



## Thermal Modeling and Correlation of the Space Environments Complex Vacuum Chamber and Cryoshroud

Erik J. Stalcup  
NASA Glenn Research Center

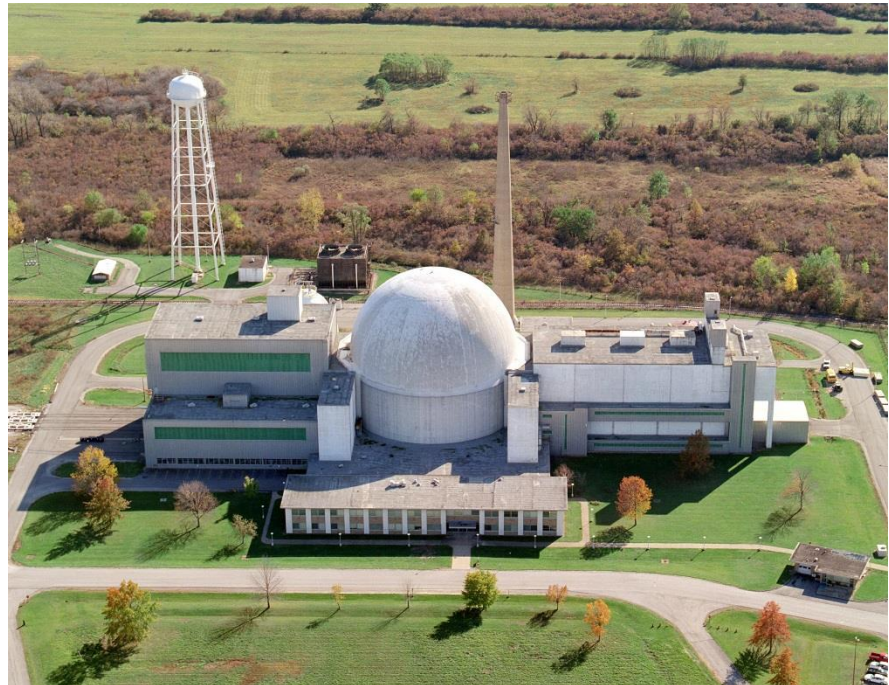


**TFAWS**  
JSC • 2018

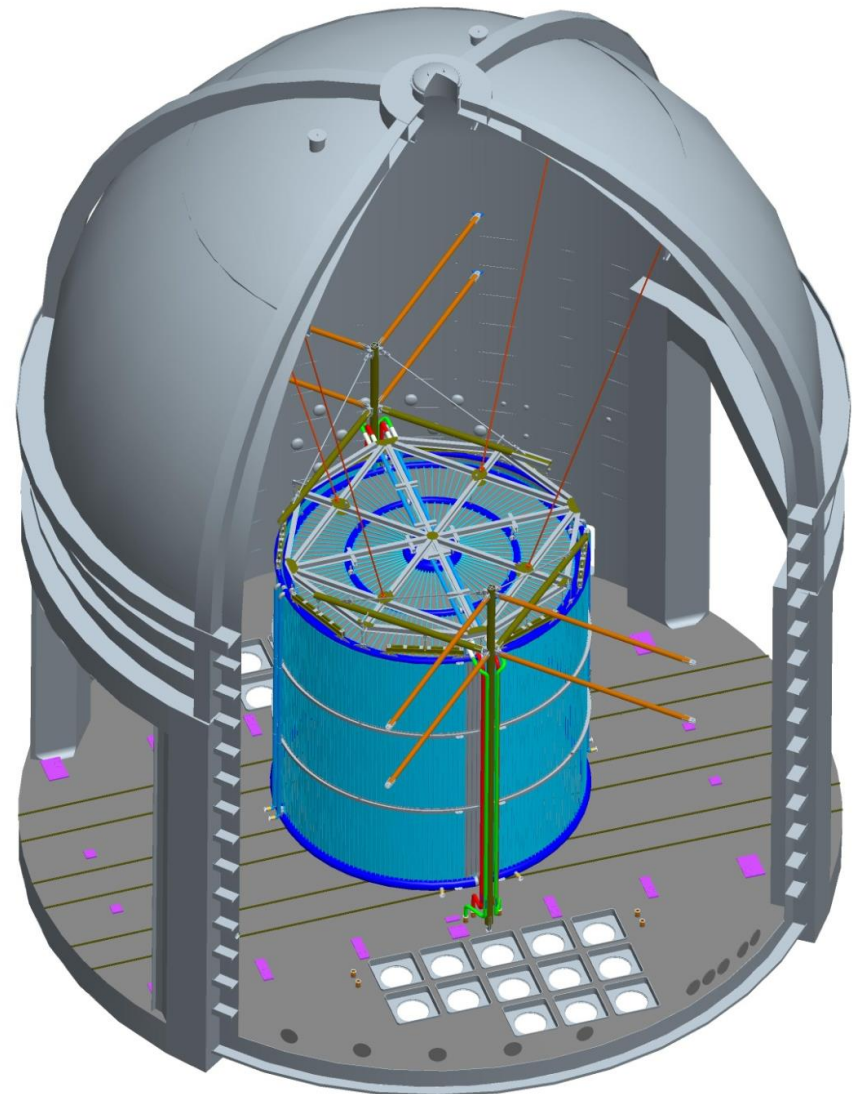
Presented By  
**Erik J. Stalcup**

Thermal & Fluids Analysis Workshop  
TFAWS 2018  
August 20-24, 2018  
NASA Johnson Space Center  
Houston, TX

- Background on the SEC Vacuum Chamber and Cryoshroud
- Model Description
- Model Correlation
  - Integrated System Tests
  - Bake-out Test
- Summary

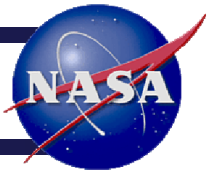


- Formerly known as the Space Power Facility (SPF)
- Located at Plum Brook Station in Sandusky, OH
- Houses large-scale test facilities including the Space Simulation Vacuum Chamber
  - Largest vacuum chamber in the world
  - 100 ft diameter, 122 ft tall
  - Cryoshroud operates between  $-250^{\circ}\text{F}$  and  $+140^{\circ}\text{F}$
  - To be used for Orion EM-1 thermal vacuum test





