Jet Propulsion Laboratory
California Institute of Technology

Mission Assurance – From Cassini to Cubesats

- An opportunity to learn for the future

D.J. Sheldon, Assurance Technology Program Office (ATPO)
Jet Propulsion Laboratory, California Institute of Technology

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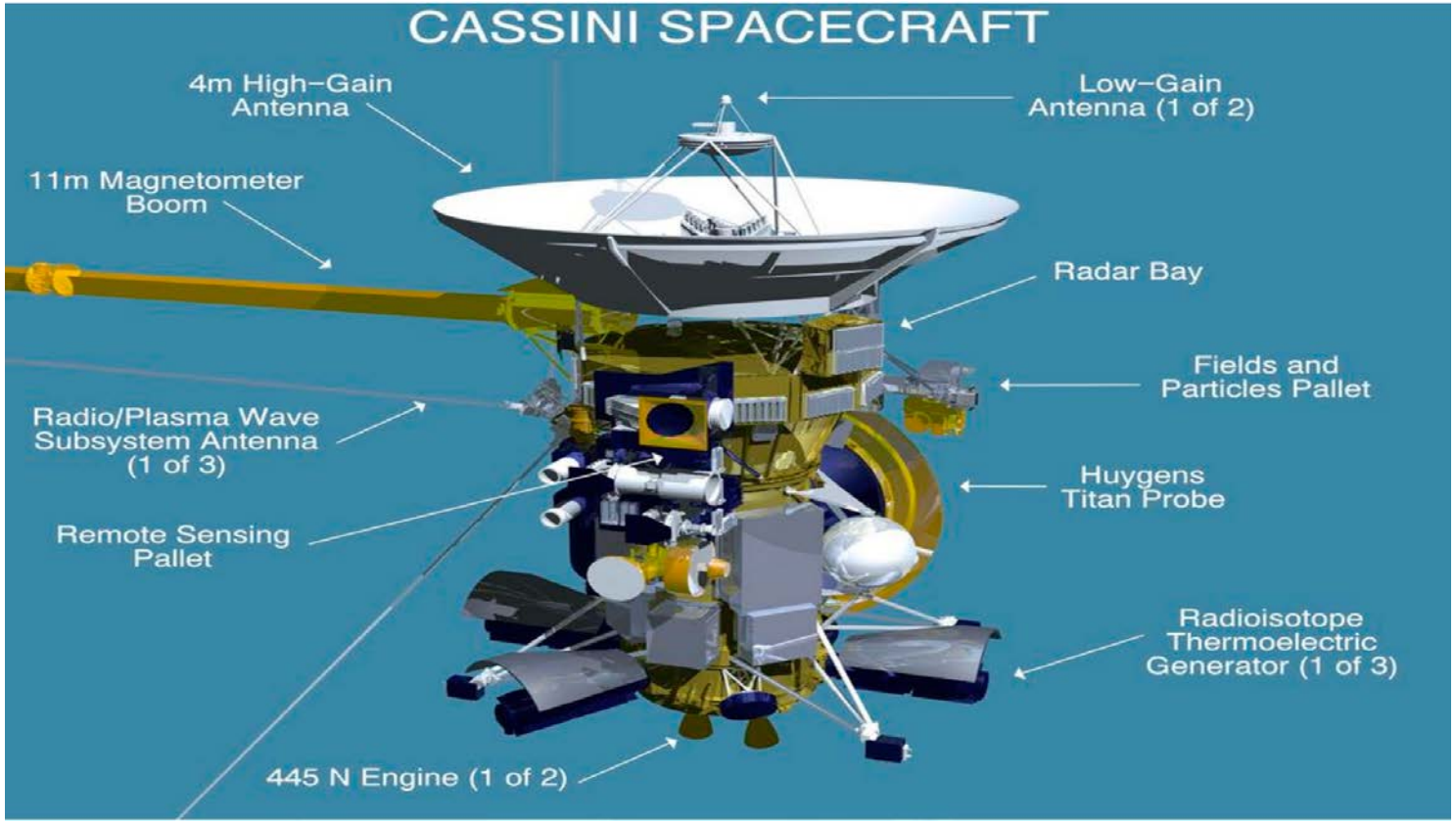
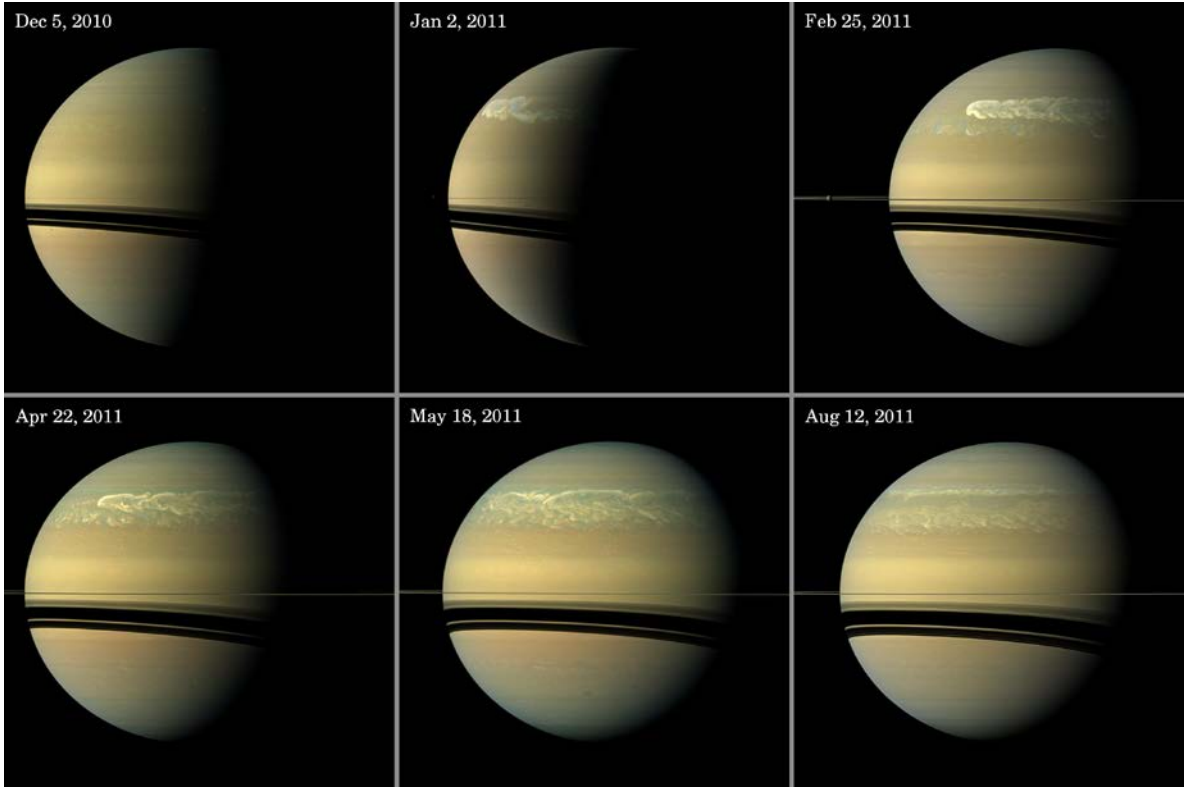
Introduction

