Jason-3 Advanced Microwave Radiometer Thermal Balance Test

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Agenda

- Jason-3 Mission
- Advanced Microwave Radiometer History
- Test Design
- Test Results
- Impact on Flight Performance
- Lessons Learned

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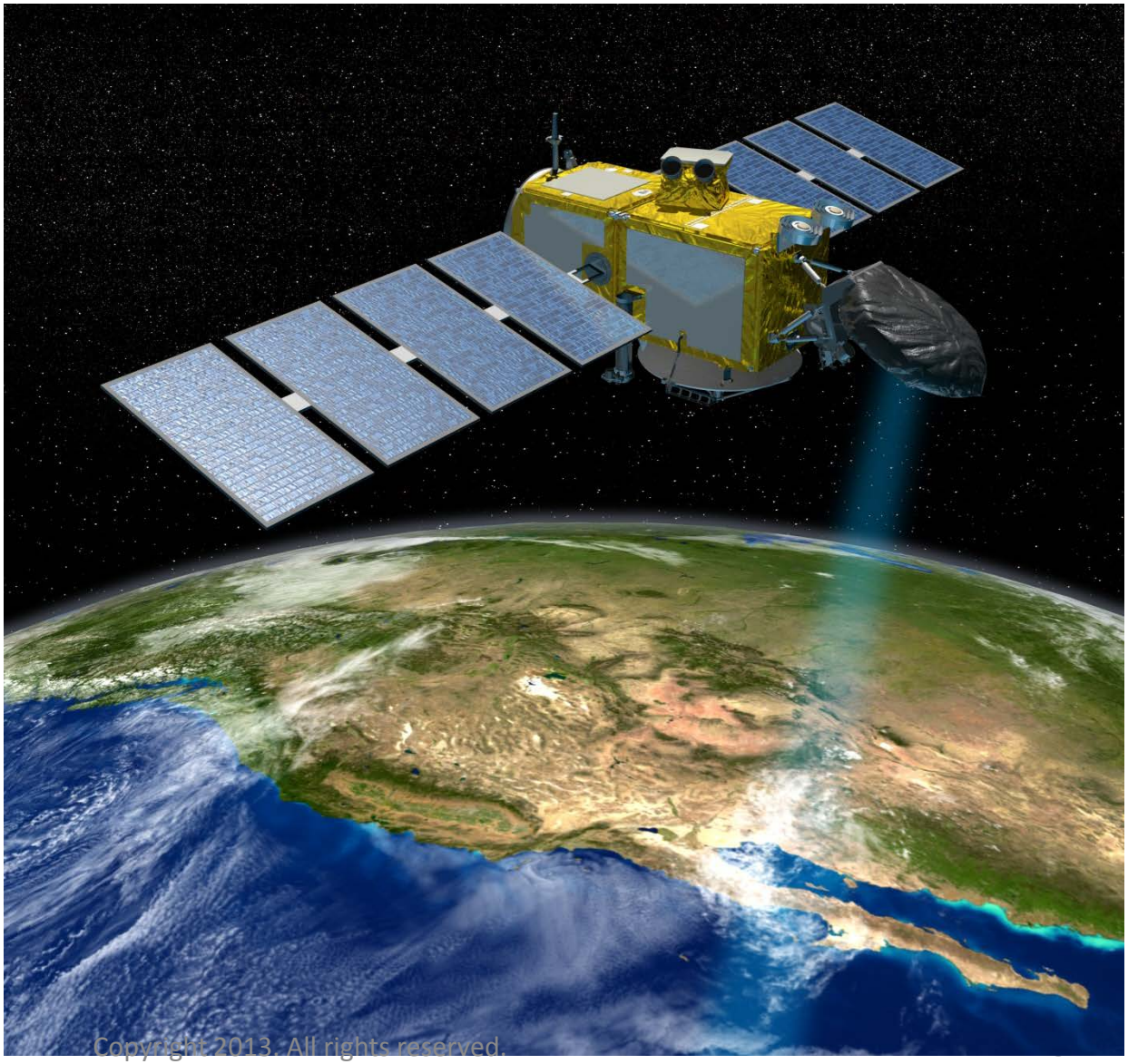
AMR and the Jason-3 Mission

- The Advanced Microwave Radiometer (AMR) flies on the Jason-3 satellite.
- AMR helps measure sea surface height for use in weather and climate studies.
- 66° inclination
- 1300 km (800 mi) altitude
- 1.9 hr orbital period



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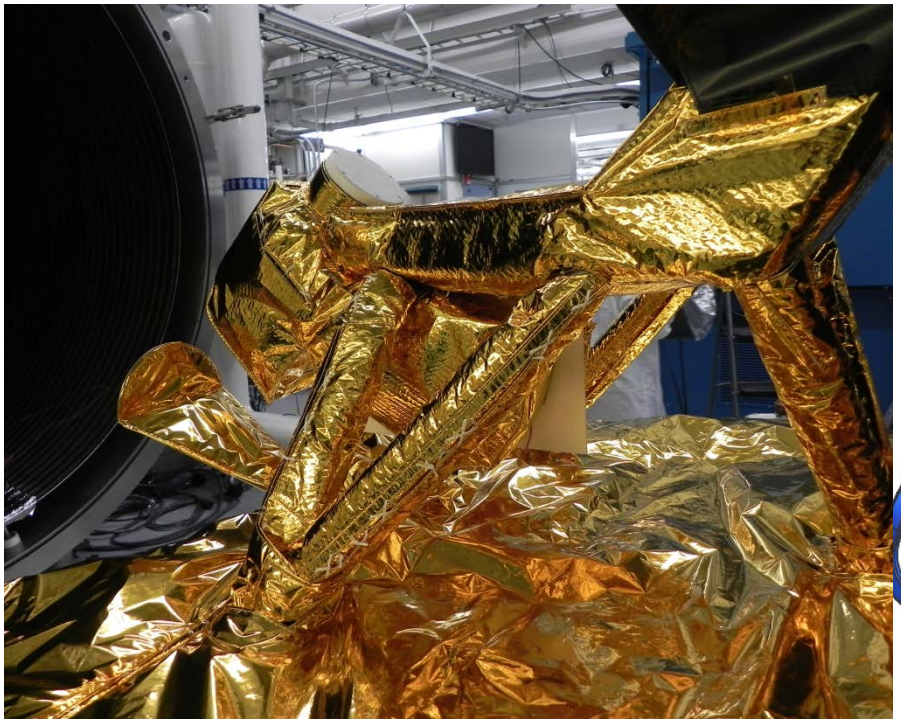
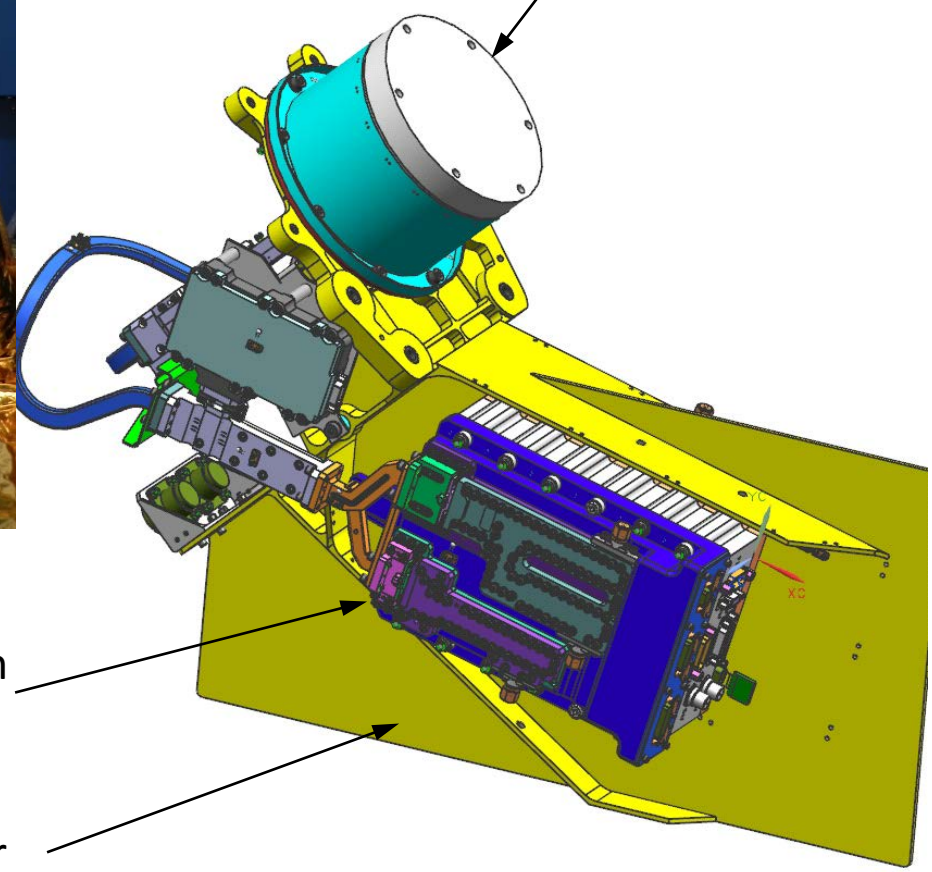
Electronics Mounted to Radiator