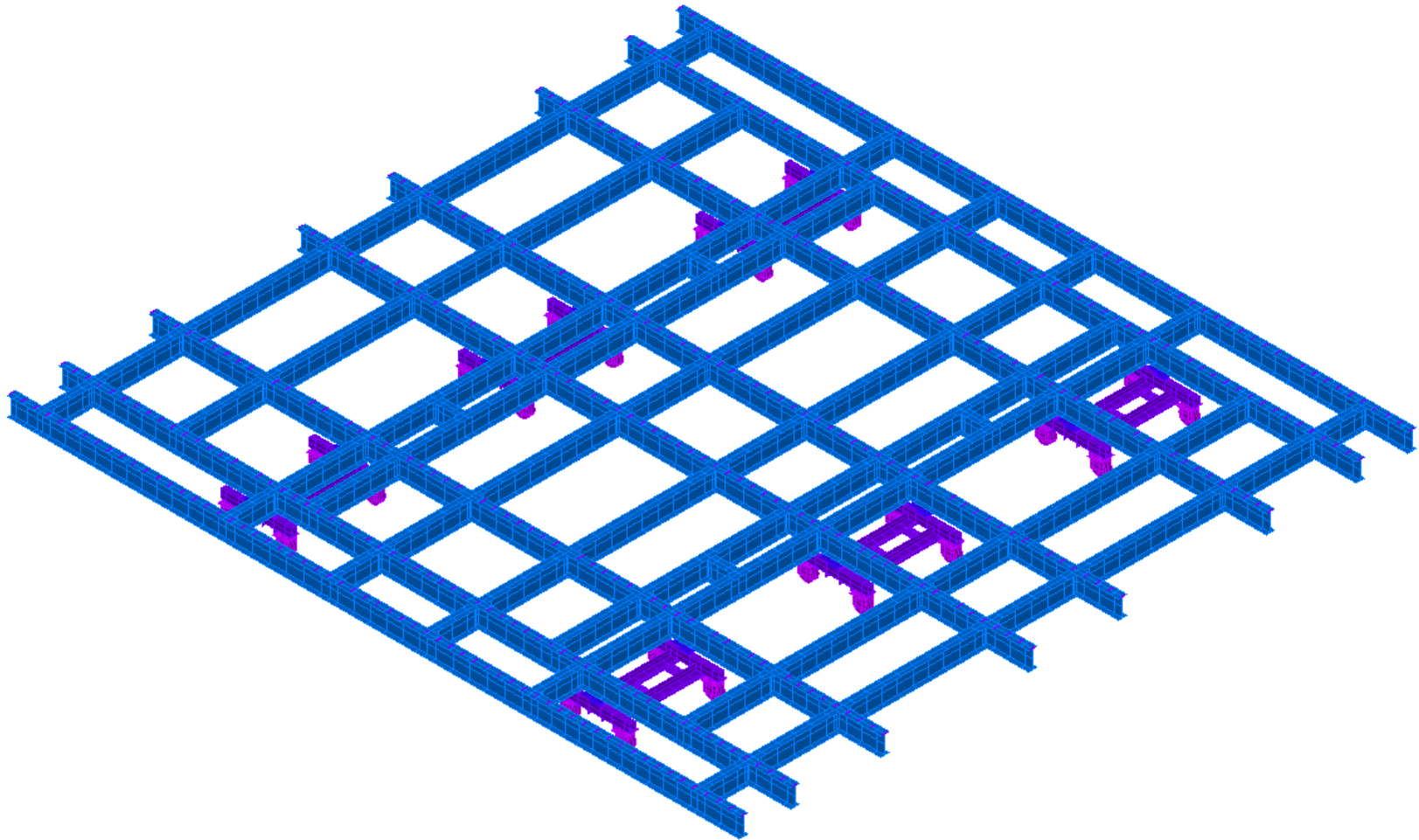
# Thermal Model Overview



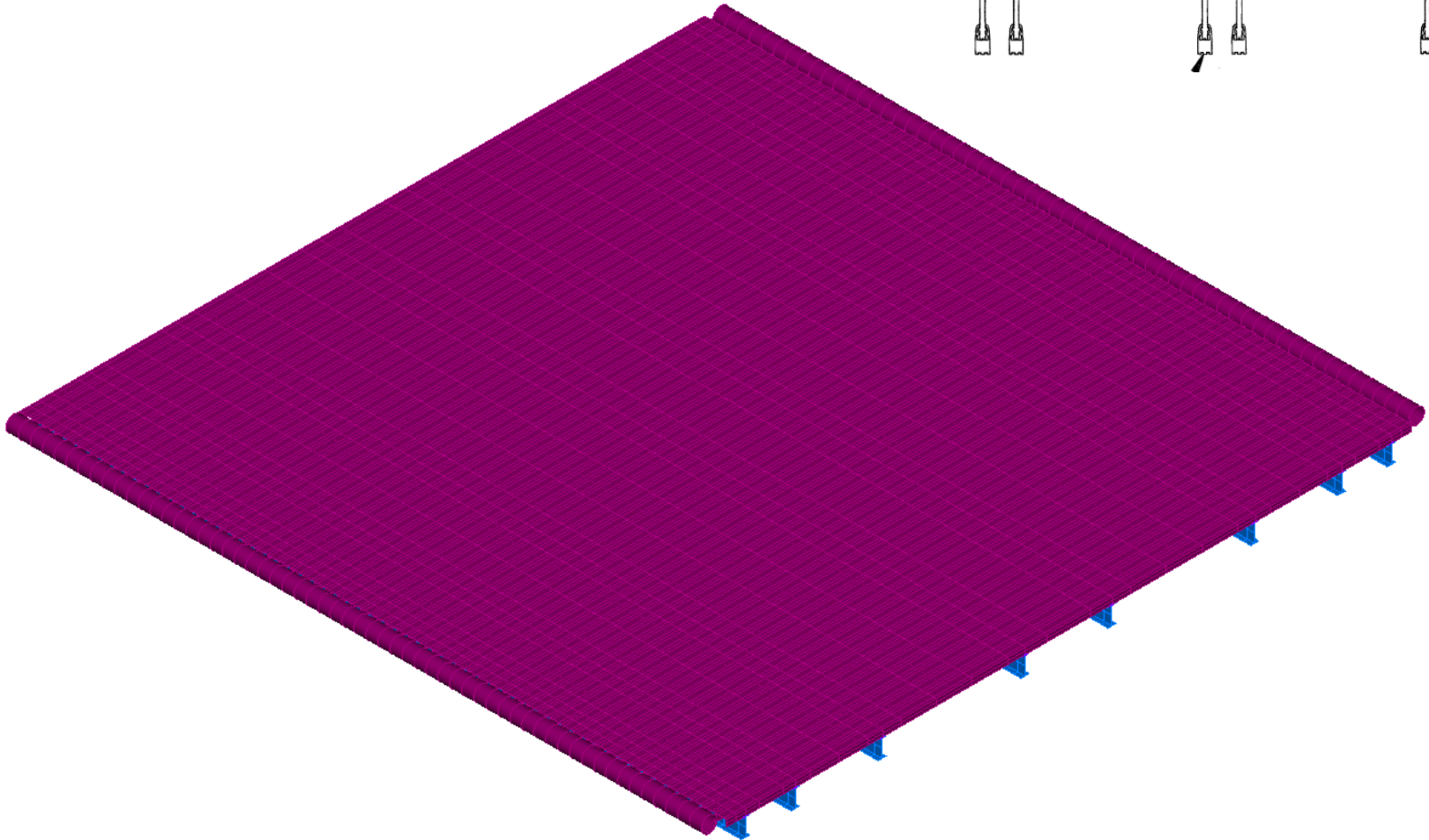
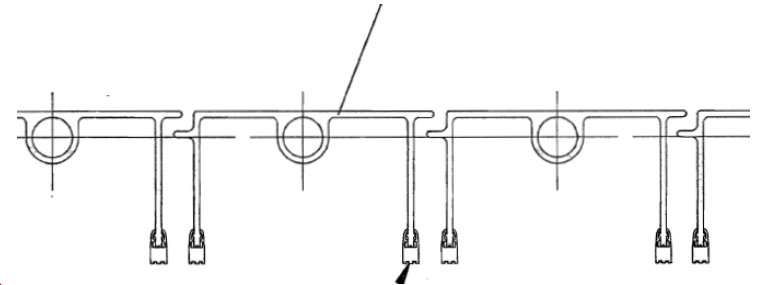
- Thermal Desktop model of vacuum chamber, cryoshroud, mechanical ground support equipment (MGSE) including fluid model of GN2
- Primary uses:
  - Predict MGSE temperatures
  - Predict heat load on GN2 system
- Includes 96 TD Temperature Measures that represent test thermocouples
- Steady state correlation with 3 tests
  - 2 hot
  - 1 cold



