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Cryogenic Multi-layered Insulation Seam Studies and Experiments

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Thermal & Fluids Analysis Workshop
TFAWS 2017
August 21-25, 2017
NASA Marshall Space Flight Center
Huntsville, AL

- Introduction
- Calorimeter overview
- Calorimeter photos
- Test results
- Thermal model discussion

Improved Fundamental Understanding of Super Insulation (IFUSI)

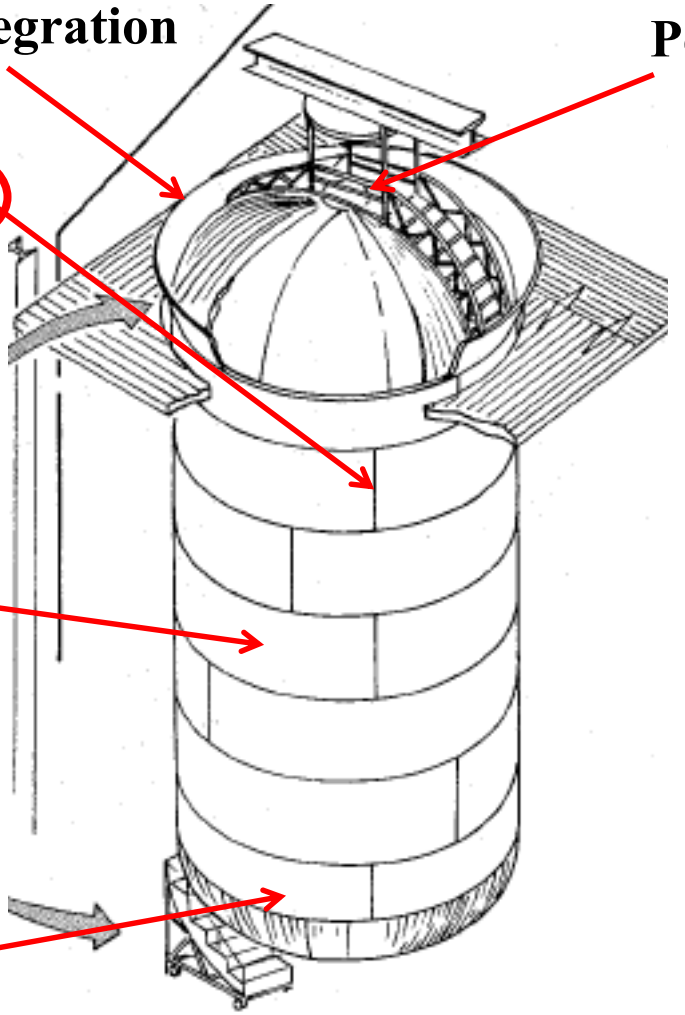
Skirt Integration

Penetration Integration
- Fill line
- Drain line

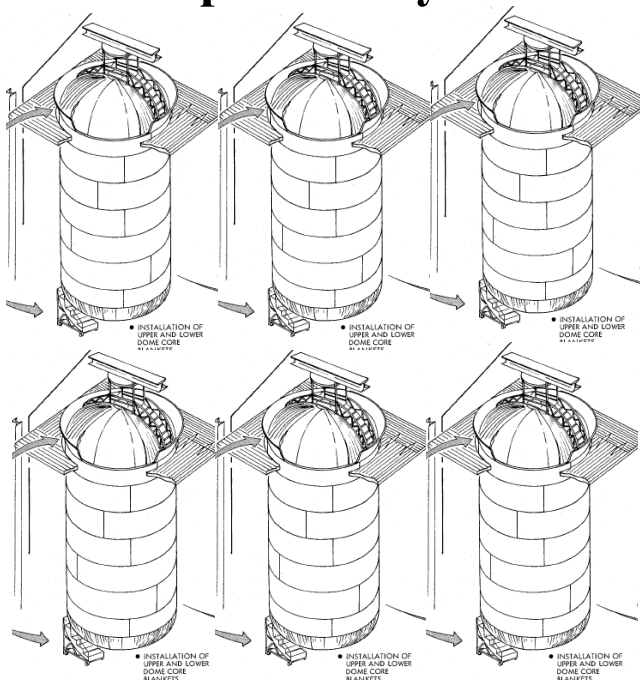
Seams

MLI Blanket Type
-Traditional
- SS-MLI
- Hybrid

Pins & Attachments

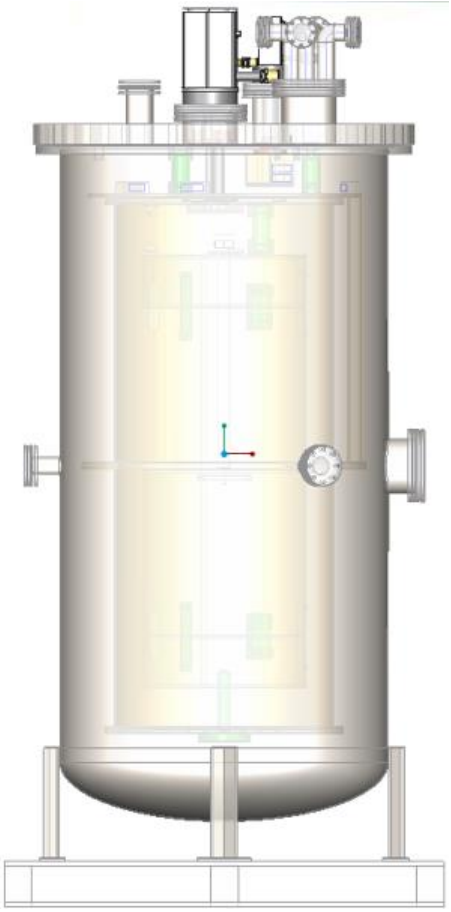


Repeatability



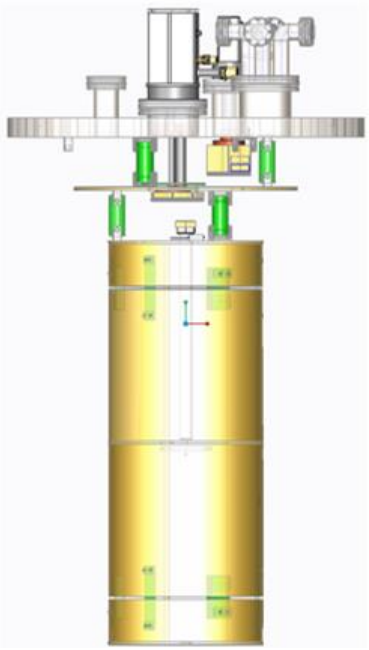
Lockheed Concept - 1969

Calorimeter Overview



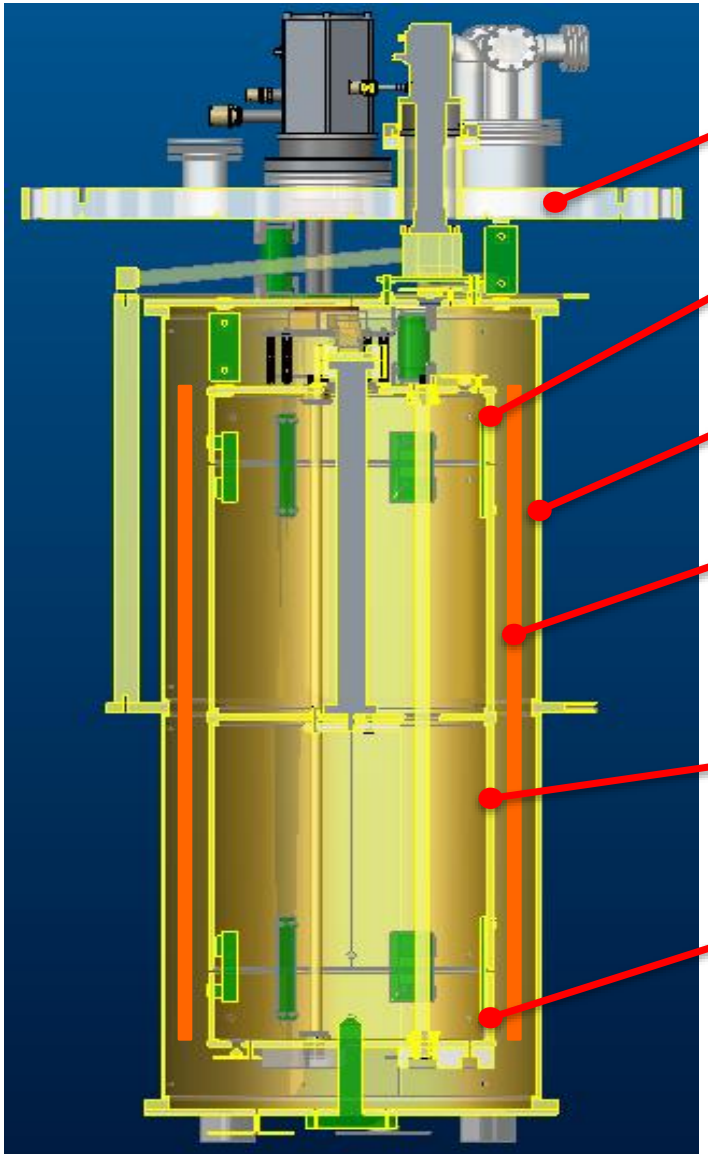
Vacuum tank

Copper auxiliary wall