Feedhorn inside cover

Electronics, covered with MLI, dissipates 15W

White painted radiator

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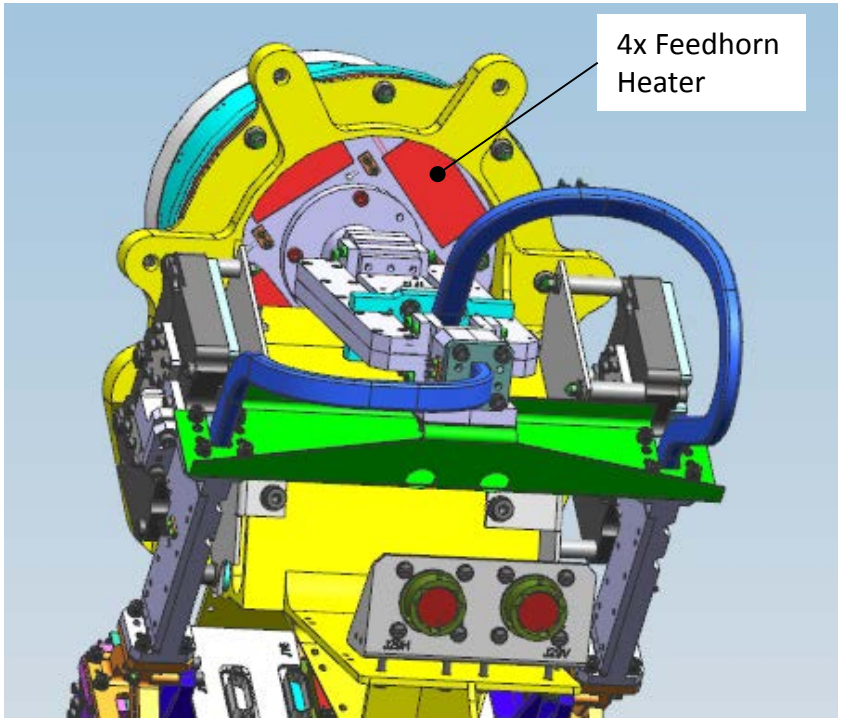
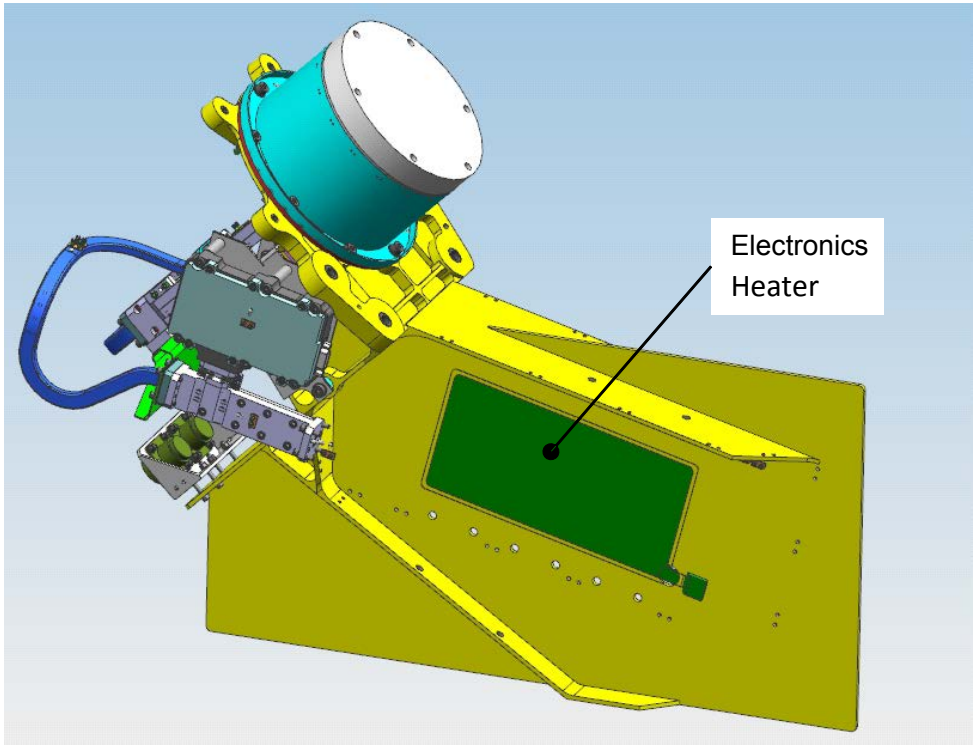
Two Flight Heaters for Stability



Control the Feedhorn bracket to 30°C

Heater control in on-off with time proportioning

Control the electronics structure to 35°C



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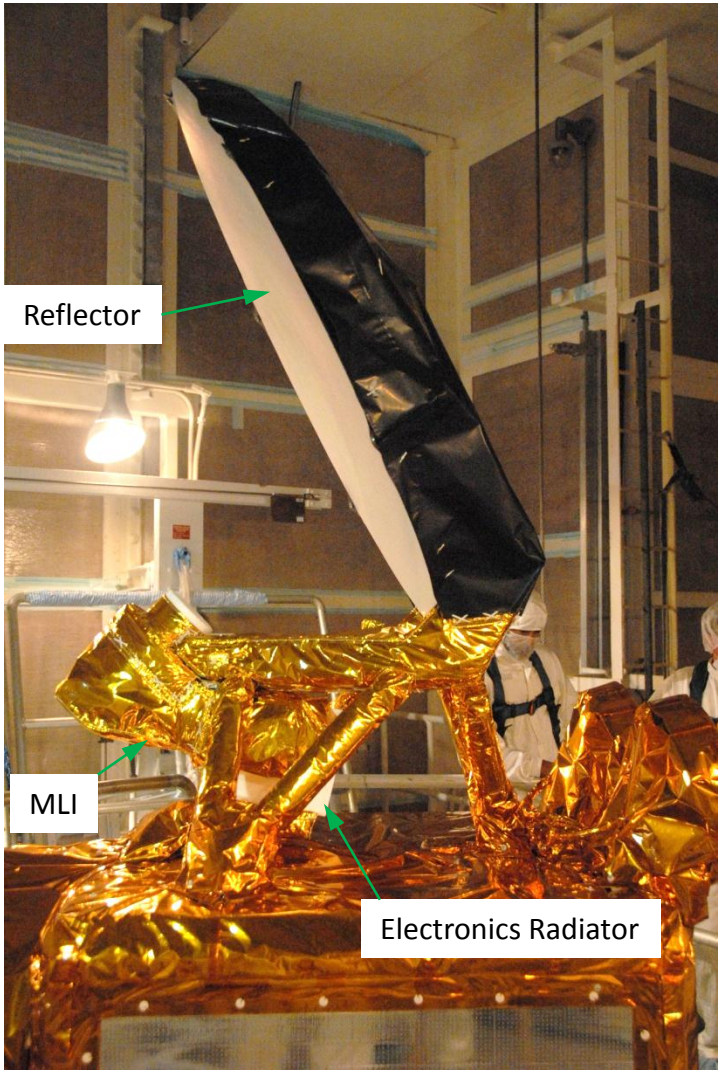
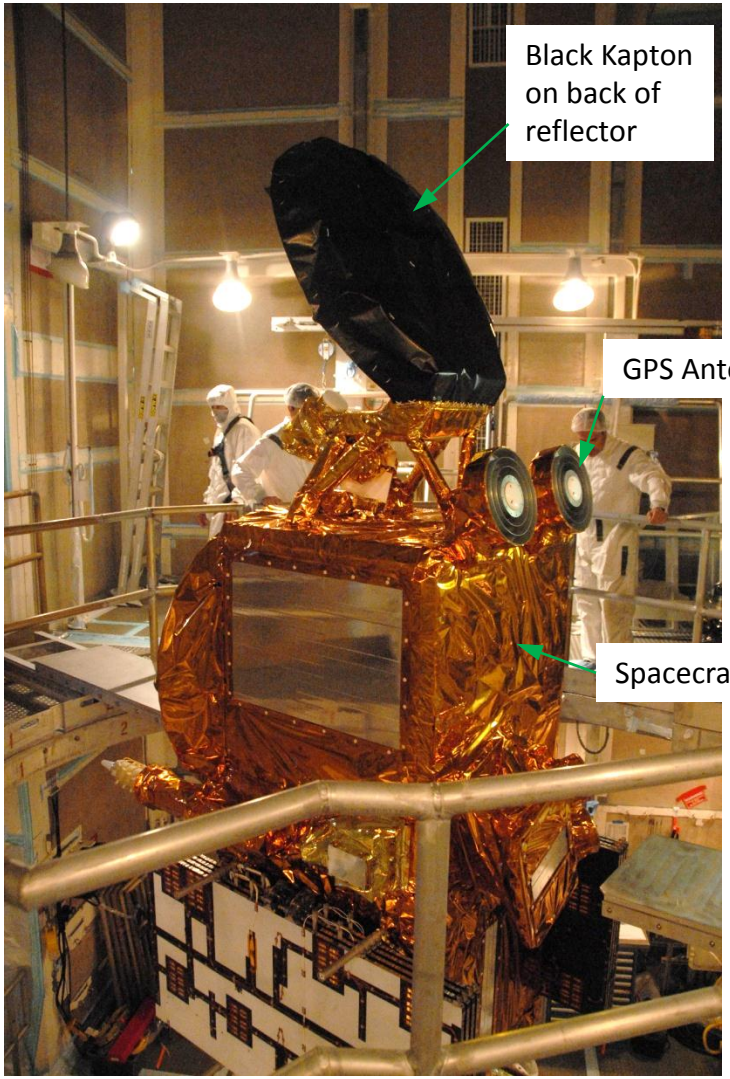
AMR on the OSTM Spacecraft





