ORIGINS Space Telescope

Cooling the Origins Space Telescope

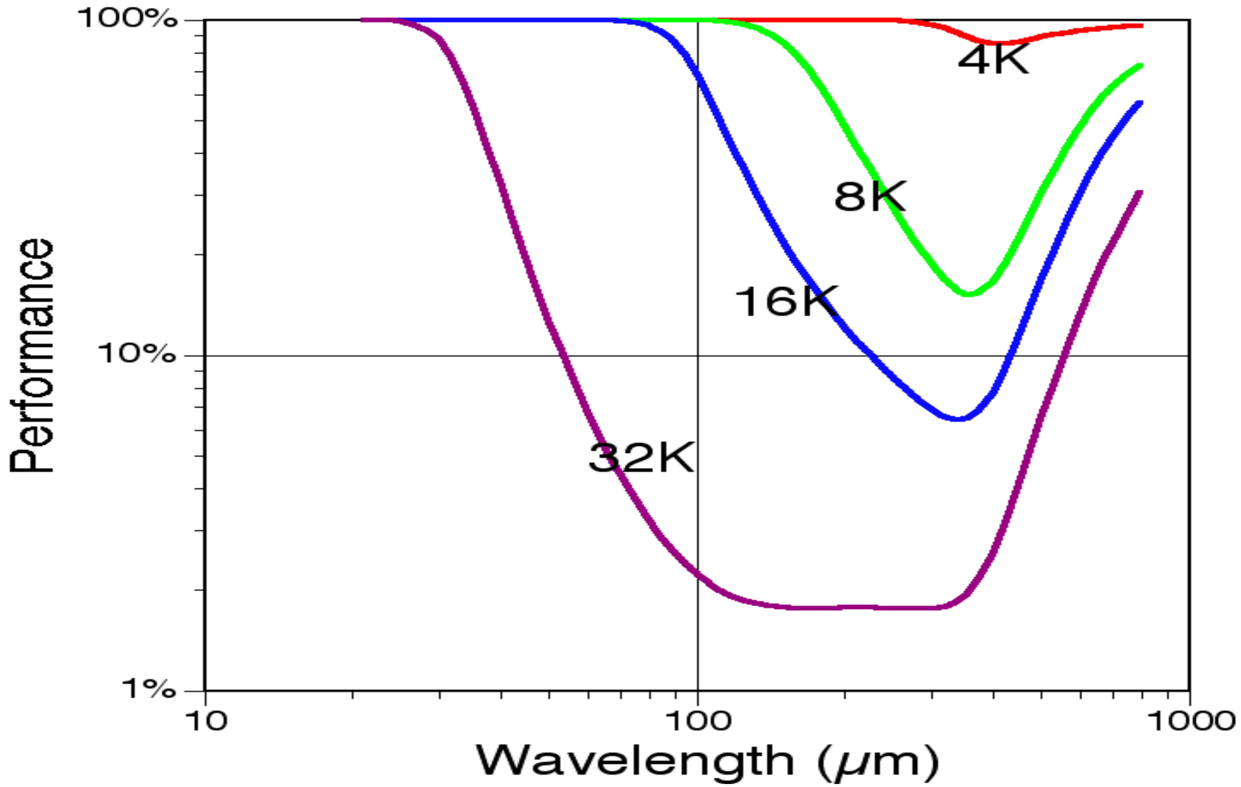
M. DiPirro, E. Canavan, L. Fantano
NASA/Goddard Space Flight Center

What is OST?