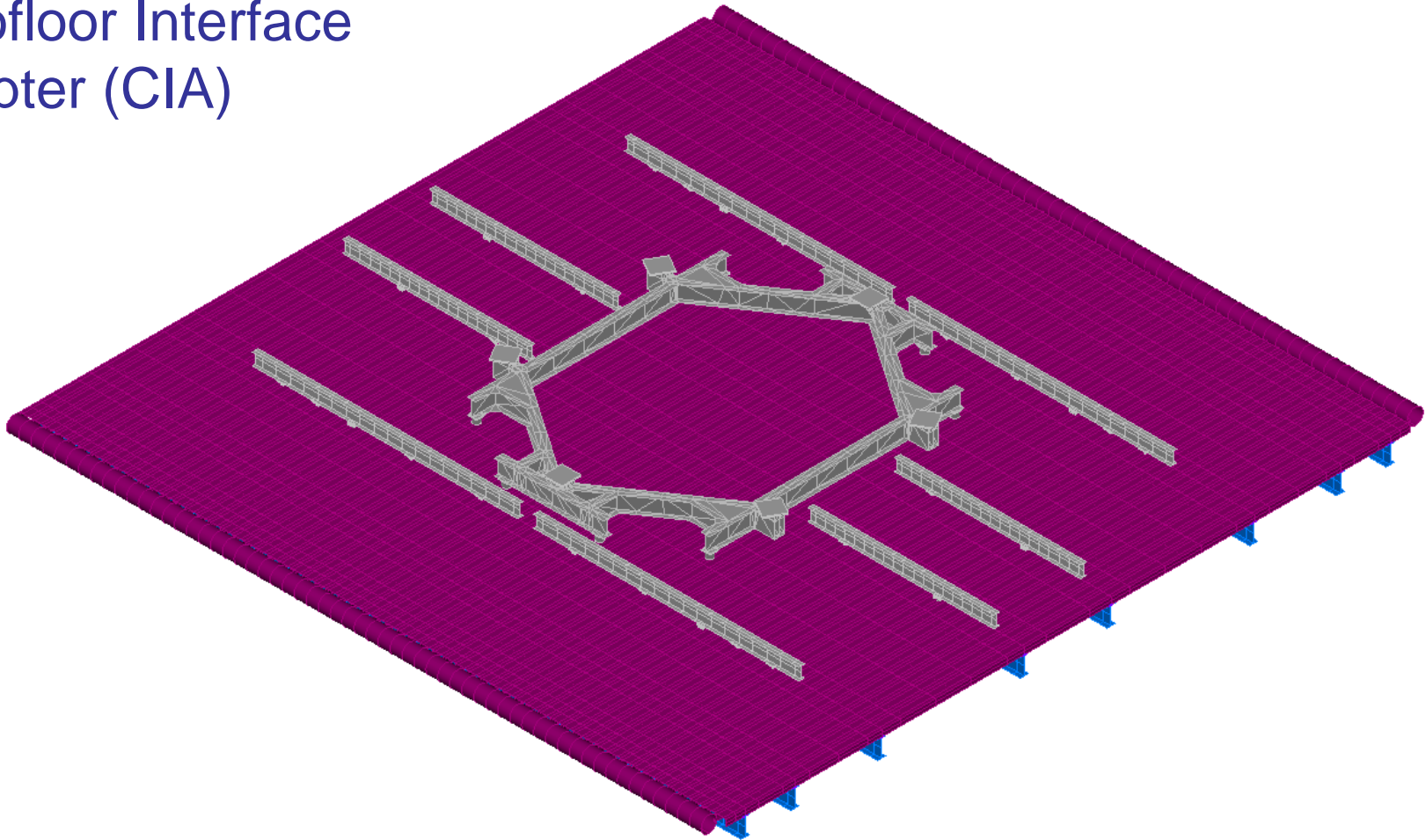
## Cryofloor Transfer Cart (CTC)



## Cryofloor



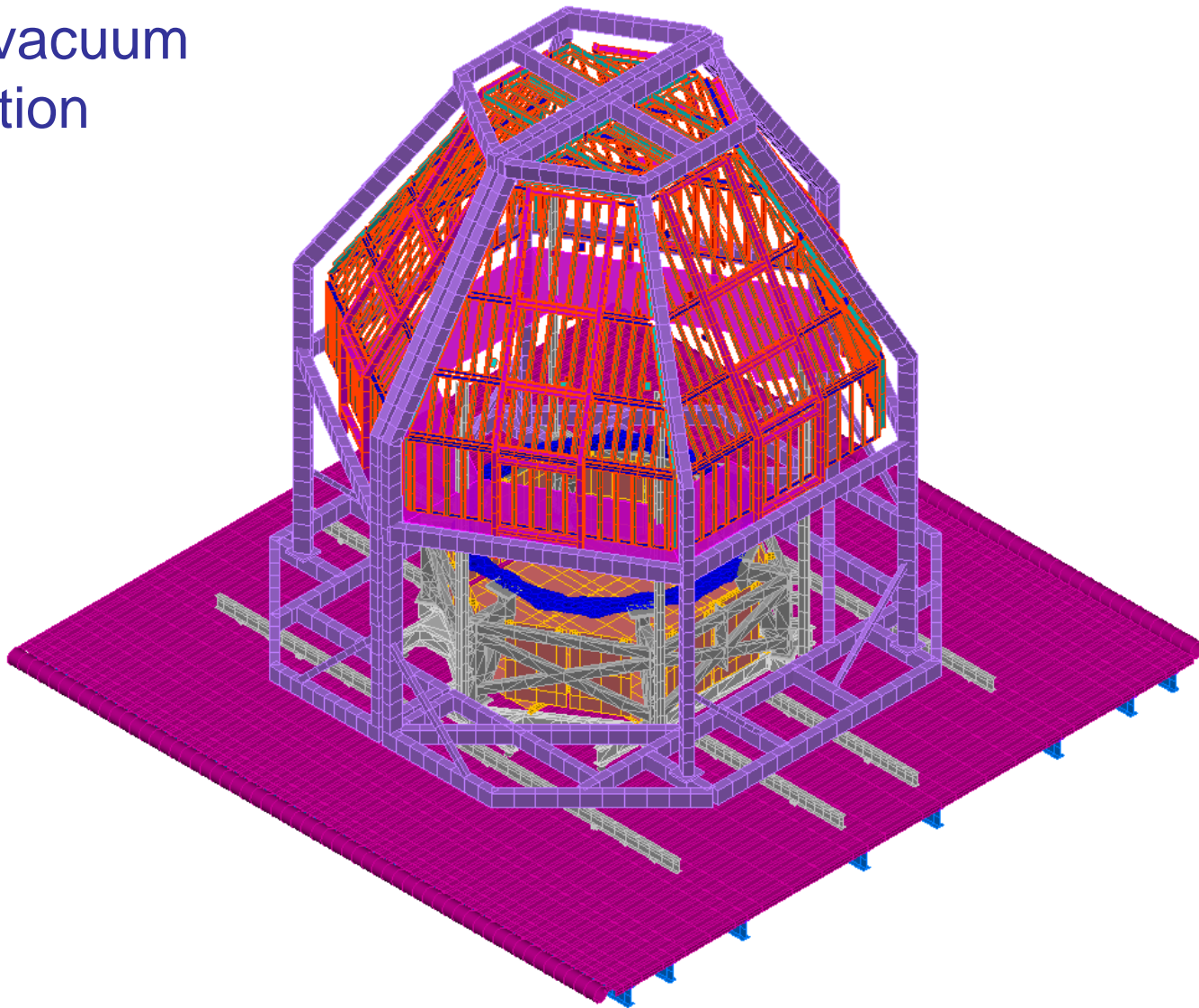
## Flat Beam Interface (FBI) and Cryofloor Interface Adapter (CIA)