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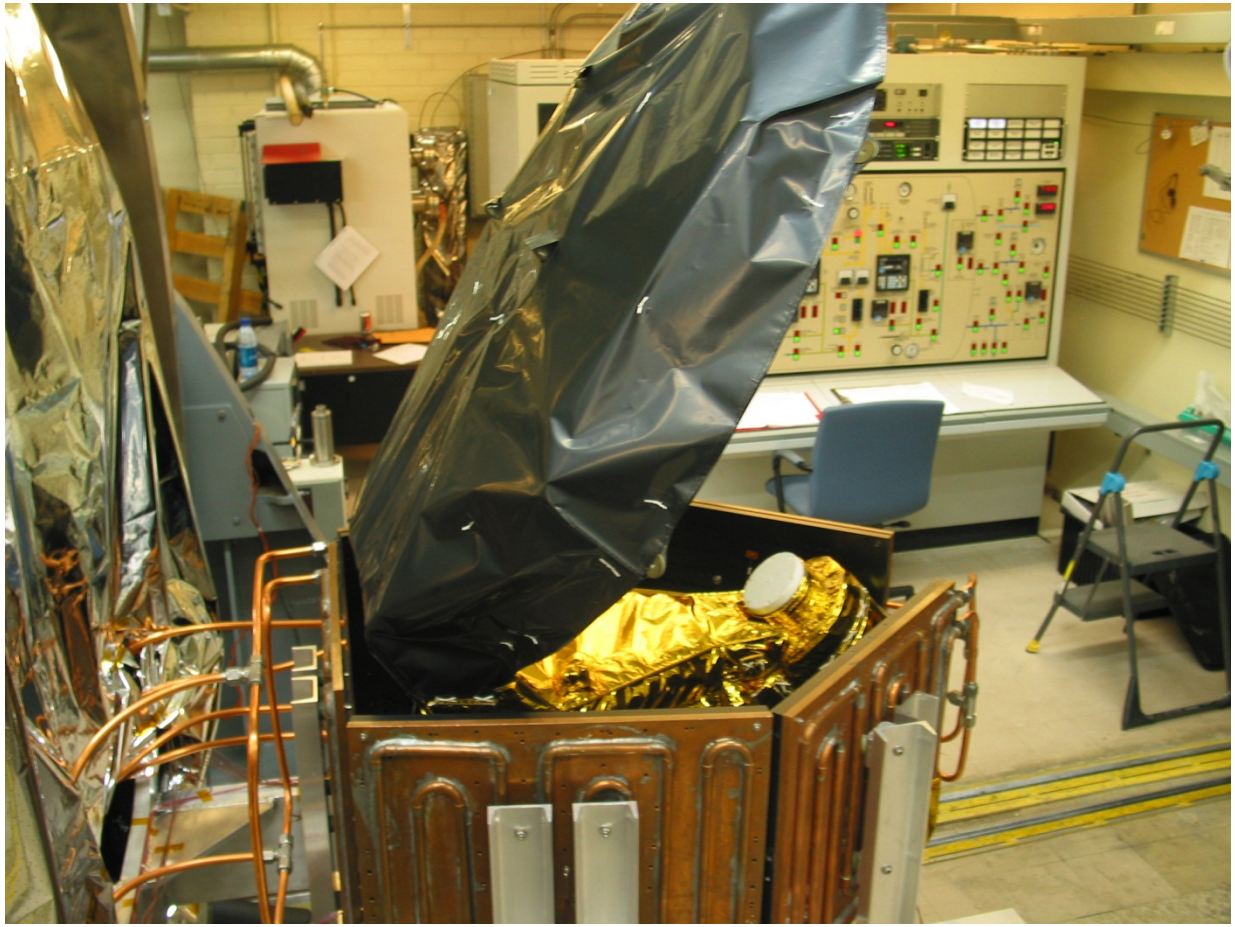
OSTM Thermal Balance History



Five IR plates simulate the transient orbital environment, including asymmetrical loading. But the spacecraft is not simulated.

Should we convert to a new fixture with spacecraft simulation?

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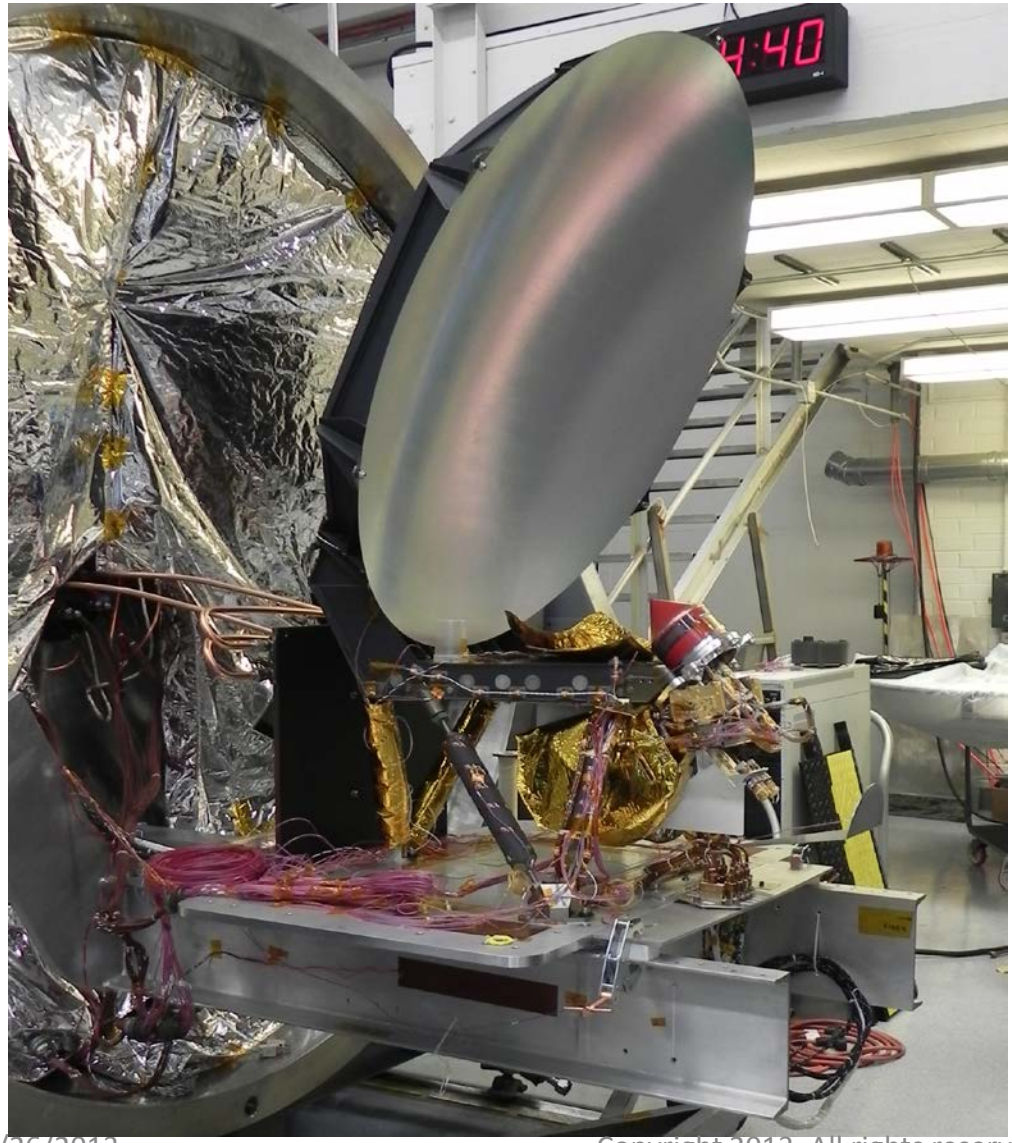
AMR partially insulated on test fixture



A new fixture simulates the spacecraft.