- JPL missions range from Flagship Class A Missions to Cubesat Technology Demonstration Missions
- Safety and Mission Assurance implementations need to be adjustable
  - Identify level of acceptable risk and minimum requirements
  - Focus on specific risk-mitigating activities
  - Allow for penetration and insight
  - Support independent risk assessment
  - Enable mission success

Cassini – Class A: A mission to Saturn



Storm Evolution on Saturn

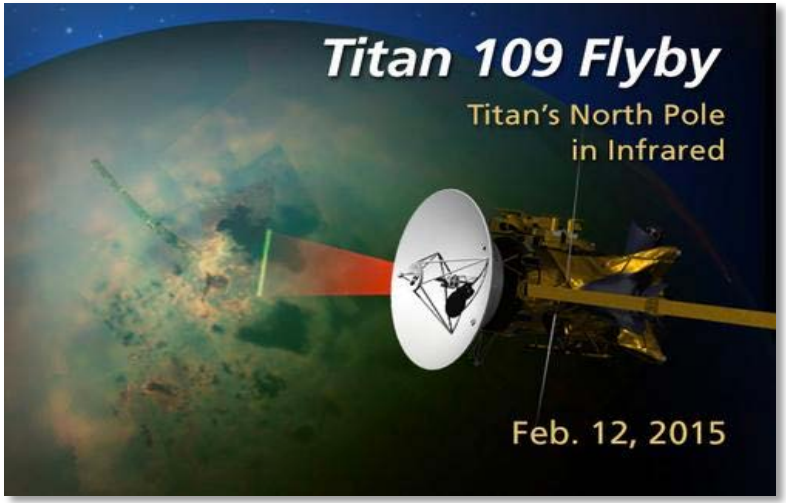


- After a storm, the air is lighter than the water-laden atmosphere below.
- It takes ~30 years for the air to become dense enough to turn on convection again.

Saturn Icy Worlds - Rhea

Cassini took images Rhea on February 9, 2015 from a distance of about 30,000 to 50,000 miles (50,000 to 80,000 kilometers).

Titan Flybys



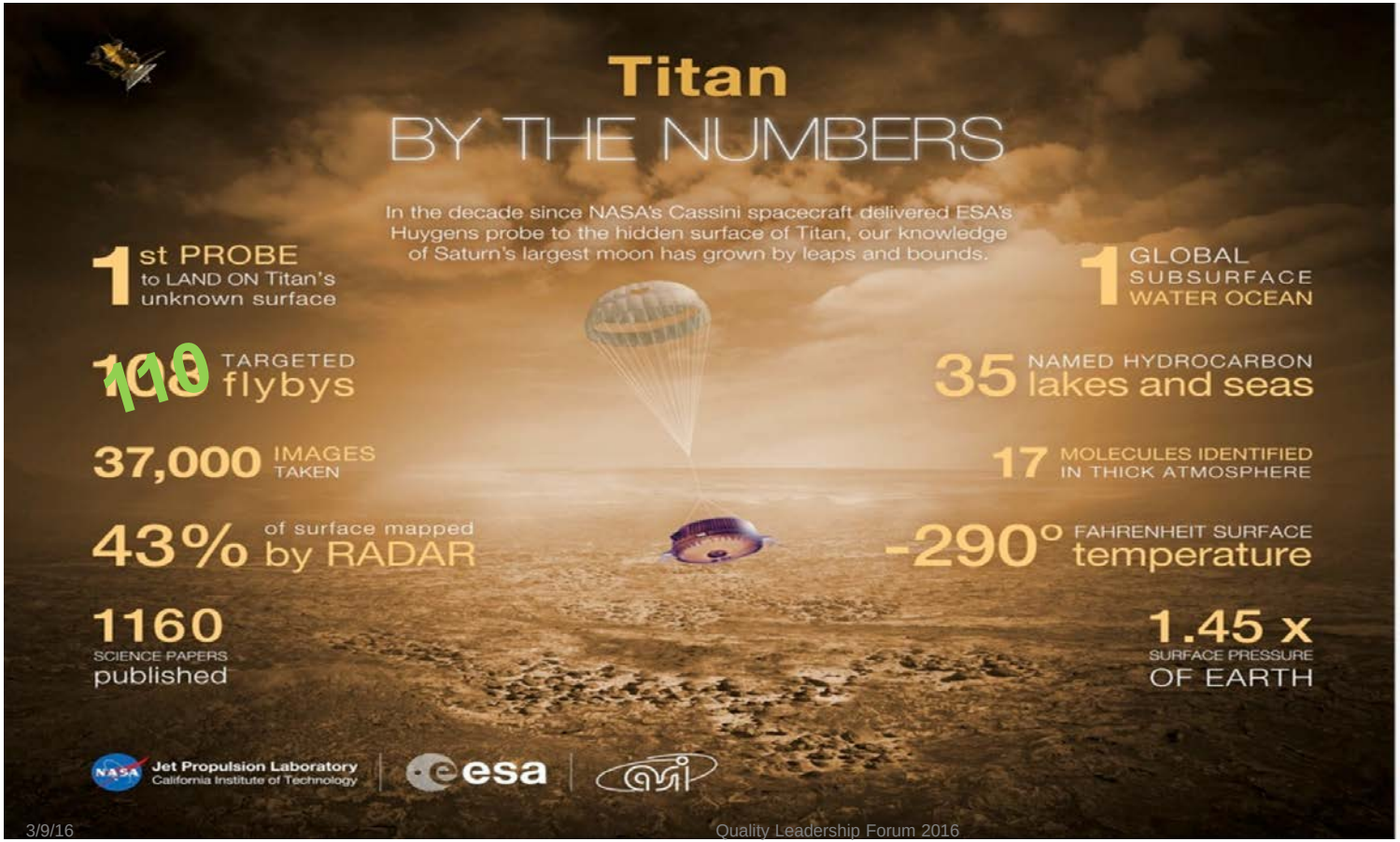
T109 – Titan flyby (1200 km)

