Selected NESC Science Mission Directorate (SMD) Related Technical Assessment Experiences

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Oscar Gonzalez, and Michael Aguilar

A GSFC Systems Engineering Seminar Series Talk

6 December 2011

Presentation Outline

- NASA Technical Fellows and their Technical Discipline Teams (TDT's)
- Guidance, Navigation & Control (GN&) TDT experiences
- Mechanical Systems TDT experiences
- Electrical Power TDT experiences
- Avionics TDT experiences
- Software TDT experiences
- Summary
- How to contact NESC at GSFC

NASA Technical Fellows and their Technical Discipline Teams (TDT's)

NASA Technical Fellows by Discipline

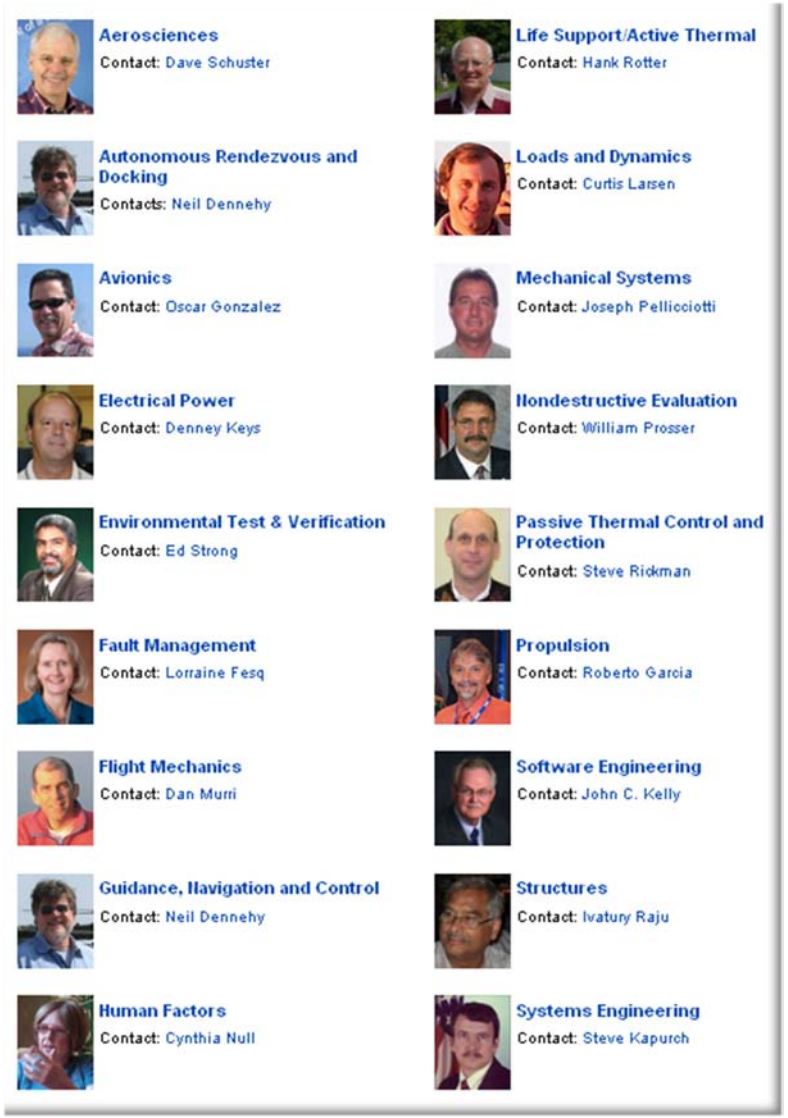
- **5 of the 15 NASA Technical Fellows are based at GSFC:**
  - **Aerosciences - Dave Schuster (LaRC)**
  - **Avionics – Oscar Gonzalez (GSFC)**
  - **Electrical Power – Denney Keys (GSFC)**
  - **Flight Mechanics – Dan Murri (LaRC)**
  - **Guidance, Navigation, and Control - Neil Dennehy (GSFC)**
  - **Human Factors - Cynthia Null (ARC)**
  - **Life Support / Active Thermal - Hank Rotter (JSC)**
  - **Loads and Dynamics - Curt Larsen (JSC)**
  - **Materials - Bob Piascik (LaRC)**
  - **Mechanical Systems - Joe Pellicciotti (GSFC)**
  - **Non-Destructive Evaluation - Bill Prosser (LaRC)**
  - **Passive Thermal Control/Thermal Protection – Steve Rickman (JSC)**
  - **Propulsion - Robert Garcia (MSFC)**
  - **Software - Mike Aguilar (GSFC)**
  - **Structures - Ivatury Raju (LaRC)**

NASA Technical Fellows Responsibilities

- Serve as senior technical expert for the Agency representing the Office of the Chief Engineer and the NESC
- Lead NESC Technical Discipline Teams (TDTs)
- Actively participate on the NESC Review Board
- Serve as an independent resource to the Agency for resolution of complex technical issues
- Lead Agency-wide discipline working groups
- Foster consistency of Agency-level standards and specifications (including “core” standards) and participate in levying standards & specifications on major programs and projects
- Promote discipline stewardship through workshops, conferences, and discipline-advancing activities
- Ensure Lessons Learned are identified and incorporated into Agency processes
- Support Agency Engineering Steering Committees

Online Engineering Communities of Practice on NASA Engineering Network (NEN)

NASA Engineering & Safety Center (NESC)



- 18 Engineering CoPs now online
- 6 sub-communities
- 1 CoP in development
- Led by NASA Tech Fellows
- Open membership so join up!

Phase 2

- Discipline-focused communications
- Provide center-by-center discipline info
- Encourage more user input
- Interactive online content
- Experts answer questions
- Allow users to join a community

NASA Technical Fellows "State-of-the-Discipline"

- **NASA Technical Fellows perform State-of-the-Discipline (SoD) assessments of their respective engineering disciplines for the OCE & the OSMA**

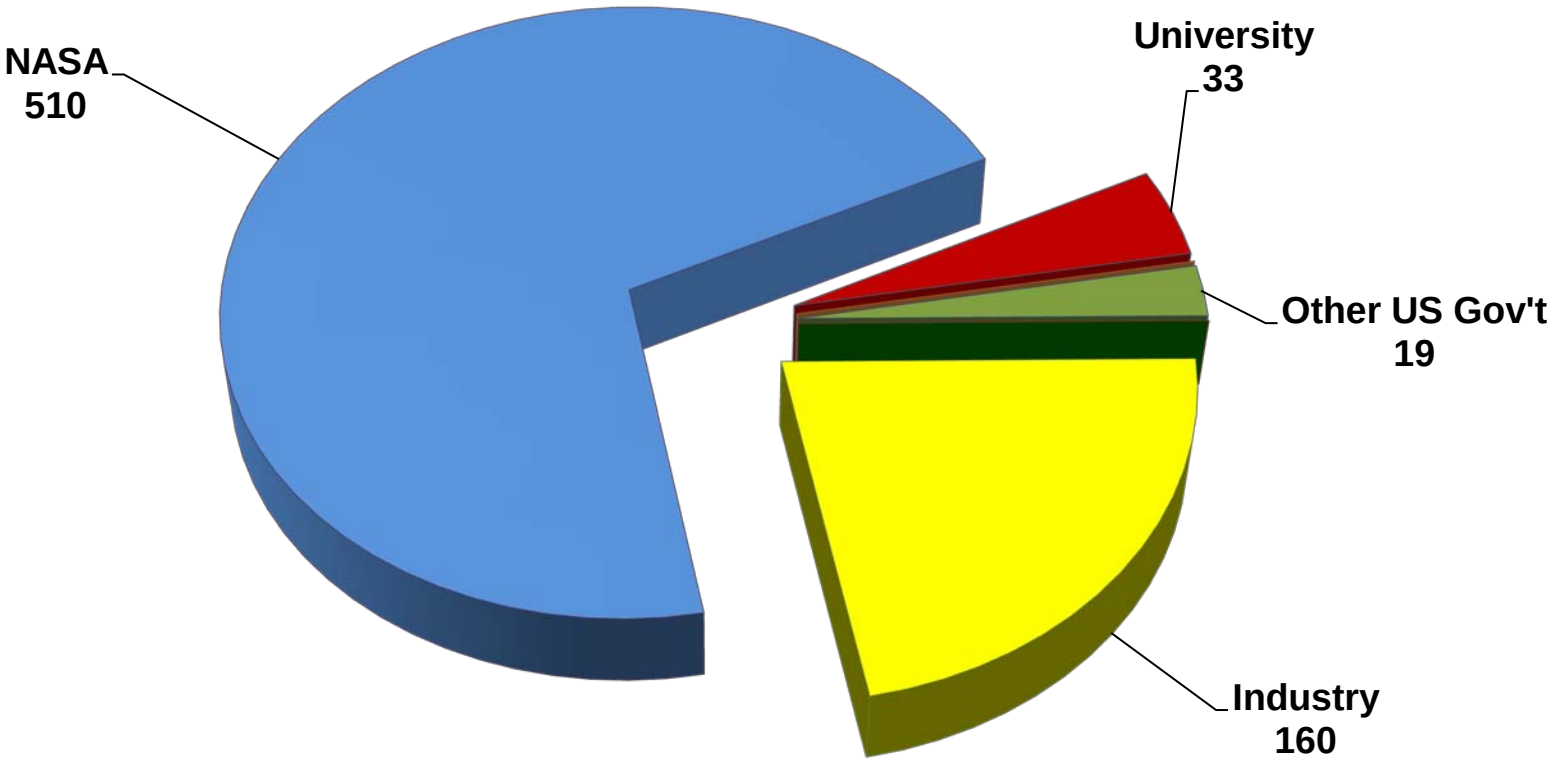
- **A common format is used by Technical Fellows for SoD assessments, including:**
  - **Discipline readiness to support goals and objectives of each Mission Directorate**
  - **Top three technical challenges / barriers for the discipline**
  - **Advocacy recommendations for the discipline (roadmap for discipline advancing tasks)**

- **In their SoD assessments, Technical Fellows outline successes, trends, challenges, and issues facing their individual disciplines and provide a roadmap for improvement**

Technical Discipline Team (TDTs)