Pros-
Hardware simulation allows direct measurements of performance. Can use the flight thermal model. Less plumbing and a simpler fixture make testing easier.

Cons-
Limited to steady state with uniform boundary temperatures.

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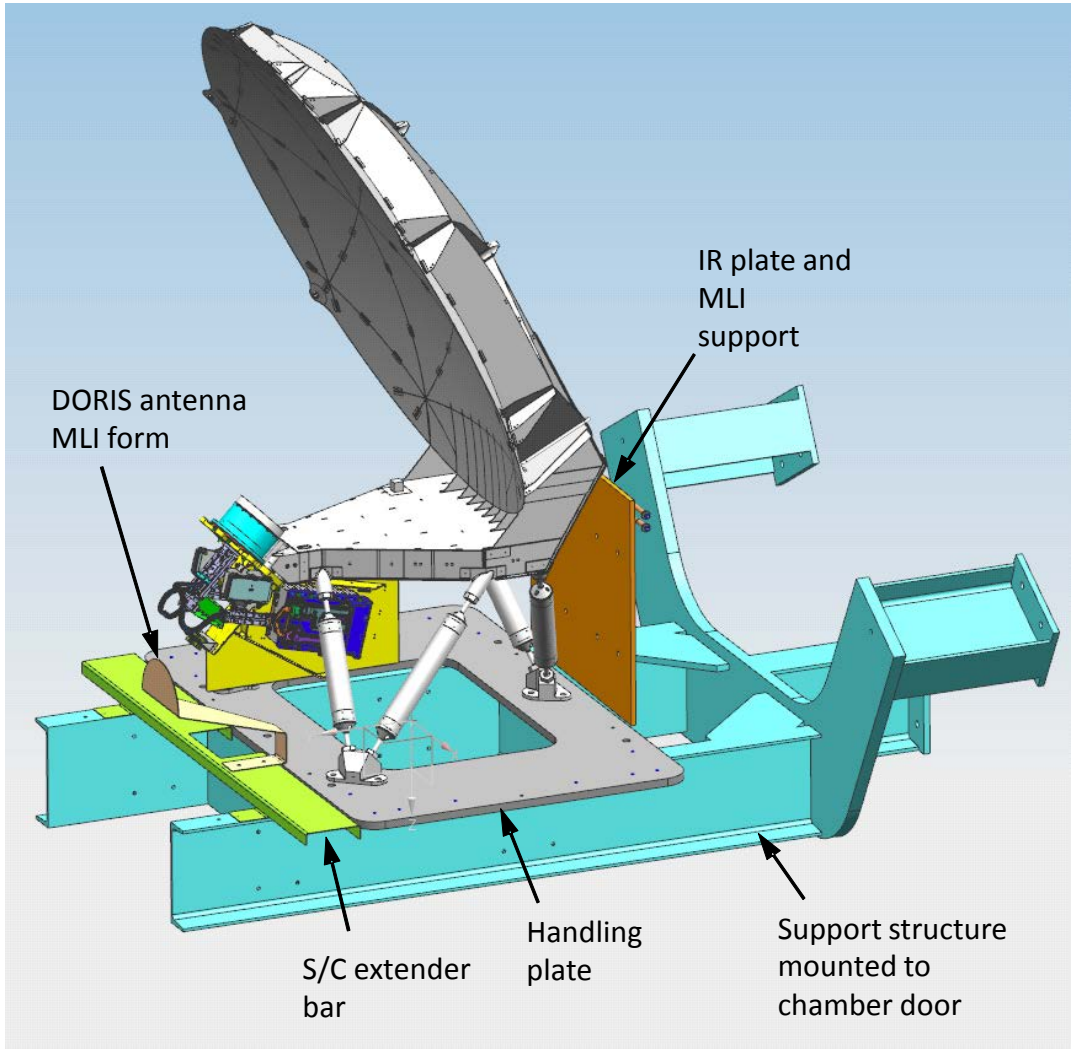
Go Ahead with Modified Fixture



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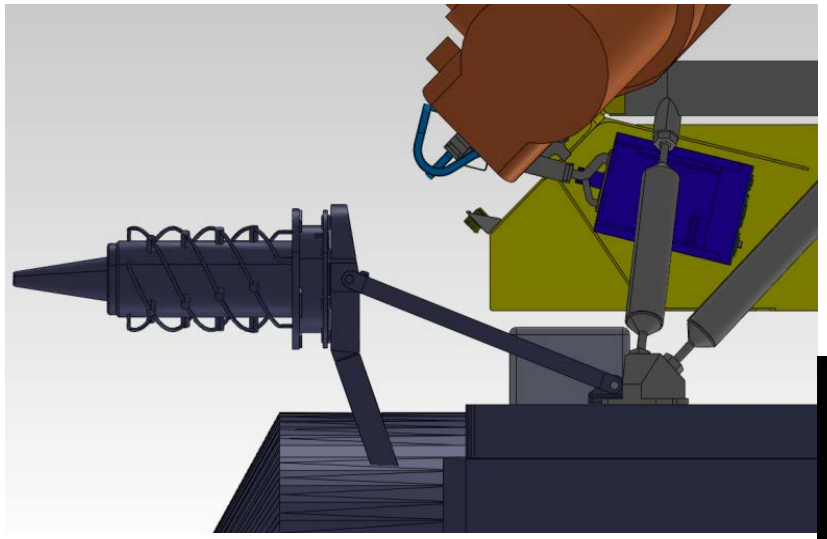
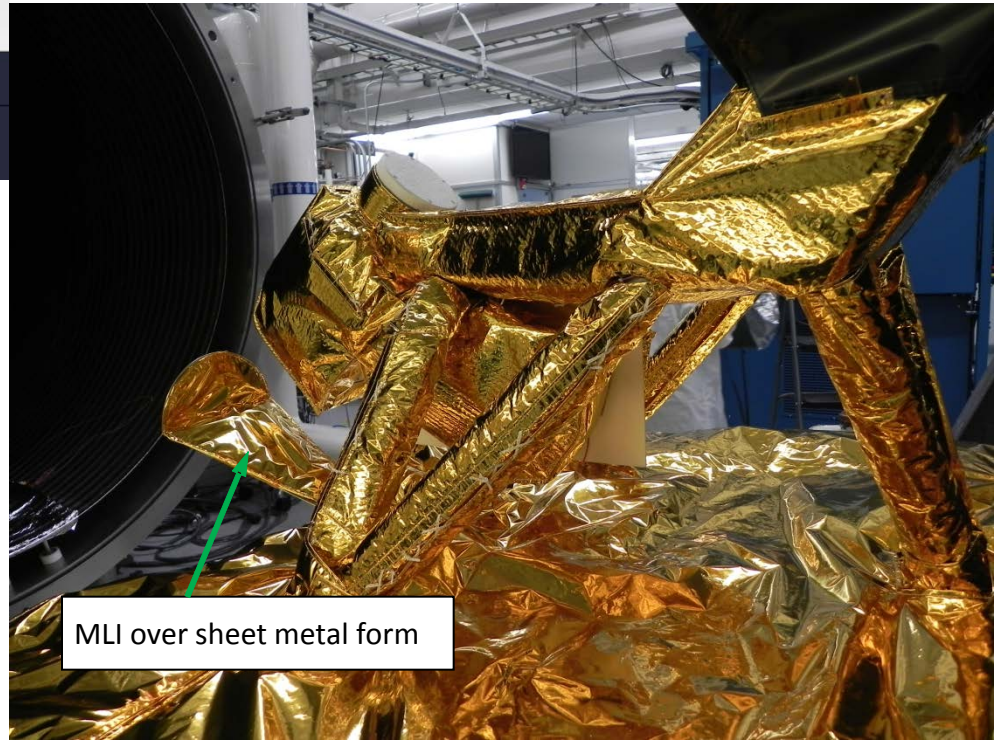
Simulate DORIS with MLI



