National Aeronautics and Space Administration

# ENVIRONMENAL TESTING
## of the
## SMAP SPACECRAFT
## (Soil, Moisture, Active, Passive)

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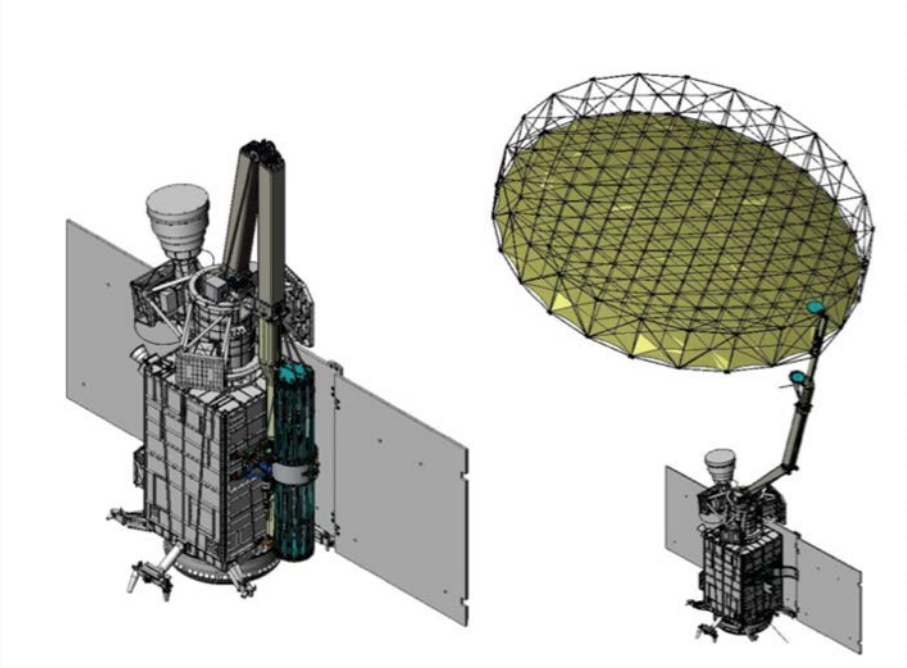
# SMAP Spacecraft



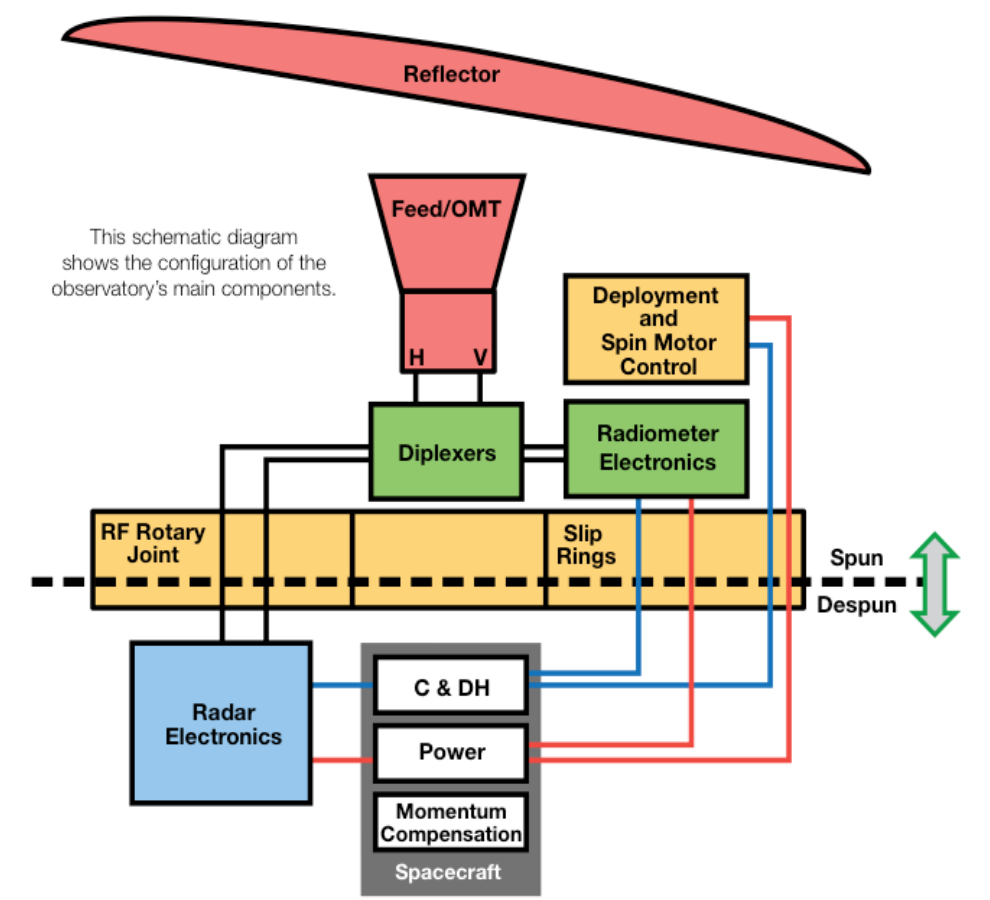
SMAP Video

# SCIENCE OBJECTIVES

SMAP science objectives are to:

- Understand processes that link the terrestrial water, energy and carbon cycles.
- Estimate global water and energy fluxes at the land surface.
- Quantify net carbon flux in boreal landscapes (northern subarctic).
- Enhance weather and climate forecast skills.
- Develop improved flood prediction and drought monitoring capabilities.