- **The NASA Technical Fellows are the leaders of National expert teams…called Technical Discipline Teams (TDT's)**
- **With their ready experts on tap TDT's are NESC's technical backbone**
- **TDT's have technically diverse membership from multiple sources**
  - NASA, industry, academia and other Government Agencies
- **TDT's provide technical support of NESC assessments**
  - Independent expertise/reviews and leadership
  - Independent test, analysis and evaluation – *not just technical opinions*
- **NASA Centers assist the Technical Fellows in the TDT formation through identification of each center's technical experts as candidate members of each discipline-specific team**
  - TDT's are primarily composed of 'part time' civil servants drawn from the engineering organizations across NASA's 10 Centers
- **TDT members develop an Agency perspective while working at their home Center**

Overall NESC TDT Participation

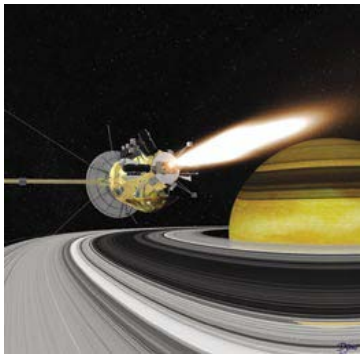


Total TDT Membership = 722
(as of June 2011)

Experiences of the NESC Guidance, Navigation and Control (GN&C) TDT

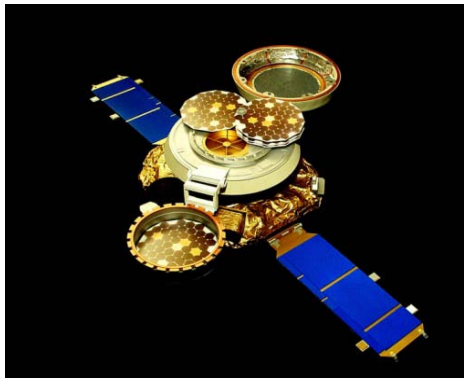
NESC Guidance, Navigation and Control (GN&C) TDT Support to NASA's Science Missions

NASA Engineering & Safety Center (NESC)



Cassini Saturn Orbit Insertion

Hubble Space Telescope Attitude Observer Anomaly (AOA)



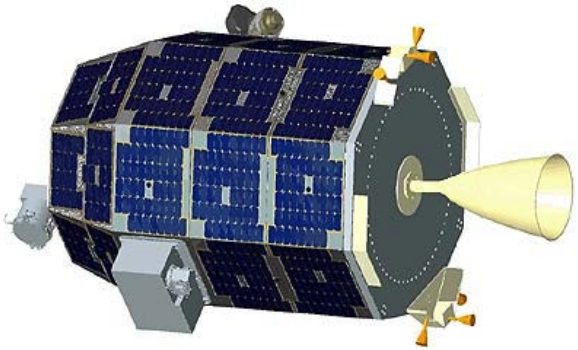
Genesis Mishap Investigation Board

Fermi (GLAST) Star Tracker Baffle

Reaction Wheel Assembly (RWA) Flight and Test Anomalies

Kepler Recurring Anomalies

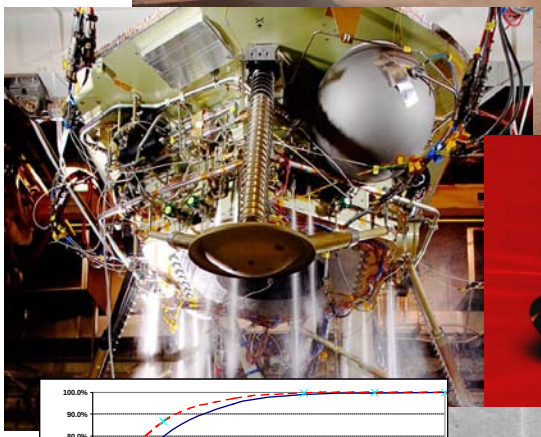
Phoenix Mars Lander Thruster-based Controllability

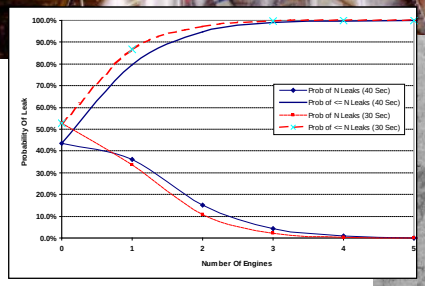


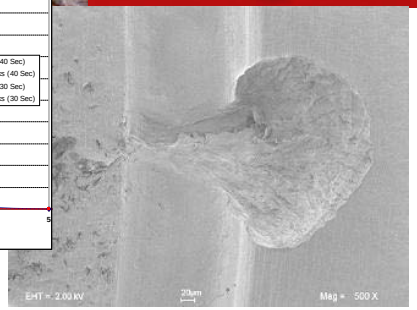
LADEE Alignment Working Group

Phoenix Mars Lander Thruster Leak Touchdown Stability Impact Assessment

- Phoenix implemented a Propulsion System Hot Fire Test Bed to study dynamic interactions
- MR107 thrusters were exposed to 200%- 800% of expected life
- Eight of the thruster valves started leaking after 200%-500% of life
- Thrusters Critical to Performing Powered Descent to Mars Surface
- Project Concern: Effect On Lander's Touchdown Stability Due To Potential Thruster Leakage?
- GN&C TDT Independent Review Team (IRT) reviewed modeling assumptions, simulation, analysis work performed by JPL and L-M
- IRT recommended thrusters "fly as is"
- Successful landing on 25 May 2008

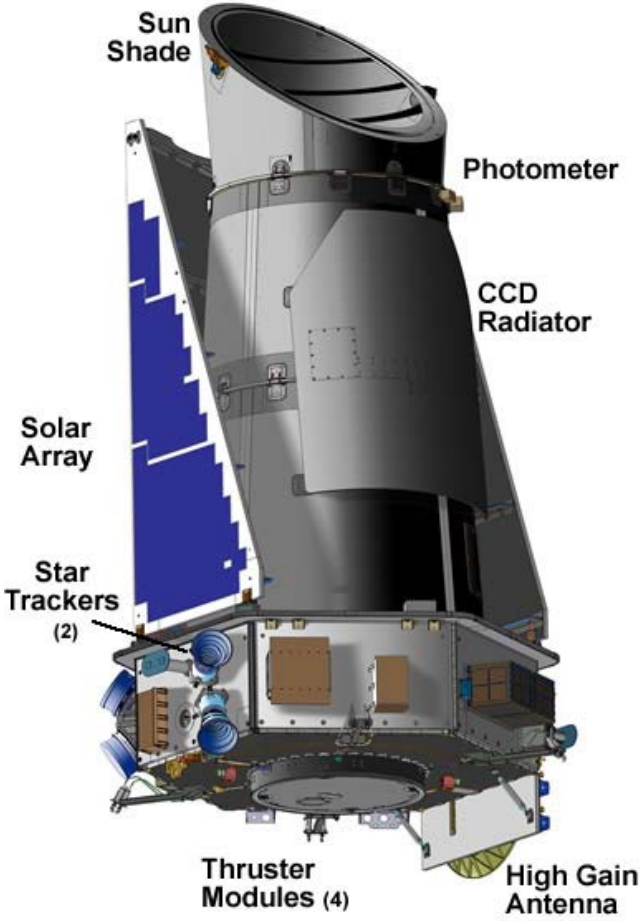






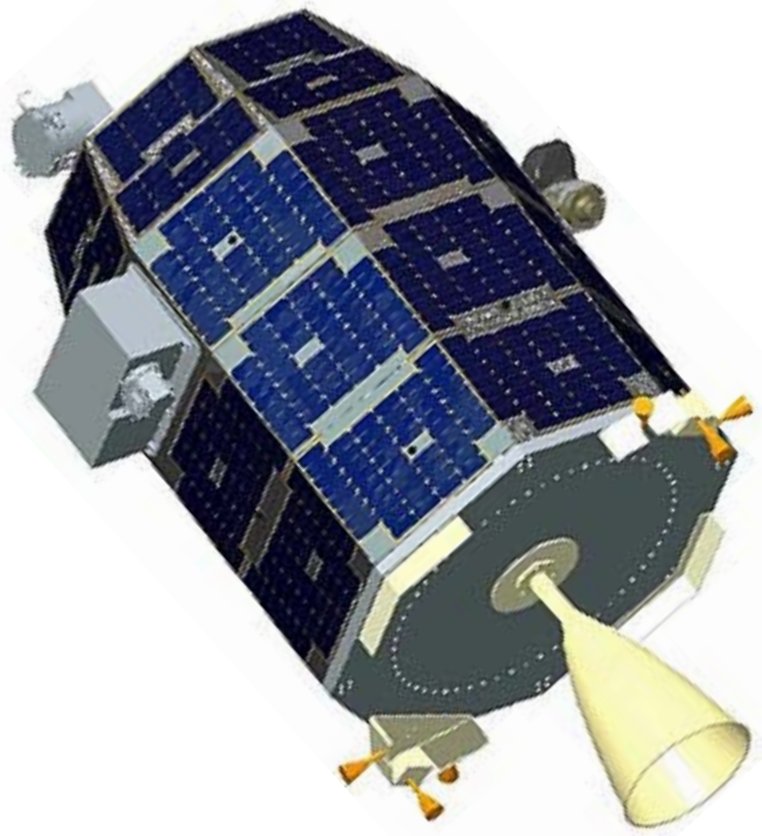
Kepler Recurring Anomalies

- **Kepler experienced recurring anomalies that interrupted science data collection**
- **Multiple Safe Hold Mode entries over period June 2009 to November 2009**
- **Star Tracker issues: unexpectedly dropping stars or declaring stars invalid then led to a 'Lost in Space' condition**
- **The GN&C TDT team reviewed:**
  - **analysis of the anomalies, including timelines and fish-bones generated,**
  - **the mitigations undertaken or under consideration, and the effects of the mitigations**
  - **the mission's anomaly response and resolution process**
  - **the planned paths to get to the root-cause of the anomalies,**
  - **remaining work to bring anomalies to closure and any residual risks.**