DORIS Antenna Simulation



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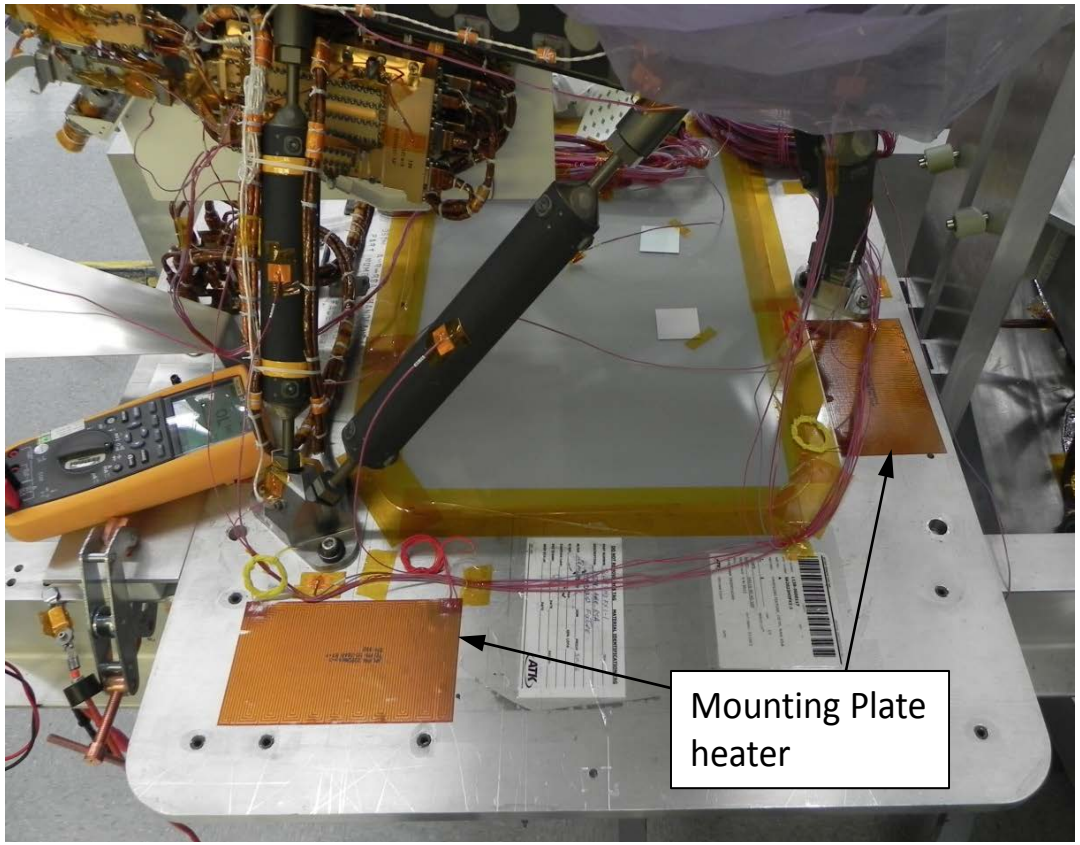
Handling Plate Simulates S/C

- **Use the handling plate to simulate the top deck of the spacecraft.**
- **Simplifies installation and provides a higher fidelity test.**



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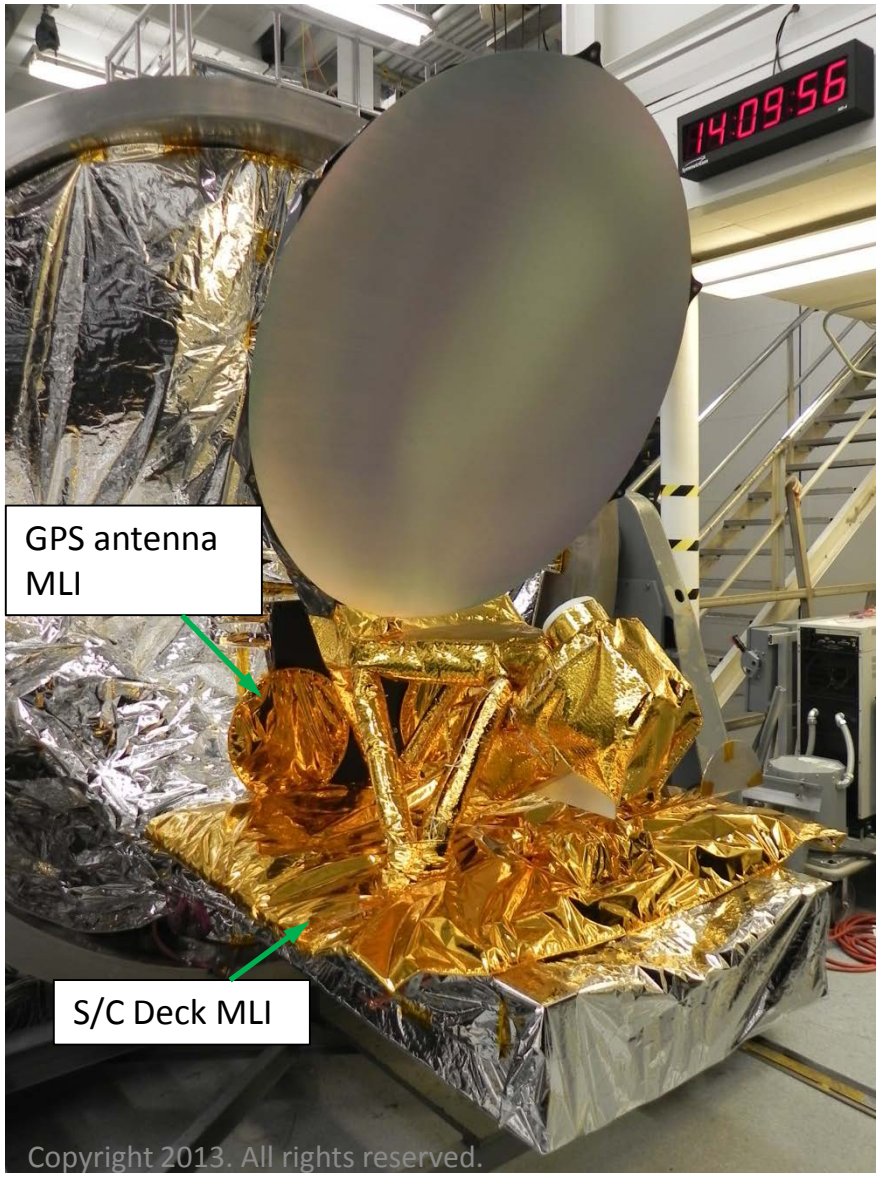
Keep One IR Plate

One IR Plate provides a controlled environment looking back (design of the support sled required removal of the door shroud.) IR plate also supports the GPS antenna MLI.



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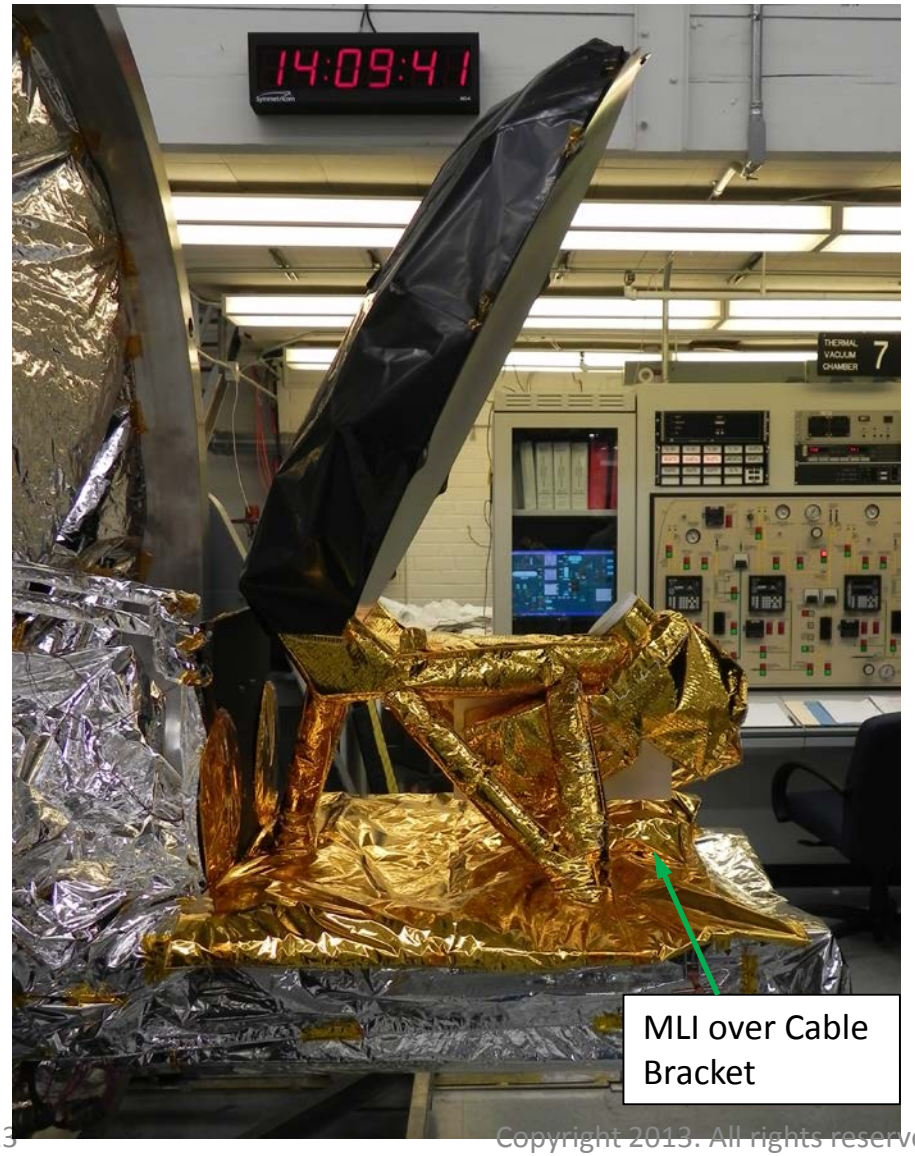
Cable Bracket Simulation