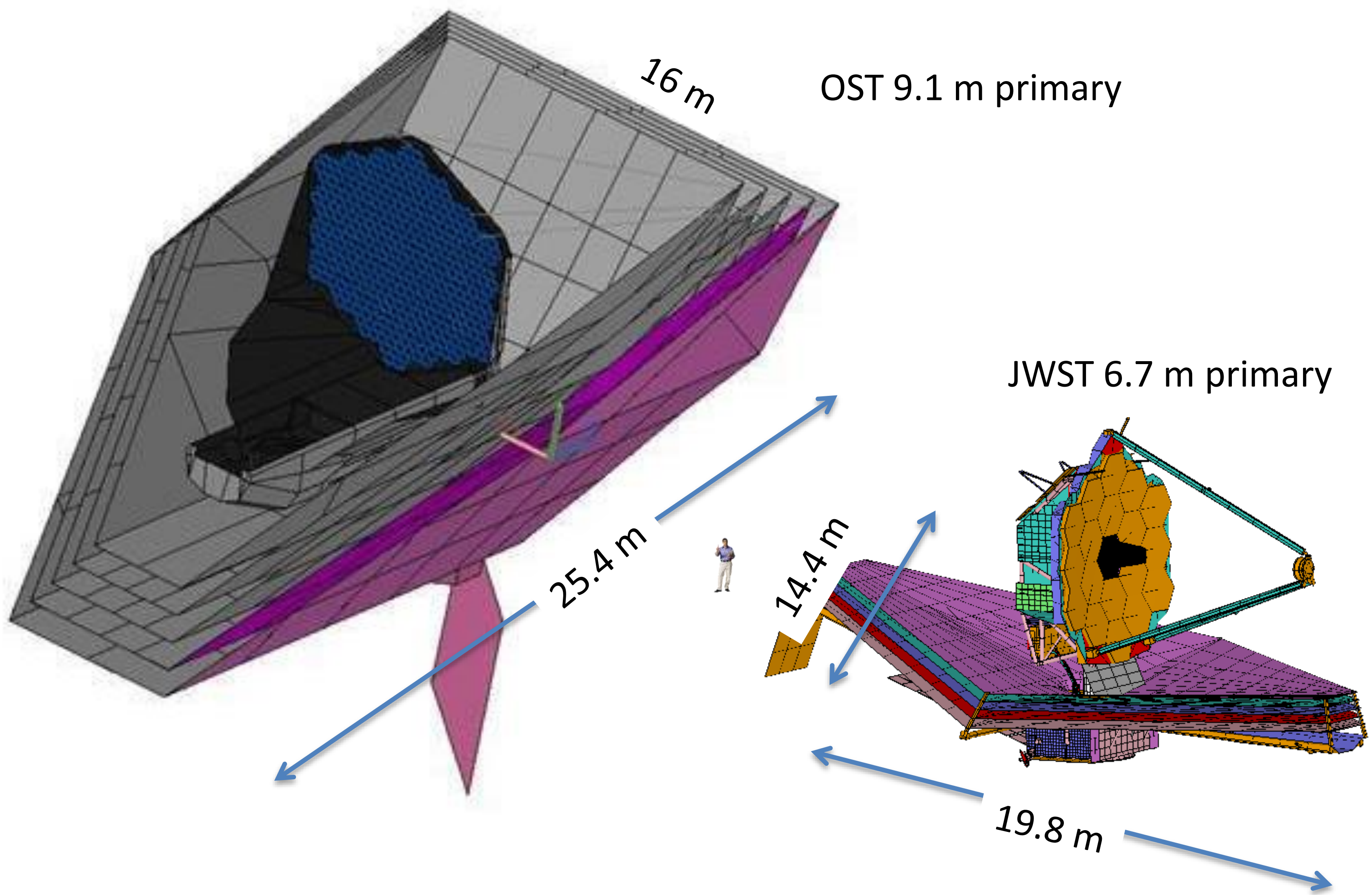
- NASA Headquarters Astrophysics Division commissioned 4 studies for one possible flagship mission to launch in the 2030's
  - Lynx (X-ray Surveyor)
  - LUVOIR (Large UV, Optical, and near InfraRed Observatory
  - HabEx (Habitable Exoplanet mission)
  - Origins Space Telescope (OST) (Far IR Surveyor)

Why Do We need a 4.0 K Telescope?

- OST will cover the wavelength range from 6 µm to 600 µm
  - The goal is to be background limited – limited by the cosmos rather than self emission from the telescope



How Big is This Thing?