# Model Description

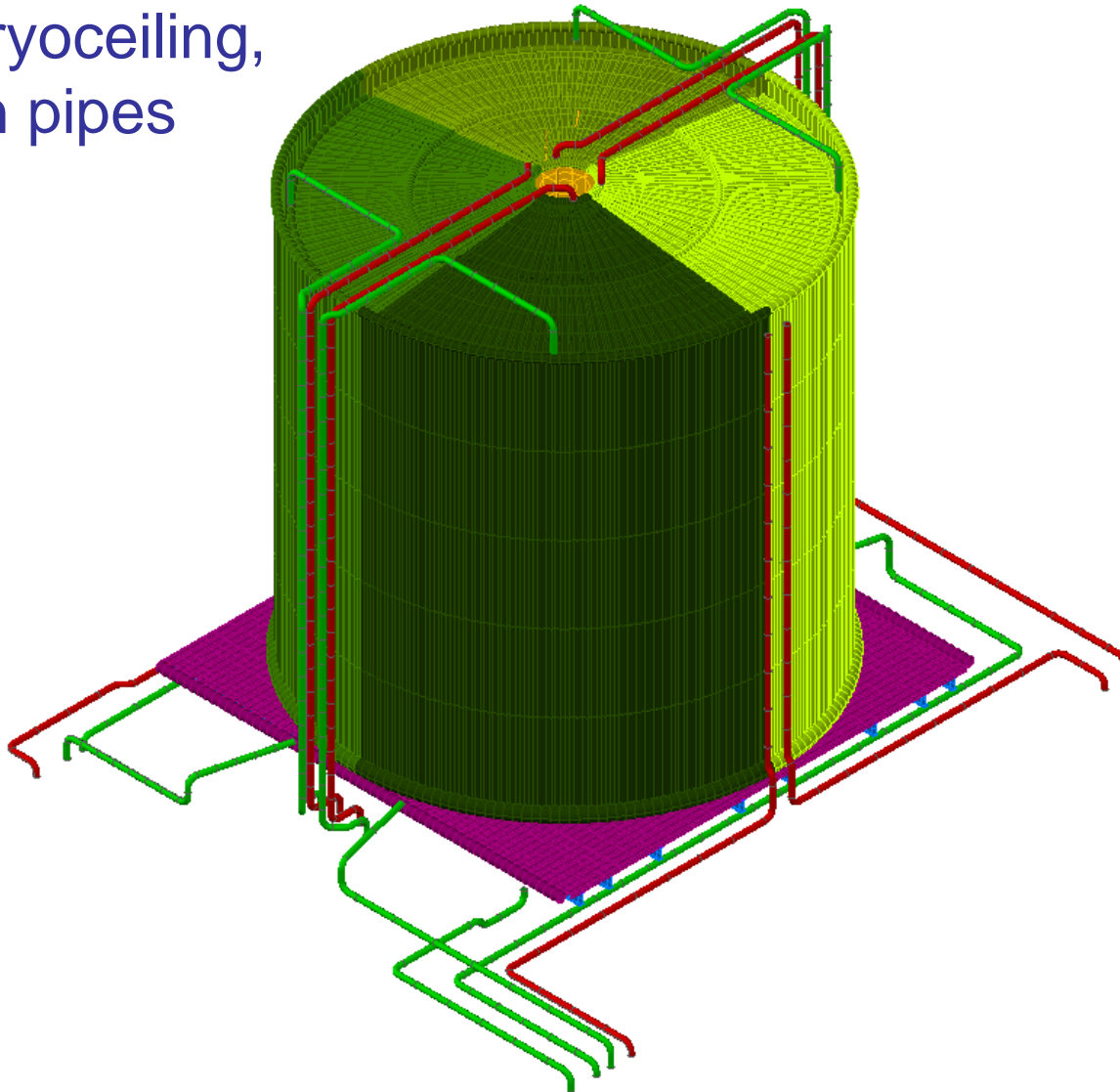
## Thermal vacuum configuration



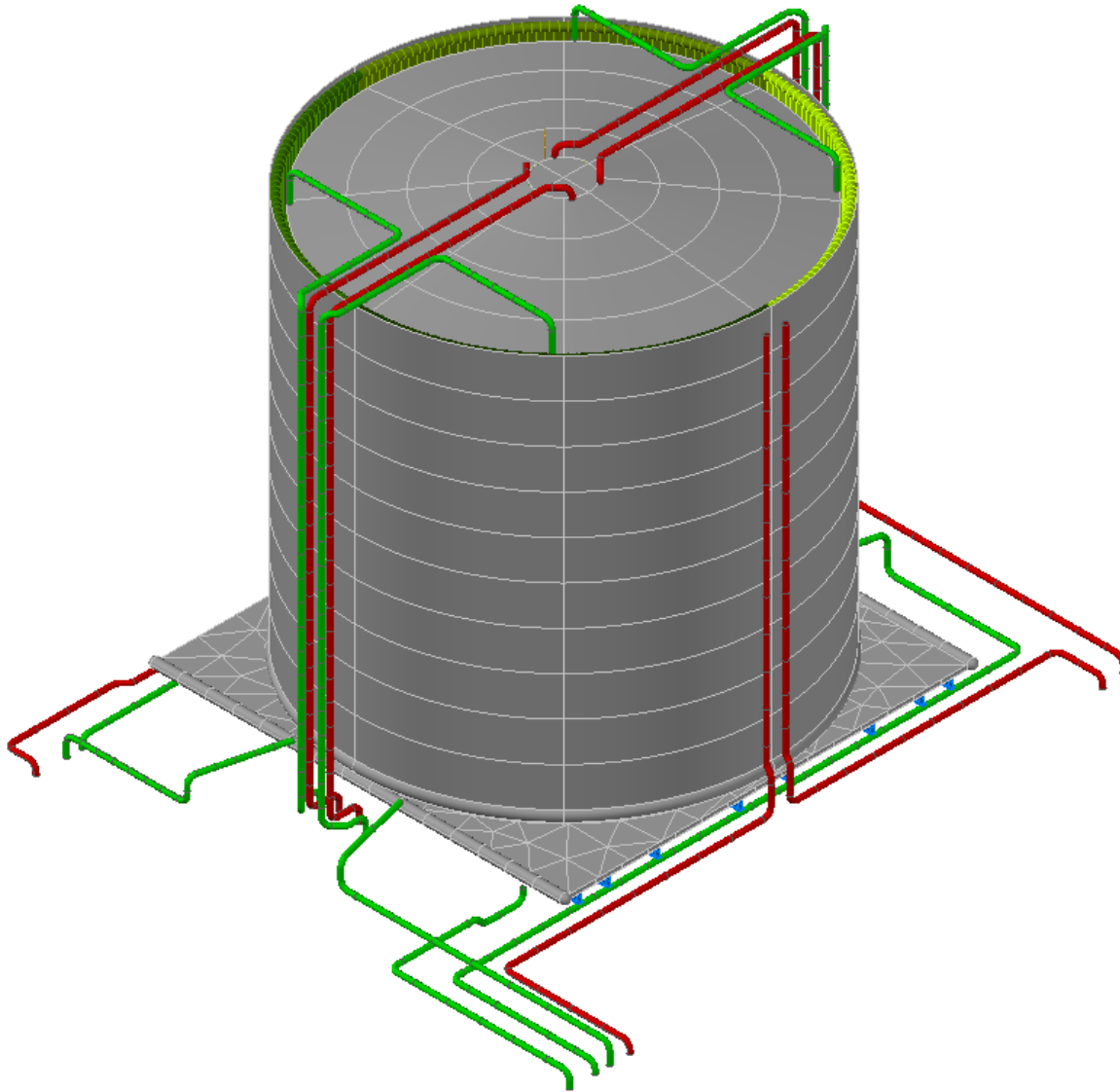


