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Soil Moisture Active and Passive (SMAP) White Painted Expanded Polystyrene (EPS) Radome Survivability Test

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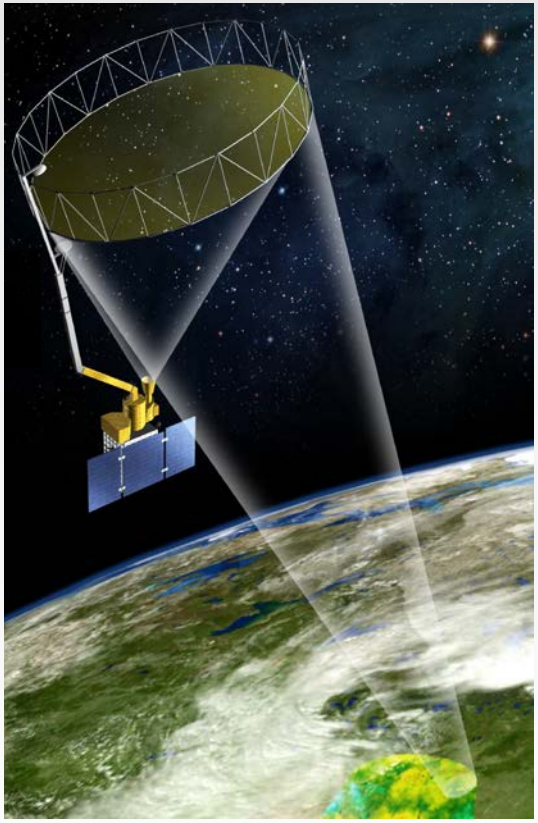
SMAP Mission Objectives



http://smap.jpl.nasa.gov/

- Direct observations of soil moisture and freeze/thaw states from space
- Improved estimates of water, energy and carbon transfers between land and atmosphere
- Enhanced weather and climate forecasts, improved flood prediction and drought monitoring

SMAP and Aquarius/SAC-D

Both fly a GSFC radiometer and JPL radar but:

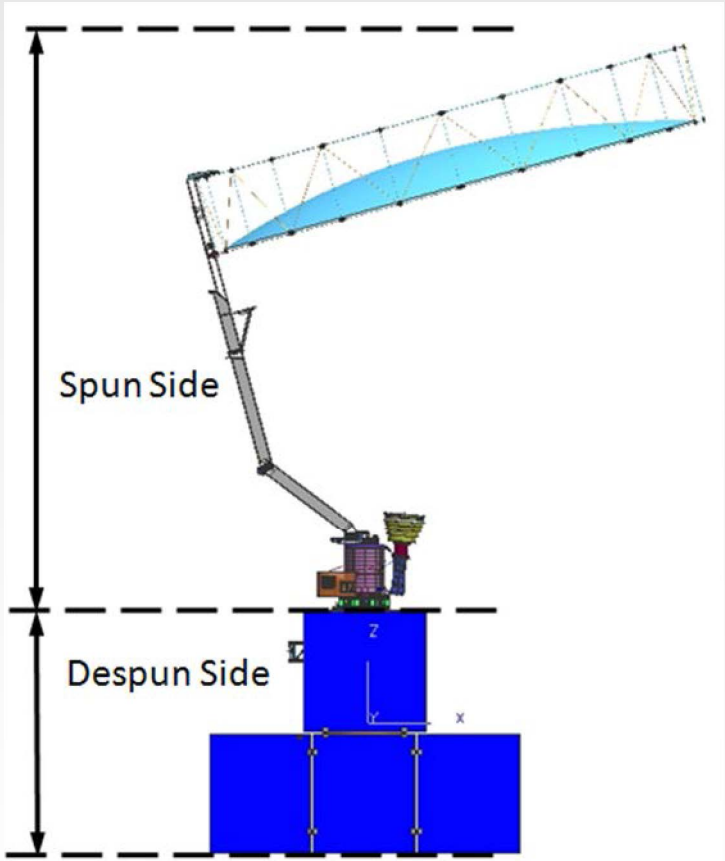
SMAP

- Measures soil moisture and freeze/thaw states
- Single feed horn exposed to the sun: radome required
- Spinning platform
- 6m deployable spinning antenna
- 0.7°C/orbit thermal stability requirement