- February 12, 2015
- Cassini observed reflections on the strait, Trevize Fretum, between Titan's seas Ligeia Mare and Kraken Mare, demonstrating that the strait is filled with liquid.

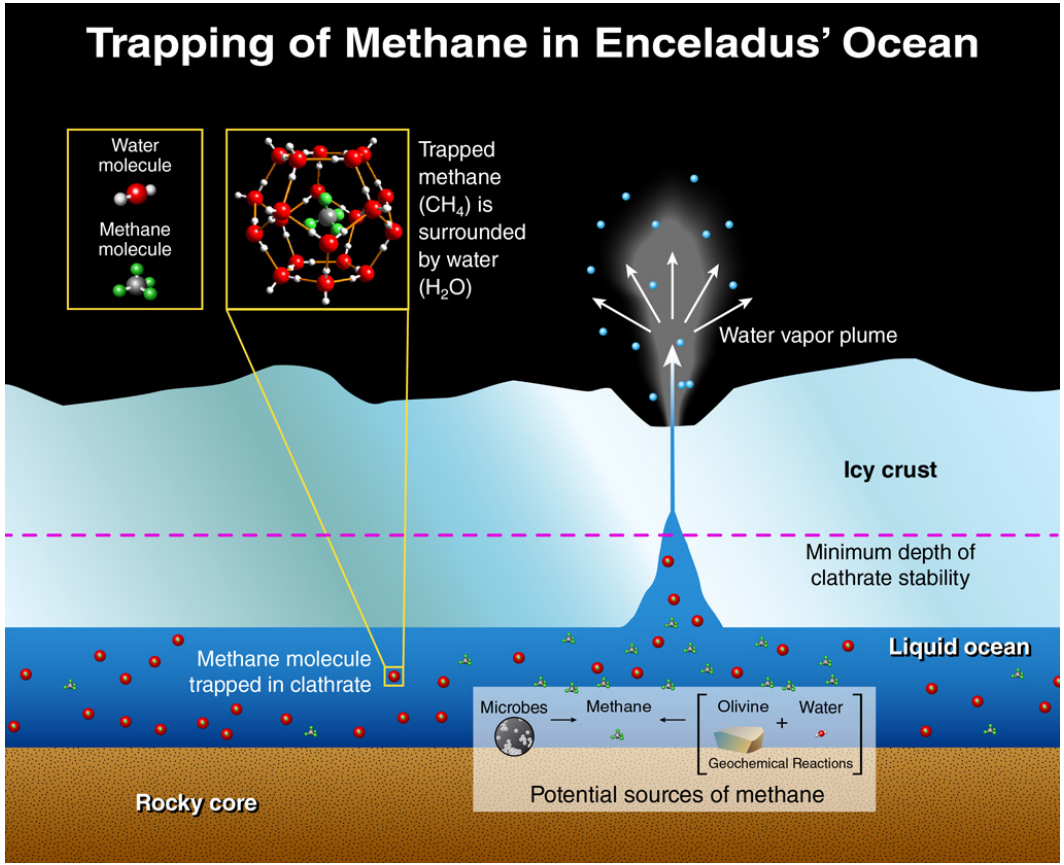
T110 – Titan flyby (2275 km)

- March 16, 2015
- Cassini broke new ground by simultaneously measuring Titan's gravitational field with the low gain antenna and making remote sensing observations of Titan.
- Unique coverage of Titan's high latitude regions that have never been mapped before for gravity.