# SMAP SCIENCE INSTRUMENTS



# SMAP SCIENCE INSTRUMENTS

**Radar**
The radar makes “active” backscatter measurements of the surface, and the ground processing system performs the
synthetic aperture radar processing to achieve a spatial resolution of 3 km across about 70% of the swath in its high-resolution mode.

Frequency: 1.26 GHz
Relative accuracy (3 km grid): 1 dB (HH and VV), 1.5 dB (HV)
Data acquisition:
- High-resolution (SAR) data acquired over land
- Low-resolution data acquired globally

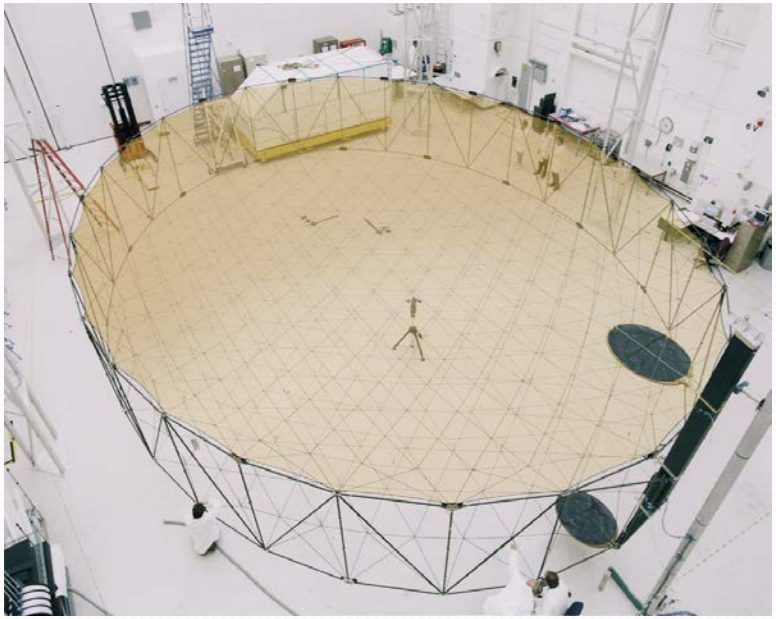
**Radiometer**
The radiometer provides “passive” measurements of the microwave emission from the upper soil with a spatial resolution of about 40 km, and is more sensitive to near-surface soil moisture and less sensitive to the effects of surface roughness and vegetation than the radar.

Frequency: 1.41 GHz
Relative accuracy (30 km grid): 1.3 K
Data collection:
- High-rate (sub-band) data acquired over land
- Low-rate data acquired globally

# SMAP SCIENCE INSTRUMENTS (2)

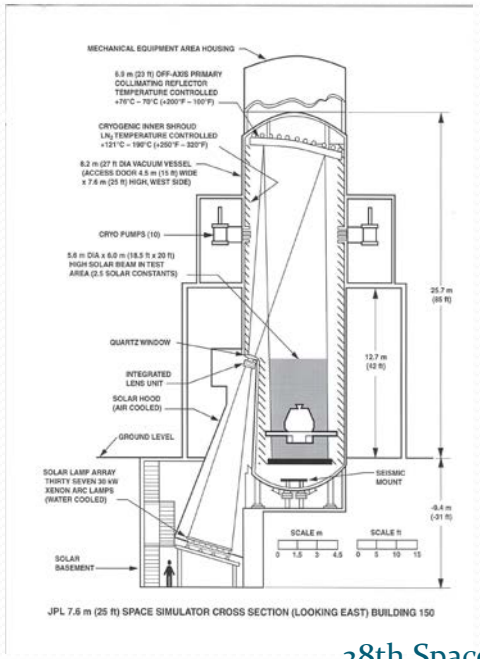
**Antenna**

Conically-scanning deployable mesh reflector shared by radar and radiometer
Diameter: 6 meters
Rotation rate: 14.6 RPM
Beam efficiency: ~90%
Spatial Resolution:
    Radiometer (IFOV): 39 km x 47 km
    SAR: 1-3 km (over outer 70% of swath)
Swath width: 1000 km



# CHAMBER INFORMATION

- Chamber Size: 27 ft. dia. x 85 ft. high
- Access Door: 15 ft. wide x 25 ft. high
- Minimum Operating Pressure: 1 x 10 -6 Torr (90 min)
- Off Axis Solar: (37) 25 Kilowatt Xenon Lamps
- Test Volume 20 ft. Di.a x 25 ft. high
- Maximum Solar Beam Diameter: 18.5 ft. Dia.