One Question

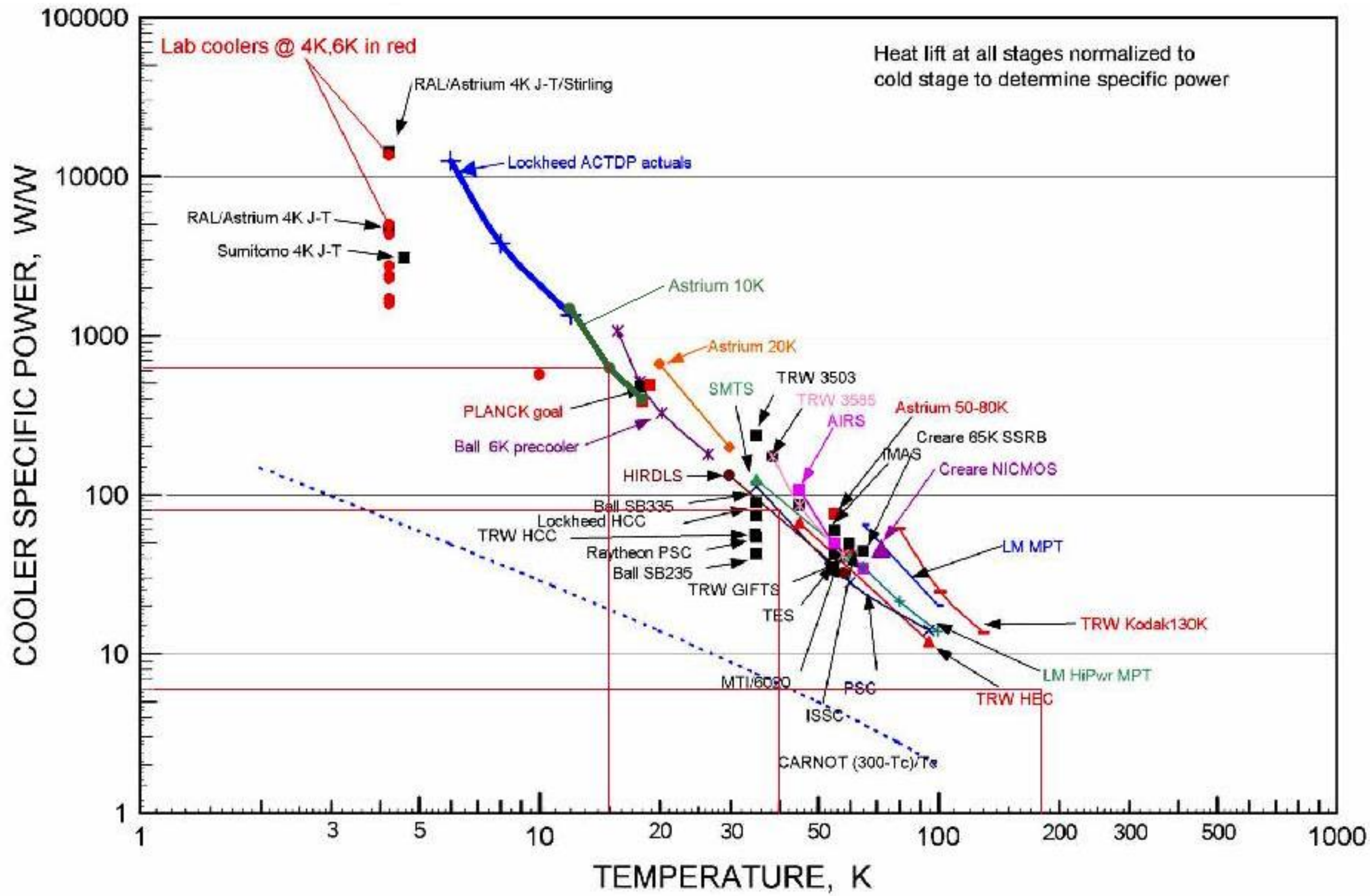
- How can we do a 9 m diameter 4 K telescope when a 6.7 m 40 K telescope (JWST) was so difficult?
  - Cryocoolers are now more mature
    - Cryocoolers at low temperature have a huge advantage over radiative cooling at low T
  - OST has a longer wavelength so the optics are less challenging
  - Low temperature has advantages
    - Low thermal contraction with changing temperatures for one
  - The design is driven by cryo/thermal considerations
  - Cryogenics leads to solutions!!!