# Model Description

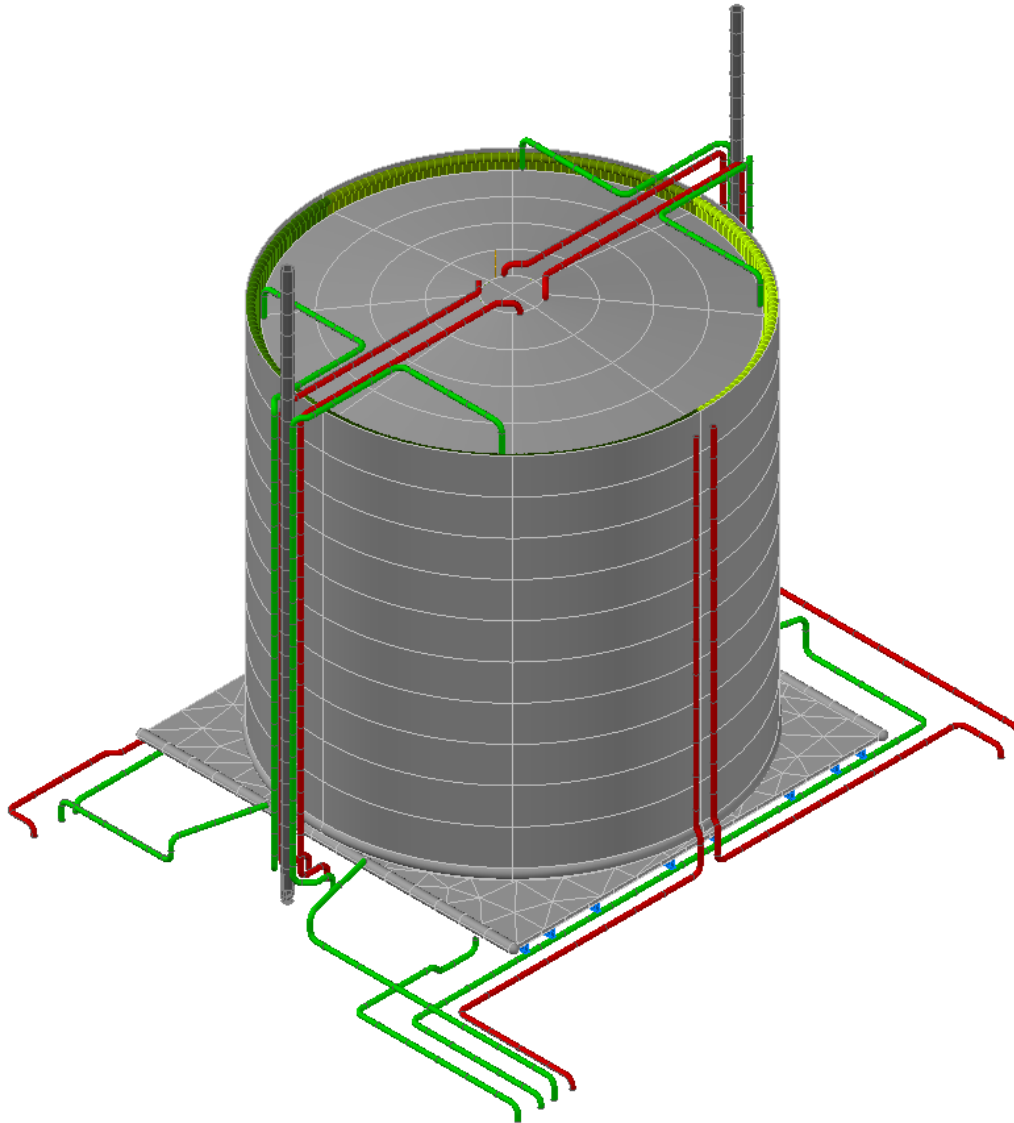
Crywalls, cryoceiling,  
supply/return pipes



