DSCOVR Contamination Lessons Learned

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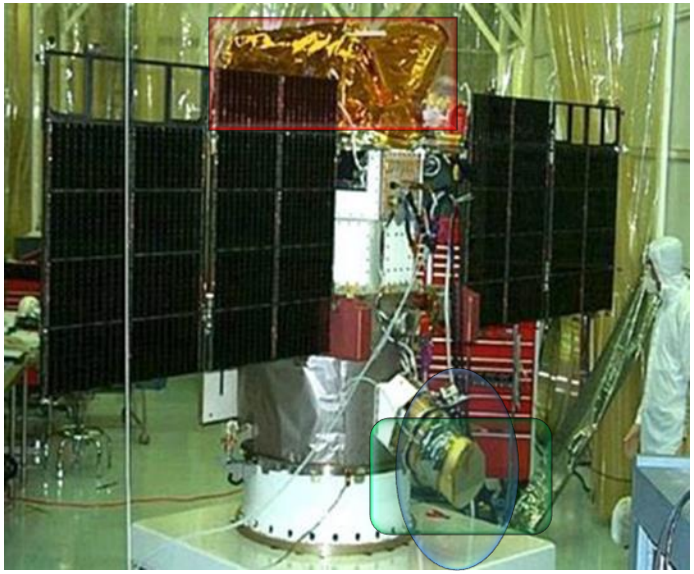
Background: Triana to DSCOVR

- Triana was developed in the late 1990's as a quick-build small explorer carrying five instruments on a NASA-based mission.
- Primary mission was Earth science via a visible-band camera and infrared radiometer. Space weather (magnetometer, electron spectrometer, Faraday cup) was secondary science.
- Observatory was slated for L1 orbit, oriented to permanent Earth and sun views.
- Manifested for a shuttle. Later removed from manifest to accommodate ISS build.
- Placed into storage after completing thermal vacuum test in Fall 2001
- Briefly removed from storage on two occasions. Permanently removed from storage in 2012 to become a NOAA-based mission.
- NOAA and NASA rededicate the spacecraft as DSCOVR. Space weather to be DSCOVRs primary mission.
- Spacecraft dismantled to box level for component testing.
- Repeated environmental tests.
- Launched on a Space X Falcon 9 in February 2015.

Then and Now: Changes Made

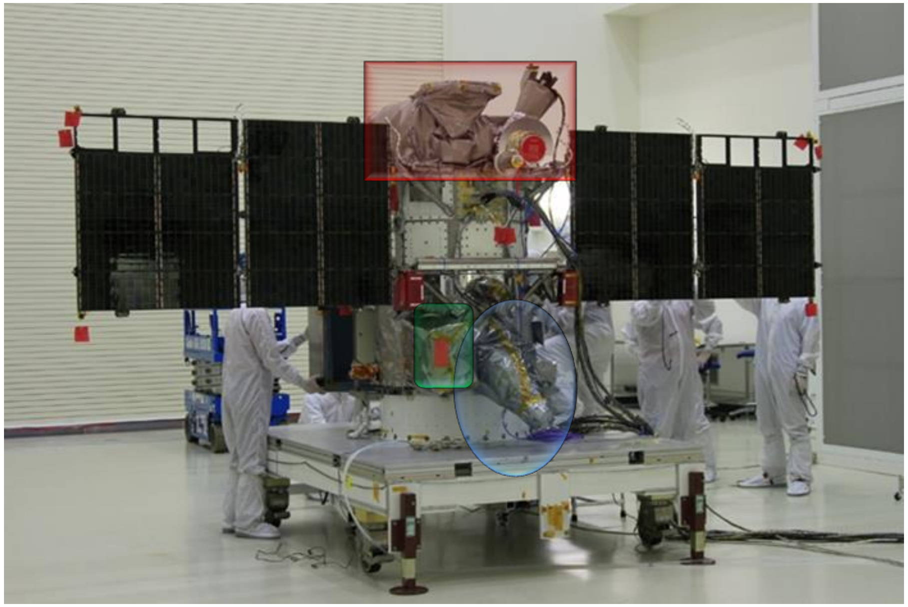
Triana in 2001



Magnetometer placed on angled cone at end of boom

Electron Spectrometer moved from boom to spacecraft bus

Camera and radiometer MLI outer layers changed from ITO-coated Kapton to Germanium-coated Black Kapton (GBK)



DSCOVR in 2015

Storage of Hardware and Information

- Triana was double bagged and placed in a metal container. Container was placed in a cleanroom and purged with nitrogen.
- Some GSE was dispersed to functional groups
- Most GSE was boxed and placed in warehouse storage.
- Documents and drawings that were in configuration management control were maintained well. Background information under personal or vendor control was sometimes lost.

