Subscale Cryo-thermal Tests of a Large 4 K Telescpoe

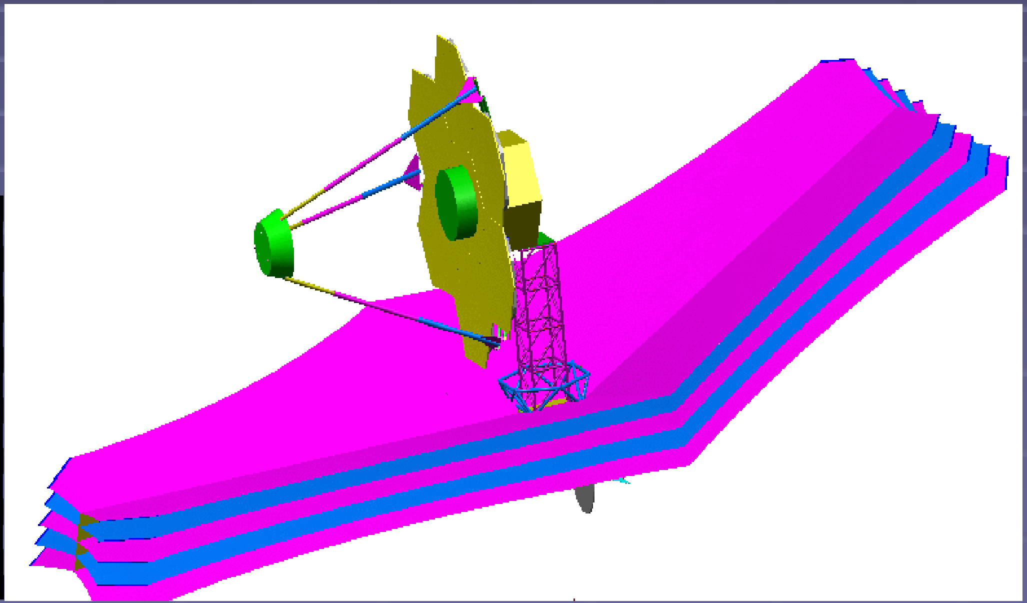
M. DiPirro, J. Tuttle, A. Mattern, S. Ollendorf, D. Leisawitz, M. Jackson, J. Francis, J. Bichell, and T. Hait

NASA/GSFC

New Paradigm in Cooling Telescopes to < 20 K

- Old method
  - Telescope is mounted in a dewar (60 cm IRAS (LHE), 40 cm WIRE and WISE (LH_2))
- Spitzer is transition to new method
  - Warm telescope (85 cm) at launch cooled by passive radiation and LHe gas
- New method
  - Passive cooling by V-groove radiators (sunshield)
  - Active cooling to low T by mechanical coolers

Spitzer to SAFIR



Open Geometry Presents Thermal Test Challenges

- Dewar had its own, known boundary (vacuum shell)
- Sunshield/V-groove radiators have open geometry with sun and deep space boundaries
  - Shield layers made of thin double aluminized kapton
  - Simulation in thermal/vacuum chamber
    - Thermal radiation from warm areas is factor of 10^6 larger than parasitics on cold areas
    - Wall reflections can easily exceed this
    - Spitzer test results nearly a factor of 10 larger than on orbit

Goals of Subscale Testing

- Design subscale test item and test chamber that preserves key thermal elements of the full scale model (warm spacecraft plus cold optics) in space
- Model the test item in T/V chamber
- Test the test item in chamber
- Verify the model
- Verify that model prediction in space is not significantly different than in T/V chamber
- Iterate as necessary