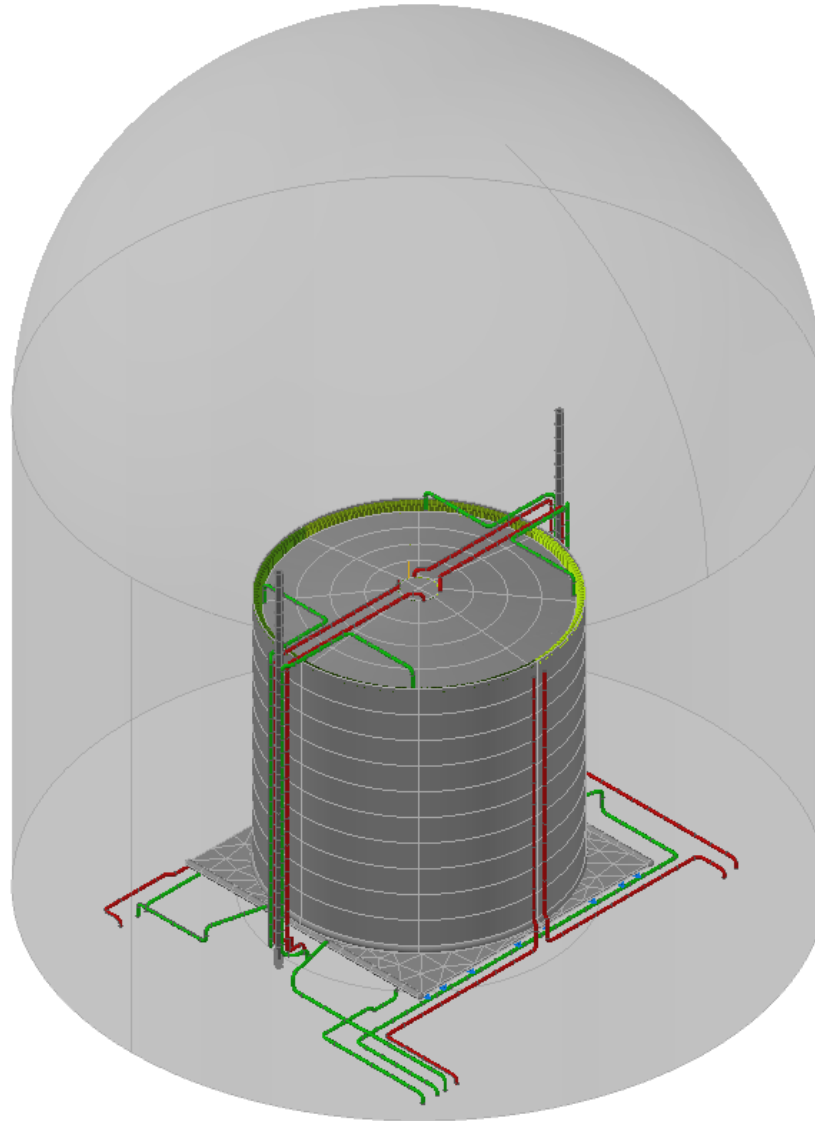
## Insulation



## Masts



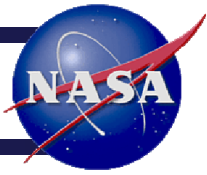
## Vacuum chamber



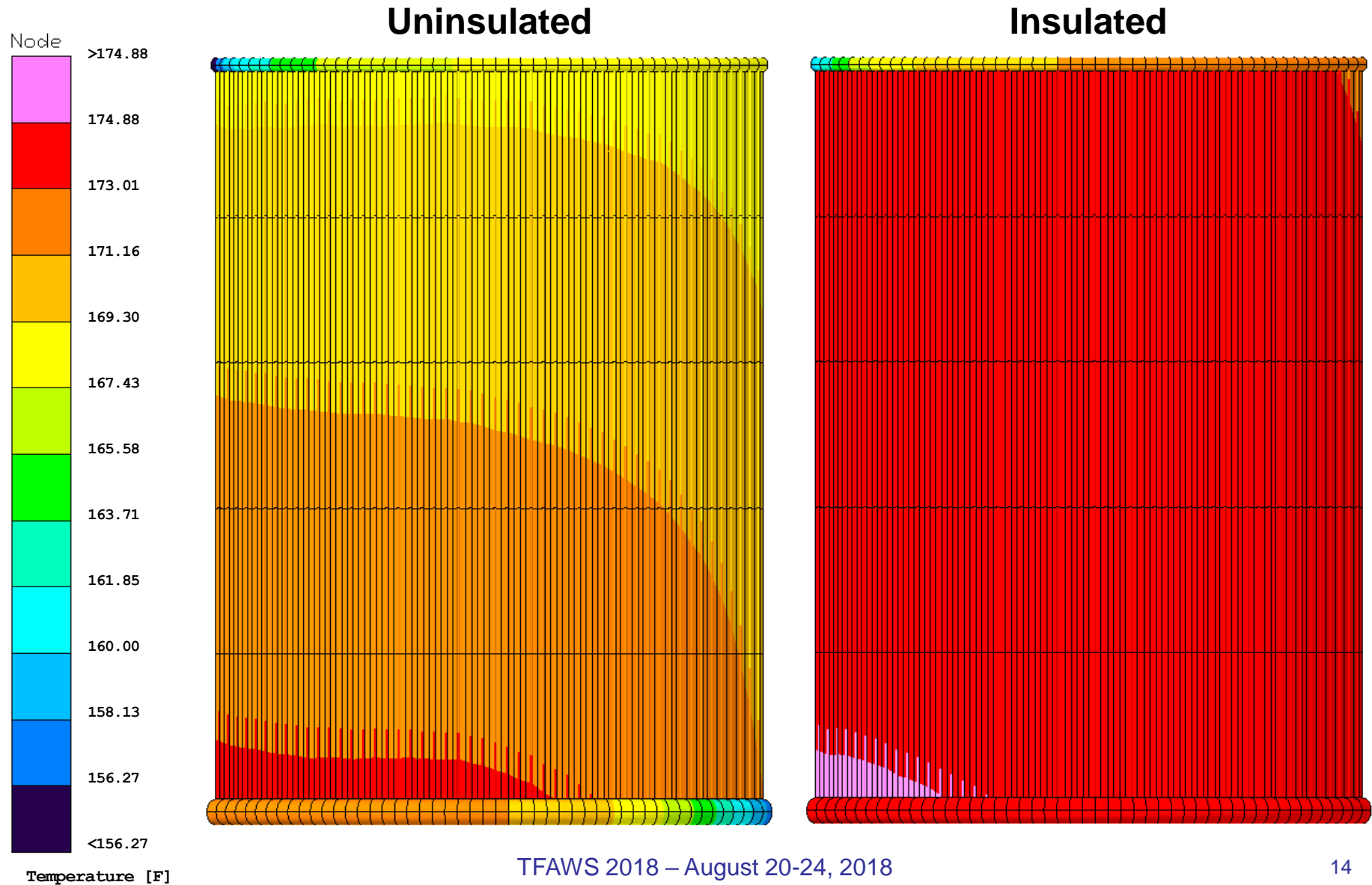




# Integrated System Tests



- Two ISTs performed with no MGSE inside the cryoshroud
  - Insulated test: operated at 170 °F for 37 hours
  - Uninsulated test: operated at 170 °F for 14 days
- Only cryoshroud thermocouples were installed