ORIGINS Space Telescope

State of the Art for cooling

- ACTDP and follow up matured coolers from 3 different companies
- Approximately 10,000 W of input power per W of cooling power
- Space Cryocooler Reliability is Extremely High
  - From Ron Ross's ongoing survey

Cooling Power Vs. T



Staged Cooling

- Utilize staged cooling to go from 300 to 0.05 K
  - Start with radiative cooling of the sunshield
  - Use 3 stages of cryocooler cooling
  - Finish with a subKelvin cooler to provide 50 mK

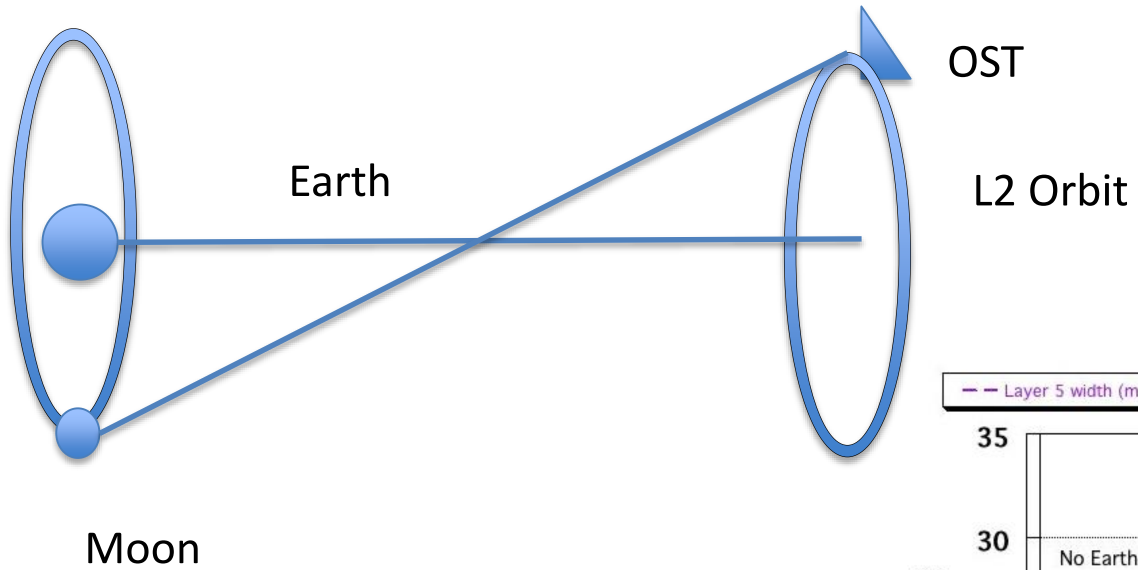
Nominal Heat Flows

- Rough calculation of the heat absorbed by the 4 K cryocooler stage is broken down as follows:
  - Telescope: radiation: 55 mW, conduction from structure 20 mW, conduction from harnesses 30 mW
  - Instrument dissipation: Maximum 100 mW mainly from low temperature preamplifiers
- Will use eight 50 mW cryocoolers in parallel which provides redundancy, 100% margin on the expected cooling load, and keeps size close to current technology