JPL 7.6 m (25 ft) SPACE SIMULATOR CROSS SECTION (LOOKING EAST) BUILDING 150

# SMAP THERMAL VACUUM TESTS
## Performed in the Space Simulator

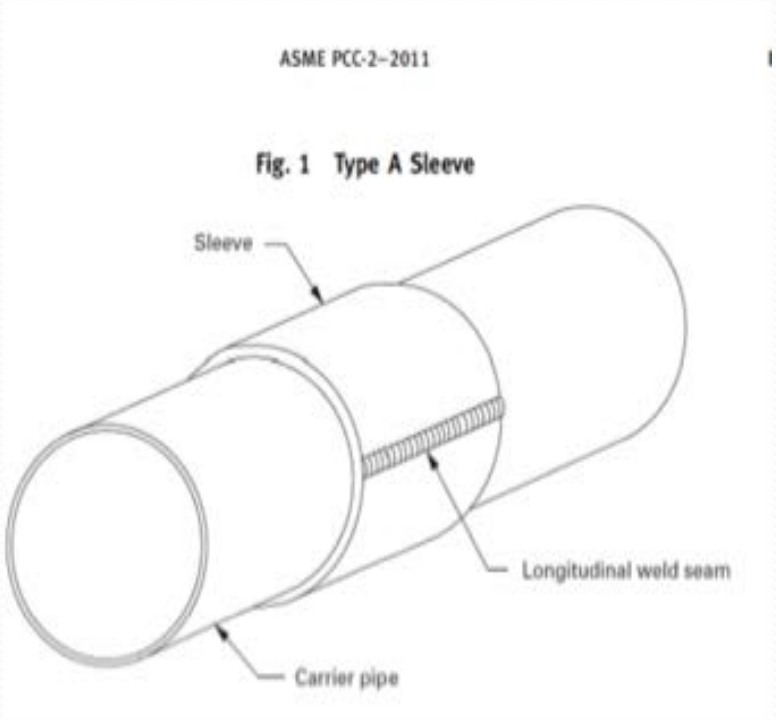
1. Floor Shroud Bi-metal Joint cryo-shock Run
2. Chamber Empty - Pre-Test Bake Out -
3. Sidewall Simulator - Verify control/uniformity of six heat exchangers, without RBA.
4. RBA (Reflector Boom Assembly) – Stowed configuration mounted the sidewall simulator
5. RBA (Reflector Boom Assembly) – Deployed configuration mounted on the sidewall simulator.
6. IR Lamp Array – Verify uniformity, with a calorimeter array.
7. SMAP Observatory - Full up spacecraft, first phase.
8. SMAP Observatory - Full up spacecraft, second phase without RBA.

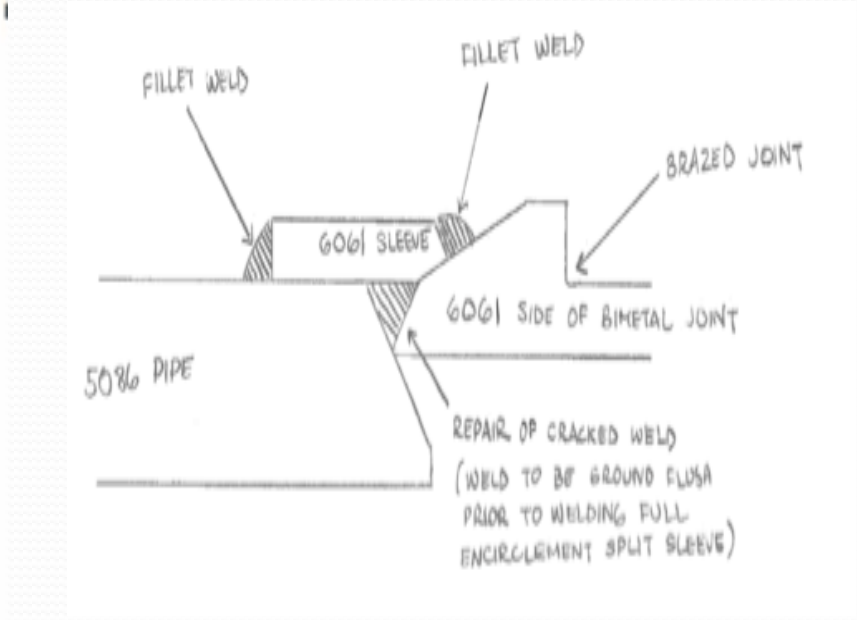
# Bi-metal Joint cryo-shock Run

Just before the most intricate and involved test that ETL was going to test in the 25 ft. chamber this year, it just so happens that during one of our facility checkout runs we get a leak in one of the six inch floor shroud bi-metal joints. We have replaced numerous bi-metal joints before but this time there were a few issues that complicated the repair.