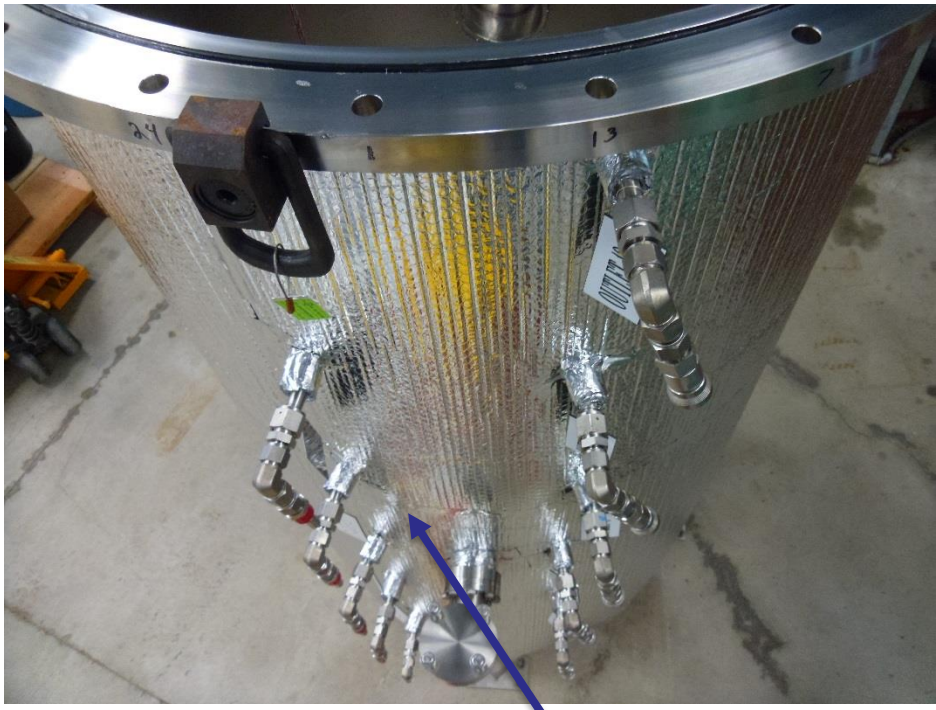


Test section

Calorimeter Cross-Section



Calorimeter



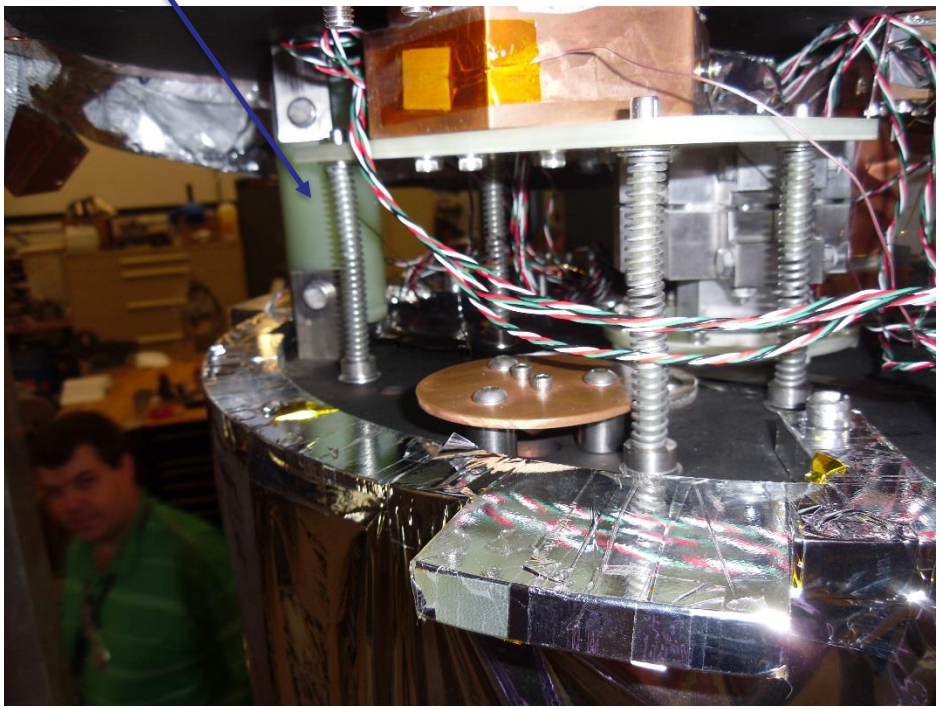
Copper

Black paint AZ-306

Water/glycol cooled jacket

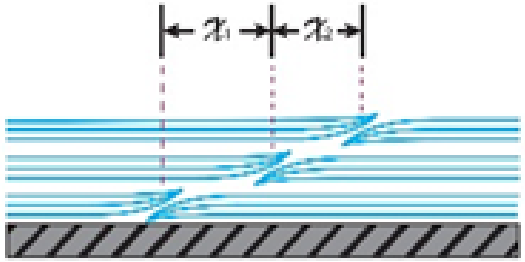
Calorimeter

G-10 support

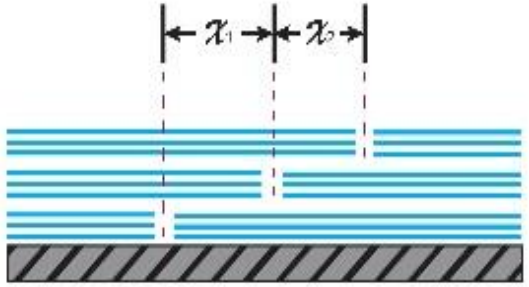


insulation

Seam configuration

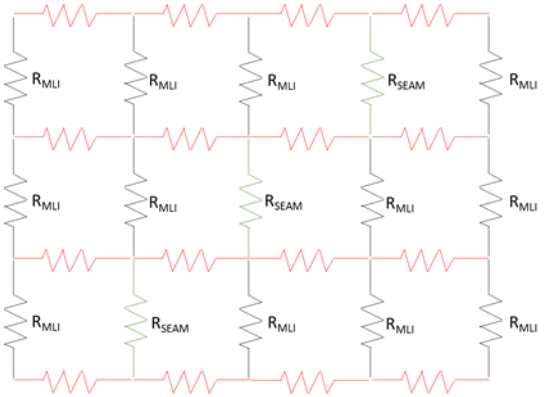


3 Blanket Overlap Staggered



3 Blanket Staggered

Desire to model staggered over lap and butt seams



Typical Solution for MLI Heat Load

- There are multiple 1-D MLI solution methods
  - Direct (a.k.a. “Layer by Layer”)
  - Semi-Empirical (“Lockheed”, “Modified Lockheed”, “Cunnington”)
  - Polynomial fits
- These solutions assume blankets are “ideal” and from laboratory calorimeter data
  - Historical tank data off by factor of 2 – 10
- Cannot use these methods to predict heat load from a seamed blanket