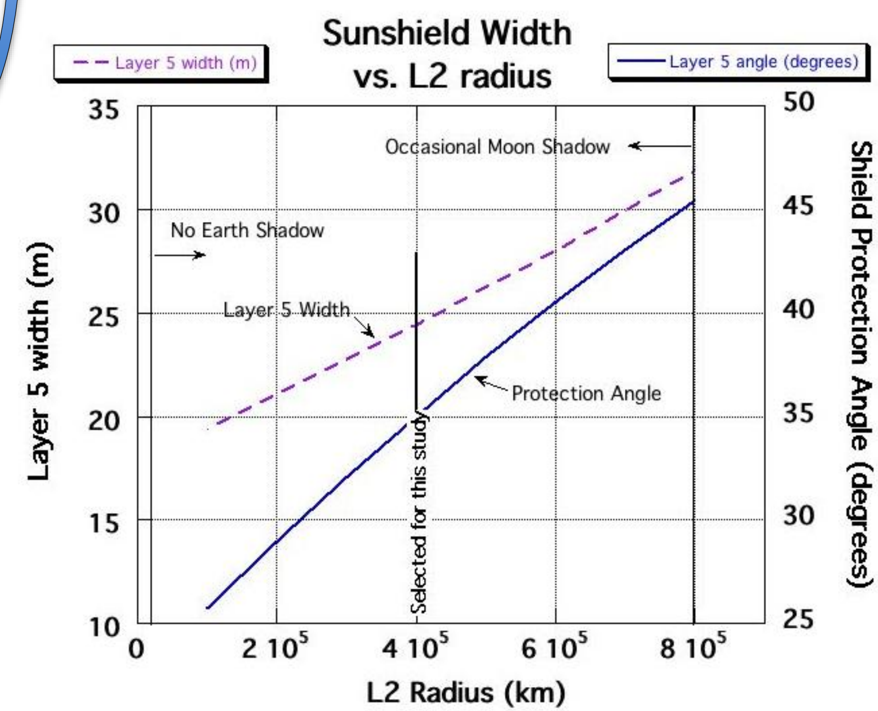
Sunshield Principle

- Radiate horizontally, block radiation perpendicular
- Practical Considerations
  - Solar pressure imbalance
  - Deployment
  - The Sun, Earth, and Moon do not stay in one place

Keep Out Angles



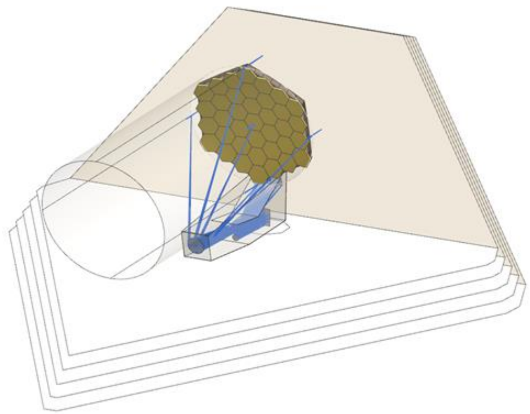
Field of Regard adds to shield size
OST Pitch=+5°/-45°, Roll = ± 5°,
Yaw = 360°