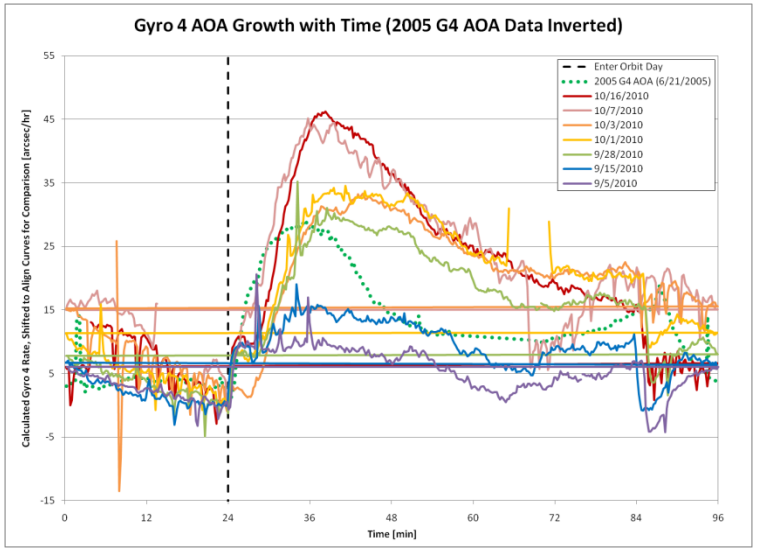
Lunar Atmosphere and Dust Environment Explorer (LADEE) GN&C Support

- **100-day Enhanced Class D mission to measure lunar dust and examine lunar atmosphere**
- **NESC was initially requested to review spacecraft stability and control during the Lunar Orbit Insertion (LOI) maneuver**
- **Members of the GN&C TDT participated in the Mission CDR and the System Integration Review (SIR) at Ames Research Center**
- **GN&C TDT members now serving on LADEE Alignment Working Group**
  - **Main engine alignment requirements**
  - **Spin balance requirements**
  - **Propellant fluid balancing during LOI**
  - **Mass properties testing**



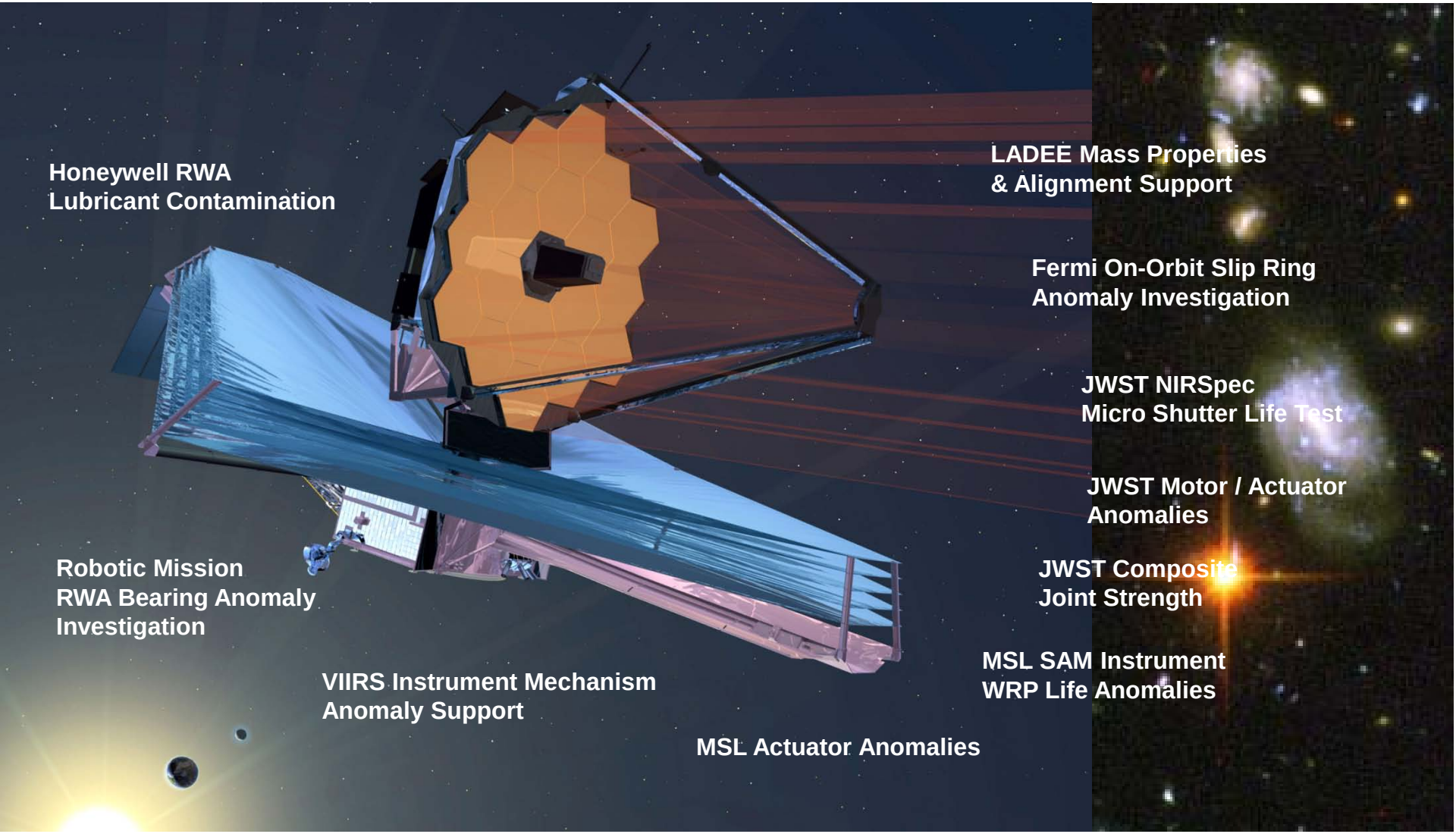
Hubble Space Telescope Attitude Observer Anomaly (AOA)

- **Hubble Space Telescope (HST) has experienced 'losses of lock' during Fine Guidance Sensor (FGS) guide star acquisitions, compromising science data collection**
- **Anomalous events are called 'Attitude Observer Anomaly' (AOA) characterized by an increasing disparity between the FGS-derived estimates of gyro bias calculated in orbit day and those calculated in orbit night.**
- **AOA's occurred in 2004-2005 and again in 2010-2011 (post SM-4 on a new set of 6 gyros)**
- **NESC's GN&C and Avionics TDT's supported the recent efforts of the AOA Anomaly Review R Board (ARB)**
- **Analysis led to on-orbit mitigation strategy (a preferred gyro heater thermal controller configuration) that has succeeded in reducing the AOA signature.**
- **AOA signature coincident with gyro thermal controller heat pulse created coincident with orbit terminator voltage transient.**
- **Increasing AOA signature magnitude believed to be caused by asymmetric corrosion-induced degradation between the seven flex leads. The orbit terminator heat pulse is believed to create mechanical motion as it travels through the asymmetrically corroded flex leads.**
- **The HST team, with the support of NESC, is continuing to study, model, and analyze the AOA phenomenon:**
  - **Thermal-Electrical-Mechanical-Chemical 'physics based' model of the gyro flex lead corrosion process**
  - **Updated probabilistic gyro life predictions**
  - **On-orbit attitude control flight software compensation**



Experiences of the NESC Mechanical Systems Technical Discipline Team

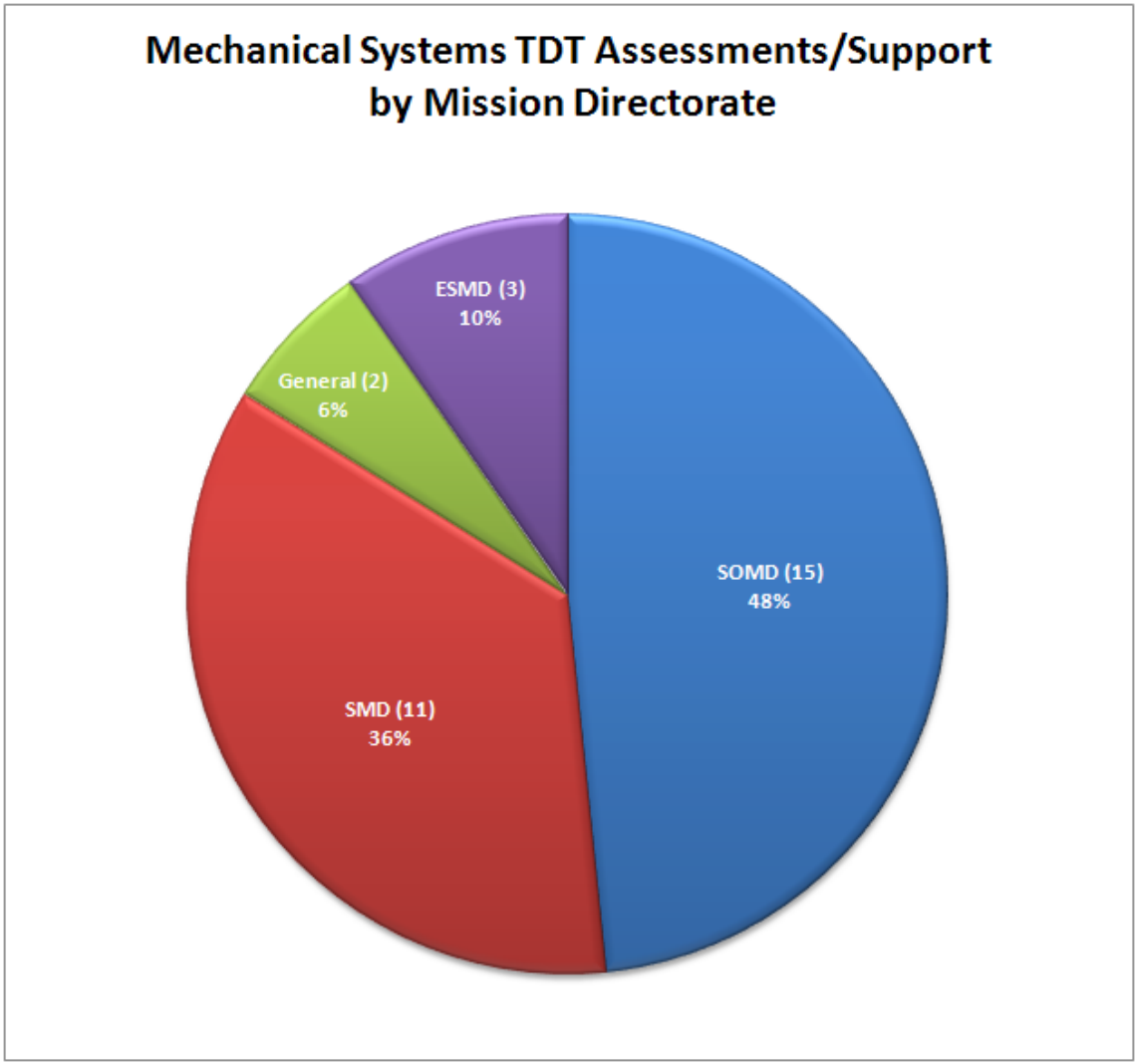
NESC Mechanical Systems TDT Support
Science Missions