Comparison to predictions and test data

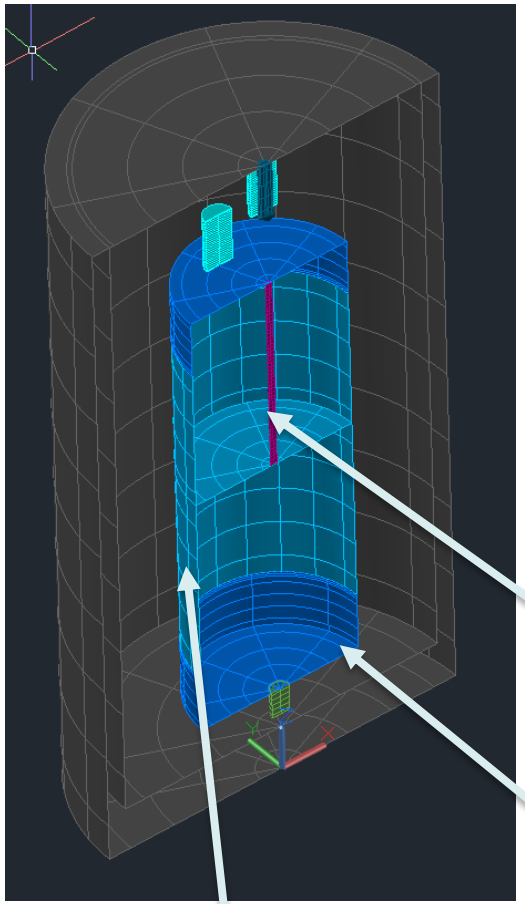
Test	Configuration	# of layers	layer density	Q_{flux}	Q_{seam}	Q_{pred}	DF	dDF
			lay/cm	W/m2	W/m	W/m2		
1	Overlap	50	17.4	0.564	0.044	0.116	4.9	0.25
2	Interleave	50	17.1	0.536	0	0.116	4.6	-
3	Butt	50	18	0.576	0.061	0.116	5	0.35
4	Butt - 1 stagger, 2 in	50	19	0.577	0.062	0.116	5	0.35
5	Butt - 1 stagger, 4 in	50	17.9	0.580	0.06	0.116	5	0.38
6	Interleave	20	16.6	0.727	0	0.28	2.6	-
7	Overlap	20	16.6	0.729	0.003	0.28	2.6	0.01
8	Butt - 1 stagger, 2 in	20	18	0.861	0.204	0.28	3.1	0.48
9	Butt - 0 stagger	20	18	0.823	0.146	0.28	2.9	0.34

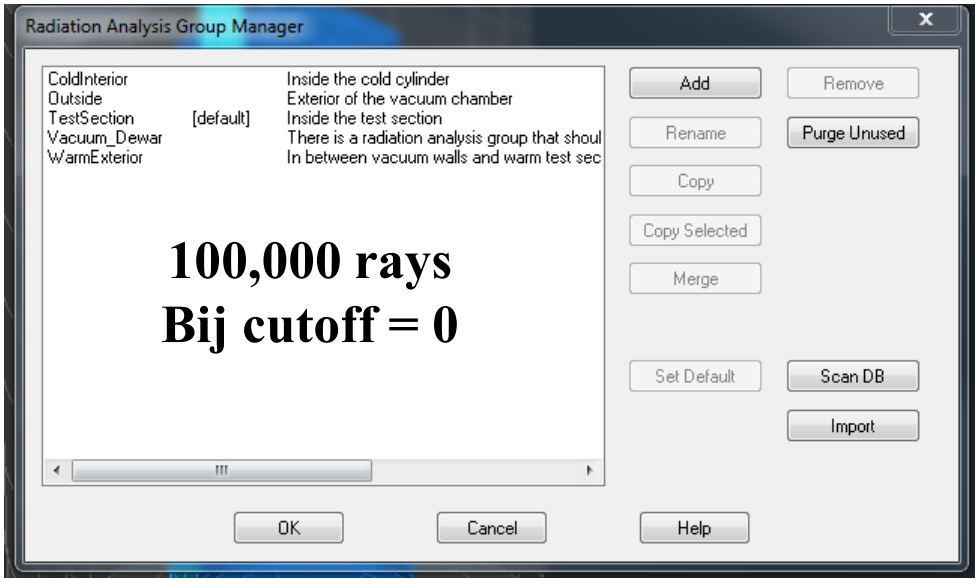
Q_{pred} using "Layer by Layer" method

Thermal Desktop model assumptions

- Steady state
- Water cooled jacket approximated with isothermal boundary node and conductor
- Cryocoolers approximated as isothermal boundary nodes at the test condition
- Temperature dependent properties (including emissivity)
- Diffuse radiation
- Optically thick layers