Aquarius/SAC-D

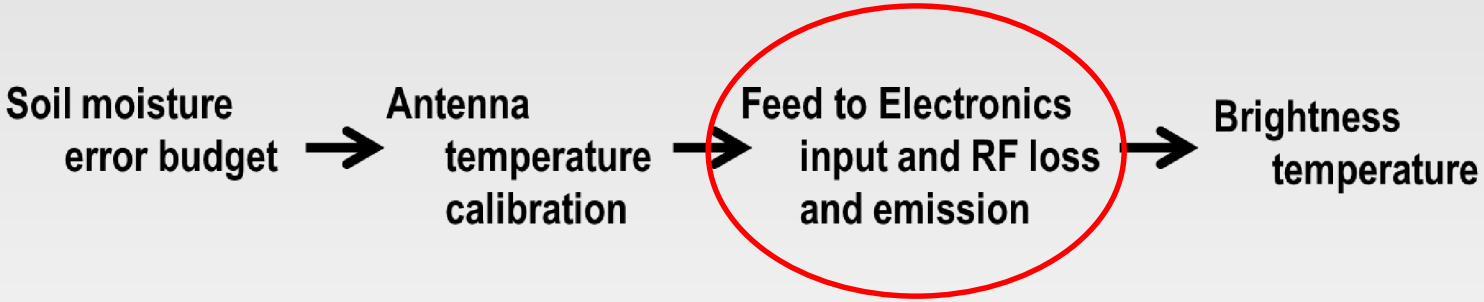
- Measures sea surface salinity
- 3 feed horns permanently shadowed: no radome
- Non-pinning platform
- 2.5m fixed antenna
- 0.1°C/week thermal stability requirement

SMAP Instrument Configuration

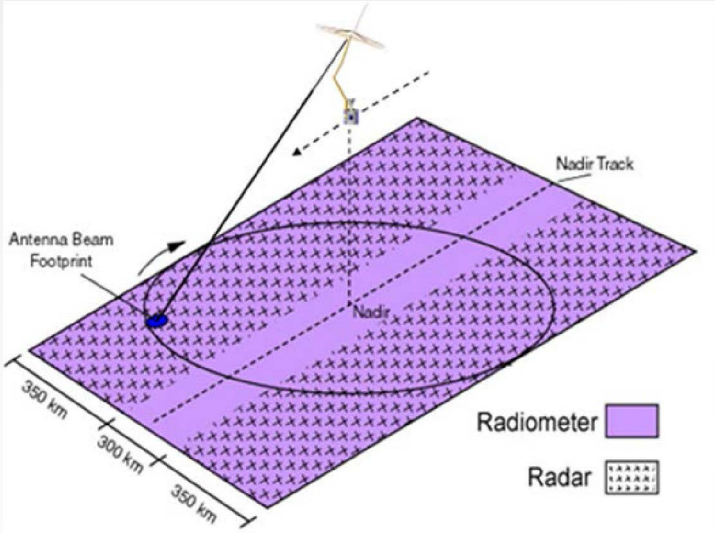


- The L-band radar components are on the despun side of SMAP
- The L-band radiometer resides on the spun side of the observatory
  - Cylindrical core structure (CS) houses Spin Mechanism Assembly (SMA)
  - 4 major assemblies mounted on CS
    - Reflector Boom Assembly (RBA)
    - Integrated Feed Assembly (IFA)
    - Radiometer Back End Assembly (RBEA)
    - Instrument Control Electronics (ICE)

Derivation of Thermal Stability Requirements

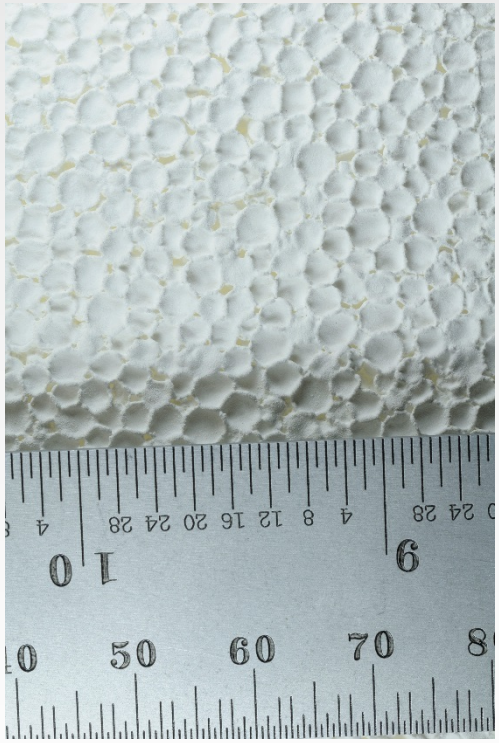


- An acceptable error was allocated to four time periods
  - Instantaneous per minute rate
  - Change per orbit, month and mission life
- Temperature knowledge of radome and feedhorn are allocated items in the radiometric error budget
  - Temperature knowledge within 60°C required for radome
  - Feedhorn orbital stability < 8°C/orbit