Titan Summary



Enceladus



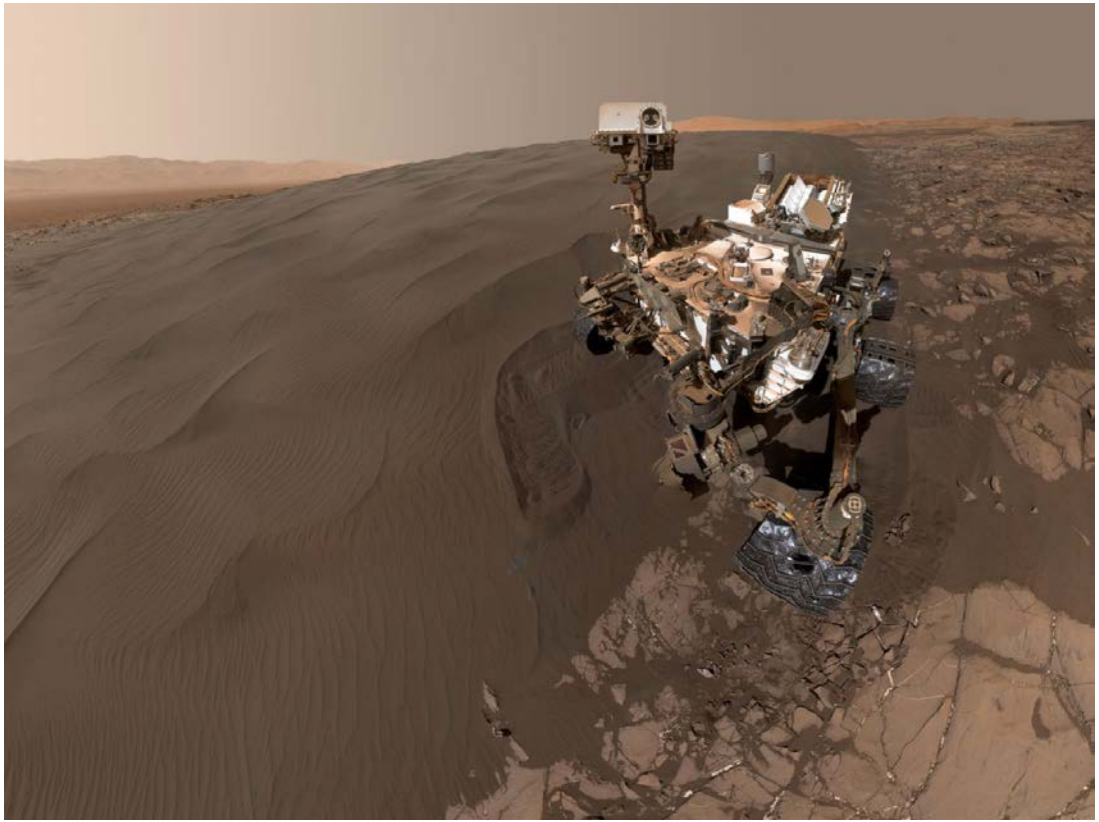
- Cassini found the first evidence of active seafloor hydrothermal vents, where seawater and the rocky core meet to form warm mineral-laden liquid.
- Abundant methane found in Enceladus' vapor plumes can only be explained by a source rapidly adding methane in the ocean, faster than it is trapped into clathrates (ice cages).
- Chemical reactions near warm hydrothermal vents are the most likely candidate for producing additional methane.

"Possible evidence for a methane source in Enceladus' ocean ," Bouquet *et al., Geophysical Research Letters,* March 12, 2015.

Cassini MA Implementation

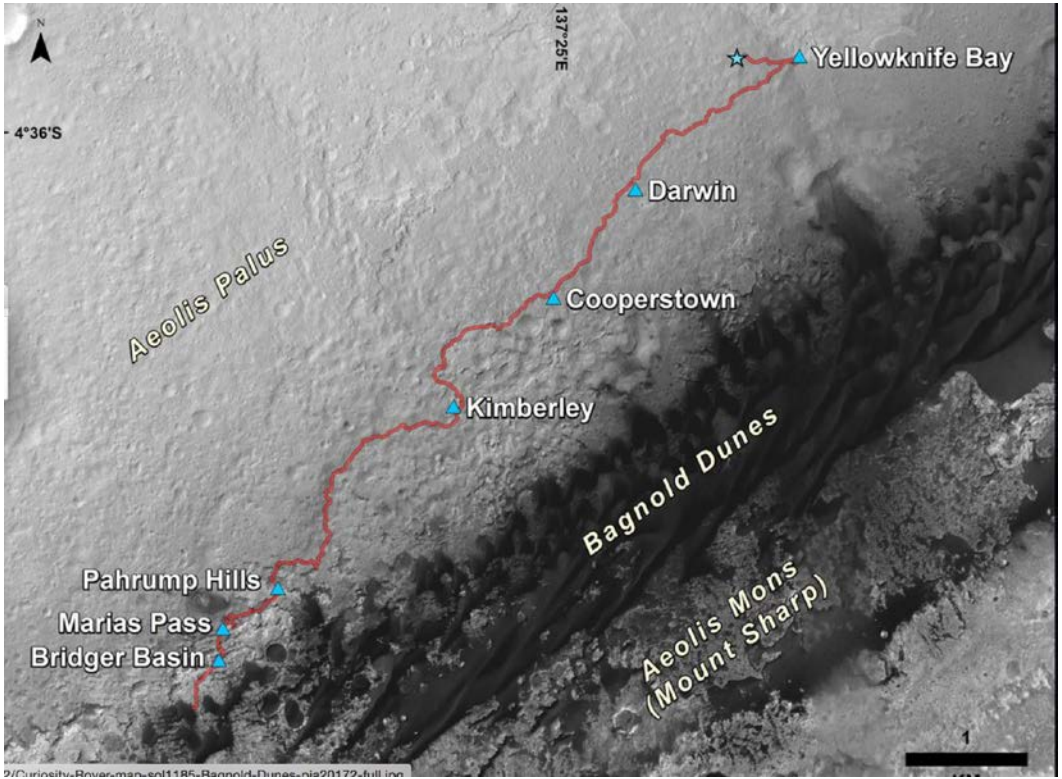
Cassini Mission to Saturn	
Mission Attribute	MA Implementation
Mission Class	Class A
Architecture	Dual string, cross-strapped architecture, few Single Point Failures Graceful degradation Multiple combinations of instruments to meet mission success
Lifetime	11-year prime mission, 9-year extended mission Class S parts, extensive parts qualification program Thorough reliability analyses and review
Environments	Outer planet, high radiation (~100 krad TID) Increased margins testing (thermal, lifetime) Tests at assembly, subsystem and system-level
Inheritance	Little inheritance Extensive HQA presence at JPL and vendors, extensive MIPS program