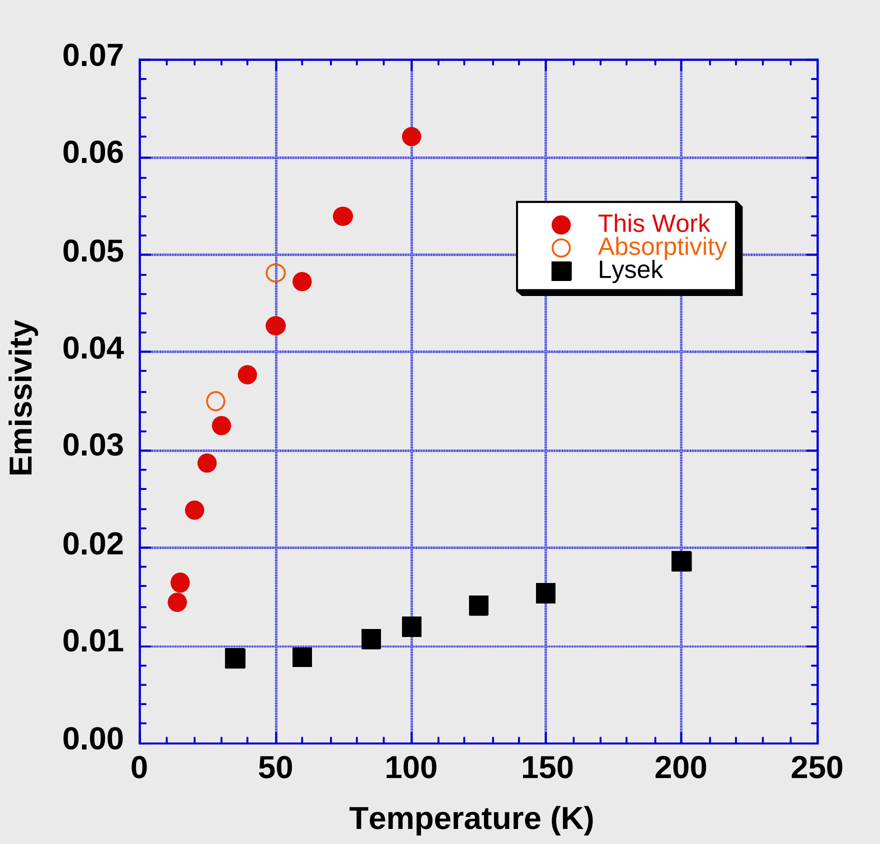
Proper "Fencing" Required

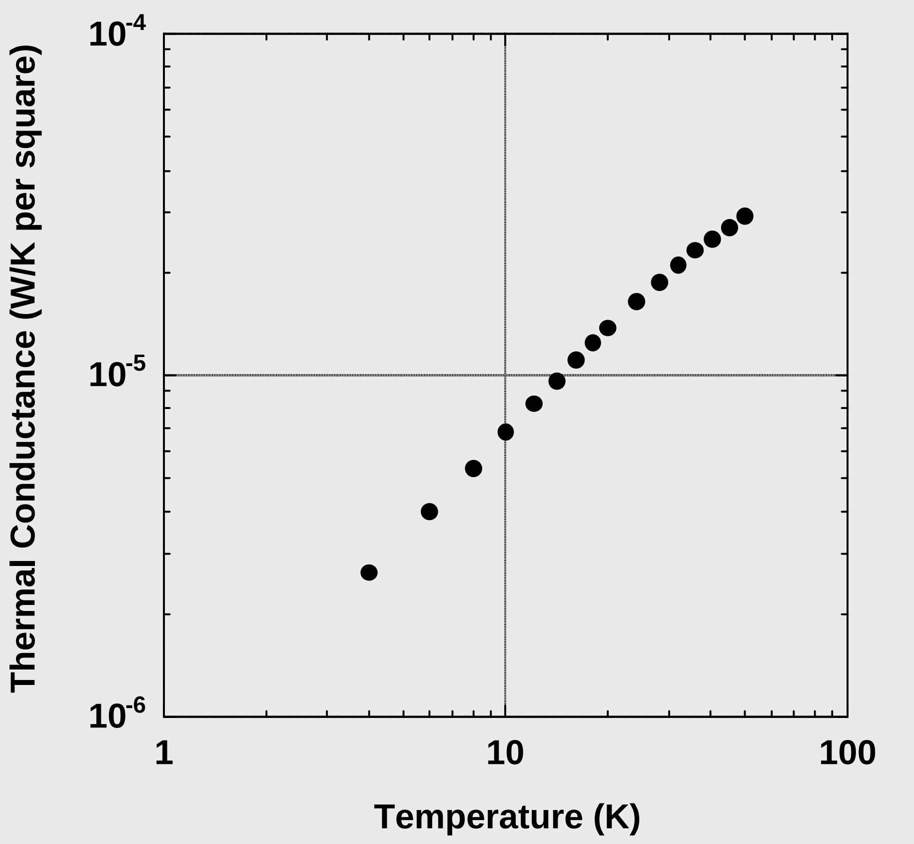
- Enclose in LHe shield only those parts at lowest T
  - Keep heat load into LHe shroud reasonable (W instead of kW)
  - Careful close outs are required
    - Avoid conduction to shroud
    - Prevent radiation from warmer area from entering

Accurate Thermal Modeling Required

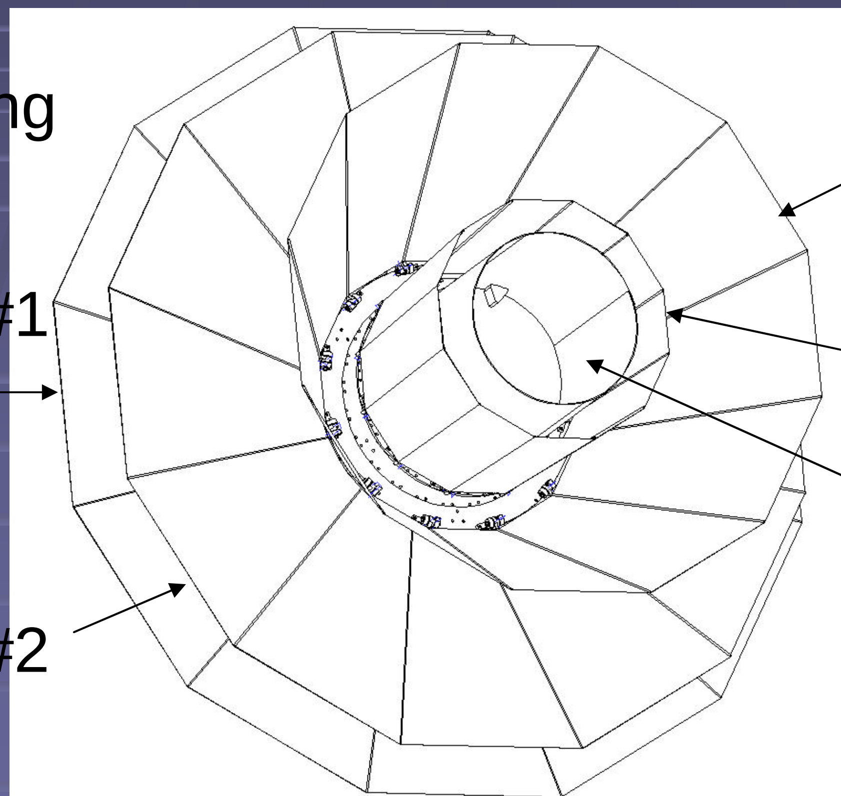
- Must have well known thermal properties
  - Double Aluminized Kapton (DAK) emissivity and conductivity at low T
- Understand shape effects
  - Wrinkles and specularity
- Correctly model test chamber walls and close-outs