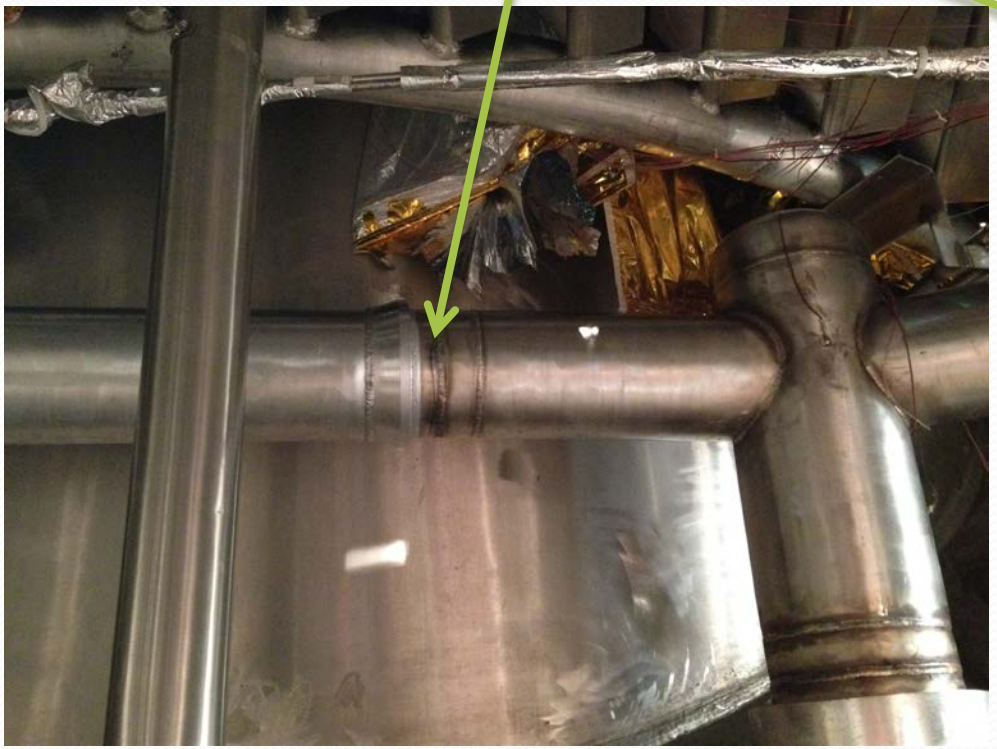
- The start of the SMAP TVAC test was scheduled to start in a week.
- The bi-metal joint was close to the sidewall of the chamber inhibiting access for the repair.
- Dis-similar series of aluminum alloy, 5086 and 6061 needed to be welded.
- The JPL safety office got involved and assigned the pressure systems group to lead the inspection effort of welding the bi-metal joint.

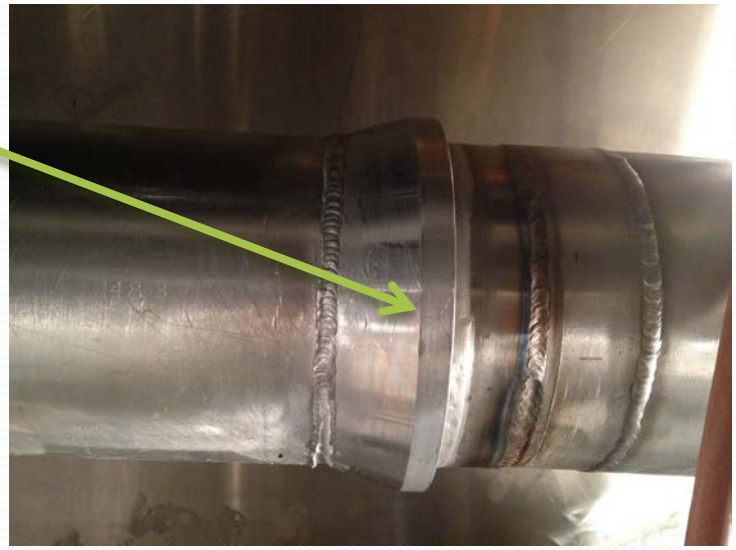
We replaced the bad joint and helium leak checked and found a leak in the weld. We tried to re-weld the seam but it still leaked. Since we only had one spare joint of the required size, we decided to patch the hole in the pipe with a sleeve as described in the sketches below.