SMAP Radome Background

- Radome (50cm diameter, 10cm thick) at the mouth of feedhorn to prevent solar entrapment
- EPS (Expanded Polystyrene) was used because light weight and transparent to RF signal (or low RF absorptivity)
- White paint (S13GP:6N/LO-1) was baselined due to the fast degradation of bare EPS solar absorptance
- Large surface irregularities (wells, pinholes) were produced during paint application due to the rough surface of bare EPS caused by mechanical cutting (instead of laser cutting)
- These surface irregularities may results in localized hot spots which could exceed the EPS glass transition temperature (starts at 96°C) under the worst-case scenario of a no-spin fault condition at the end of mission



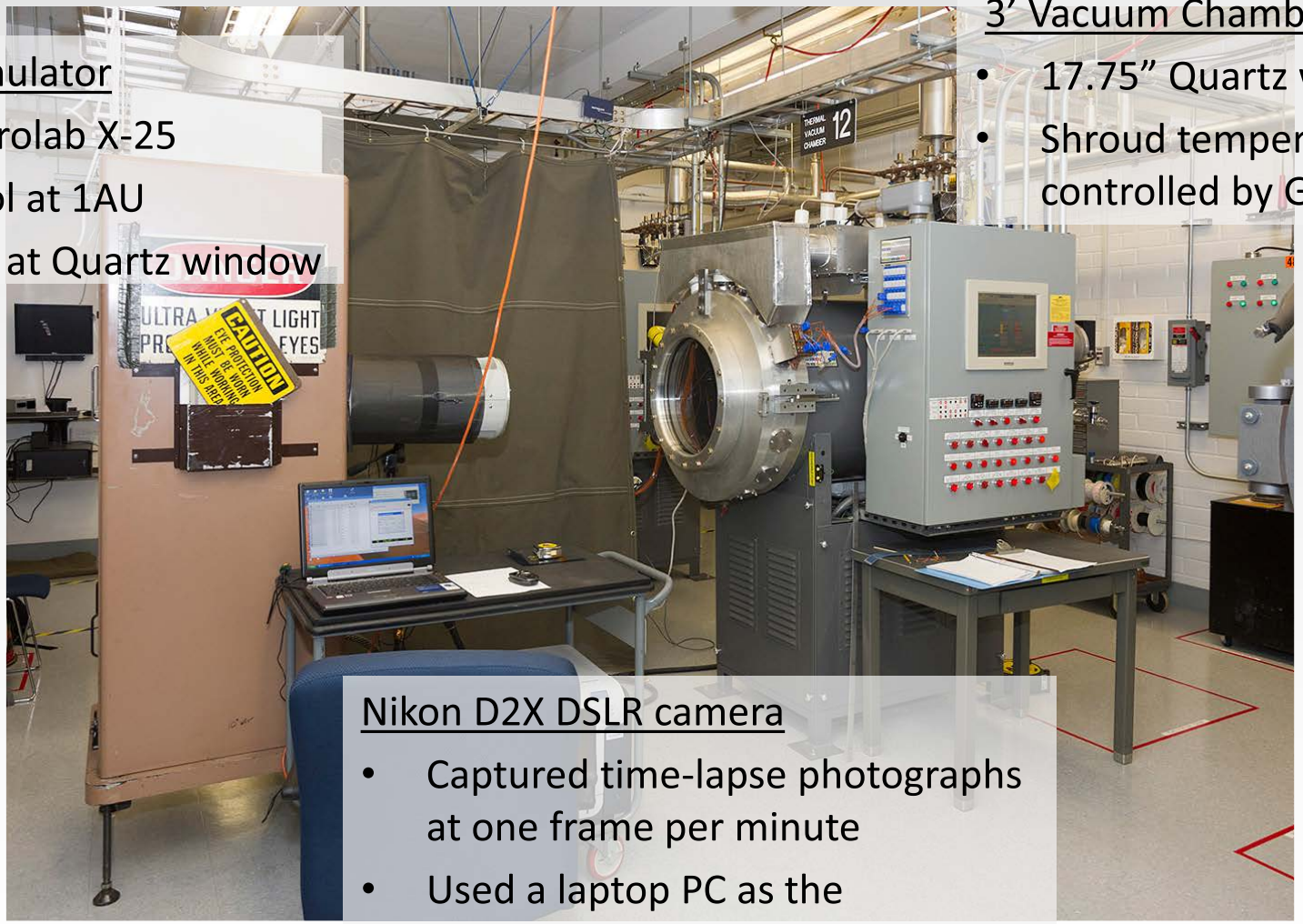
Test Objectives

- Subject the test article while in vacuum to a pre-determined solar flux value that produces the expected radome surface temperature
  - End-of-mission, no-spin fault condition
- Verify the radome survivability and assess the solar-trapping effects on the radome surface
  - Optical properties Pass/Fail criteria shall be within 20% of baseline measurements:
    - 10% assumed for measurement error plus 10% for the actual property change
  - Dimensional Pass/Fail criteria that dimensions post-test shall be within 0.125” of the baseline measurements
  - Color
    - Previous EPS testing indicated a yellow or brown discoloration due to extended exposure

Test Article

- Two coupons from the flight radome paint process
  - White paint was applied at the same time as the flight radome unit
  - The coupons had not been subjected to any additional thermal tests
- Each coupon was 3.25”L x 3.25”W x 1”D

Test Facility



Solar Simulator

- Spectrolab X-25
- 2.5 Sol at 1AU
- 9”x9” at Quartz window

3’ Vacuum Chamber

- 17.75” Quartz window
- Shroud temperature controlled by GN_2

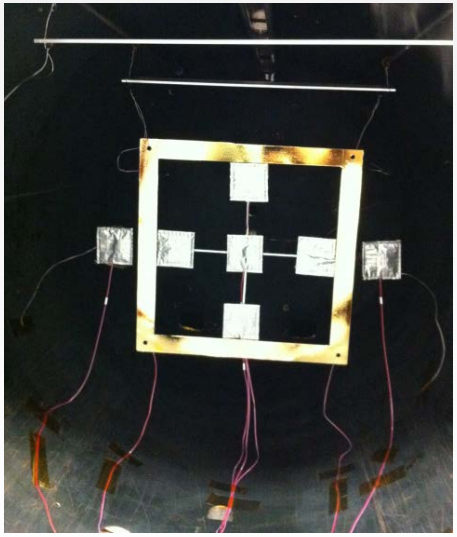
Nikon D2X DSLR camera

- Captured time-lapse photographs at one frame per minute
- Used a laptop PC as the intervalometer

Solar Beam Survey

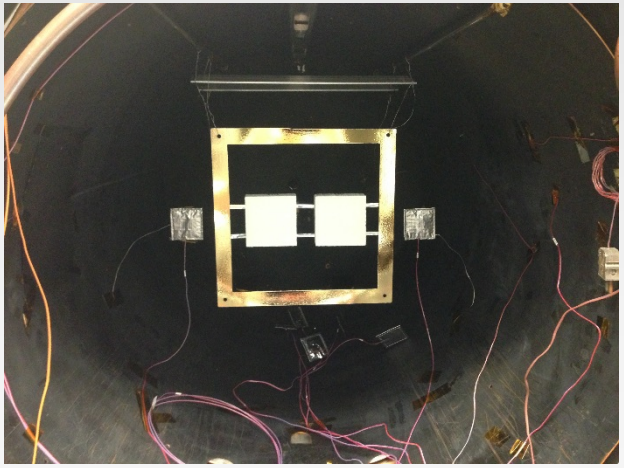
- Calorimeter
  - Front Face: Germanium Kapton
  - Thermocouple attached at the back of the front sheet
  - MLI on the back