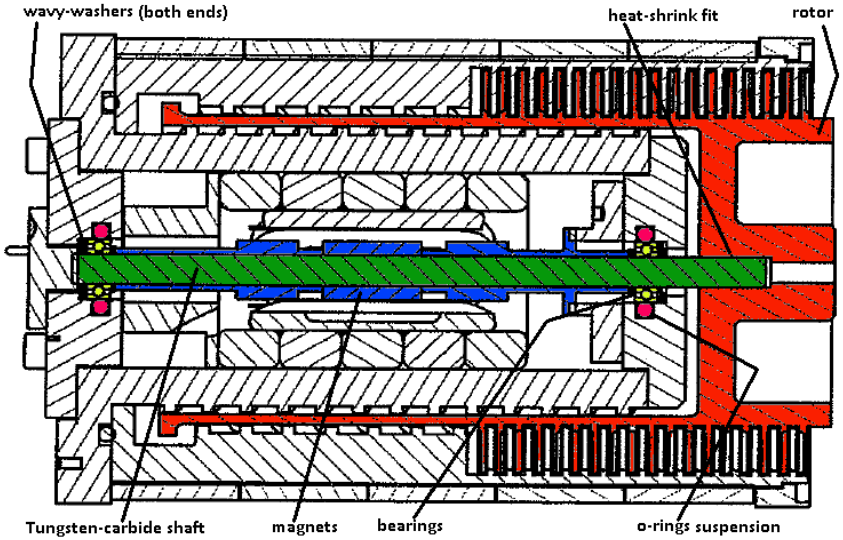
Mechanical Systems TDT Metric

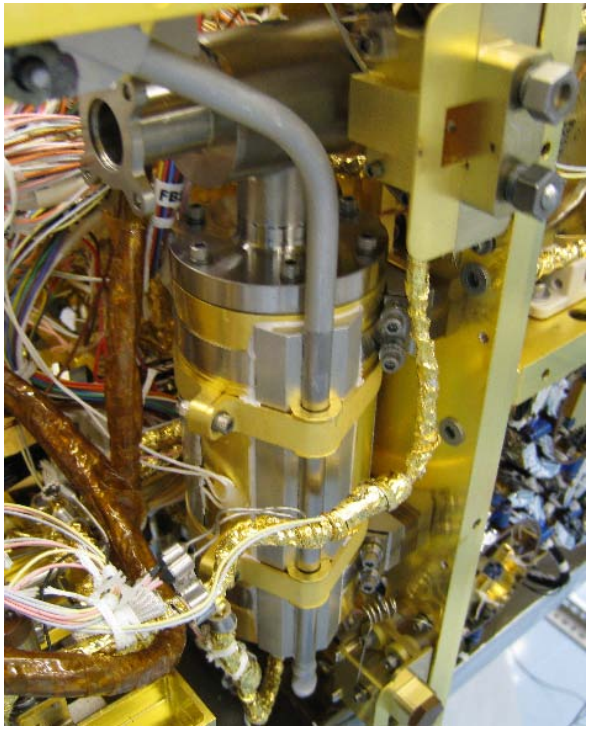
- **TDT Core Membership**
  - Civil Servants = 20
  - Industry = 5
  - University = 0

- **Assessments (31 Total)**
  - Total TDT Full Assessments = 17
    - 7-Open, 10-Closed
  - Support Assessments = 14
    - 1-Open, 13-Closed
  - Total Closed Assessments = 23
  - Assessments Opened Since Jan-2008 = 15
  - Assessments Opened Prior to Oct-2008 and Still Open = 3
    - Fastener STD
    - SARJ
    - Orion Seat Attenuation



- **Wide Range Pump (WRP)**
  - **Pumps (2) operate at 100000 rpm, but have a rotor bending frequency equivalent to 30000 rpm (500 Hz).**
  - **Pumps pass thru resonance on their way to the operational speed.**
  - **Visco-elastic distortion of butyl o-rings that suspend the rotor bearings provide damping and absorb imbalance energy.**





WRP Issues:

- **Loses balance**
- **Bearing retainer cracks**
- **Fails at start-up**
- **Material strength**
- **High loads**

MSL SAM WRP Life Anomaly - Resolution

- **Lubricant Life is not a concern with SuperMeldin retainer**
  - **Based on consistent results from ALTU7, ALTU8 and LTU2 Life testing.**

- **Issues of Concern**
  - **Can't get through Resonance due to imbalance.**
    - Don't completely understand what is causing the variability in balance effects from thermal cycling. Why do some units balance better and faster than others?
    - Does balance stay stable throughout operational life and thermal cycles such that it does not affect start up and operation on Mars?
      - History to support that the balance does not wander off cumulatively with cycles, rather it repeats the same path with each cycle based on pre-assembly operation during balance.
    - SAM Project Mitigation:
      - LTU2 Life testing will undergo many thermal cycles but probably not as many as on Mars.
        - Roughly, 1/2 of the time will be spent at +20°C (10 T/C Plateaus), 1/4 time at +60°C (5 T/C Plateaus), and 1/4 time at -40°C (5 T/C Plateaus).
        - For every start-up of LTU2 at -40°C, (~200 for 2x Life), WRP Temperature is raised to +20°C, then allowed to drift down to -40°C. No known change in balance to date.
  - **Effect of a cracked Meldin Retainer.**
    - Cracked retainers found post assembly during balance operation. Why not caught during pre-assembly inspection?
      - Is there a retainer loading event during operation not understood that causes a crack.
      - Low Pressure (LP) end bearing load increases when operating on Mars (from Life Test on Earth) by approximately +6%.
    - System effect of a cracked retainer has not been verified; therefore, assume catastrophic.
    - SAM Project Mitigation:
      - Detailed retainer inspection post retainer installation (recently implemented) and intermittent inspection during balance.
        - Analysis indicates crack could be initiated during retainer installation or during balance start-up.
      - Believe that balance operation is a screening for bad retainers.
  - **These concerns for anomalies are not necessarily operational life time dependent and could randomly occur at any time during the mission.**

- **Potential Risk Reduction Suggestions**
  - **Life test more fully assembled units - Variation from unit to unit balance creates repeatability uncertainty.**
  - **Life test thermal cycling to mimic mission operation on Mars since apparently, T/Cs affect balance.**
  - **Run a pump with a known cracked retainer and it survives 1x life could reduce the risk from a cracked retainer.**
    - Complete – Survived 2.4x Life.

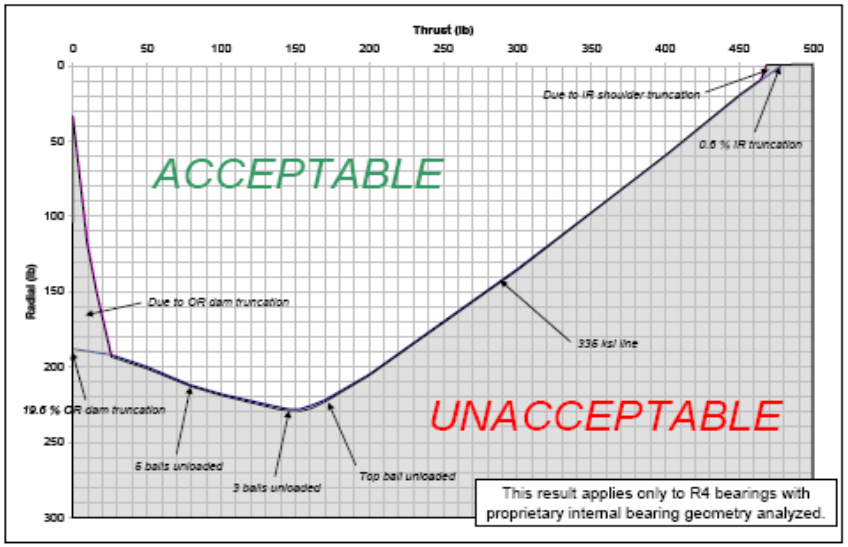
- **Hardware is integrated onto the instrument which is integrated onto the MSL Rover. No anomalies with the WRP noted to date.**

RWA Anomalies

- **The JPL Chief Engineer and Kepler Project requested an independent review be done by NESC to validate the risk posture and plans for the RWA usage for the Kepler mission.**
  - **NASA / Industry evaluation team brings together mechanism, tribology and ACS experts across the country.**
  - **Findings and recommendations are applicable to multiple NASA Projects.**
  - **Team becomes a consulting panel for NASA Projects in addition to Kepler (such as GLAST and OCO)**
- **Follow-on effort to support OCO-2 RWA selection by team members.**
- **Continue to support Honeywell & Ithaco Type A, AA, and B wheel investigations as requested.**

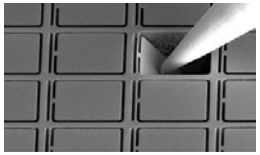
GLAST EM Anomaly Bearing

RWA Bearing Capacity



JWST NIRSpec Microshutter Life Test - Background

- **NIRSpec is an instrument that will allow scientists to capture the spectra of more than 100 objects at once. Because the objects NIRSpec will be looking at are so far away and so faint, the instrument needs a way to block out the light of nearer bright objects.**
- **The microshutters were developed to help solve this problem. Micro shutters are tiny cells that measure 100 by 200 microns, or about the width of three to six human hairs.**
  - The microshutters are arranged in a waffle-like grid that contains over 62,000 shutters (Instr contains 4 grids).