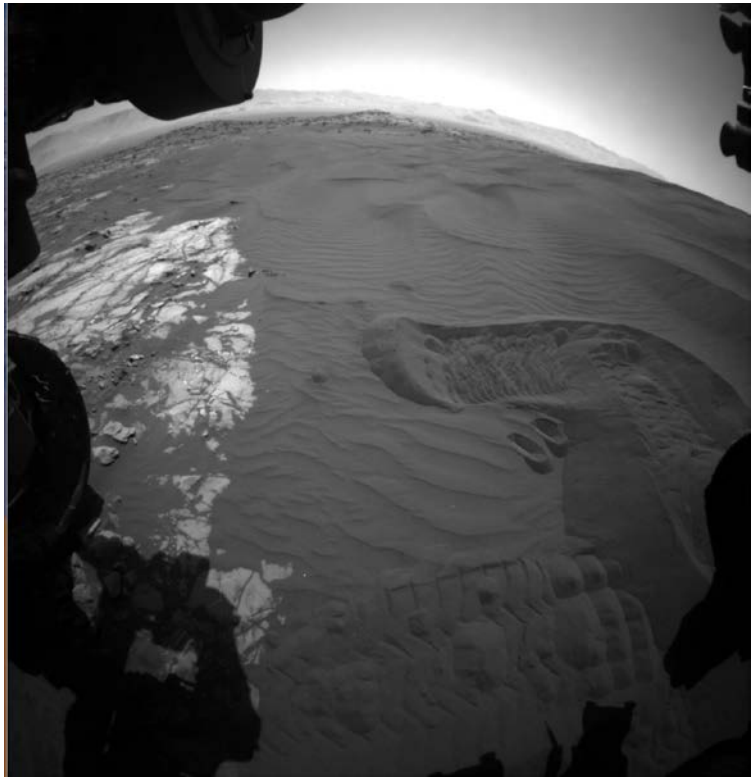
Mars Science Laboratory (MSL) – Class A/B



- System performance nominal.
- Completed Namib portion of Bagnold Dunes campaign.
- Currently in traverse.
- Upcoming is dunes imaging portion of campaign and a likely drill on Naukluft Plateau.