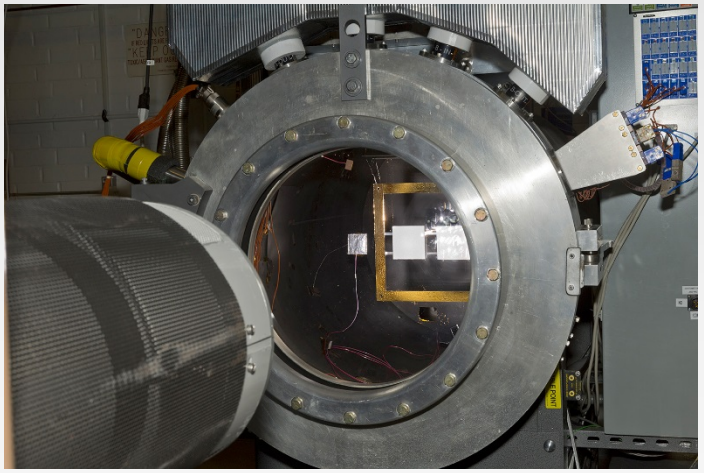
Calorimeter (Germanium Kapton)



- Locations of the calorimeter
  - 5 inside of test frame
  - 2 outside of test frame: used for monitoring the beam intensity throughout the test
- Beam survey at 22” from the Quartz window