DAK Emissivity and Conductivity





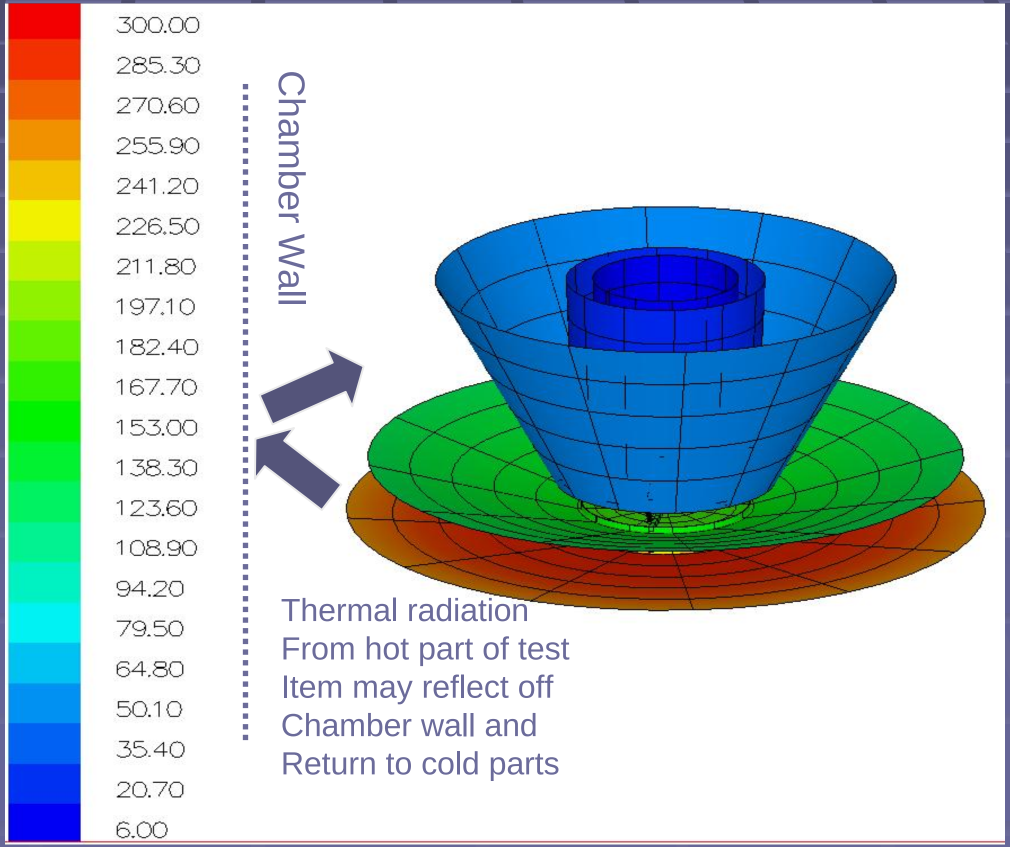
Subscale SPIRIT Test Article



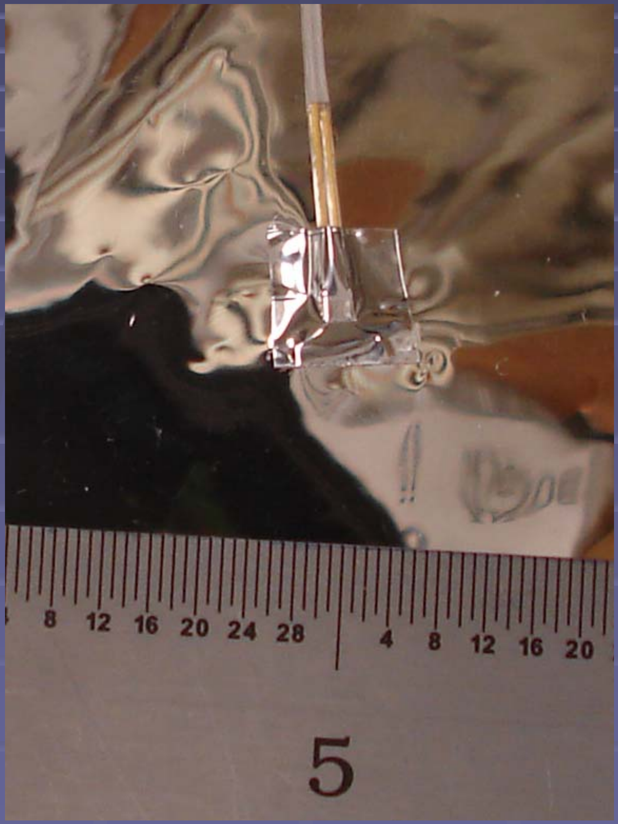
Thermal Prediction of Test Article in Chamber vs. Space