Cable bracket blocks some of the view from the radiator.

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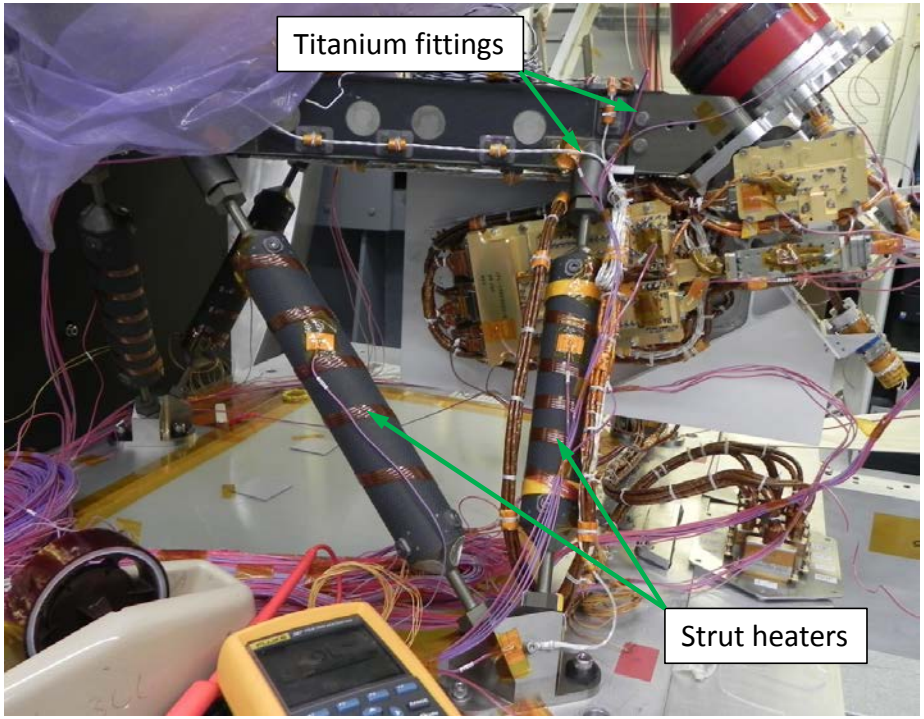
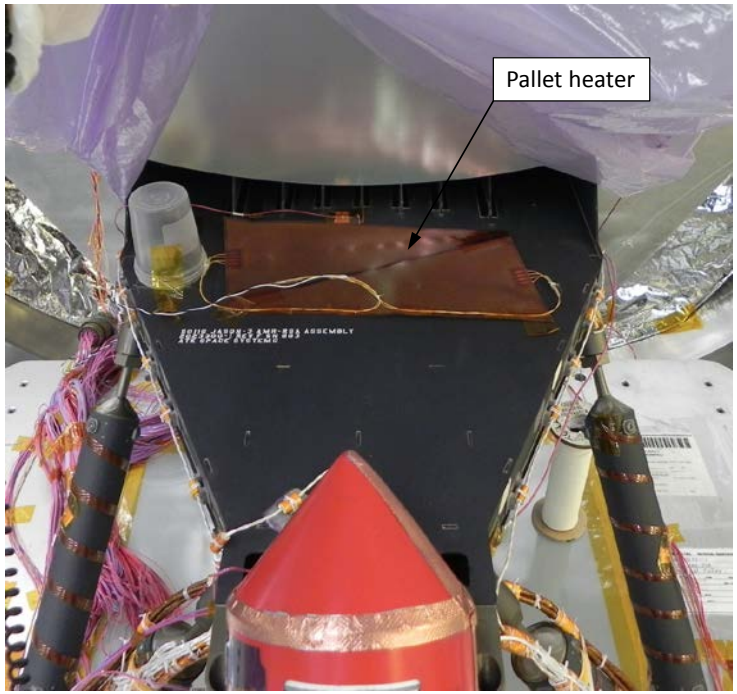
Safety Heaters Required for Fittings

Use left-over spiral propulsion line heaters for the struts





Dry mounting required for heaters. Acceptable due to very low power density.

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5 Cases Characterize System

Case	Description	Electronics	Electronics Heater	Shroud and IR Plate
1	Hot Steady-State	On (15W)	Control to 35°C	-24°C
2	Hot Steady State	Off	Fixed at 22.4W	-24°C
3	Cold Steady-State	On (15W)	Control to 35°C	-88°C
4	Cold Steady-State	Off	Fixed at 32.7W	-88°C
5	Safe Hold	Off	Control to 10°C	-88°C

- **Electronics temperatures of Cases 2 and 4 are intended to match Cases 1 and 3.**
- **Constant power implemented with duty cycle control of heaters**

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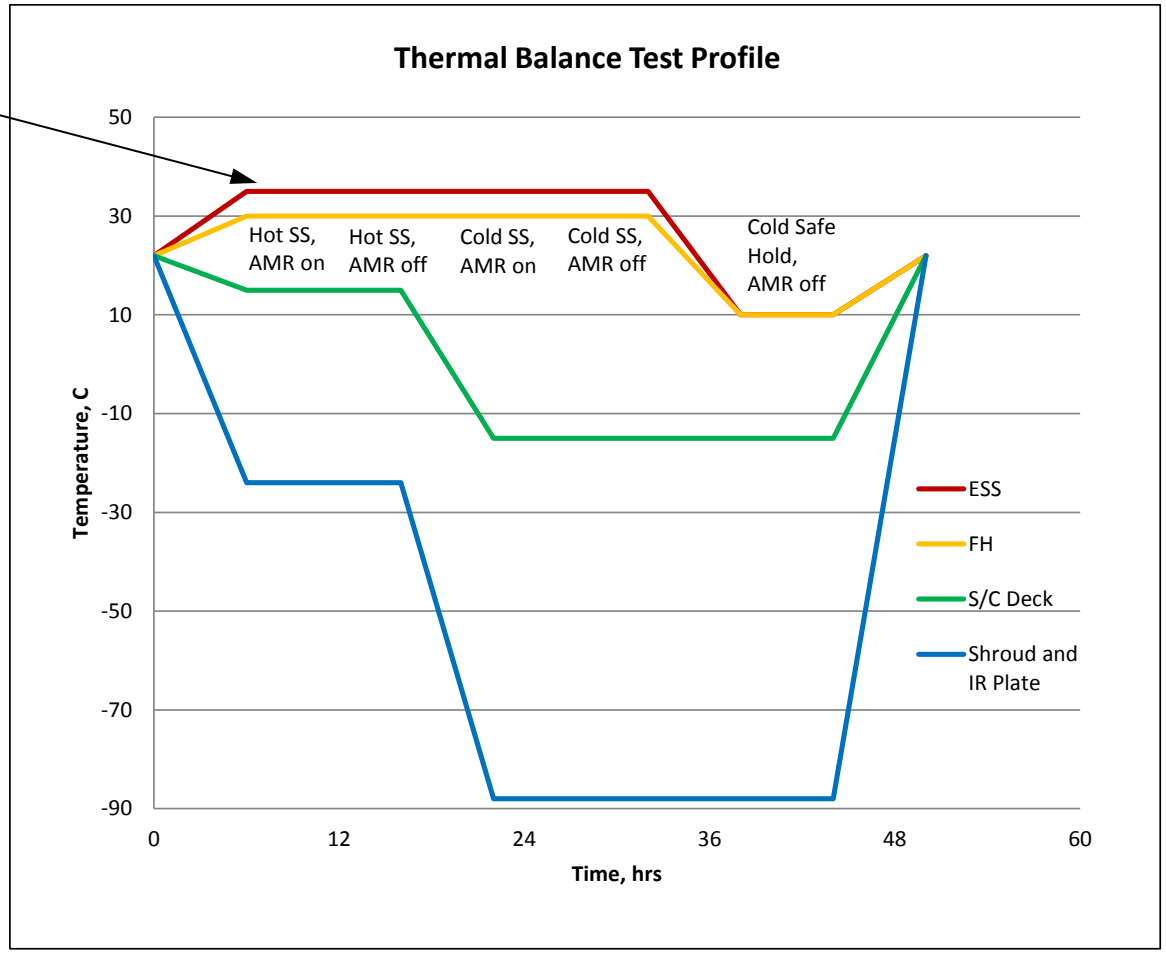
AMR Thermal Balance Test Profile

Ideally, there is no change in temperature for these 4 cases.



