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 ~16 hours 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.