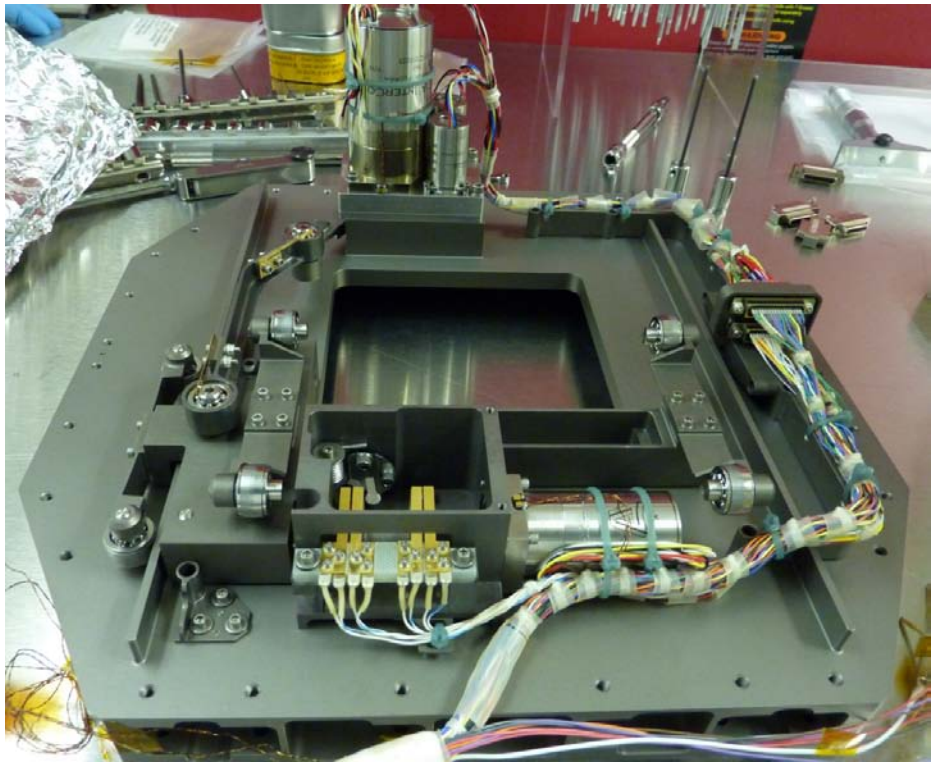
- **The microshutter cells have lids that open and close when a magnetic field is applied. Each cell can be controlled individually, allowing it to be opened or closed to view or block a portion of the sky.**

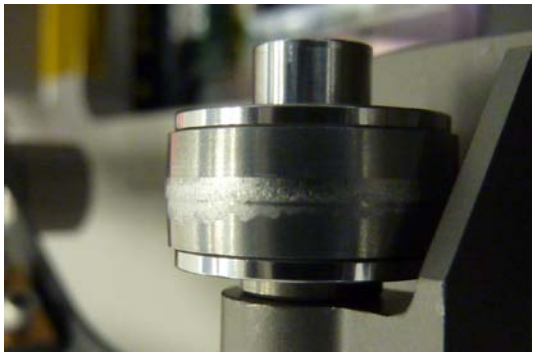
JWST NIRSpec Microshutter – Problem Statement

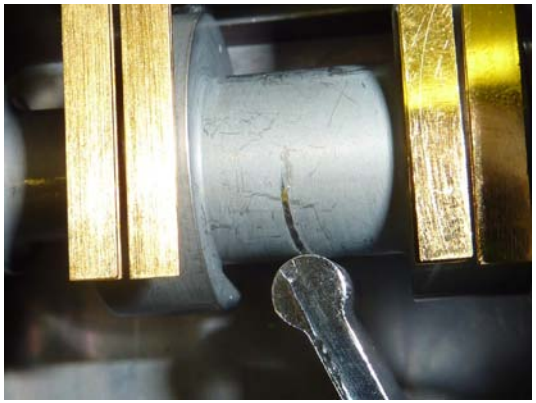
- **Evaluate the Life Test Results from the Micro-Shutter Mechanical Subsystem including the Translation Stage and Launch Lock mechanisms.**
- **2x Life equates to 96,000 Translation Stage cycles at cryogenic temperatures, and 1,200 cycles at cryogenic plus 800 cycles at room temperature for the Launch Lock**
- **Pass / Fail criteria was based strictly on performance of the mechanism at the completion of the test.**
  - **Mainly: Peak operating current, operating current change from the baseline, and resolver count changes.**
- **At completion of the life test, the Translation Stage and Launch Lock mechanisms were disassembled and inspected.**
- **All performance requirements were satisfied and the design was declared qualified from that perspective by the Micro Shutter Project Team.**
- **Results of the inspection revealed wear of the moving parts (rollers and tracks), as well as debris from the worn hardware.**

JWST NIRSpec Microshutter – NESC Contribution

- **NESC performed evaluation tests of baseline flight material to evaluate wear progression.**
- **Tests also in process to evaluate potential replacement materials to significantly reduce roller interface wear.**



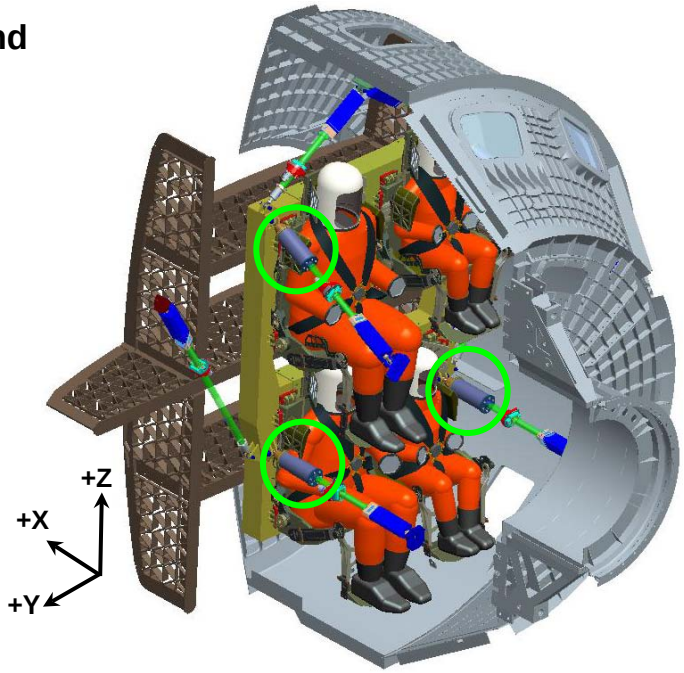


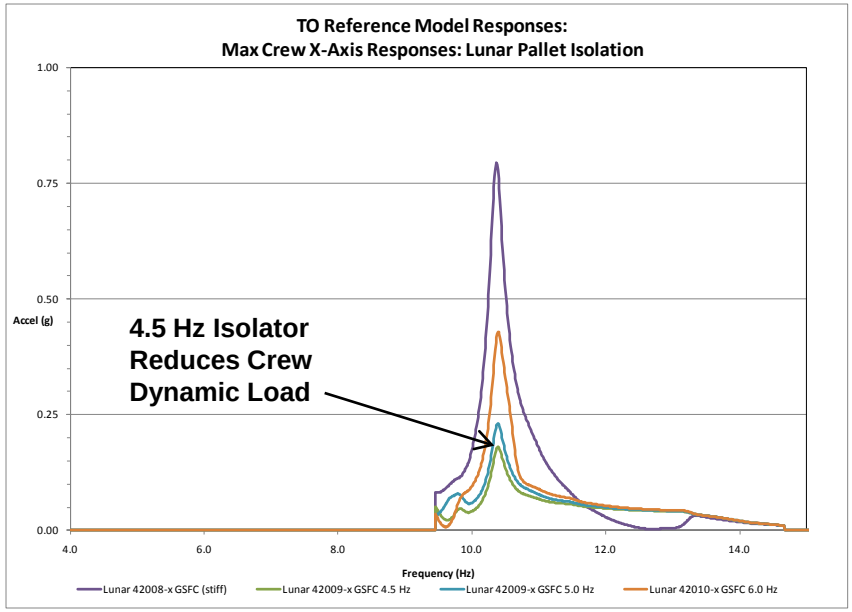


NESC Mechanical Systems TDT Support
Ares-I Thrust Oscillation Mitigation – Pallet Isolation

NASA Engineering & Safety Center (NESC)

- **Isolator hardware designed and 5 isolator assemblies built and tested at component, strut and pallet system level.**
  - **Includes one 600 lb/in assy with flight-like isolator lock-out mechanism.**
- **Different spring stiffnesses for each of the +Z axis struts and the –Z axis struts**
  - **+ Z Axis D4200-1 K = 600 lbs/in Spring**
    - Weight = 11.2 lbs ea. (actual)
  - **- Z Axis D4200-3 K = 1200 lbs/in Spring**
    - Weight = 13.7 lbs ea. (actual)
- **All load bearing machined parts and the springs are manufactured from Titanium 6Al – 4V**
- **Both spring designs have a common interface so that the machined parts are the same in both configurations**