Thermal Desktop Model





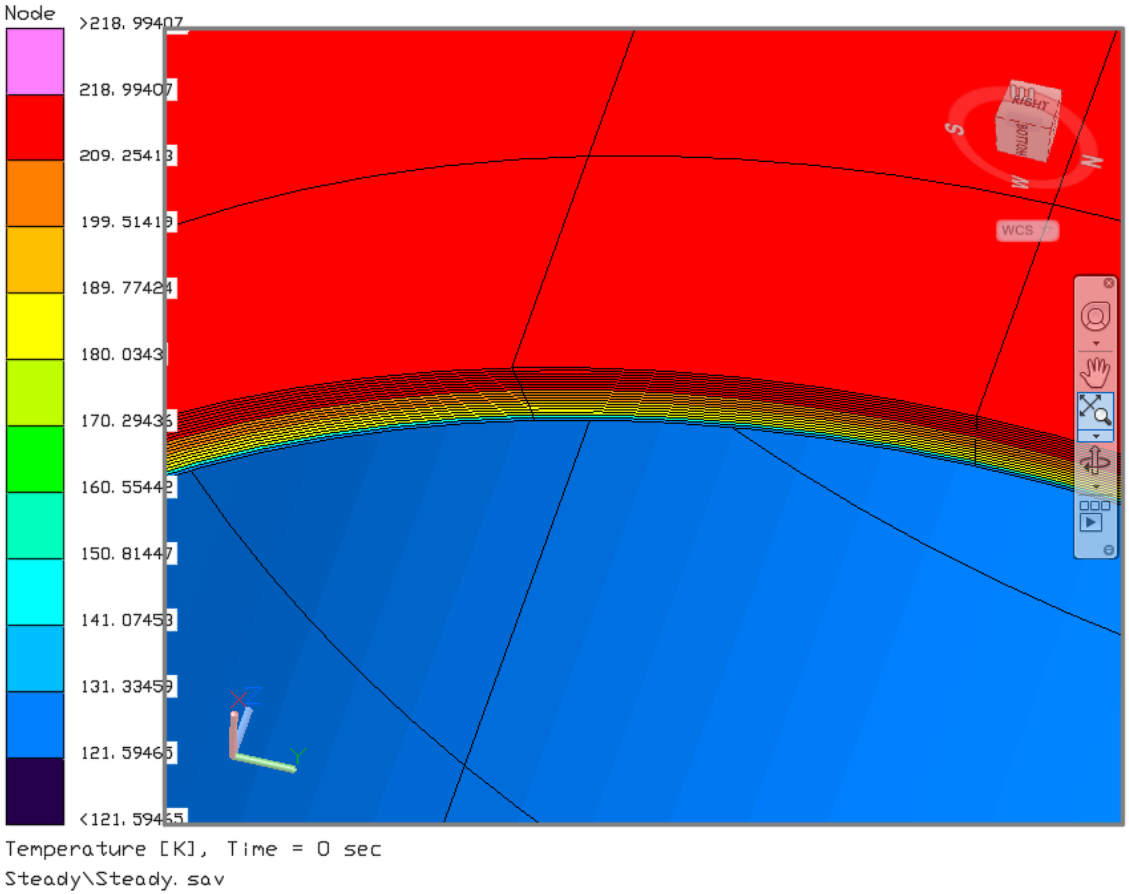
100,000 rays
Bij cutoff = 0

aluminum 6061 rod

Cold guard

Test section

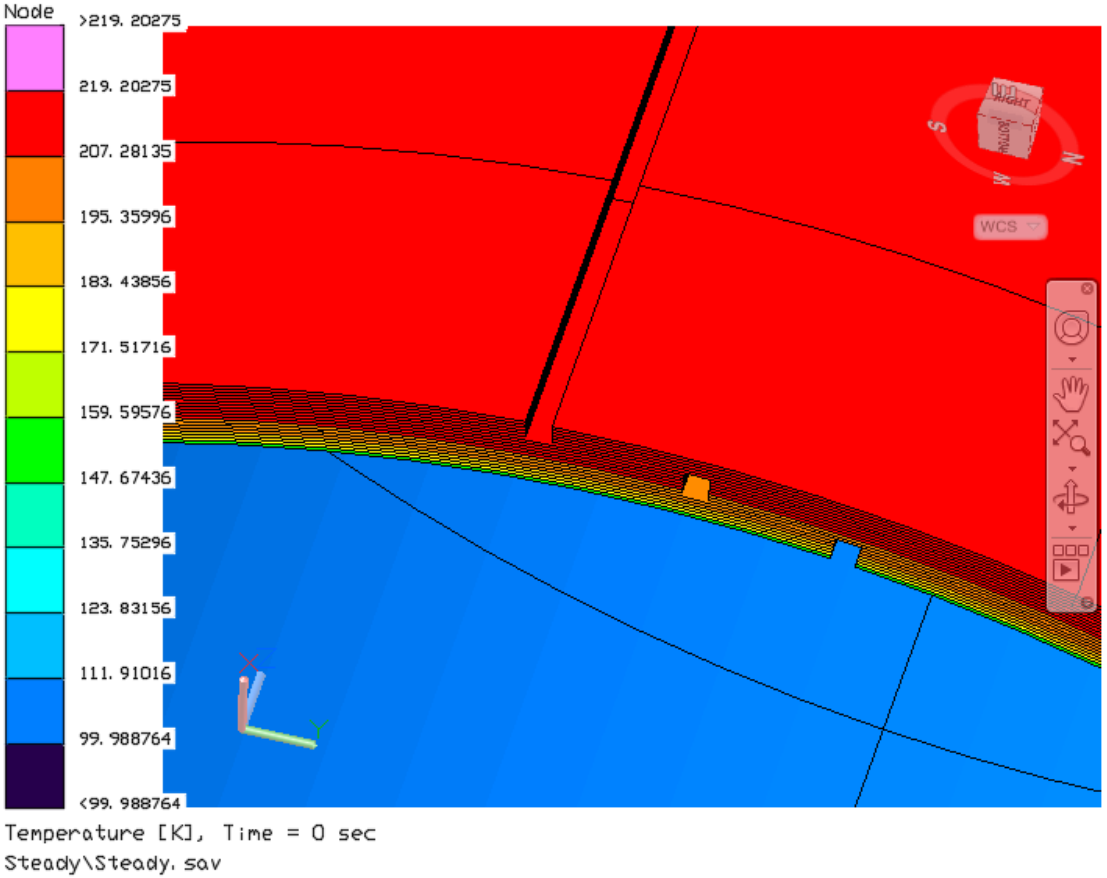
20 layer interleave



$Q = 0.30$ W

$Q_{flux} = 0.216$ W/m^2

Staggered, two inch spacing, actual gap



$Q = 0.37$ W

$Q_{flux} = 0.27$ W/m^2

$Q_{seam} = 0.06$ W/m

2.3 times lower than measurement

Conclusions and Forward Work

- TD can be used to model MLI in detail, including seams, to within a factor of ten of the true answer
- When correlated / validated, the model will be used to tabulate a set of results useful for first order estimates at the system level

Acknowledgements

- This work was funded by the Space Technology Mission Directorate's Evolvable Cryogenics Technology Demonstration Mission under the Improved Fundamental Understanding of Multi-Layer Insulation task.
- Dr. David Chato, NASA GRC (ret)
- Dr. Ebiana, Cleveland State University

Questions

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References

- McIntosh “Layer-by-Layer MLI Calculation Using a Separated-Mode Equation” Advances in Cryogenic Engineering, Vol. 39, Plenum Press, New York, 1994