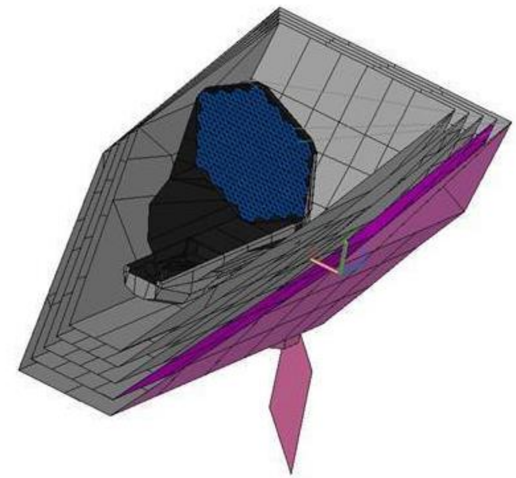


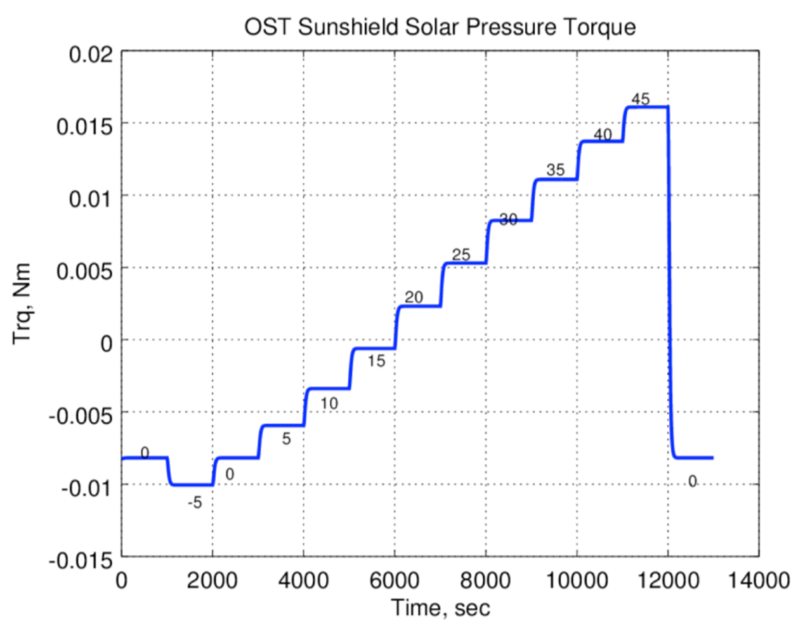
Solar Pressure

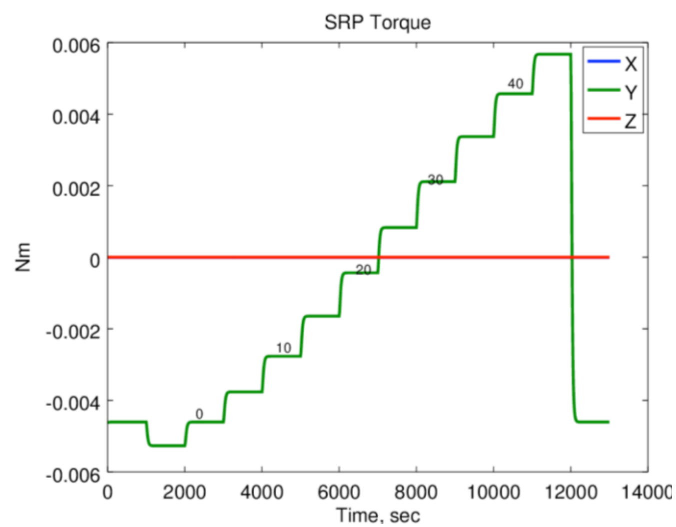
- Ideally the center of solar pressure (~9 μPa) and center of mass are in the same place
- Any offset must be overcome with momentum wheels and propulsion
  - Aside from mass, frequent propulsive maneuvers disrupt observing time
- [Two Cases]