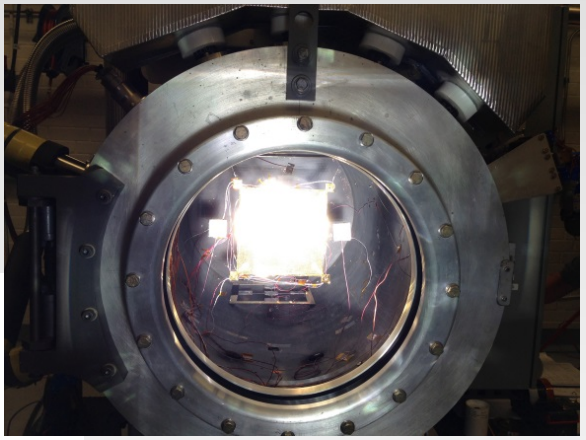
Test Setup

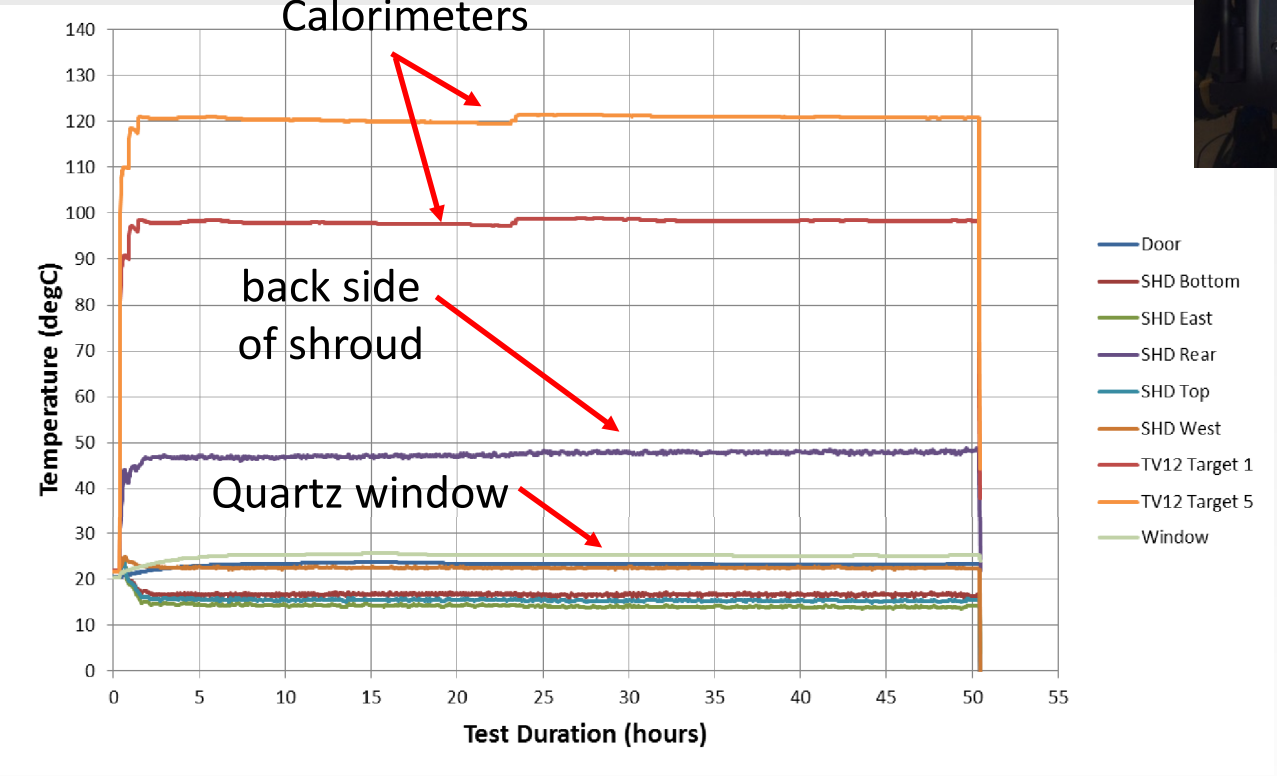




- Test articles mounted within a frame hung by stainless wires at 22” from the Quartz window
  - Two reference calorimeters used to monitor beam intensity
- Averaged beam intensity of 1725W/m^2 at 22” from the Quartz window used to simulate degraded optical properties at the end of 3 year mission
- Test duration was 50 hours based on JPL material experts recommendation

Test Conditions

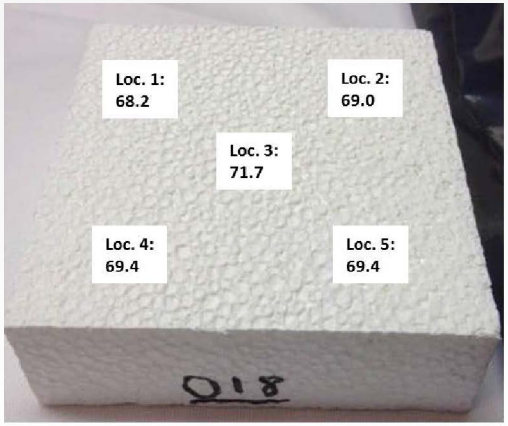


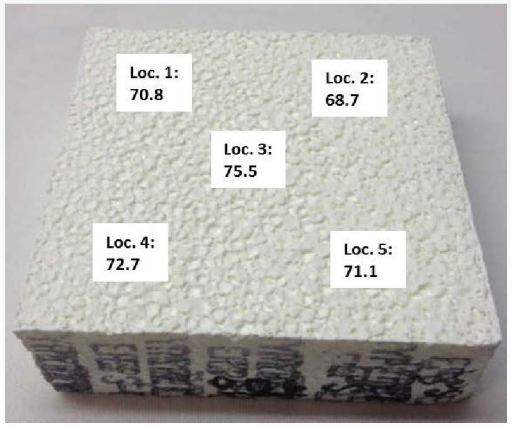


- Solar illumination applied
  - 1420W/m^2 for 30 min
  - 1585W/m^2 for 30 min
  - 1725W/m^2 for 50 hr
- Back side of shroud was warm due to beam illumination even though it was flooded with GN_2

Test Results: Optical Property Measurements

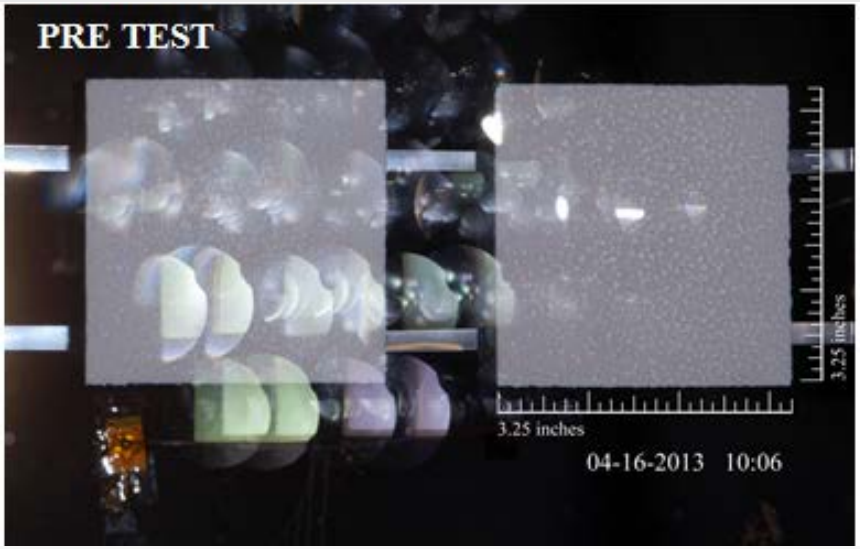