At this point there is little change from chamber effects

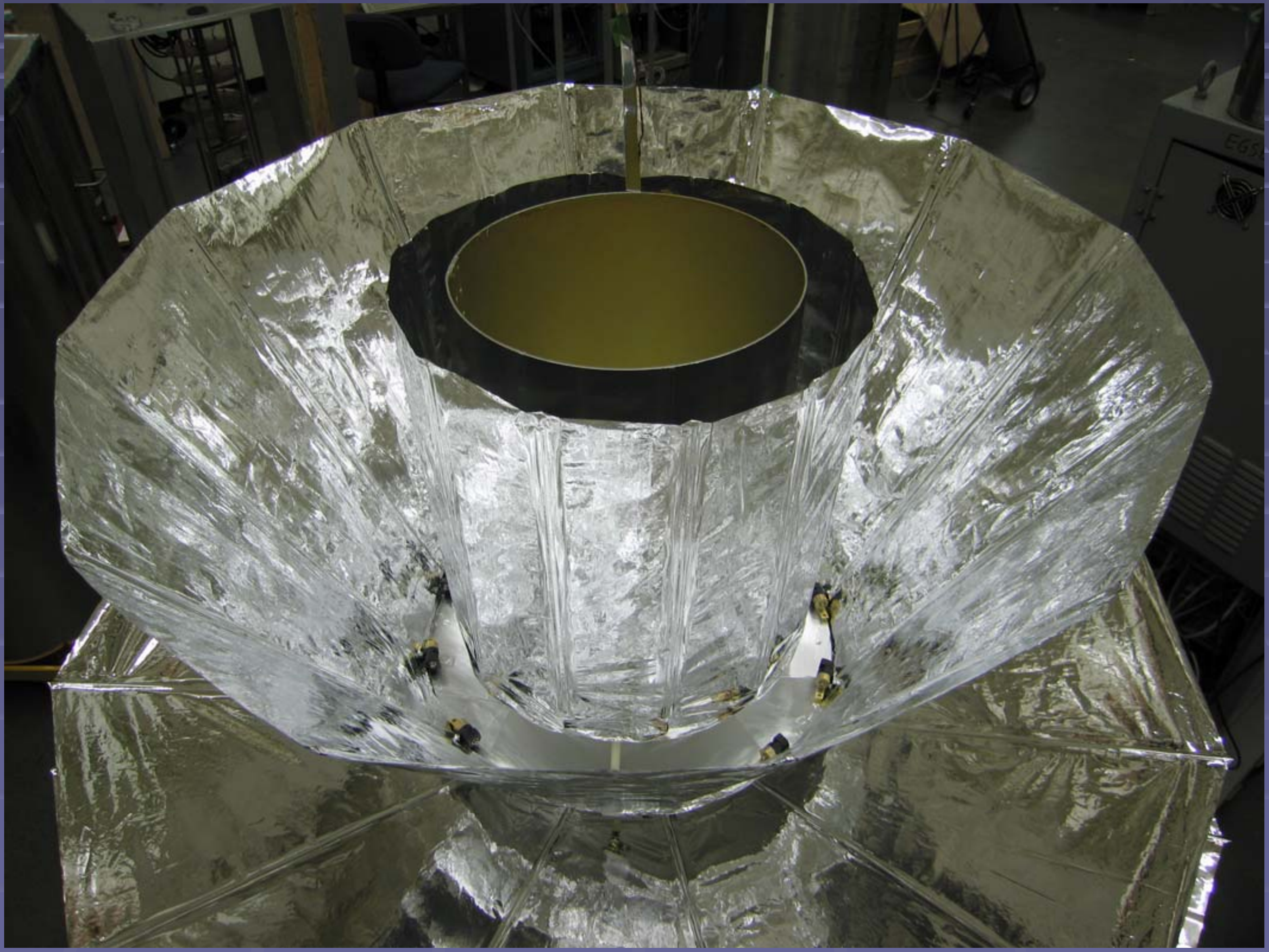
This will be proven only when test is complete



Thermometer Mounted on Shield



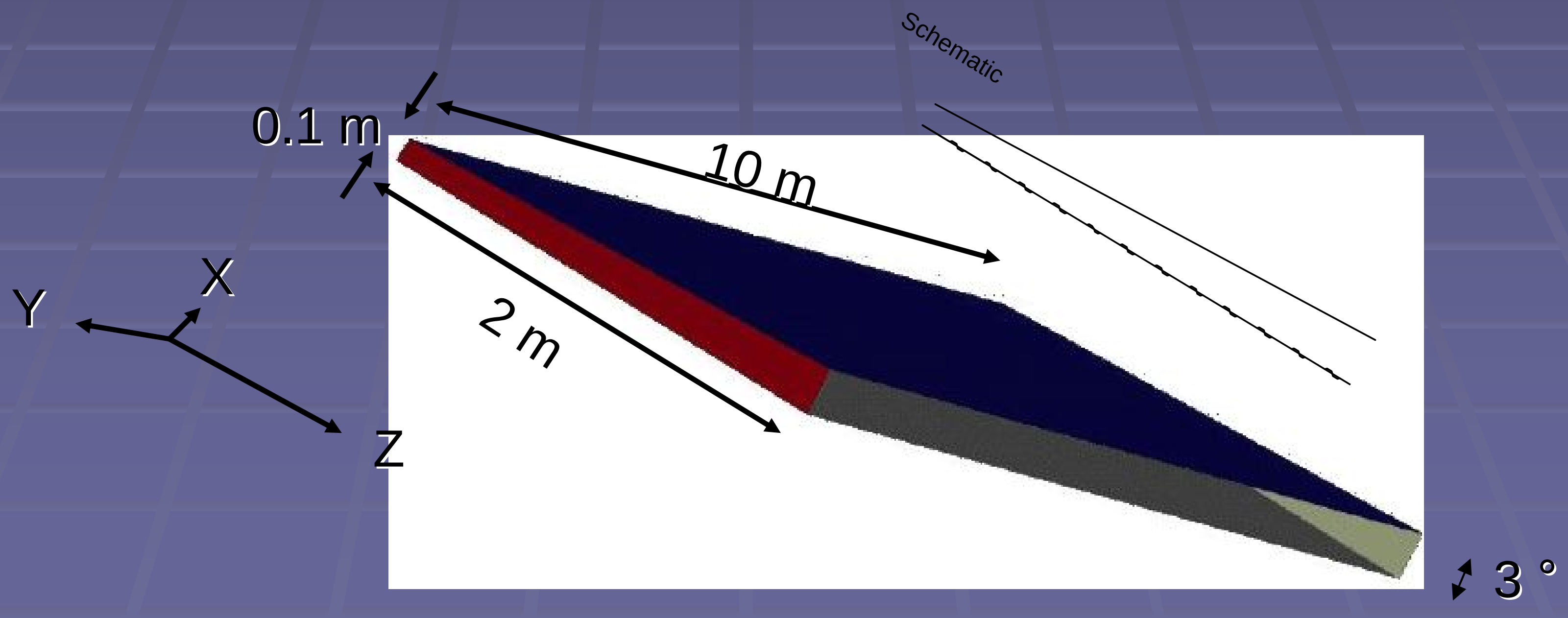
Real Surfaces



Wrinkle Study Geometry

Two 2 meter x 10 meter flats separated by 0.1 meter at one end and angled 3° to each other.