Node  
>174.87

174.87

172.33

169.77

167.23

164.68

162.14

159.58

157.05

154.49

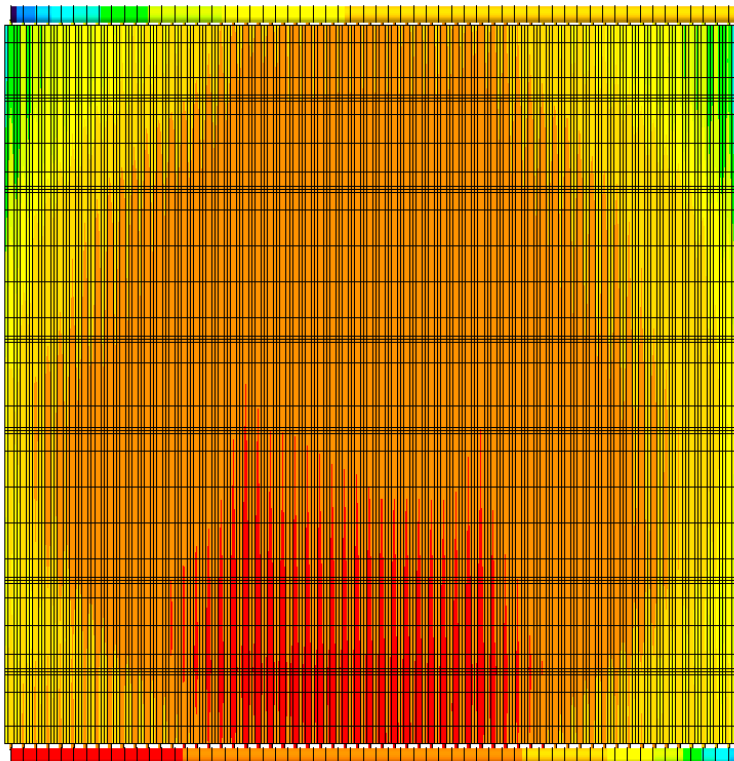
151.95

149.40

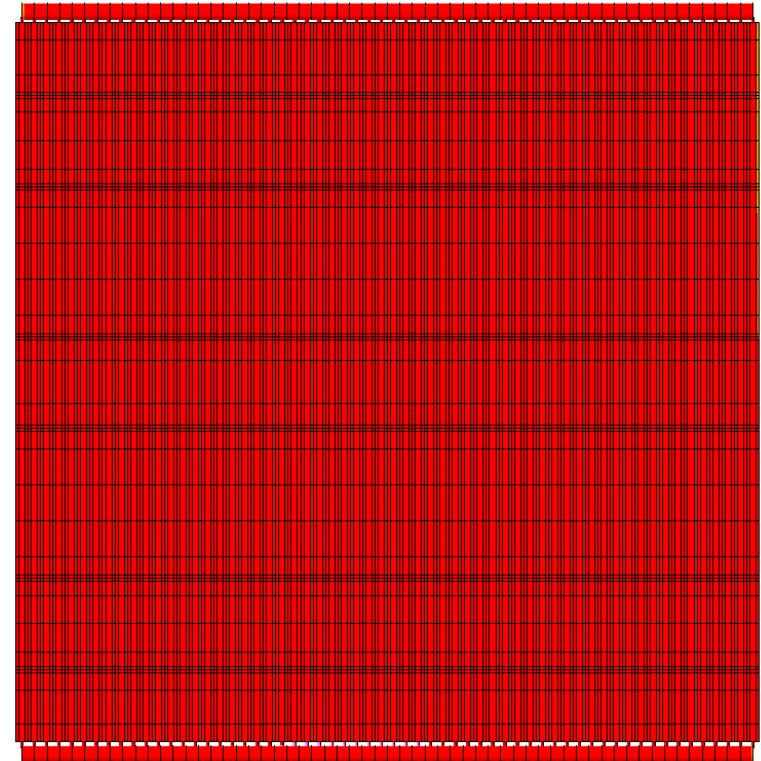
<149.40

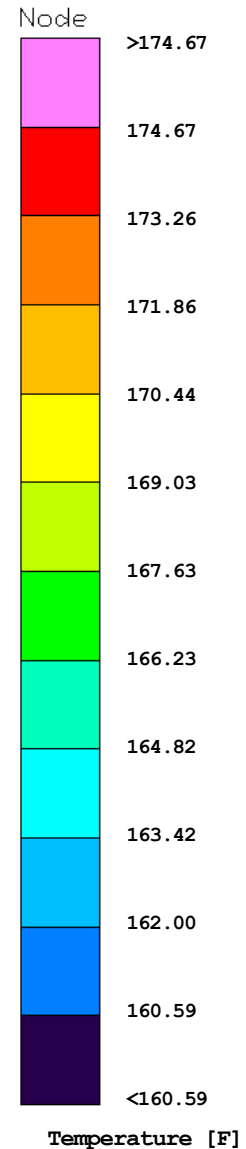
Temperature [F]