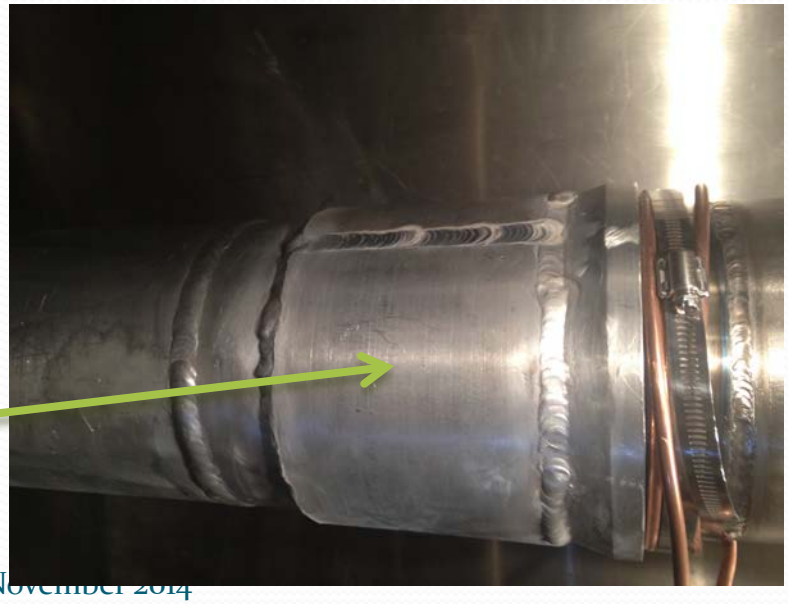


**Six Inch Bi-Metal Joint**







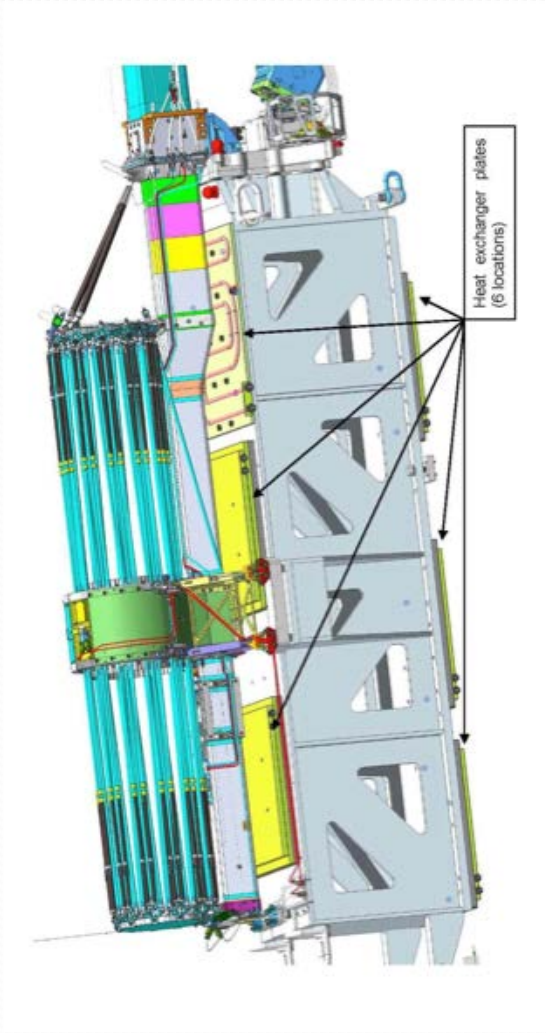
**Repaired with “Sleeve” Welded on**

## Sidewall Simulator Test

- Multiple Zones (6)
- Interaction between zones
- Large Thermal Mass 800 lbs. (362.8 kg)
- Slow Response Time (Hours)
- Temp Requirement +/- 2 ° C

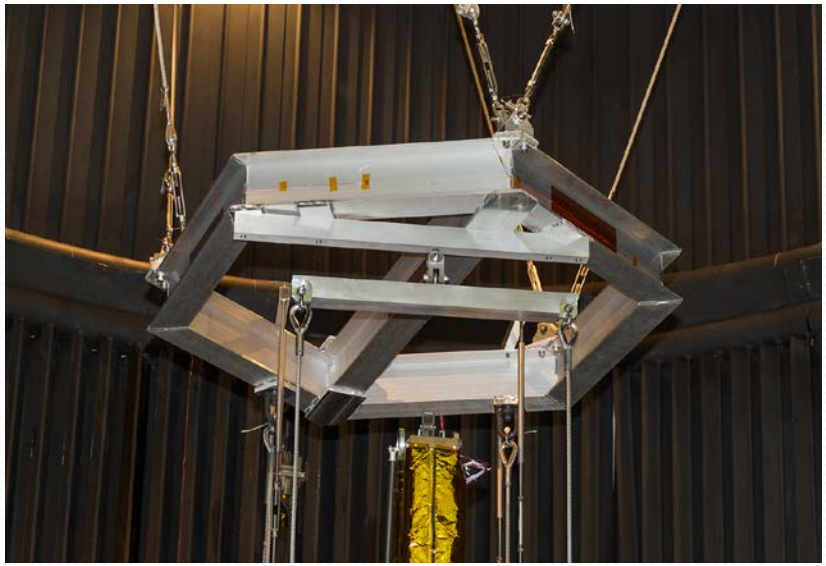
# **RBA** (Reflector Boom Assembly) Stowed and Deployed configuration