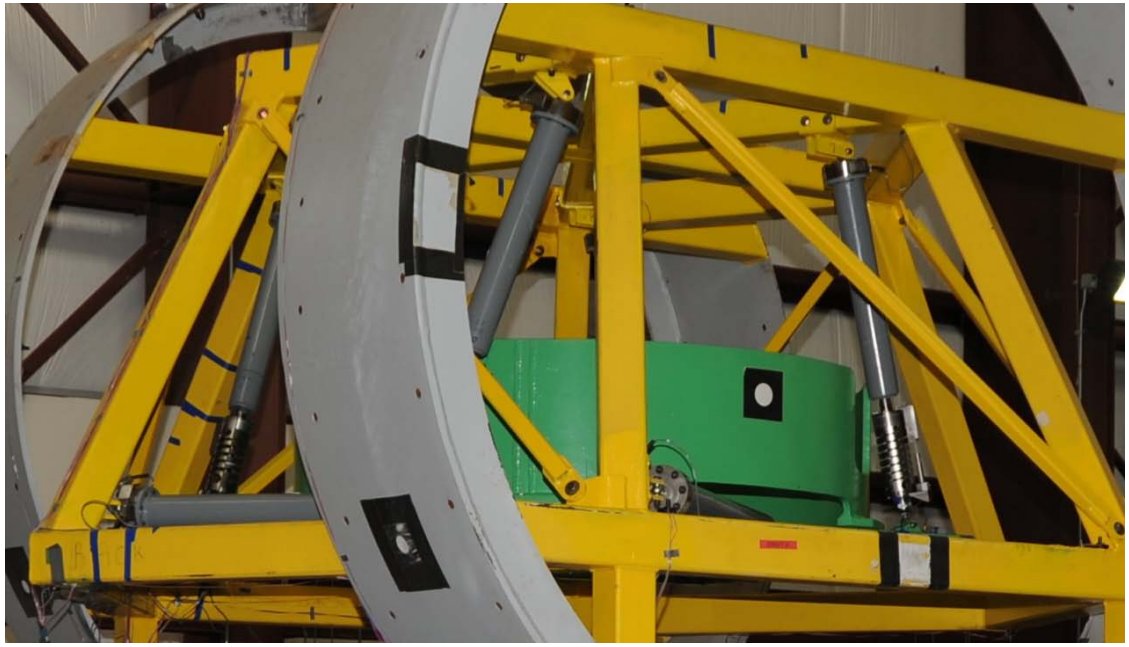


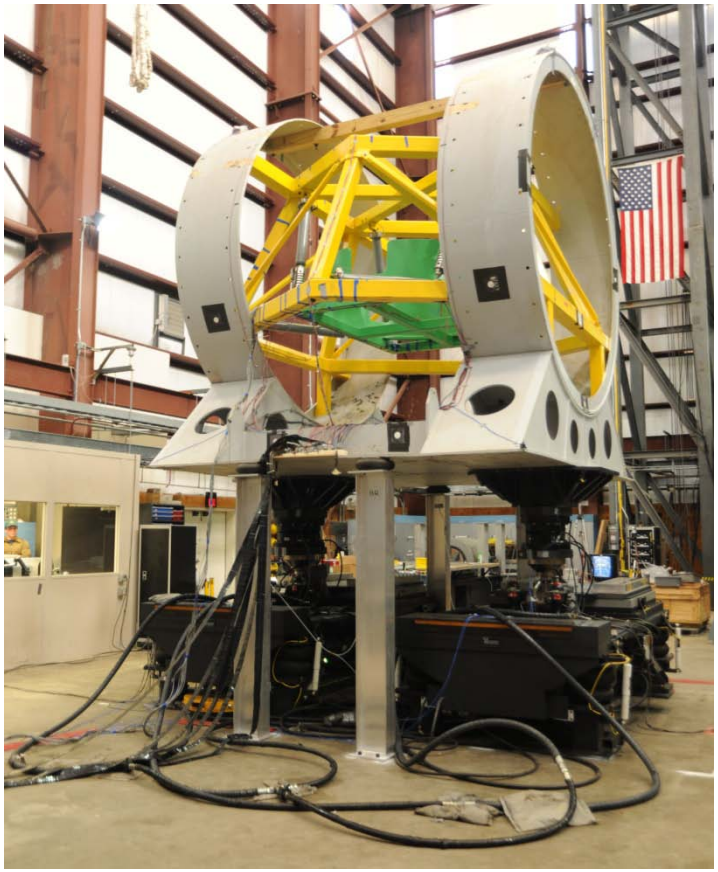


Isolators installed onto Wire Bender Struts in preparation for System Drop Testing at LaRC started April 20.

Ares-I Thrust Oscillation Mitigation – Isolator Vibration Test

- **Vibration Test at Dahlgren Naval Facility, VA**
  - **Test results indicate that the isolation system for this hardware provides a reduction of dynamic load to about 20%-30% of the input.**
  - **It is important to note that without any isolation, there was actually dynamic amplification of about 125% to 150% of the input acceleration at the crew pallet.**





Development a NASA-STD for fasteners.

- Standard Complete & in final review & signature process
- Workshop held May 18-20, 2010

NASA TECHNICAL STANDARD	NASA-STD-5020
National Aeronautics and Space Administration Washington, DC 20546-0001	Approved: MM-DD-YYYY Superseding NASA-STD-XXXXR

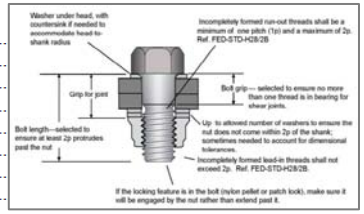
REQUIREMENTS FOR THREADED FASTENING SYSTEMS IN SPACEFLIGHT HARDWARE

DRAFT 1 – JANUARY 19, 2011

This official draft has not been approved and is subject to modification.
DO NOT USE PRIOR TO APPROVAL.

MEASUREMENT SYSTEM IDENTIFICATION:
METRIC/SI (ENGLISH)

THIS STANDARD HAS NOT BEEN REVIEWED FOR EXPORT CONTROL RESTRICTIONS; CONSULT YOUR CENTER/FACILITY/HEADQUARTERS EXPORT CONTROL PROCEDURES/AUTHORITY PRIOR TO DISTRIBUTION OF THIS DOCUMENT.



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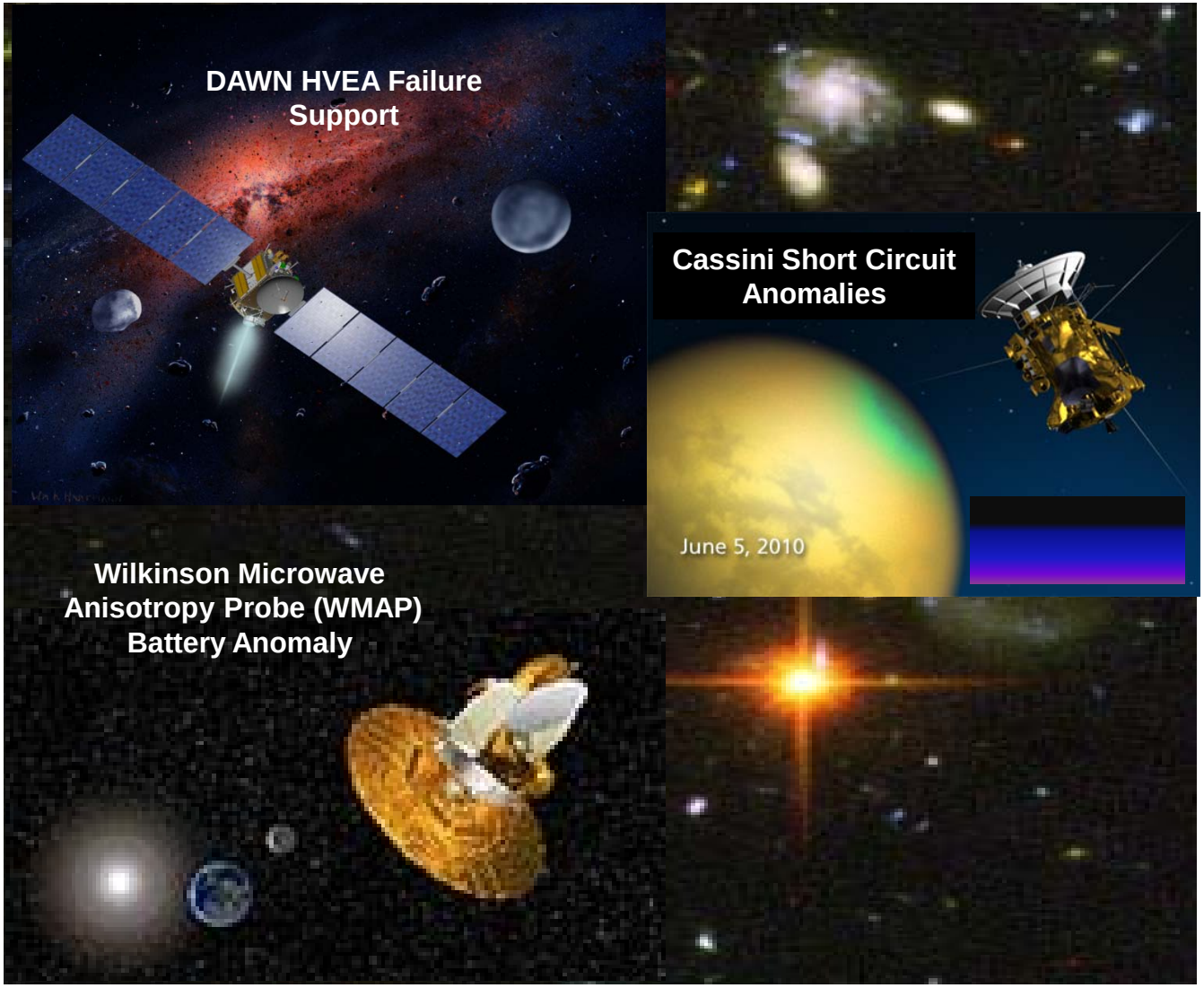
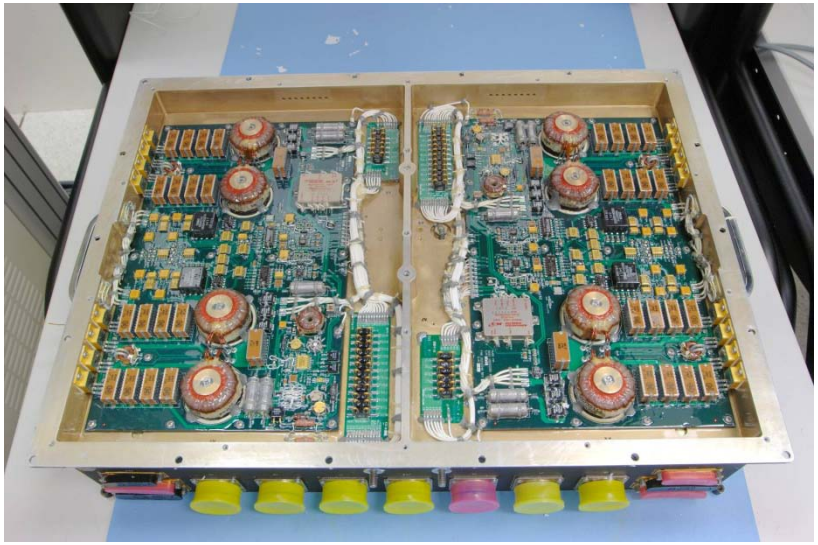
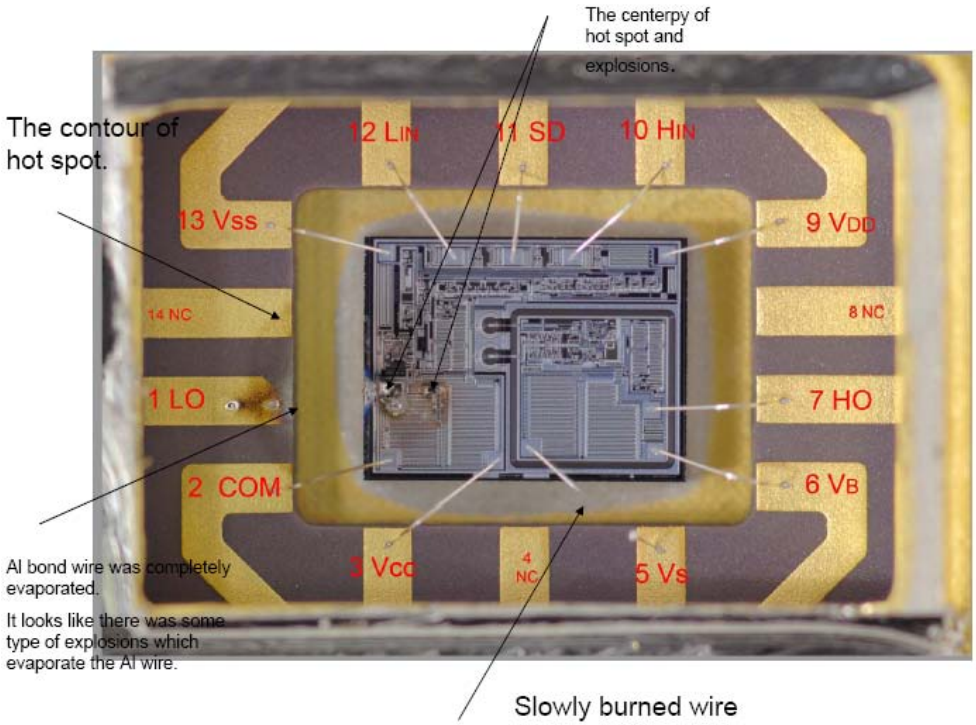
Experiences of the NESC Electrical Power Technical Discipline Team

