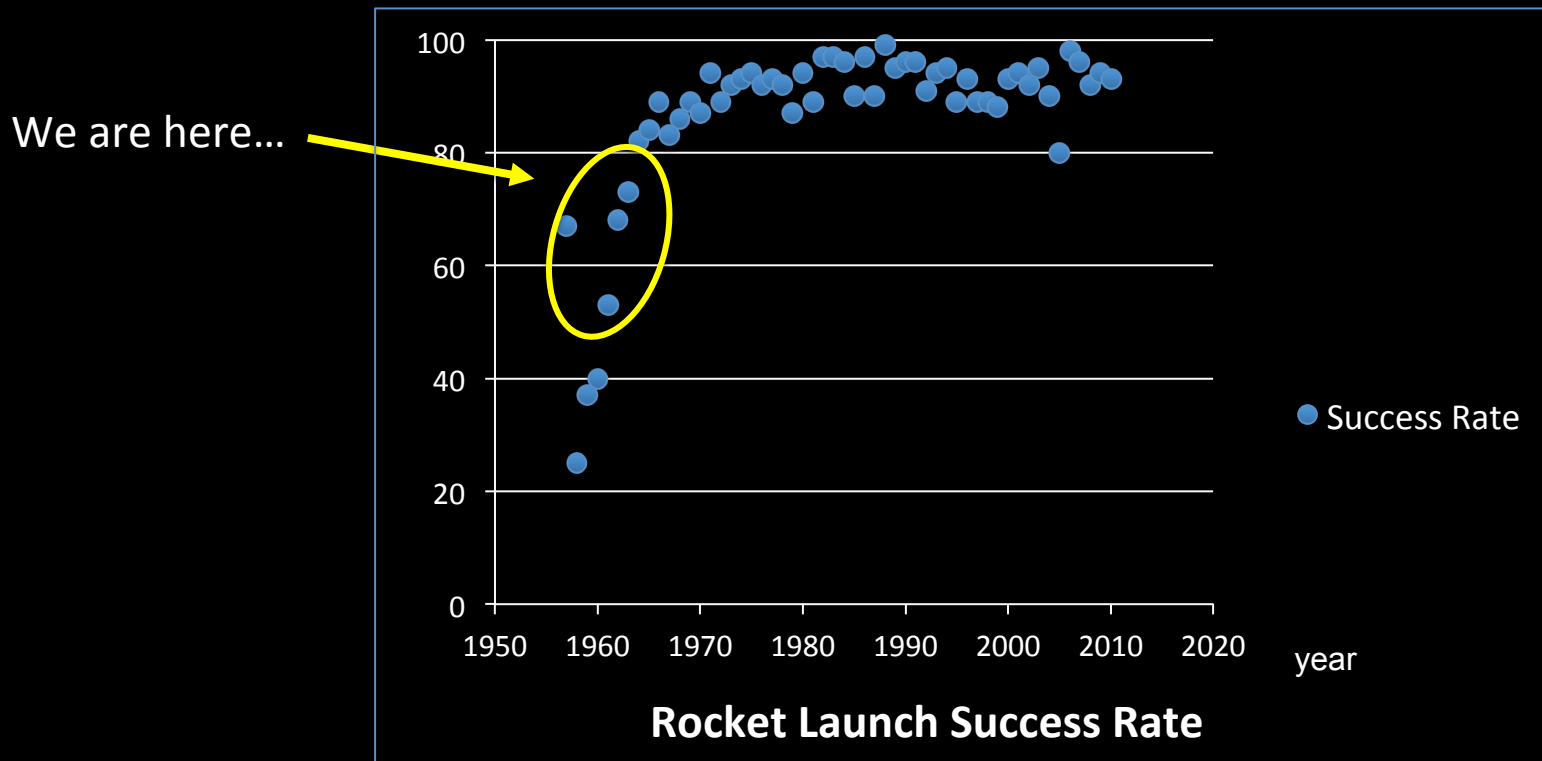
# Planetary CubeSats

There are many paths to mission failure with “standard” CubeSats.

# The State of CubeSats: CubeSats Are in the 1960s



Overall robustness is analogous to the early days of space flight.



*Current state metrics are not sufficient for targeted  
Goddard science mission objectives.*

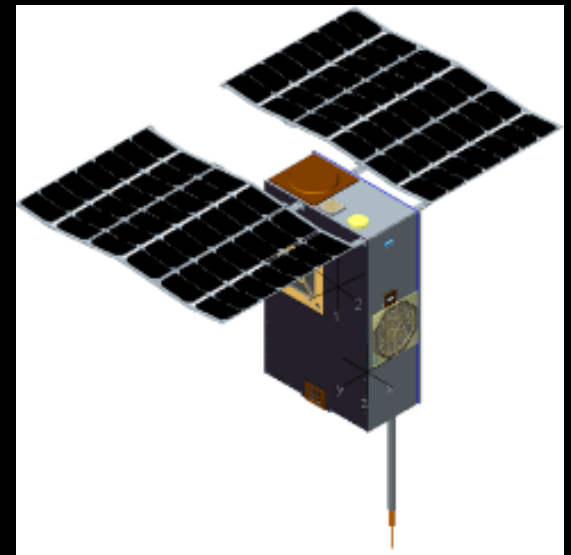


# Beyond Dellingr: Robust SmallSat Science Beyond LEO

**Goddard Modular SmallSat Architecture (GMSA)**- Deliver robust SmallSat science and facilitate cost and schedule efficiencies via modularity, flexibility, extensibility.

*Dellingr+* derives mission robustness from GSFC end-to-end space systems acumen

- Build systems when necessary
  - Rad-hard /tolerant Command and Data System
  - Rad-hard/ tolerant Electrical Power System
- Buy systems when appropriate
  - Engage vendors to mature or verify robustness/ performance
- Spacecraft system architecture resilient to anomalies



GSFC-JPL, other government agencies, and Federally funded organizations are discussing a collaborative SmallSat reliability improvement initiative with industry.

# Dellingr... and Beyond: Take Homes



- Dellingr is more than a spacecraft; it's a compelling science mission surrounded by inquiry and findings
- CubeSats are in the 1960s. GSFC *science-engineering-systems* acumen matures them significantly
- Internal development activities have postured Goddard for reliable Planetary CubeSat-SmallSat science
- An interagency initiative led by Goddard and JPL targets increased SmallSat mission robustness with minimal cost impact





Thank you.