		Solar Absorptivity											IR Emissivity		
Sample	Location	pre	Avg	$(X_i - X_{avg})^2$	s	Median	post	Avg	$(X_i - X_{avg})^2$	s	Median	change, %	pre	post	change, %
006	1	0.208	0.218	0.0001082	0.010	0.220	0.197	0.214	0.000276	0.008	0.217	-5.3	0.902	0.908	0.67
	2	0.208		0.0001082			0.216		5.76E-06			3.8	0.905	0.899	-0.66
	3	0.233		0.0002132			0.22		4.1E-05			-5.6	0.904	0.912	0.89
	4	0.22		2.56E-06			0.218		1.94E-05			-0.9	0.907	0.91	0.33
	5	0.223		2.116E-05			0.217		1.16E-05			-2.7	0.909	0.904	-0.55
018	1	0.197	0.204	4.624E-05	0.008	0.201	0.196	0.200	0.000016	0.012	0.196	-0.5	0.899	0.901	0.22
	2	0.196		6.084E-05			0.222		0.000484			13.3	0.901	0.903	0.22
	3	0.207		1.024E-05			0.2		0			-3.4	0.895	0.906	1.23
	4	0.218		0.0002016			0.194		3.6E-05			-11.0	0.896	0.9	0.45
	5	0.201		7.84E-06			0.188		0.000144			-6.5	0.902	0.906	0.44