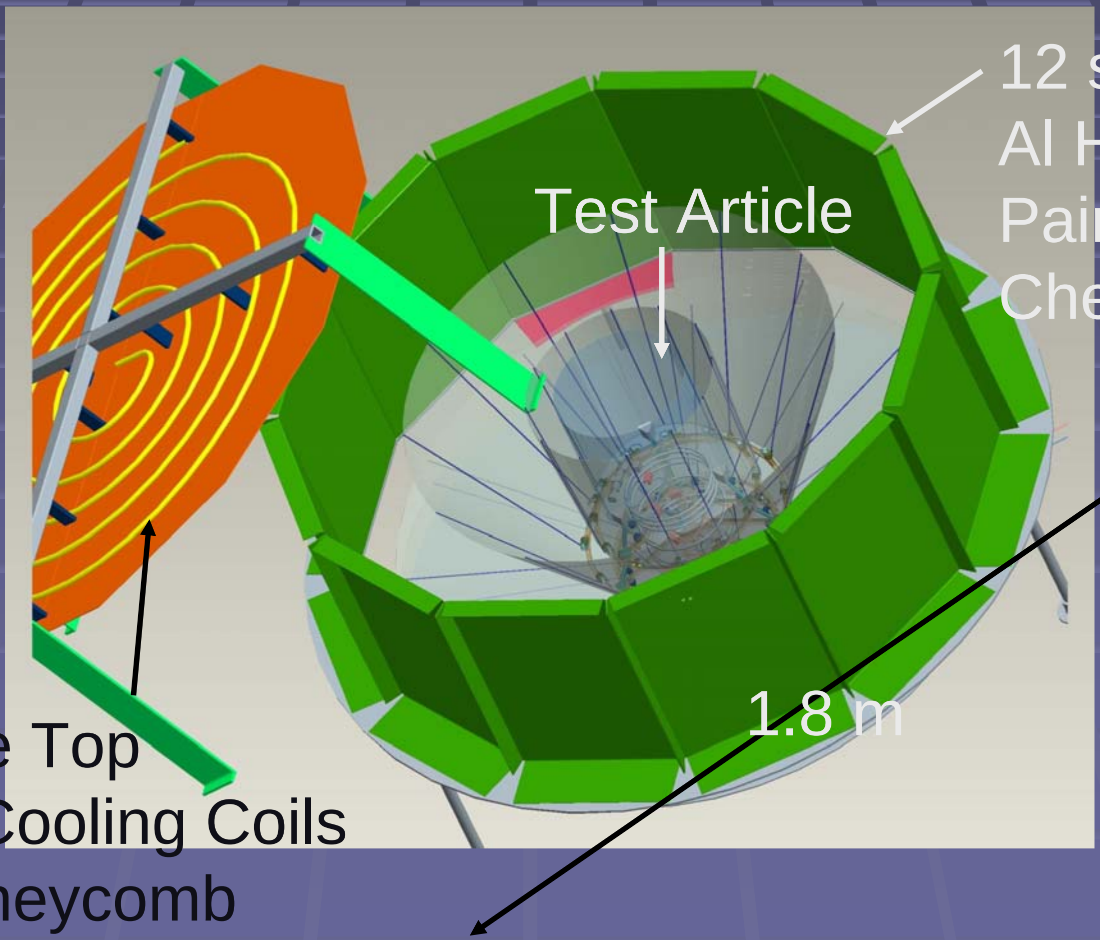
- Long sides are open to space (Closest approach side changed to reflective)
- Short sides are either open or reflective
- One side held at 18 K and one side held at 50 K, emissivity = 0.01, specular
- Wrinkles applied to one side