Bagnold Dunes on the road Mount Sharp – sol 1229

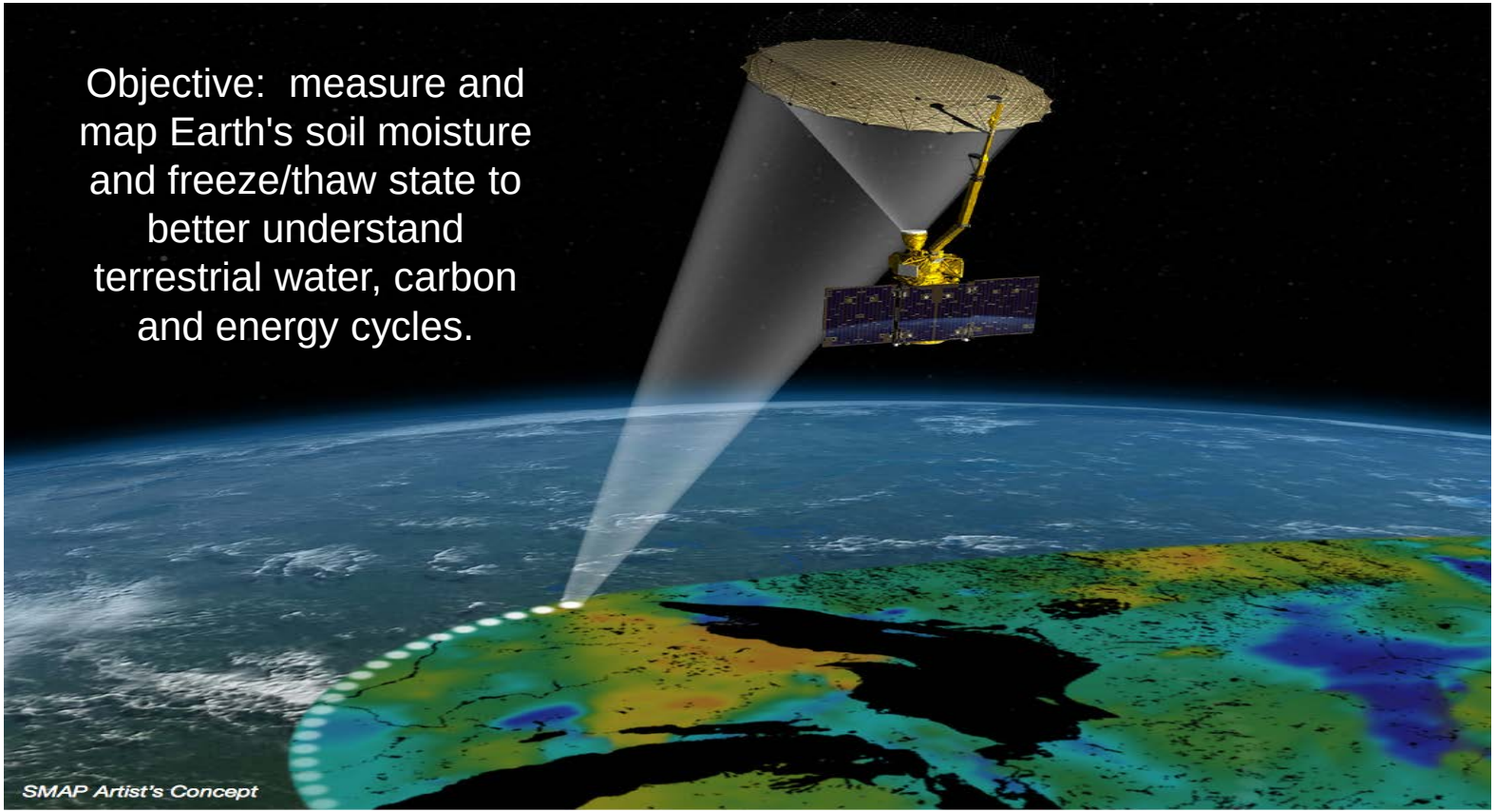




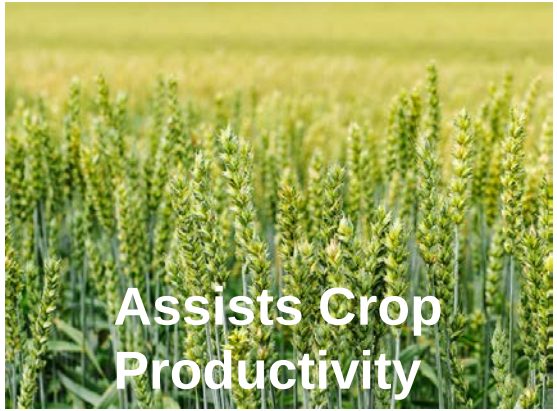
MSL MA Implementation

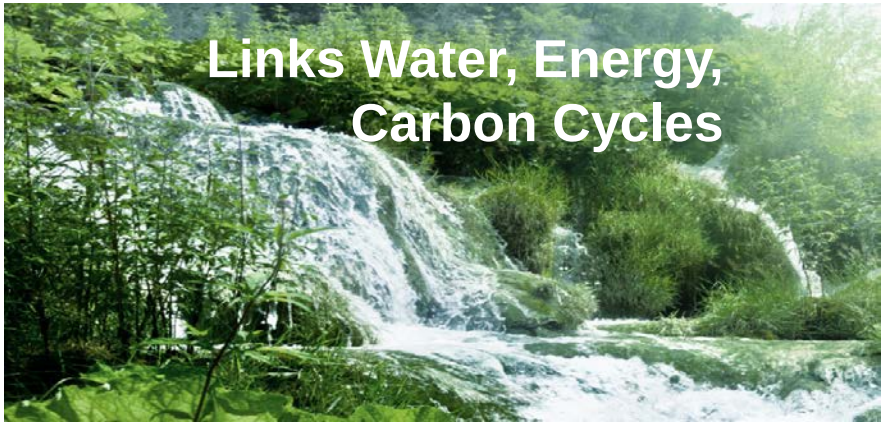
Mars Science Laboratory - Mars Surface Rover Mission	
Mission Attribute	MA Implementation
Mission Class	Class A/B
Architecture	Dual string, Block-redundant, limited cross-strapped architecture, few Single Point Failures Multiple combinations of instruments to meet mission success
Lifetime	23 month prime mission, 3+ year extended mission Class B+ parts, full lifetime and environmental parts assessment Thorough reliability analyses and review
Environments	Daily deep thermal cycles Significant component thermal cycle testing (thermal lifetime) Tests at assembly, subsystem and system-level Low TID radiation (<10 krad)
Inheritance	Little-no inheritance Extensive HQA presence at JPL and vendors, extensive MIPS program