## Uninsulated

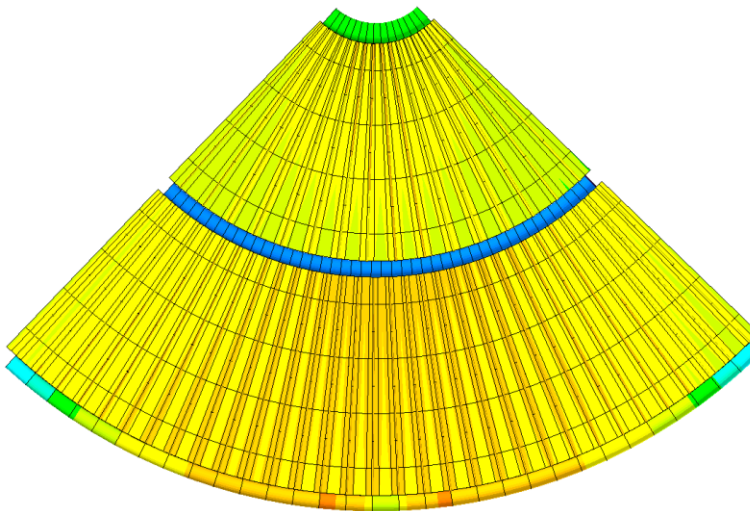


## Insulated

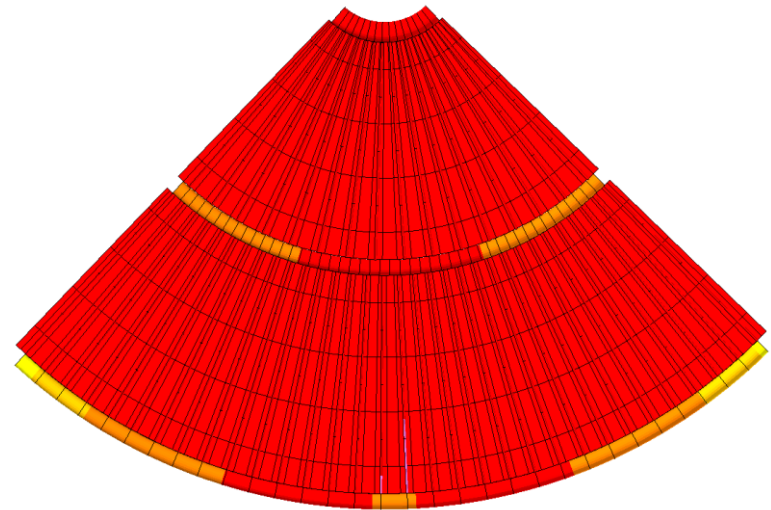




**Uninsulated**



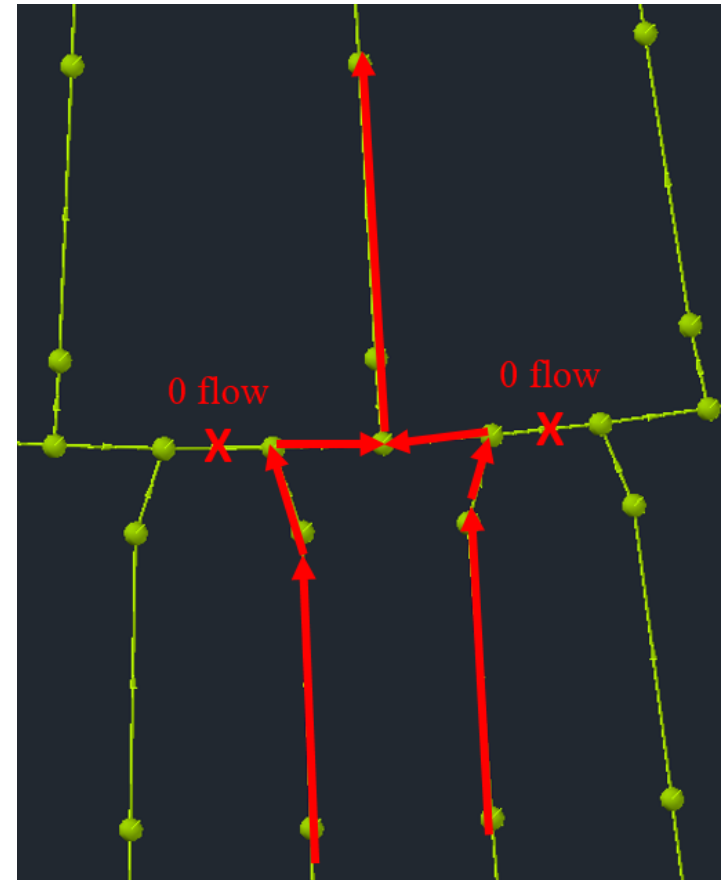
**Insulated**





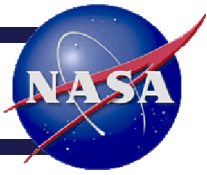
- Generally good agreement between model and test data except cryoceiling intermediate header
- Model predicted large regions of zero flow
- Adding 5x multiplier to heat transfer coefficient resulted in much better agreement

	Insulated IST	Uninsulated IST
Average Error (°F)	0.3	0.6
RMS Error (°F)	1.1	3.7





# Bake-out Test



- Bake-out was performed to collect data on chamber cleanliness, pressure environments, and operations
- Consisted of several hot and cold plateaus
- Correlating from data at -263 °F for 3 days
- Only FBI and CIA inside cryoshroud
- Correlation approach:
  1. Reevaluate cryoshroud predictions
  2. Adjust contact conductances for MGSE inside and in contact with cryoshroud (FBI, CIA, CTC)
  3. Adjust insulation and contact conductances for MGSE outside cryoshroud (masts)

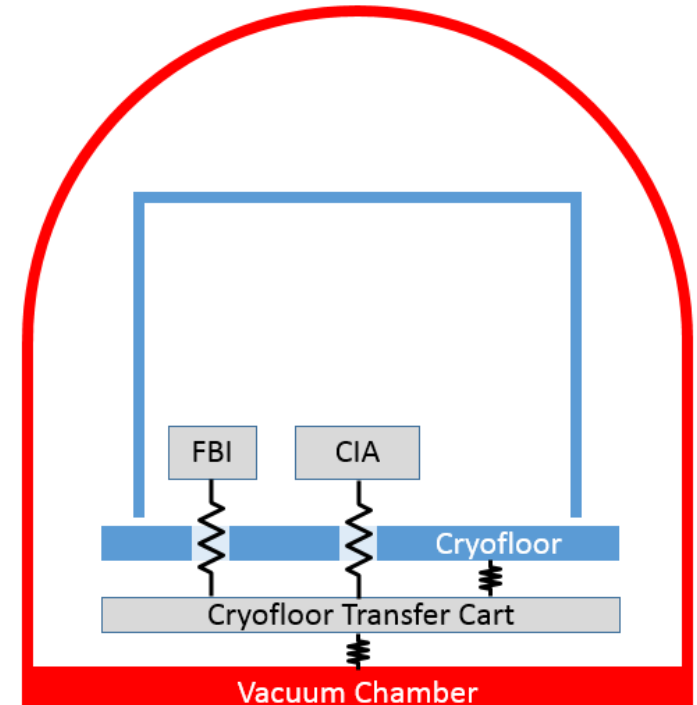


# Bake-out Correlation



- Reevaluating cryoshroud predictions:
  - 81 thermocouples on cryoshroud
  - RMS error = 1.6 °F
- Still acceptable, no changes needed

- Adjusting contact conductances between:
  - FBI and CTC
  - CIA and CTC
  - Cryofloor and CTC (via isolators)
  - CTC and chamber floor (via dollies and wheels)
- Utilized SINDA/FLUINT optimization algorithms
  - Seeking values of the 4 contact conductances that minimize the RMS error for the 12 thermocouples on these structures
  - Converged in 43 iterations
  - RMS error = 5.3 °F





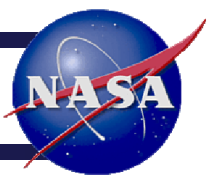
# Bake-out Correlation

- Uncorrelated model predicted warmer temperature outside the shroud
  - Increasing insulation emissivity had little effect
  - As-installed photos showed considerable contact between insulation and cryoshroud
- Utilized SINDA/FLUINT optimization algorithms
  - Adjustable parameters of contact conductance between
    - Insulation and cryoshroud
    - Masts and chamber floor
  - Minimizing RMS error for 3 thermocouples (2 on mast, 1 “floating”)
  - RMS error = 5.0 °F





# Bake-out Correlation



- Overall, model is well correlated
- Potential source of error is the assumption that contact between large surfaces is uniform, e.g. insulation and cryoshroud, cryofloor and CTC

	Cryoshroud (81 TCs)	Interior (12 TCs)	Exterior (3 TCs)	Total (96 TCs)
<b>Average Error (°F)</b>	-0.9	0.1	4.7	<b>-0.3</b>
<b>RMS Error (°F)</b>	1.6	5.3	5.0	<b>2.6</b>



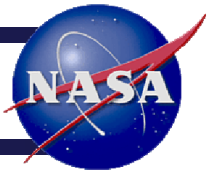
# Summary



- Model is well correlated, RMS error = 2.6 °F
- Using SINDA/FLUINT optimization algorithms is an effective way to do model correlation
- Future work
  - Transient correlation with bake-out data
  - Integration with vehicle model and facility FLUINT model



# Acknowledgements



Thanks to the thermal team at NASA GRC and Plum Brook: Jim Yuko, Barbara Sakowski, Jarred Wilhite, Henry Speier, and Erin Reed. Thanks to Justin Elchert and Katie Oriti who developed earlier versions of this model.

## Questions?