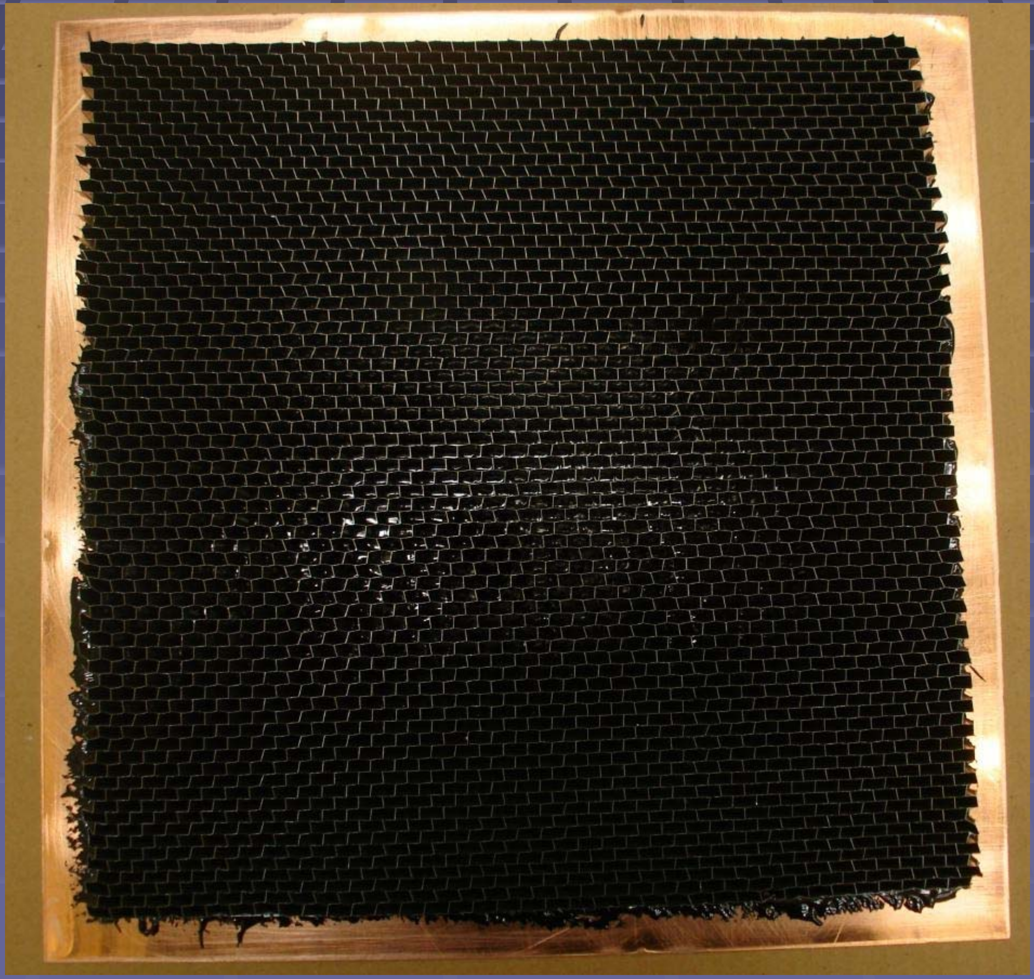
Wrinkle Study Summary

- Wrinkles tested depend less on shape and more on amplitude and density
- Wrinkles that are a substantial fraction of the separation have factors of 2-ish effect on 18 K heat load
- Wrinkles that are less than 10% of sheet spacing seem to affect heat load proportionally to their area coverage - i.e., proportionally smaller amplitude but same wrinkle area gives same heat load
- Appears to be a cosine effect on direction of wrinkle
  - Wrinkles parallel to escaping radiation have almost no effect
- Wrinkling both sides increases heat load effect by 36% (not factor of 2)
  - Small difference between in-phase and out of phase
- Wrinkles toward the closed end have the biggest individual effect
  - Diffuse is factor of 3 higher heat load than specular
- Less than 0.2% change by increasing the number of nodes on a flat surface
- Our geometry will be less sensitive due to larger angles between shields