NESC Electrical Power TDT Support
Science Missions



- **Dawn High Voltage Electronics Assembly (HVEA)**
  - **Rapid turnaround request submitted to NESC to evaluate the HVEA failure during Assembly Test Launch Operations (ATLO) and assess the corrective actions taken to repair the electronics as well as determine any additional analyses needed to resolve failure investigation and assist in evaluating root cause.**





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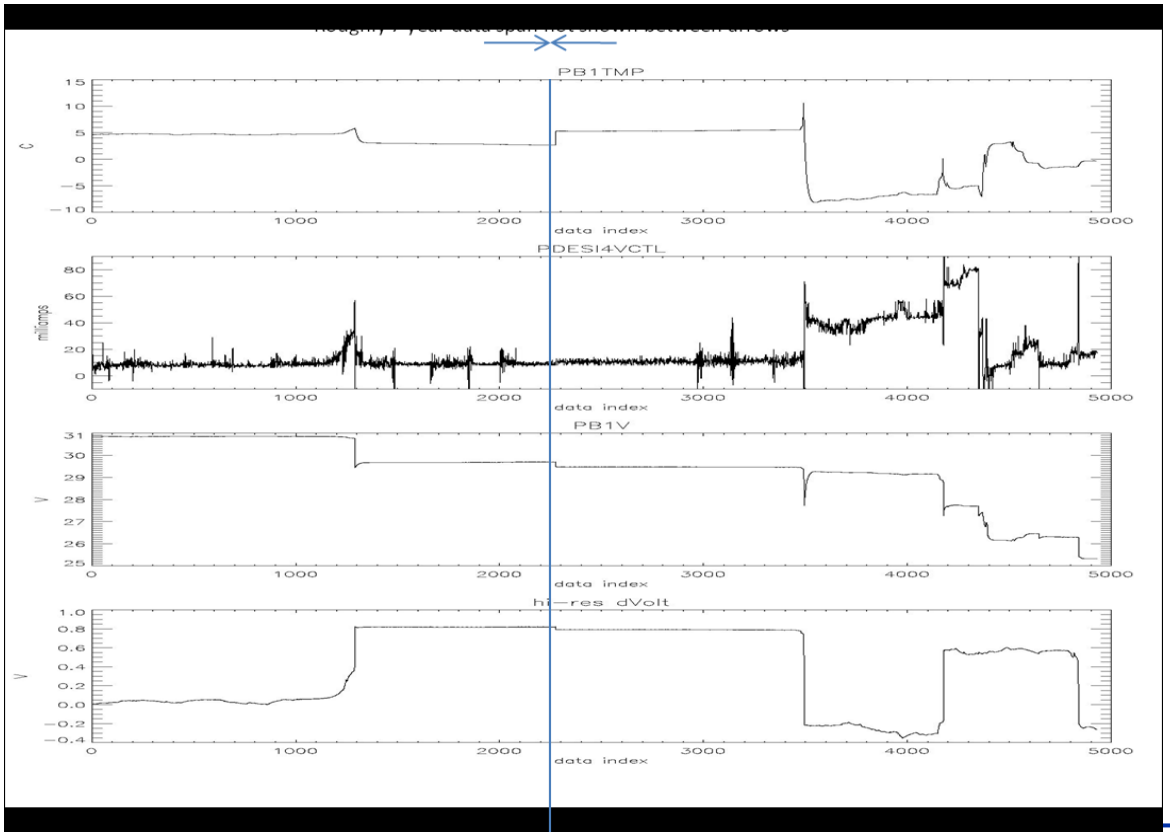
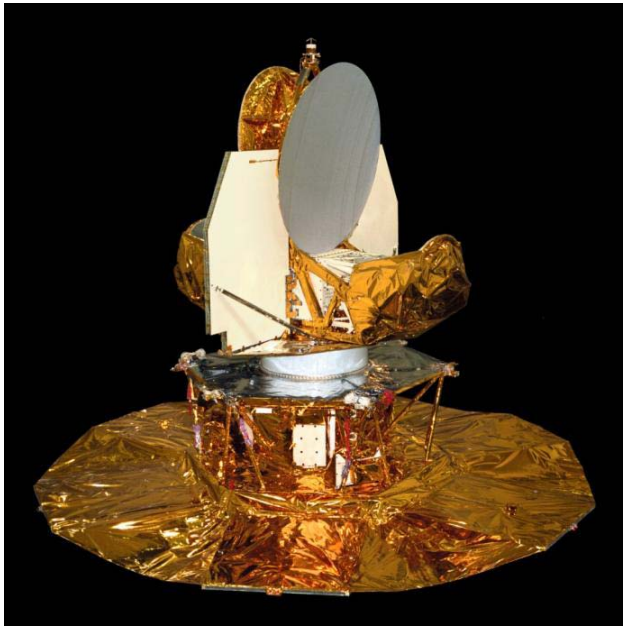
- **Summary of independent investigation:**
  - During ATLO testing HVDC side swap commanded (Side B to Side A)
  - Pre-charge of capacitors did not occur (observed as most likely due to inadvertent enable of EPS load shed setting, incorrect configuration prior to turn-on)
  - Side A output relay was closed (operator error)
  - On board computer (OBC) telemetry was lost, most likely due to a bus under-voltage on low voltage side with this most likely due to a large inrush current demand from the battery
  - At subsequent Solar Array Simulator turn-on, HVEA was observed to have behaved as if it was turning on into a short circuit, peak current ramped to greater than 40 amps, cleared, and then appeared to behave normally
- **Final investigation findings:**
  - Failure caused by improper configuration and operator error
  - Team evaluation of potentially stressed EEE components provided project the opportunity to replace prior to launch window closing

Wilkinson Microwave Anisotropy Probe (WMAP) Battery Anomaly

- **W-MAP extended mission operations threatened as a result of rapid and unexpected falling bus (battery) voltage.**