Solar Torque - Two Cases



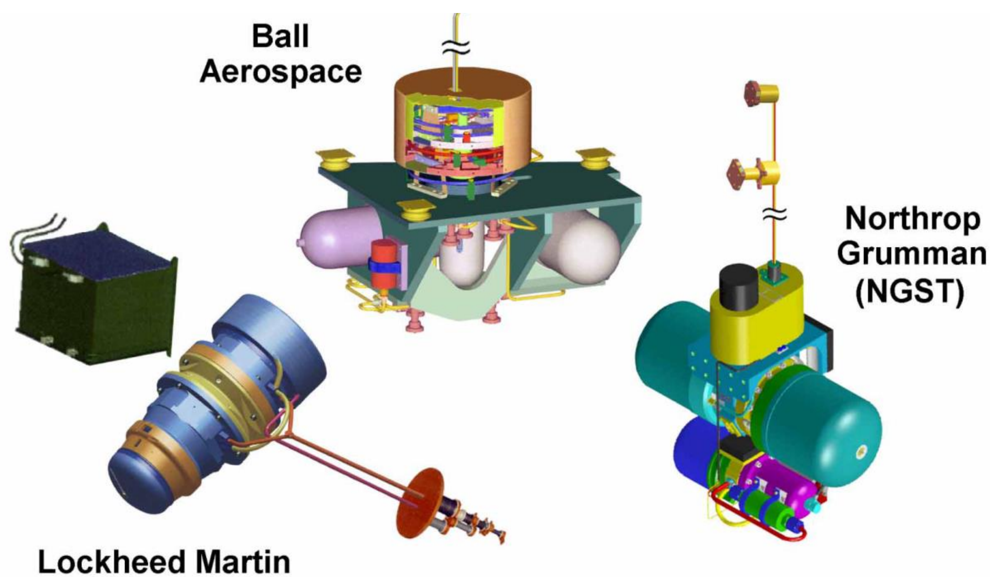






Cryocooler Considerations

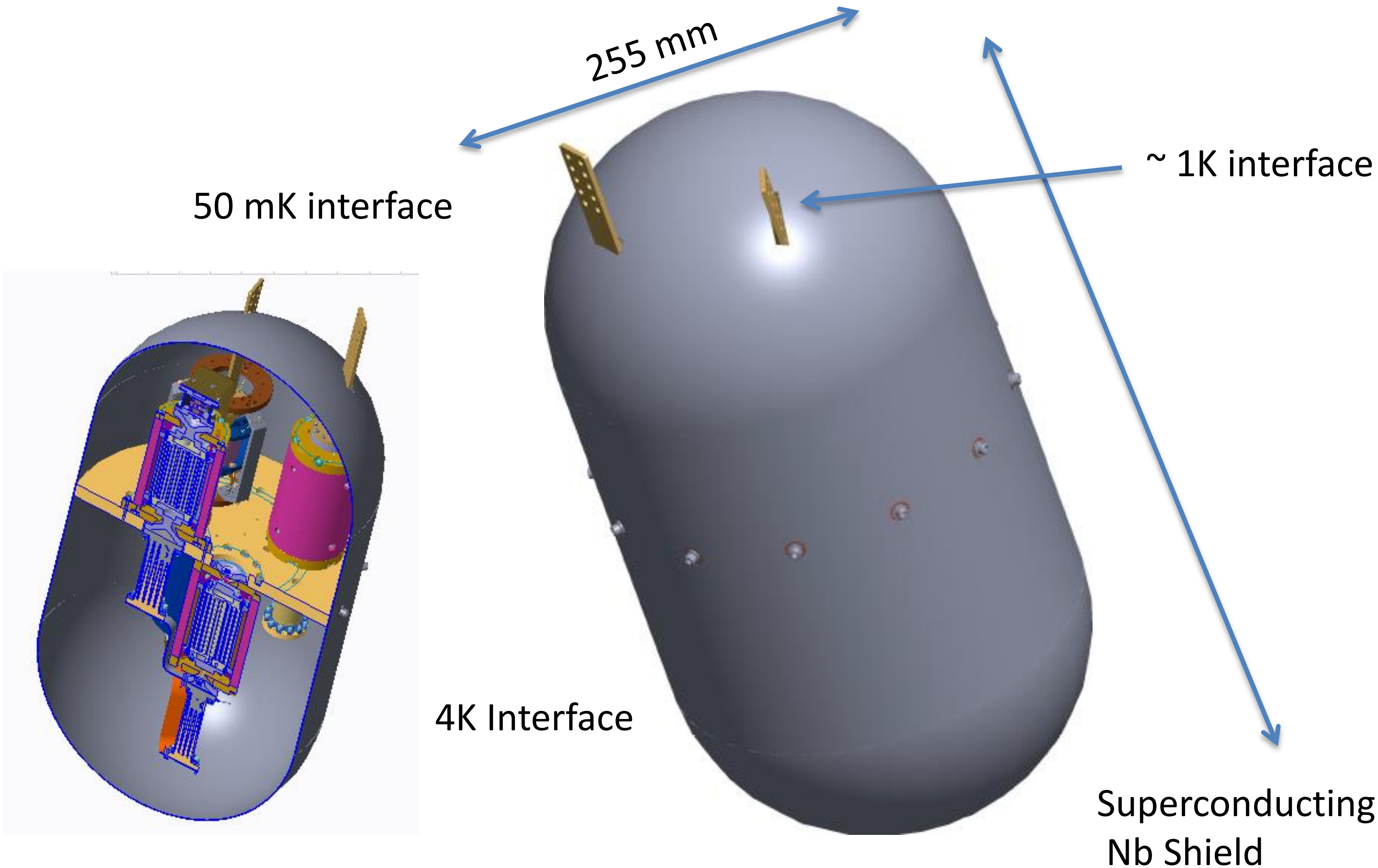
- Staged heat extraction
- Vibration issues
  - Not so much for image stabilization as for microphonics on detectors
- Packaging and distributing cooling
- 50 mW cooling at 4 K plus 20 K and 70 K cooling for 500 W of input power



Sub-Kelvin Cooling

- Instruments whose detectors require cooling to less than 1 K will be sized to accommodate a provisional sub-Kelvin cooler. Such a cooler is currently at TRL4 and will be at TRL6 by the end of the current SAT (end of 2019)
  - Up to 5 µW continuous cooling at 50 mK (max duty cycle)
  - Up to TBD mW cooling at ~1K
  - Heat rejection to 4 K
    - 6 mW (at max duty cycle), 3 mW at min duty cycle
  - Magnetic shielding to provide < 1µT at the boundary of the cooler
  - Mass ~ 21 kg
  - Volume (see graphic)

Multi-Stage ADR Sub-Kelvin Cooling



ORIGINS Space Telescope

Summary and Conclusions

- The Origins Space Telescope is being studied as a flagship class astrophysics mission for the 2030's
  - 9.1 m diameter primary operating at 4 K
    - Cooling is achieved by proper staging of radiative coolers (sunshields), mechanical cryocoolers
  - 4 K and lower instruments
    - 3 instruments require subKelvin (50 mK) temperatures which could be provided by new continuous adiabatic demagnetization refrigerator