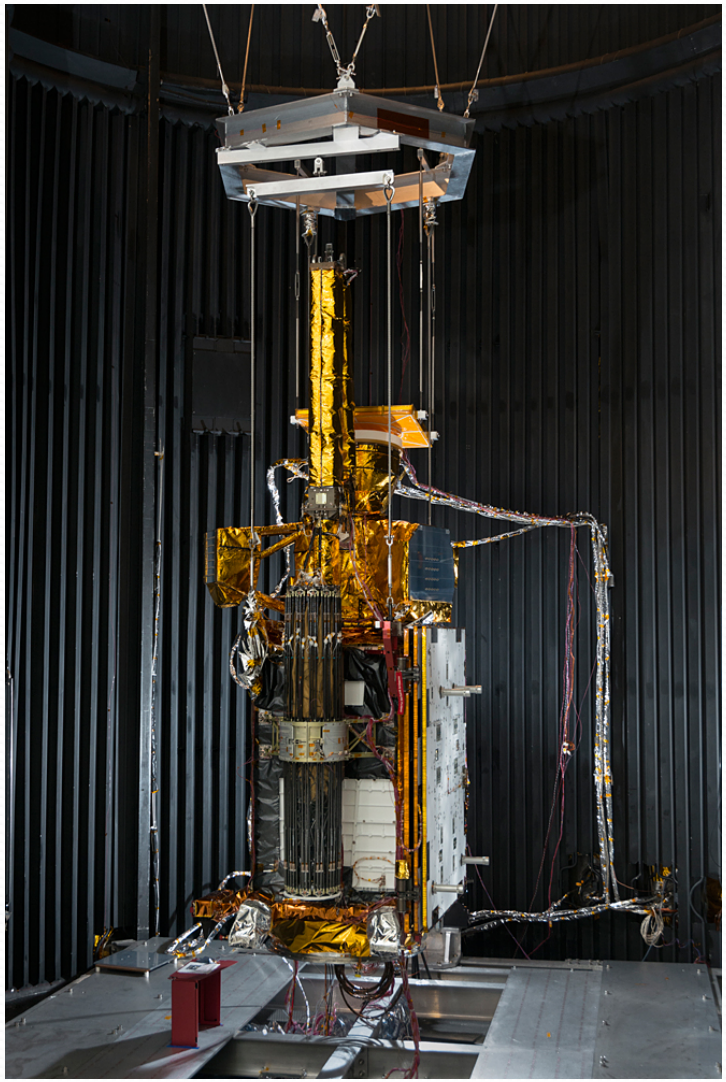
- Tested in a “stowed” configuration.
- Testing includes one cycle each at the non-operating cold and non-operating hot temperature extremes.
- Following this non-operating cycle are three cycles each at the operating cold and operating hot temperature extremes.
- A cradle release (pyro firing) and partial deployment (first motion) (another pyro firing) of the RBA was performed at the final (third) cold operational temperature extreme.


Heat exchanger plates
(6 locations)

# SPACECRAFT INSTALLATION

The spacecraft was installed in the chamber by mounting the spacecraft on a dolly, rolling the dolly up ramps to a false floor in the chamber, and then it was lifted with a monorail crane and attached to six cables. These cables were connected to three chamber hard points located at the 50 ft. level. The false floor was then removed from the chamber before the test was started.