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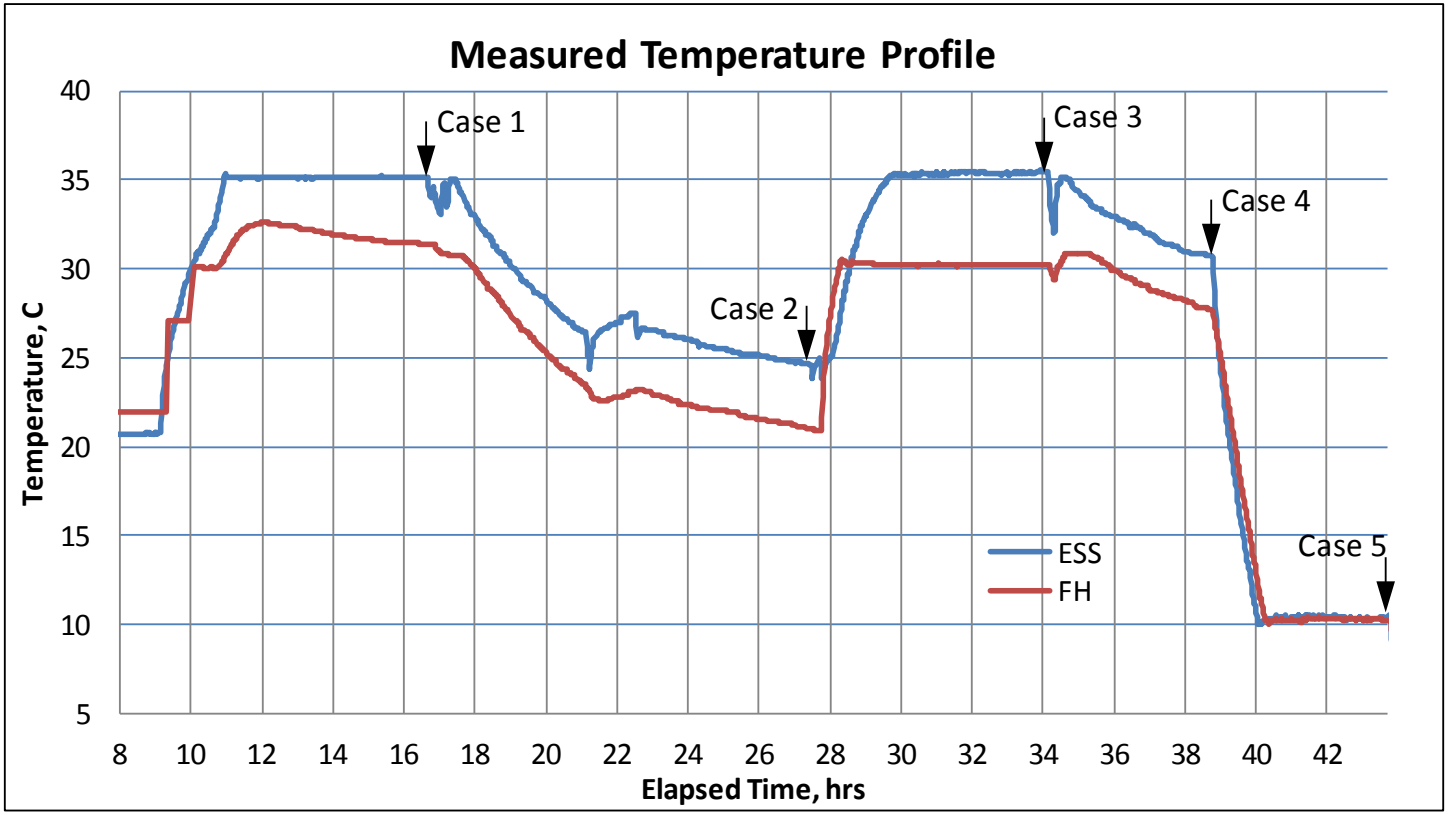
Measured Temperature Profile



- **Cases 2 and 4 are cooler than 1 and 3 indicating an anomaly in power dissipation.**
- **Steady state extrapolation is needed for Case 4.**

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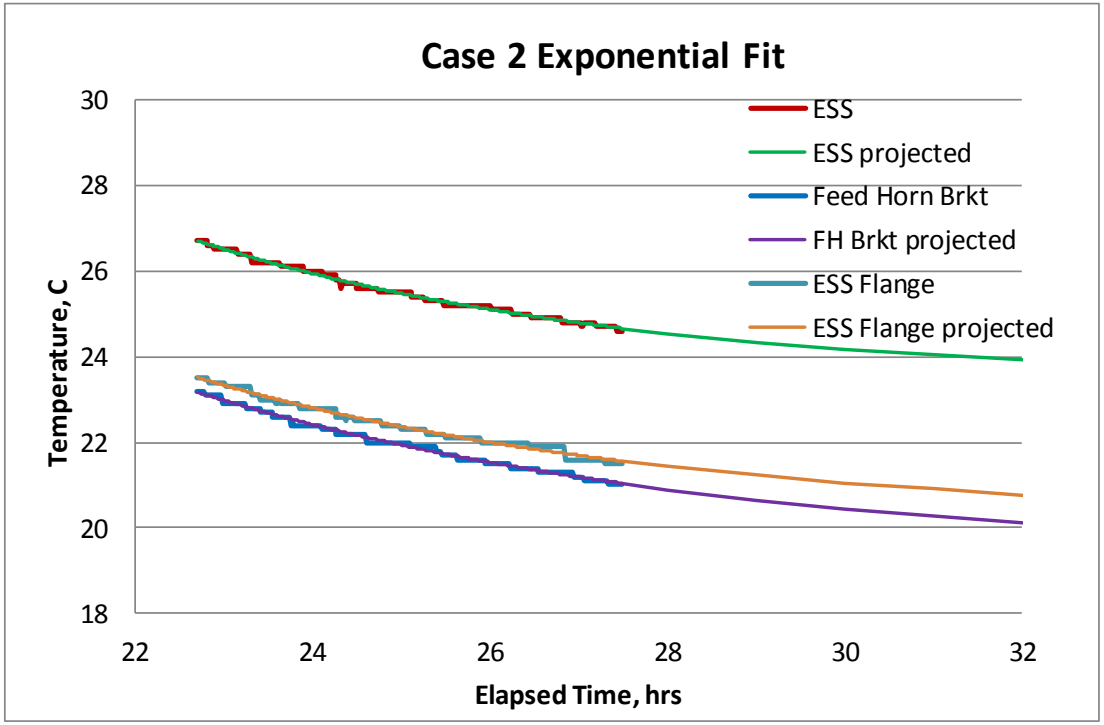
Extrapolate to Steady State



Steady state errors in the test data ranged from 1.1°C to 2.0°C

Make projections with: $T = Tfinal - (Tinitial - Tfinal)\exp(-t/\tau)$

Use Excel to:

- Get differences to test data
- Square the differences
- Sum the squares
- Use the Solver to minimize the sum of the squares

Result: Tfinal and Time Constant

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Be careful with heater power

- **AMR heater control is on-off with time proportioning**
  - Nominal maximum power is 25W
  - Nominal cycle period is 16 seconds
- **Actual cycle period, resistance, and voltage are different**
  - Actual cycle period is 19.4 seconds due to an idiosyncrasy in the controller, but on time is unchanged. This causes a 12% reduction in power.
  - Actual heater resistance, as recorded on the assembly instructions, is 32.7Ω instead of 31.4Ω. This causes a 4% reduction in power.
  - Actual voltage is 32.5V instead of 35V. This causes a decrease of 14% in power. (And we ran the initial test predictions at 28V!)
- **Corrected heater power is 30% less than nominal**