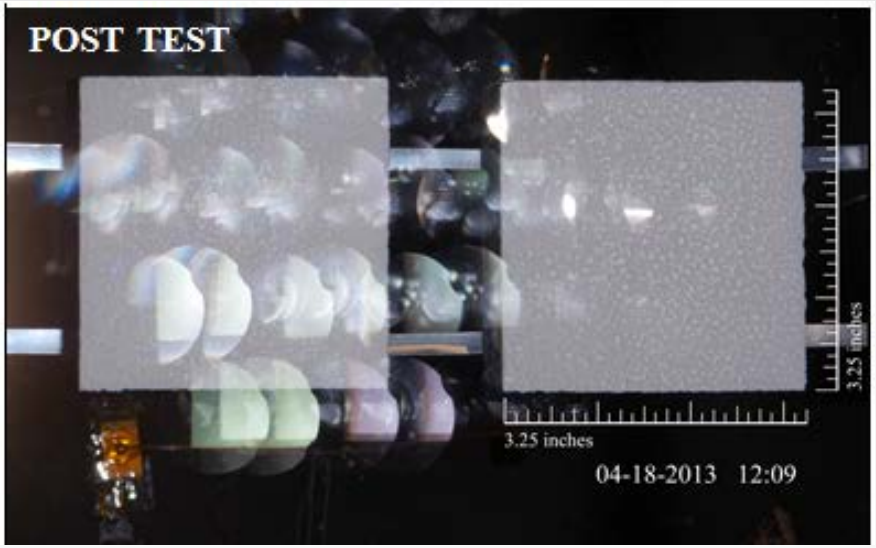




- No optical property change
  - Minor changes may be attributed to measurement source error as well as the inability to repeat the exact measurement location with the source sensor (and size differences in the pinhole/well/cavity seen by the sensor at those two slightly different locations)

Test Results: Dimensional Measurements and Color





- No visible dimensional change
  - Pass/fail criteria: one EPS grain size of 0.125”
- No visible color change
  - No yellow or brown discoloration due to extended exposure

Summary

- The two EPS coupons survived the test based on the established pass criteria for three separate metrics: dimensional, optical property, and color
  - There were no visual changes in the dimensional or structural integrity of the two coupons
  - No EPS color or dimensional changes were visible in the 100 second movie created from photos taken at 1 frame/minute throughout the entire test
- A 2% net decrease in the average solar absorptance of each coupon based on five measurements per coupon
  - The suspected cause for this is the location variation of the measurement source sensor in the pre- and post-test measurements
- If any hot spots exist locally, they did not cause any observable permanent deformation when comparing scaled coupon photographs before and after the test
- The test results bolster confidence that there is a high probability the radome will survive under the worst-case scenario of a no-spin fault condition at the end of mission

Current Mission Status

- Launched on Jan 31, 2015
- Spin-up to 14.6 RPM on March 26, 2015
- Completed Commissioning Phase successfully
  - PLAR (Post Launch Assessment Review) on May 6
- 3 safing events but kept spinning
- Good science data and stable temperatures

Radome (and the rest of the observatory) healthy!