Soil Moisture Active Passive (SMAP) – Class C



SMAP – Why it Matters

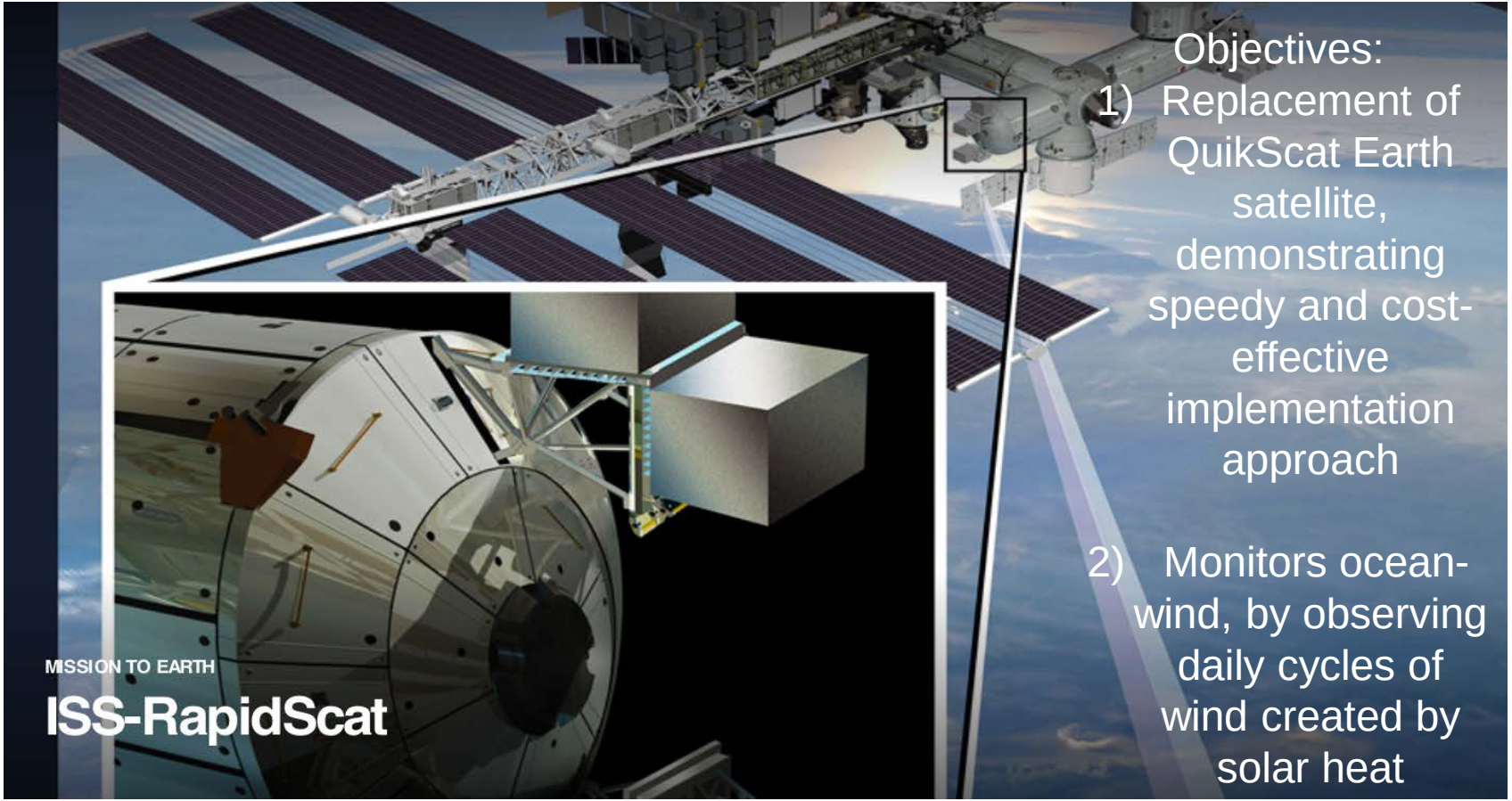




SMAP MA Implementation

Soil Moisture Active Passive Earth Orbiter	
Mission Attribute	MA Implementation
Mission Class	Class C
Architecture	Single string with selected block redundancy Two instruments share key single string elements; both required to meet mission success
Lifetime	3 year prime science mission Class B parts Selected reliability analyses and review
Environments	Earth orbital shallow thermal cycling Limited component thermal cycle testing Tests at assembly (limited), subsystem and system-level Low TID radiation (<10 krad) South Atlantic Anomaly
Inheritance	Significant inheritance on Engineering hardware and software Moderate HQA presence at JPL and vendors, reduced MIPS program

Rapid Scatterometer - International Space Station (ISS)



Objectives:

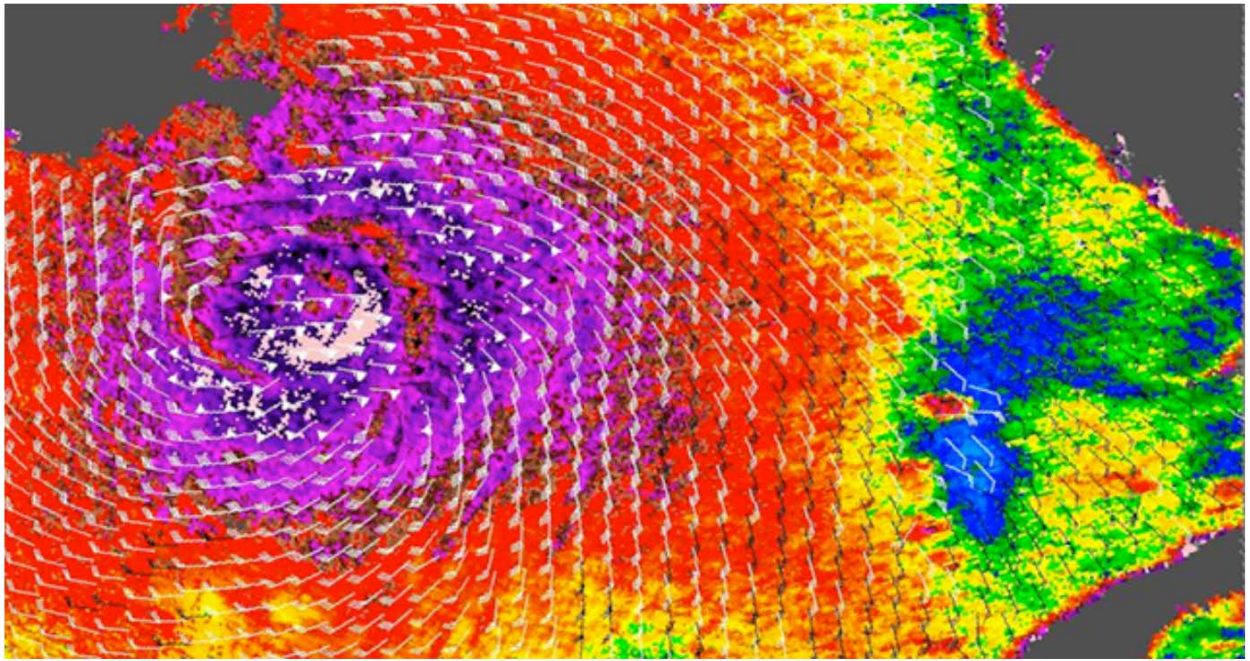
1) Replacement of QuikScat Earth satellite, demonstrating speedy and cost-effective implementation approach

2) Monitors ocean-wind, by observing daily cycles of wind created by solar heat

ISS-RapidScat –Technology Demonstration

NEWS | JULY 7, 2014

NASA's RapidScat to Unveil Hidden Cycles of Sea Winds



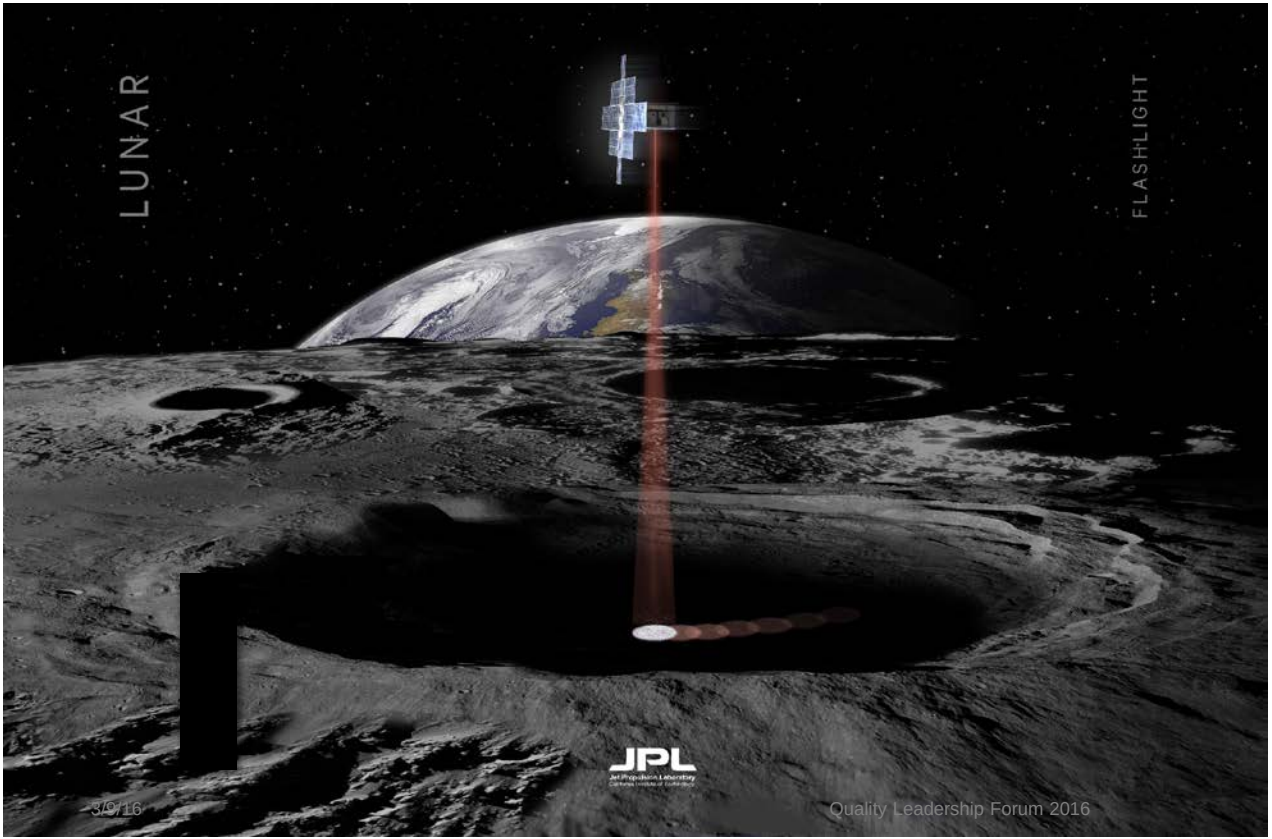
A 2005 image of Hurricane Katrina in the Gulf of Mexico from NASA's QuikScat scatterometer shows the kind of ocean-wind data that ISS-RapidScat will provide. In this image, the highest wind speeds are shown in purple and barbs indicate wind direction. Image credit: NASA/JPL-Caltech