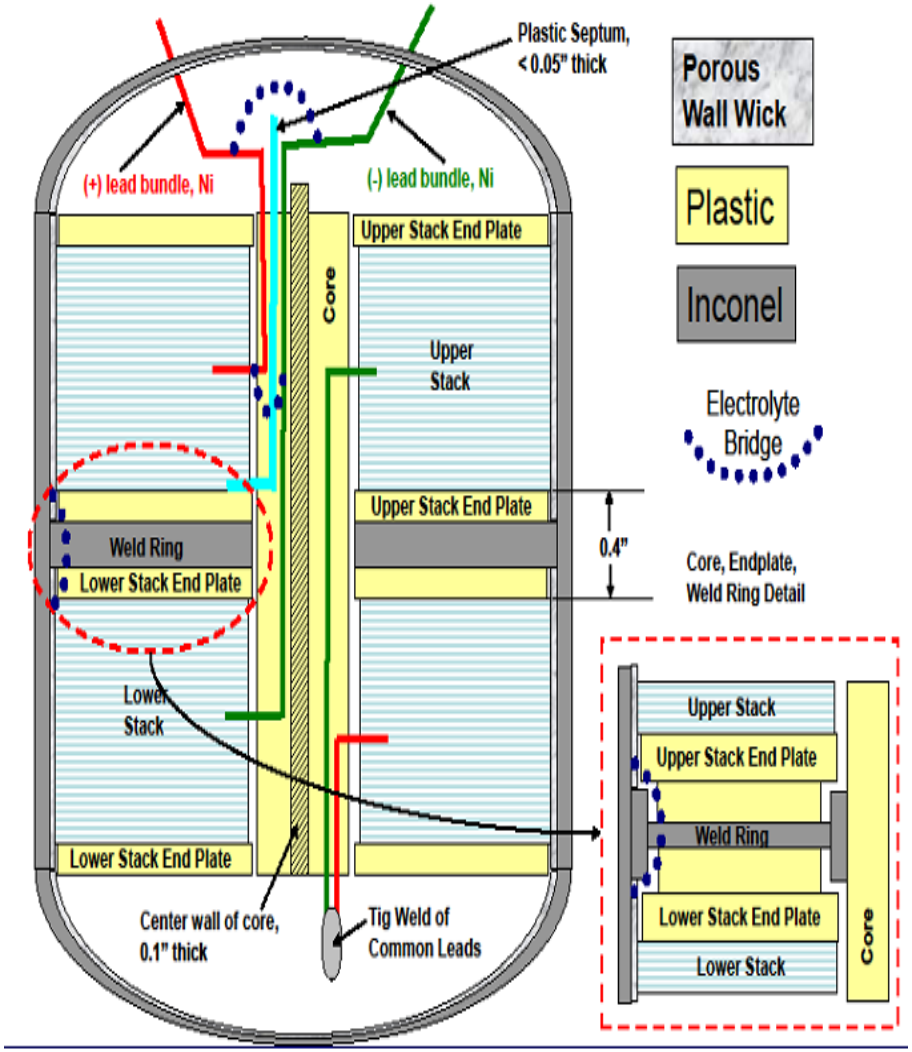




- **NESC requested to perform independent investigation into the cause of anomaly and recommend potential solutions**

WMAP Battery Anomaly Investigation Results Summary

- The observed WMAP flight battery on-orbit behavior with the WMAP flight battery was atypical for IPV NiH2 cells and appeared to be unique in nature for CPV cells.
- With two series connected cell stacks within a single pressure vessel, charge transport mechanisms can exist between the cells potentially degrading performance in one, or both, cell stacks due to electrolyte bridging (verified in lab testing).
- Revised charge profiles and durations with appropriate limits on temperature provided to maintain sufficient battery voltage necessary to complete mission.



Cassini Short Circuit Anomalies

- Cassini spacecraft launched in 1997
- Multiple high and low bus rail short circuits observed recently on the Cassini Plasma Spectrometer (CAPS) instrument feed as well as another observed short circuit associated with the Radioisotope Thermal Generator (RTG)
- Project requested NESC support to independently determine potential source of short circuits and provide recommendations for planned future operation of Cassini Plasma Spectrometer (CAPS) instrument

Experiences of the NESC Avionics Technical Discipline Team

NESC Avionics TDT Support to NASA's Science Missions

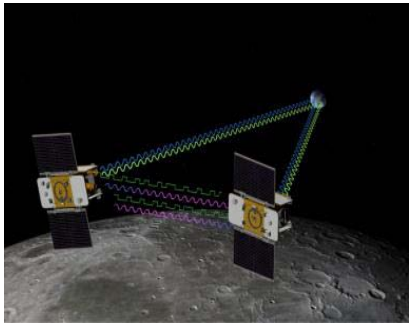
Diverse Experiences of the NESC Avionics Technical Discipline Team ranges from:

Assessments:

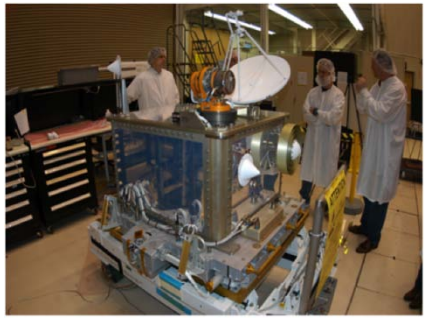
Hubble Space Telescope
Gyro Anomaly

Toyota Unintended Acceleration

Support:



Reaction Wheel Assembly
Comparator Anomaly



CONNECT
SPACE Wire Communication

Mission Operations Voice Equipment (MOVE) Keyset
Mishap investigation

Consultant:

EEE Parts selection criteria for the Commercial Crew Program, Etc.

Avionics TDT
Core Members & Support

Avionics Team	Members List per NASA Center										
	ARC	DFRC	GRC	GSFC	JPL	JSC	KSC	LaRC	MSFC	SSC	Industry**
Avionics TDT Core Members	Kuok Ling	Michael Delaney	Glenn Williams Glenn Lindamood	Oscar Gonzalez - TF Mitch Davis - Deputy George Jackson - Deputy Kenneth Label Henning Leidecker Jeff Dumonthier	Mike Gross Randy Blue	Robert Scully Frank Baiamonte Lanny Plaisance	Ken Hattermans Hung Nguyen Peter Johnson	Yuan Chen	Matt McCollum		Robert Kichack Michael Bay George Slenski Mike Johnson
Avionics Steering Committee	Kimberly Wagenbach	Glenn Bever (ASC)	Therese Griebel	Janet Barth	Raphael Some	Patrick S. Pilola	Arnold Postell, Chair	Robert Hodson	Kurt Jackson	Mark Hughes	
Communities of Practices Leads		***FPGA**** Michael Delaney	***E3*** Cathy Lewis	***Radiation Effects*** Ray Ladbury ***Avionics Arquitecture**** TBD	***Telecomunications*** DanRascoe	***Wireless Communication*** George Studor	***Connectors & Wiring*** Ken Hattermans ***Avionics Training**** Phil Tang	***EEE Parts*** Yuan Chen			

* Under Development

** Contractor

Hubble Space Telescope
Gyro Anomaly

Gyro Components

Motor Lead Touching Center Shaft with 400-500 Ω resistance

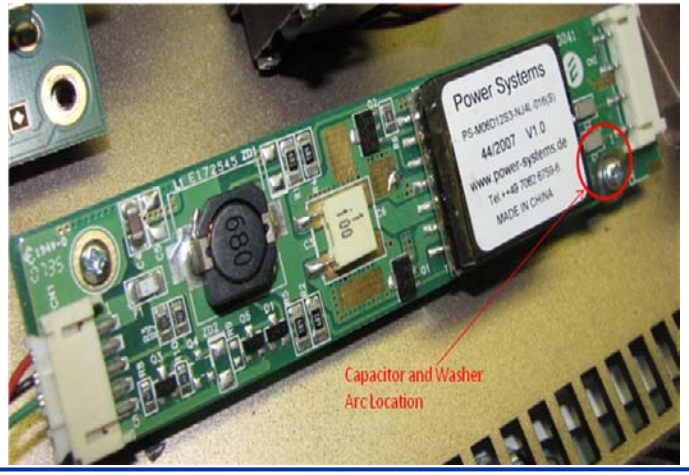
. The increasing AOA signature magnitude is believed to be caused by asymmetric corrosion-induced degradation between the 7 flex leads. The orbit terminator heat pulse creates mechanical stresses as it travels through the asymmetrically corroded flex leads, these impose a force on the float.

- **This team has created new tools to aid in monitoring the AOA degradation (in all operational modes)**
- **Post SM3B gyro complement had AOA signatures in 4 of the 6 gyros; G2(2002), G4(2005), G6(2008) & G1(2008). However, not all of the AOA signatures impacted science operations.**
- **Based on a sample size of 2, it is believed that the Enhanced Flex Lead gyros have a greater propensity for the AOA signature to degrade more quickly than the Standard Flex Leads.**

Mission Operations Voice Equipment (MOVE) Keyset
Mishap investigation

- **<u>What happened</u>: WSTF contract employee noticed 'burning smell', which was tracked to MOVE keyset in another room**
- **<u>Why happened</u> : There was an arc of sufficient voltage and current to sustain itself across the high voltage inverter board output terminals and ground**

- **Mishap investigation team:**
- **1) Independently validate the vendors root cause analysis:**
- **a) ARCING from the High Voltage Power supply output to the power return caused the observed problem (as previously stated by the Keyset manufacturer).**
- **b) Keyset Manufacturer failed to properly implement the use of non-conducting mounting hardware mitigation recommendations (issued by the third party High Voltage power supply vendor) in some of the Keysets.**
- **2) Root Cause and mitigations: were not able to clearly identify what was the event that initiated the arcing,**
- **3) Mitigations:**
- **i) Replace all conductive mounting hardware in the proximity of the power supply high voltage terminals by non conductive hardware (as recommend by the third party power supply vendor).**
- **ii) re-route speaker wires away from the high voltage terminals.**
- **iii) added sleeve covering the speaker wires increasing the effective dielectric constant of the affected wires.**
- **iv) Conformal coat all exposed high voltage terminals with appropriated non corrosive, flexible material.**
- **V) Provide adequately rated fuse at the input of the High voltage Power Supply.**



Experiences of the NESC Software Technical Discipline Team

NESC Software Reviews/Consultations

- **JWST Floating Point Integration Consultation**
  - **During the initial integration of the Java Script software to the JWST C&DH, unacceptable loading on the RTOS occurred. Consultation with the NESC corrected the problem (compilation flag settings) that eliminated a full development build (3-months) that had been scheduled to fix the anomaly.**
- **Glory Integration Reset Consultation**
  - **During integration testing, the Glory processors would reset daily. Consultation with the NESC recommended adding enhanced instrumentation into the processor interrupts. The instrumentation identified a hardware defect in the processor core.**
- **MLAS Development at Wallops**
  - **The NESC at GSFC identified the benefits of building the MLAS FTV at the Wallops facility and championed the selection to the NESC management. The development of the MLAS FTV at Wallops highlighted the benefits of the Wallops facility.**
- **cFE Software Architecture Review**
  - **The NESC TDT Software Architecture Review Board (SARB) hosted a review of the cFE/CFS software at GSFC. The 2-day review found the software very promising as a command and control architecture. The SARB will be actively involved in promoting the use of the cFE/CFS software throughout the agency.**

Summary

The NASA Technical Fellows set the example for engineering excellence within the Agency

The NASA Technical Fellows provide unique overarching technical perspectives not usually available to Agency decision makers

THANK YOU!

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