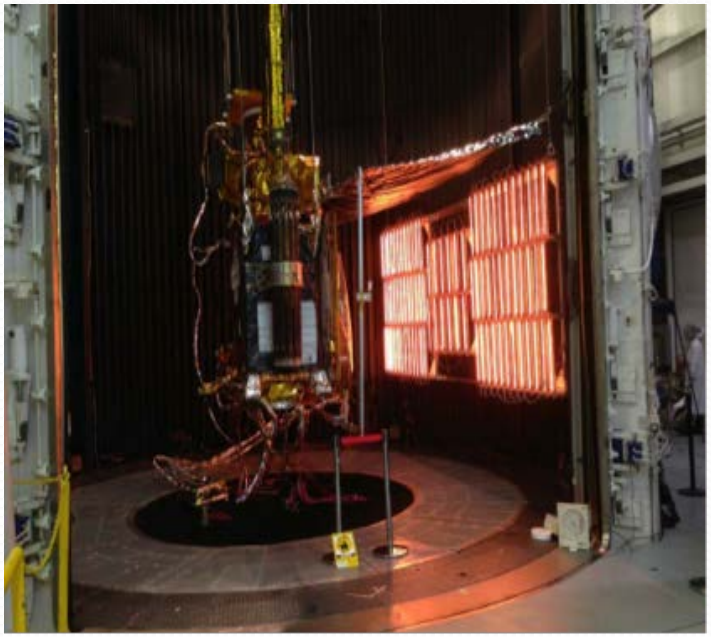


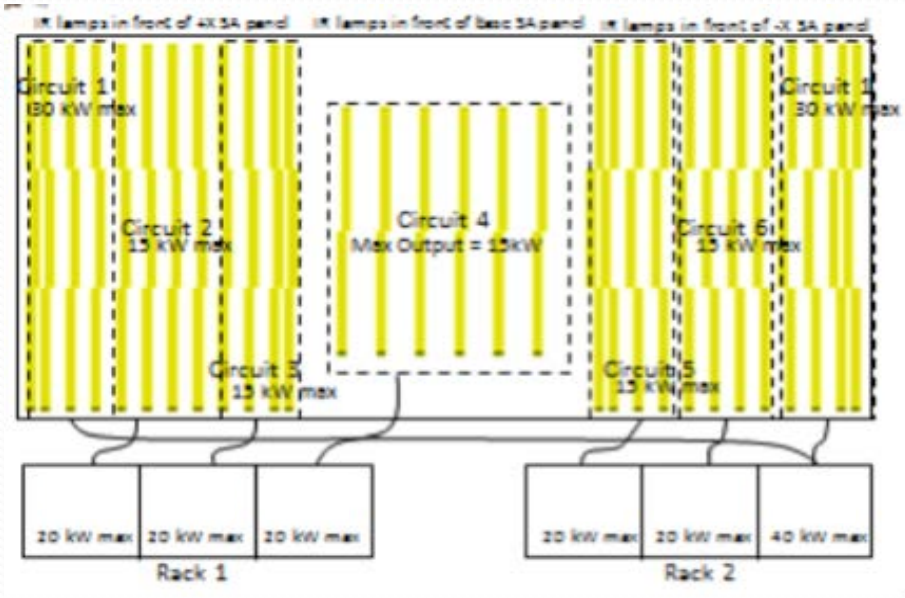
# IR LAMP ARRAY – Dry Run/ In Air

Verify flux uniformity

The characterization test is intended as a dry-run test of the lamp array to identify (and fix) any potential operational and flux uniformity issues long before its use at the observatory-level thermal balance test.

The characterization effort, including acquiring operational experience of the new SMAP lamp array, reduces thermal risk and increases the likelihood of successful usage when combined with flight hardware.