› Full image and caption

RapidScat MA Implementation

RapidScat - ISS Payload	
Mission Attribute	MA Implementation
Mission Class	Unclassified, Technology Demonstration
Architecture	Single string instrument
Lifetime	No requirement for lifetime however ISS berth would be available for up to two years Mix of COTS parts and fully flight qualified and screened parts No reliability analyses and review
Environments	Earth orbital shallow thermal cycling Workmanship test at system-level Low TID radiation (<10 krad) South Atlantic Anomaly
Inheritance	Full inheritance review at the instrument level, limited inheritance reviews at the box, element and component levels Limited HQA presence at JPL, limited MIPS program

Lunar Flashlight – Technology Demonstration Cubesat

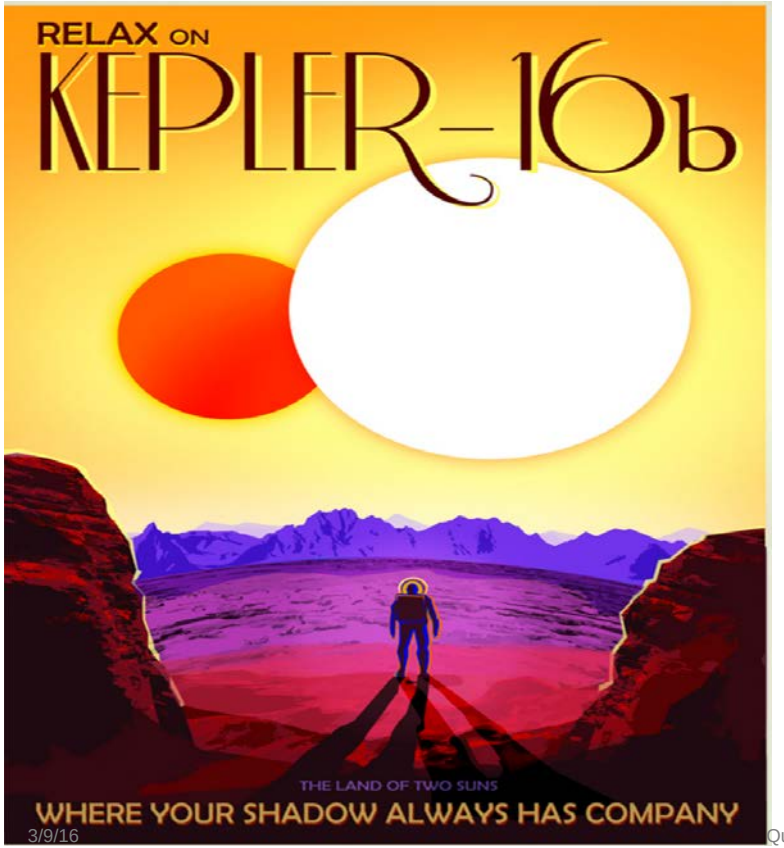


- Lasers in 4 different bands illuminate the lunar surface with a 3 deg beam (1Km)
- Light reflected off the lunar surface enters the spectrometer to distinguish water ices from regolith
- Elliptic orbit
- Perilune: South Pole
- JPL-MSFC team
- 6U, 11kg Cubesat
- SLS EM1 Launch 7/2018
- Phase E <1year

Lunar Flashlight MA Implementation

Lunar Flashlight Cubesat Technology Demonstration Mission	
Mission Attribute	MA Implementation
Mission Class	Unclassified, Technology Demonstration
Architecture	Single string cubesat
Lifetime	8 month prime deep space mission Mix of screened COTS and formal Rad tolerant parts Destructive SEE parts assessment & TID analysis and measurement No reliability analyses and review
Environments	Deep space thermal cycling Workmanship test at system-level Board/system level TID assessment Low TID radiation (<10 krad)
Inheritance	Some cubesat components inherited Very limited HQA presence at JPL, vendors have some heritage, no MIPS program

Conclusions



- Mission Assurance has a fundamental role in the successful development and operation of NASA's spacecraft
- Mission Assurance programs and personnel must be flexible and risk focused
    - Adjusting requirements and approaches appropriately to accepted risk posture
- Cubesats/smallsats will continue to challenge traditional mindsets
- Opportunity for innovation is now…

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