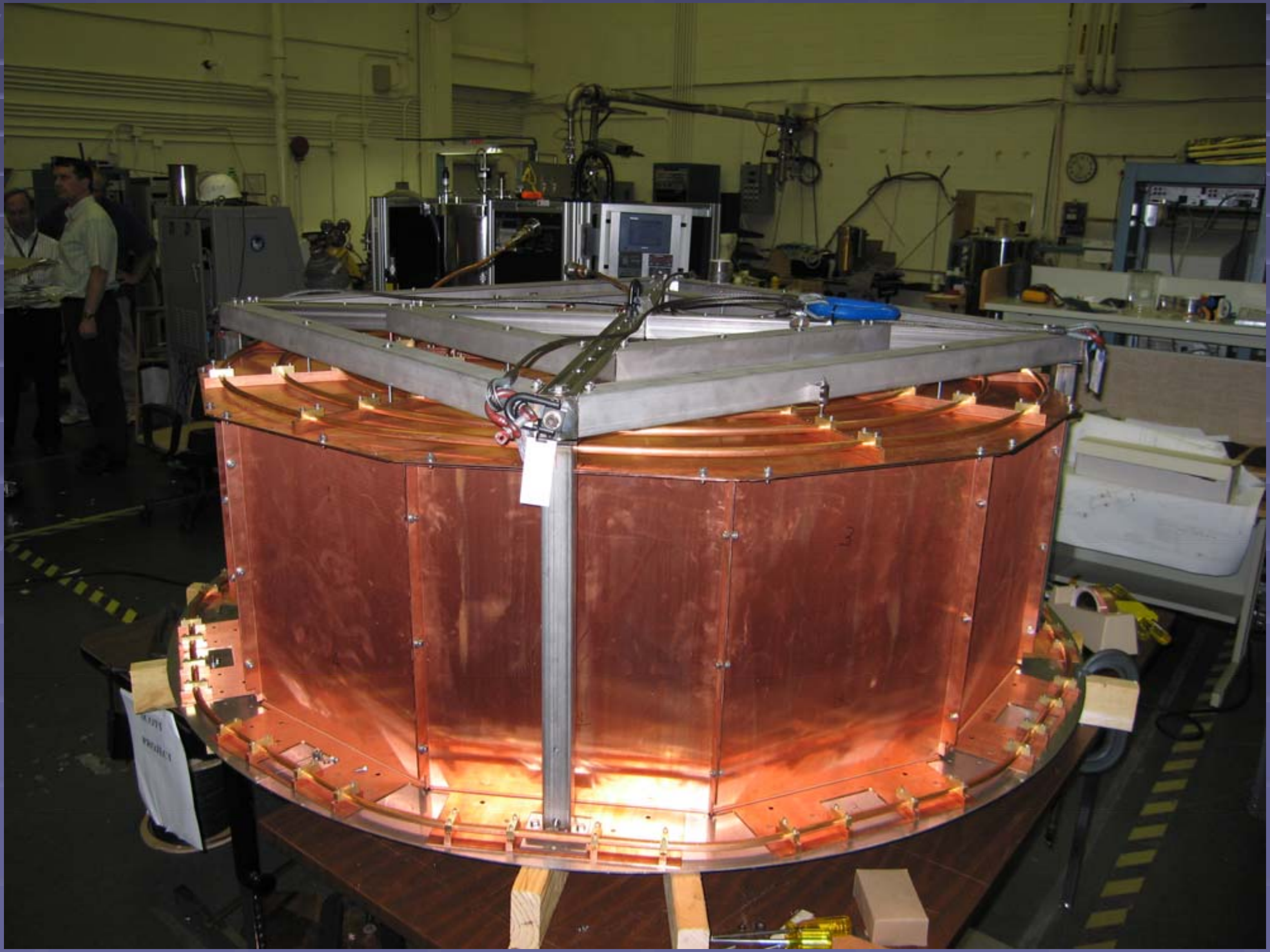
LHe Shroud Around Test Article



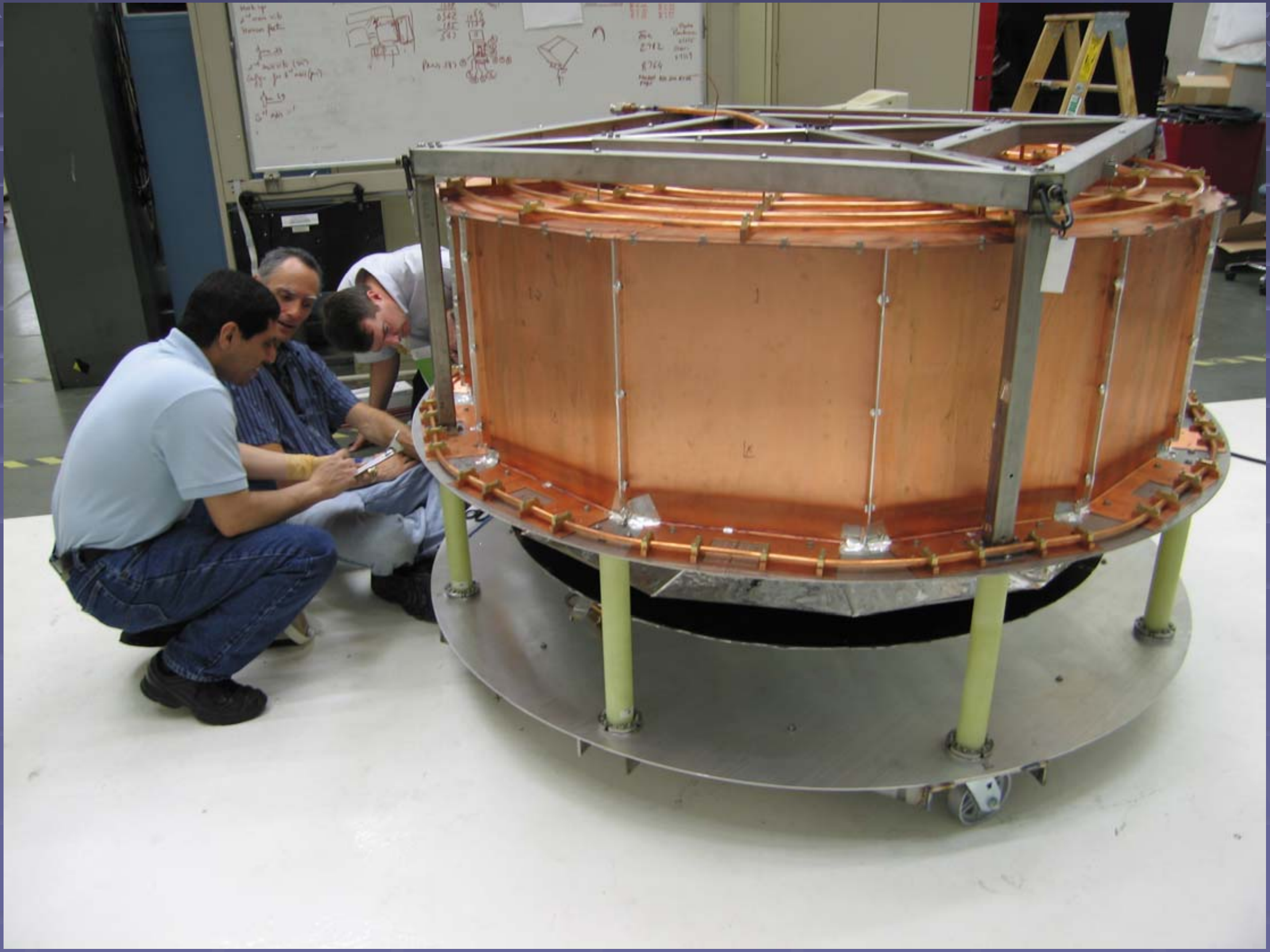
Al Honeycomb Makes a Very Black Surface



Before Outer Blanket



Fully Assembled



With External Blanket

Voila

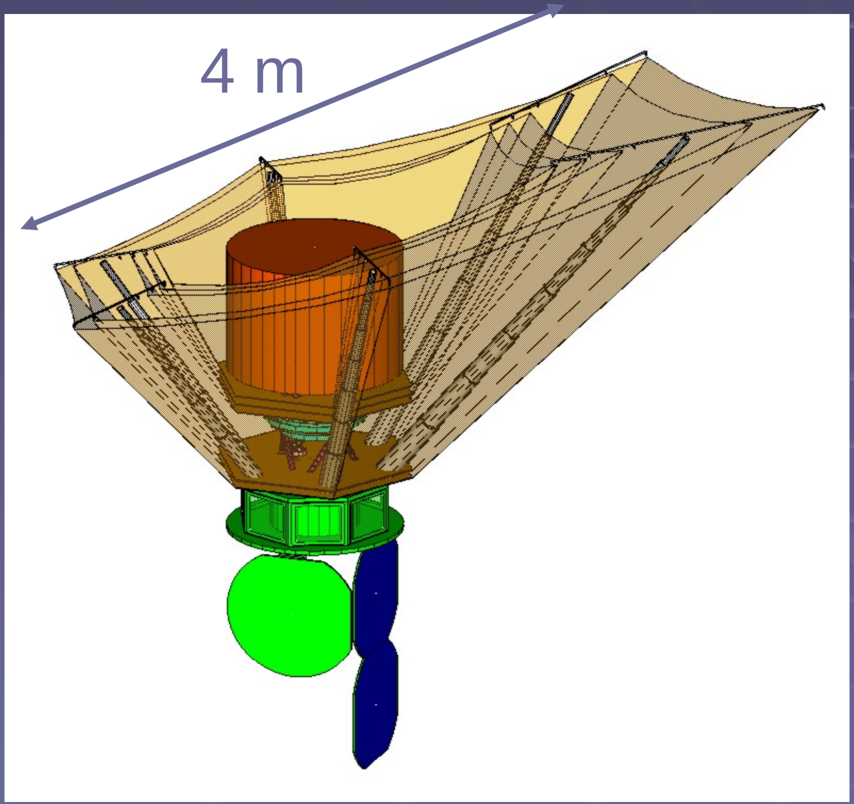
In Thermal Vacuum Chamber

Test Plan

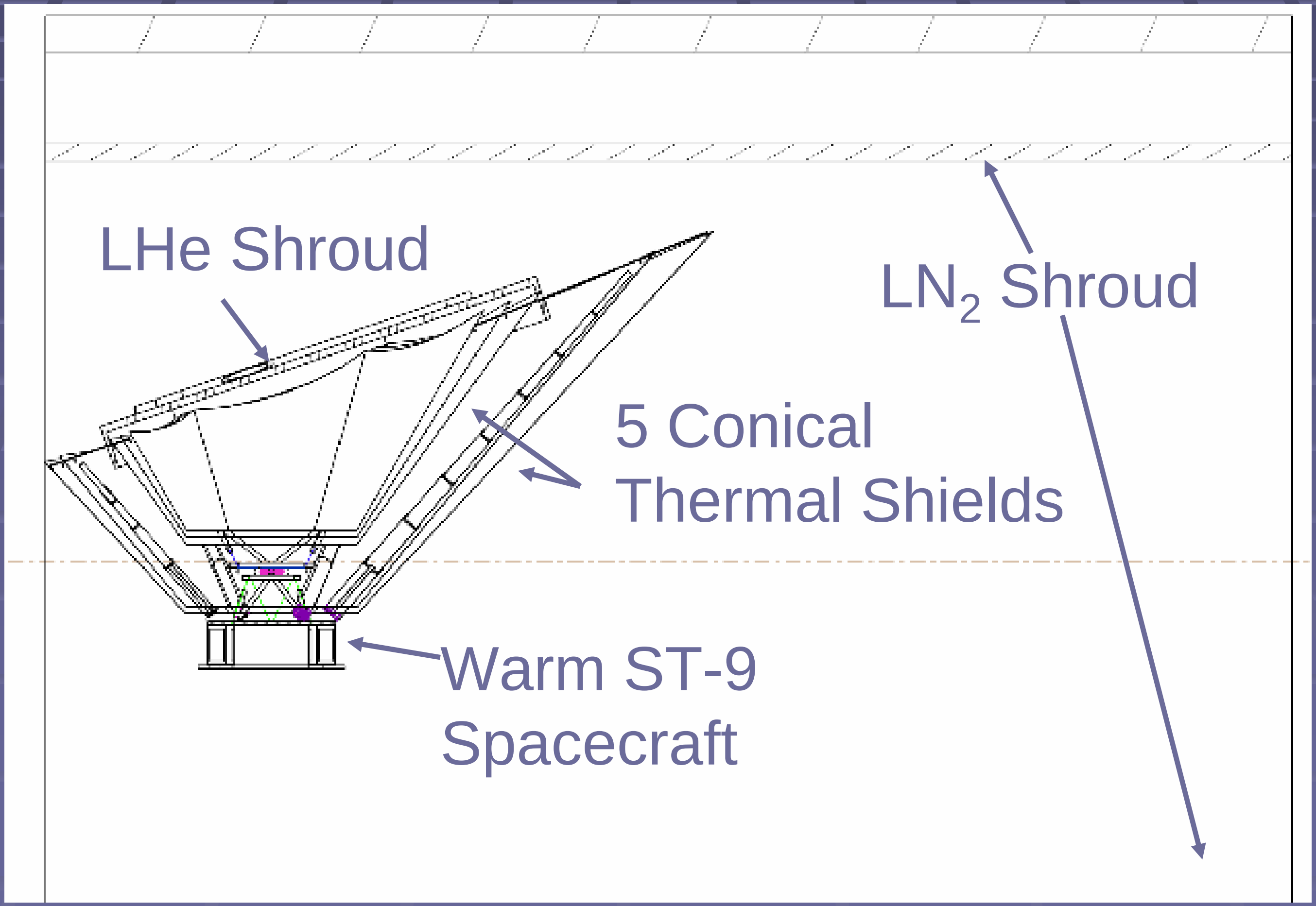
- Actively cooled stages simulated by temperature controlled straps to LHe shroud
  - Allows measurement of parasitic heat to each stage
- Heater plate & exposed kapton layer give low cost solar absorptance simulation
- Strategically located heaters will provide stimuli to verify thermal model
- Thermometers provide sensitive measurements even on DAK itself
- 80 K test will help direct future full scale tests
  - Will we be able to verify workmanship on the full scale version with an 80 K test only?

ST-9 Large Space Telescopes

- One of system technologies studied for possible flight in 2010
- ST-9 LST will test an actively cooled inner thermal shield to protect cold optics of a future 4 K large space telescope
  - Extends JWST from 90 K to 20 K
  - Extends Spitzer from fixed to lightweight deployable shields



1/2 Scale LST in Test Chamber



Summary

- We have designed, built and tested a subscale test article and shrouds to demonstrate the cryo-thermal design of a future large 4 K telescope
- If ST-9 LST moves forward to flight, this concept will be further proven in space