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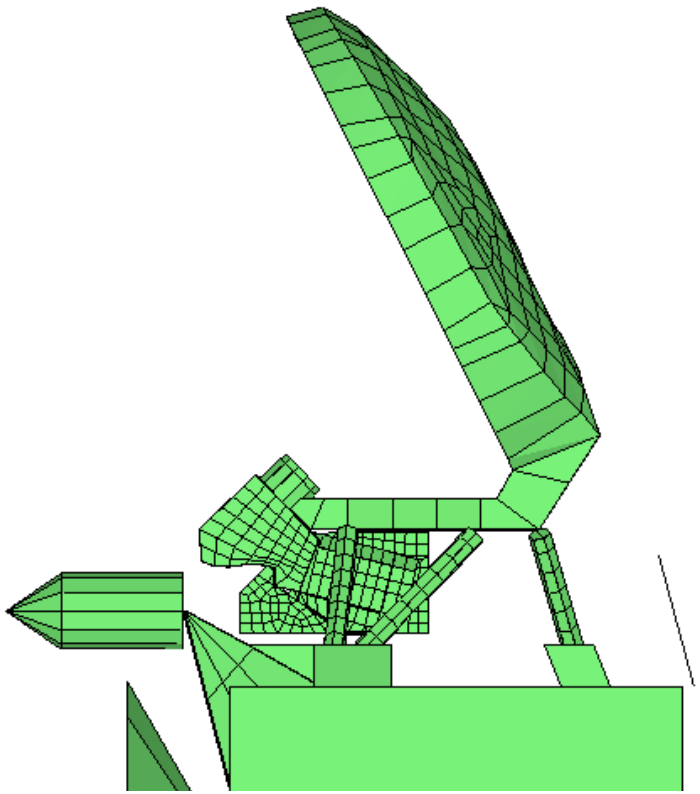
Preliminary Results



Run the flight model with the corrected heater power and projected steady state temperatures.

	Location	Meas., °C	Pred., °C	Diff., °C
Hot Operation	Feedhorn bracket	31.4	28.6	-2.8
	Electronics	35.2	34.3	-0.9
Hot Heaters Only	Feedhorn bracket	19.3	18.5	-0.8
	Electronics	23.5	24.5	1.0
Cold Operation	Feedhorn bracket	30.2	23.4	-6.8
	Electronics	35.5	31.1	-4.4
Cold Heaters Ony	Feedhorn bracket	25.6	19.2	-6.4
	Electronics	28.8	24.7	-4.1
Cold Survival	Feedhorn bracket	10.2	6.0	-4.2
	Electronics	10.5	6.5	-4.0

Result- Hot cases good, cold cases too cold

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Correlate with a Decrease in e*

MLI effective emissivity has a bigger effect on the cold cases and a smaller effect on the hot cases. Reduce the e* from .05 to .025.

	Location and Description	Meas., °C	Pred., °C	Diff., °C
Hot Operation	Feed horn bracket	31.4	32.3	0.9
	Electronics	35.2	37.5	2.3
Hot Heaters Only	Feed horn bracket	19.3	21.6	2.3
	Electronics	23.5	27.1	3.6
Cold Operation	Feed horn bracket	30.2	29.1	-1.1
	Electronics	35.5	36.0	0.5
Cold Heaters Only	Feed horn bracket	25.6	24.6	-1
	Electronics	28.8	29.4	0.6
Cold Survival	Feed horn bracket	10.2	10.8	0.6
	Electronics	10.5	10.7	0.2

All differences are now within 5°C and most are within 3°C.

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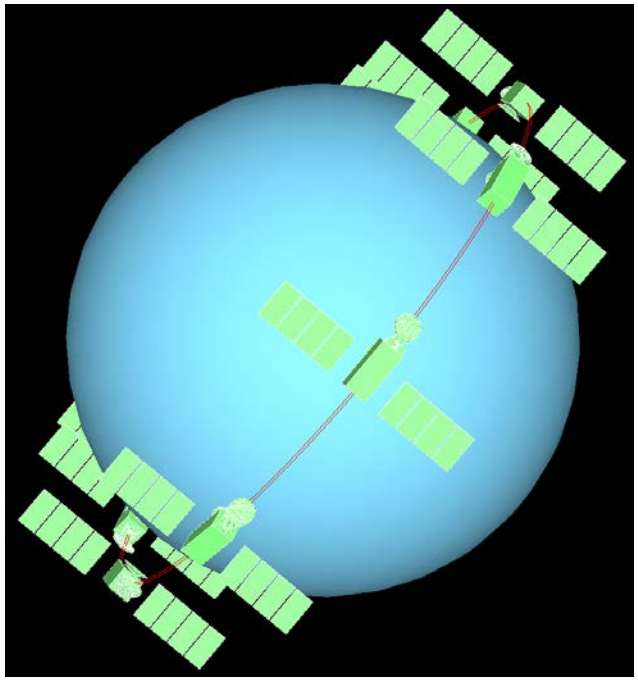
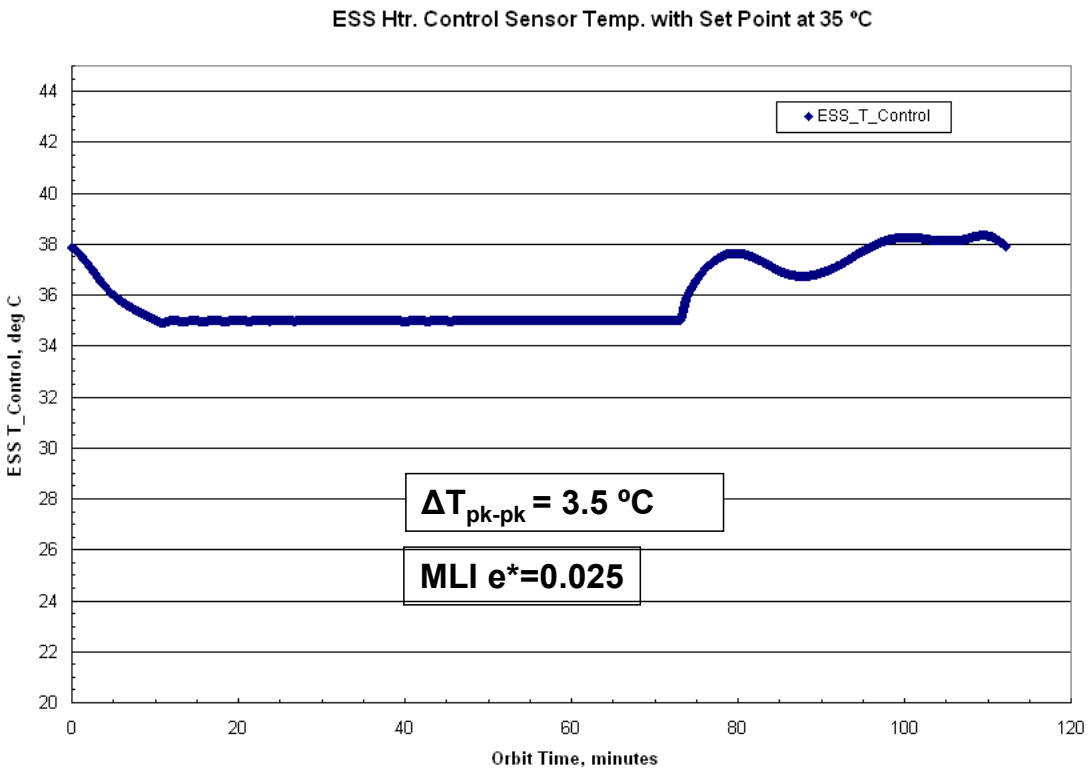
Impact on Flight Performance



Maximum electronics temperature is 1°C warmer



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Lessons Learned

- Safety heaters can be installed without adhesive if the power density is low.
- Simulate the spacecraft. This produces a higher fidelity test and eliminates the task of creating a thermal model of the test fixture.
- Project to steady state with an exponential roll-off curve fit in real time. Rate-of-change requirements can easily miss the steady state temperature.
- Thoroughly investigate the electrical power. Heater duty cycle, circuit resistance, and voltage have significant effects.

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Conclusions

- **A reduction in the effective emissivity from .05 to .025 produces good correlation for all 5 test cases. All predictions match the measured temperatures within 5°C and most predictions match within 3°C.**
- **The impact on flight performance is an increase in hot case temperature of 1°C.**

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