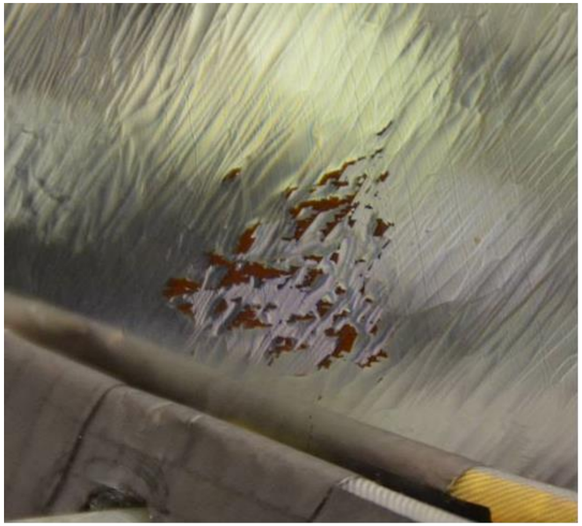
- CC group retained all bakeout data and reports from Triana
- In future, request data stored by vendors as deliverables

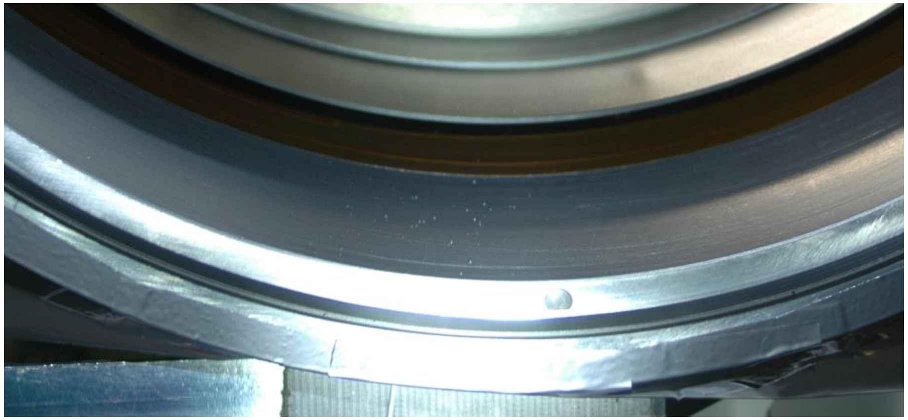
Unpacking

- Needed to evaluate materials list for limited-life items
  - Lubricants were biggest concern
  - All were considered still usable
- Needed to review parts list for items with known problems as reported through industry alerts
  - Some electronics parts had been flagged a few years earlier
  - Flight battery determined to be unusable. Changed to a new Lithium Ion battery, which required some mechanical modifications to the bus
  - Thermal control surfaces looked fairly good upon first look
    - Some dark spots seen on Silver Teflon and GBK surfaces. Measured within thermal specification
    - White paint still within thermal specifications and adhering well
    - Conductivity of surfaces needed to be evaluated
- Boom removed, deployed and inspected
  - Saw some slight splintering on fiberglass struts
  - Mild paint wear was touched up with Z306
  - No major work needed. Were able to re-install and fly
- All mechanisms thoroughly tested

Thermal Control Surfaces

- Most thermal control surfaces degraded quickly with handling
  - NS43C paint powdered throughout I&T; repaired with Z93C55
  - Germanium flaked from some tape surfaces
  - High temperature MLI frayed at edges; backed with SS mesh to strengthen
  - Phosphoric-acid etched nickel inside radiometer began flaking. Stripped and recoated with Z306
  - ITO conductivity questioned, noticeable cracks seen on some surfaces. ITO Kapton outer layer replaced with GBK layer
  - All produced conductive particles, which were a problem for the high-voltage Faraday Cup
- Root cause not clear: time alone, too dry for too long or a combination