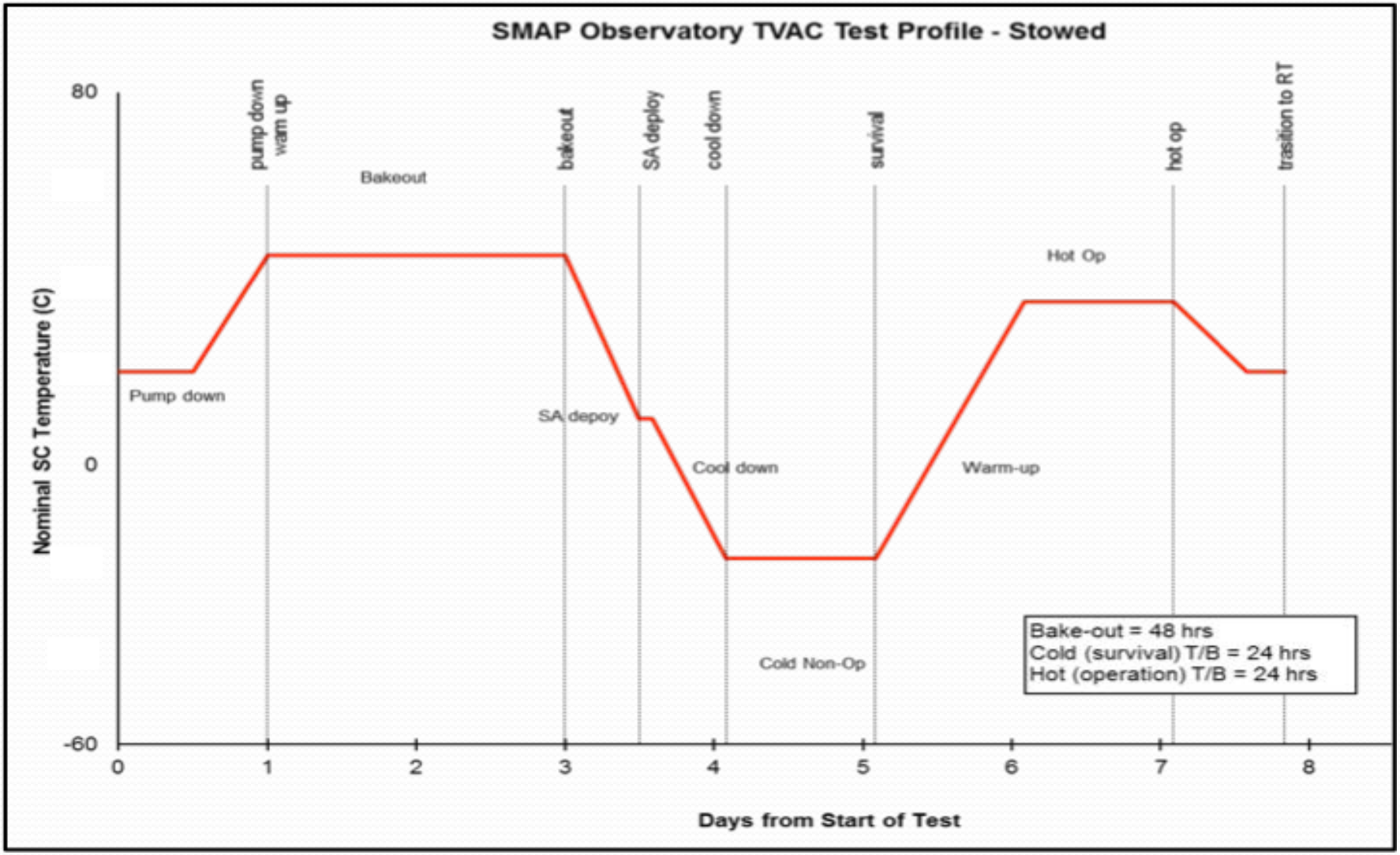


## **SMAP OBSERVATORY -** Complete spacecraft, first phase

The primary test objective of this procedure is to support the SMAP Thermal Balance Test. This includes the necessary flight system electrical and software configuration for each phase of the test.

Other objectives include the following:

- Perform a pyro release solar array deployment (during stowed configuration test).
- Perform Baseline SOH (state of health) and verify all observatory Interfaces function at various temperatures.
- Gather data for the flight computer to correlate internal clock data with temperature.
- The spacecraft was set to test mode for the duration of the test. A baseline functional test will be performed prior to the start of this test and following the completion of the stowed TVAC test.


SMAP Observatory TVAC Test Profile - Stowed
Nominal SC Temperature (C)
80
0
-60
pump down
warm up
Bakeout
bakeout
SA deploy
cool down
survival
hot op
trasition to RT
Pump down
SA depoy
Cool down
Cold Non-Op
Warm-up
Hot Op
Bake-out = 48 hrs
Cold (survival) T/B = 24 hrs
Hot (operation) T/B = 24 hrs
0
1
2
3
4
5
6
7
8
Days from Start of Test

# SMAP Observatory - Stowed Config TVAC Test

| Test Case | Description | Test Objective | SC Temp (°C) | Chamber Pressure (Torr) | Shrouds (°C) | IR Lamp ($W/m^2$) | Estimated Duration (Hours) | Elapsed Time (Days) |
|---|---|---|---|---|---|---|---|---|
| 1 | Pump-down | High vacuum | 20 | Atm to 300 then to $10^{-5}$ | 20 | 0 | 24 | 1.0 |
| 2 | Bakeout | Contamination control | 45 | $< 10^{-5}$ | 40 | 0 | 48 | 3.0 |
| Cold Cases | | | | | | | | |
| 3 | Cool Down | Cool SA hinge to -50°C | 0 | $< 10^{-5}$ | -60 | 0 | 24 | 4.0 |
| 4 | Solar array deploy | Deploy at cold | 0 | $< 10^{-5}$ | -60 | 0 | 2 | 4.1 |
| 5 | Survival (cold non-op) | Design validation<br>Heater validation<br>RBA thermal balance | -20 | $< 10^{-5}$ | -60 | 750 | 24 | 5.1 |
| 6 | Transition to hot (cold to hot) | Hardware time constant<br>Model correlation | -20 / 40 | $< 10^{-5}$ | -30 | 1100 | 24 | 6.1 |
| Hot Cases | | | | | | | | |
| 7 | Hot Op | Science characterization<br>Hardware verification<br>Design validation<br>RBA thermal balance | 40 | $< 10^{-5}$ | -30 | 1100 | 24 | 7.1 |
| 8 | Transition to RT (hot to ambient) | Hardware time constant<br>Model correlation | 40 / 20 | $< 10^{-5}$ | 30 | 0 | 18 | 7.8 |
| Chamber Break | | | | | | | | |
| | | | | | | Total Time (hours) = | 188 | |
| | | | | | | **Total Time (days) =** | **7.8** | |

# TEST LIKE YOU FLY

One of the most important lessons in the space launch business is that hardware and software must be tested in the same manner that they will be flown. Exceptions to the test-like-you-fly approach have resulted in mission failures and represent an increased program risk that must be addressed.

For example: The Mars Polar Lander one of the three testing deficiencies included; “The thermal design of the propulsion subsystem was incorrectly characterized in system thermal-vacuum test due to an error in the thermal model, causing major errors in the propulsion thermal design that went undetected until after launch”.

There are numerous software and hardware tests that are performed on a spacecraft; most are done at a sub-assembly level. But the key to a successful mission is an “End to End” test, which will identify anomalies not discernable in any other test before launch. End to end testing provides a uniquely effective opportunity for flight ops team familiarization, training and process validation.

# SUMMARY AND CONCLUSION

- The SMAP spacecraft thermal vacuum testing consisted of eight separate tests from the checkout runs to repair verification runs to two functional tests of the complete SMAP spacecraft
- The 25 ft. chamber space simulator ran flawlessly with only a few minor issues
- The project test requirements were met and or exceeded. The project was satisfied with the results and how the chamber performed
- In conclusion, the only recommendation was that the chamber/building is old (completed in 1961) and has been updated in the past but now needs additional upgrades to several of its operating systems to meet future testing needs