Budgets and Modeling

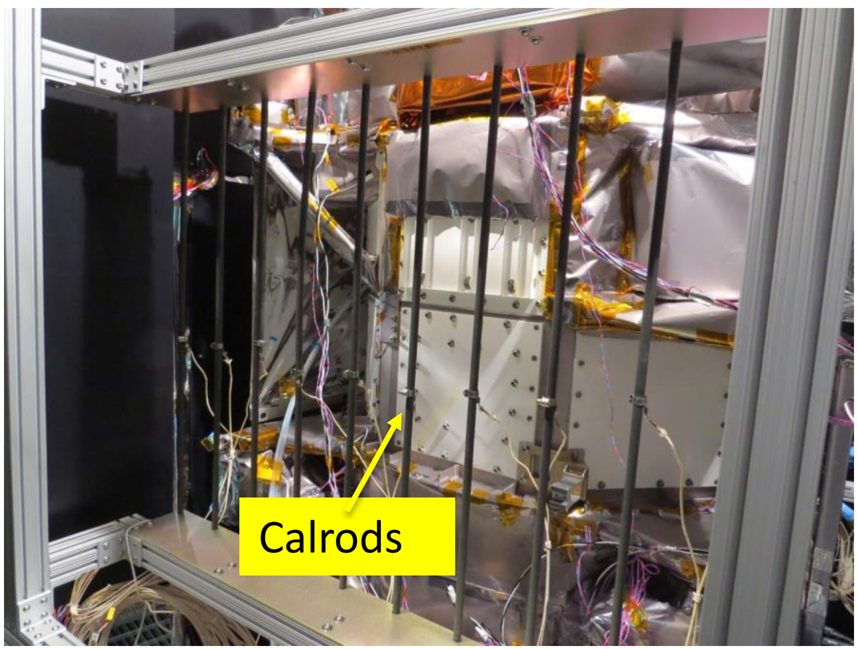
- Needed to take a fresh look at the contamination budget and verification methods.
  - A new approach may have developed in intervening years.
  - For DSCOVR, budget was only slightly modified to reflect better understanding of instrument sensitivities.
  - Needed to upgrade magnetic cleanliness procedures
- Updated all contamination models
  - Knowledge of thruster plume shape and behavior advanced while Triana/DSCOVR sat in storage
    - Thruster plume shape in model changed from cone to tear drop
    - Better and more complete information on exit gas properties
  - Thruster plume model was no longer considered valid and needed to be redone
  - On-orbit molecular transport model still valid. Only needed update to account for move of spectrometer and magnetometer
  - Need to know assumptions and parameters to evaluate the models. Data retention from Triana days was key.

Purge

- GSE-disconnect purges on camera, radiometer, faraday cup, electron spectrometer
- Purge would have been easier to use as a T-0 disconnect
  - Drag-on system designed for shuttle
  - Purge connection points had aged poorly and were difficult to replace
  - Redesign would have been difficult and expensive
  - Electron spectrometer had no instrument purge port and would still need drag-on line
- Purge panels required updates in order to be used for DSCOVR
  - Pressure relief valves now needed
  - Filter models obsolete, new versions were smaller
  - Switched to newer set of purge panels rather than update old panels

Bakeouts and Thermal Vacuum Test

- Diffusion caused outgassing rates to rise to pre-bakeout levels
  - Solar array took 3 days to return to pre-storage outgassing rates
  - Known phenomenon that was seen consistently throughout program
  - Needed to build that time into test estimates
- During storage preparations, some internal thermocouple wires were snipped too short, removing labels and complicating test preparations and data collection.



- Used three-step process to prepare new calrods for first use with DSCOVR
  - Placed in highbay and run hot to burn off worst volatile species
  - Placed in chamber and run hot with hot walls, no QCM
  - Run in chamber with QCM to certify outgassing rate

- Should certify calrods at 100% power to allow for contingency during test.

Environments and Bagging

- Know your environmental limitations and emergency access procedures
  - Lost power in B7/10/15 complex for 2 days after 2012 derecho storm
    - Temperature went to 80°F, humidity to 70%
    - Purge remained operational
    - No evidence of condensation seen
    - Limited emergency access stickers to project personnel at the time
- By end of program bagging had become a long process
  - Needed to cutout, then individually bag star tracker, solar array harnesses, mag boom to distribute weight evenly
  - Needed to triple bag for move to/from mag test site and for moves around ASO since observatory was being moved via forklift
  - Needed a cart with nitrogen bottle and purge panel to keep purge active during forklift moves
  - Extra bagging required close eye on internal bag temperature and dew points
  - Placed temperature and RH monitors in bags to track changes

First NASA Mission on Falcon 9

- DSCOVR launched on a Space X Falcon 9
- Instituted magnetic, particulate and molecular cleanliness requirements.
- Fairing was cleaned to an acceptable level
- "Diving boards" used to access observatory for closeouts
- Purge gas certified to Grade B. Purge operated well throughout Falcon 9 operations. Disconnected ~16hours prior to launch during final closeouts.
- Magnetic controls successful: flight magnetometer sees very little background noise.
- Contamination controls successful: camera and radiometer are operating well.