

A composite image of space. The bottom half shows a view of Earth from space, with blue oceans, white clouds, and a thin layer of atmosphere. The top half is a deep space scene with a large, detailed Moon on the right, a smaller reddish planet in the upper right, and a dense field of stars with blue and white hues.

Predictive thermal control applied to HabEx

Thomas Brooks

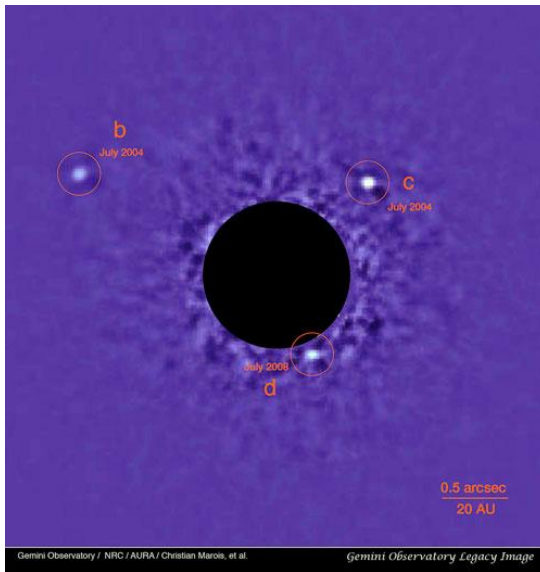
Marshall Space Flight Center

256.797.3147

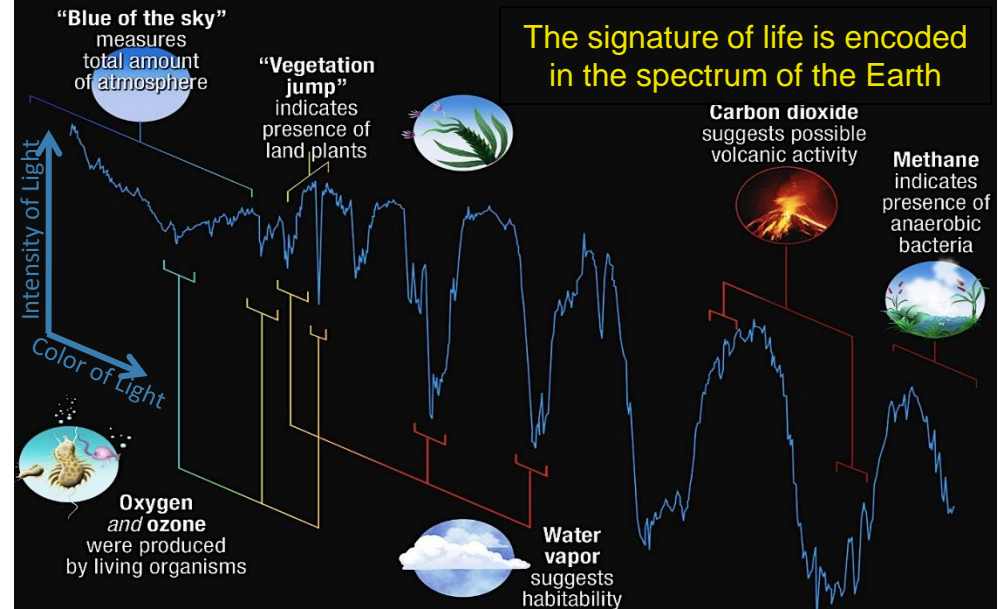
HabEx Brief Background



Science Objectives

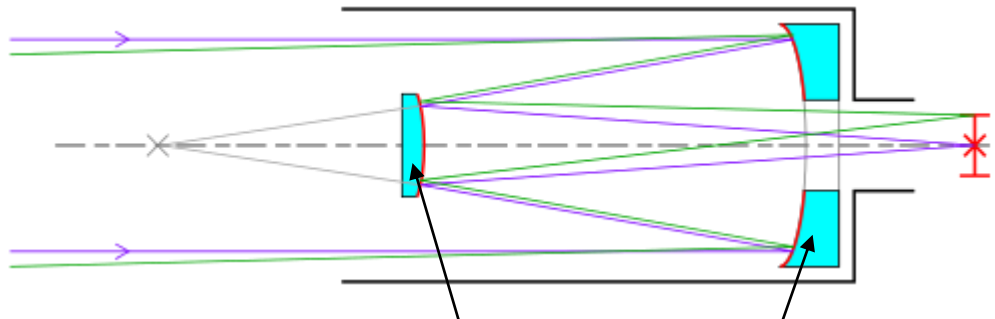


Example of exoplanets imaged with a ground based system.^[1]



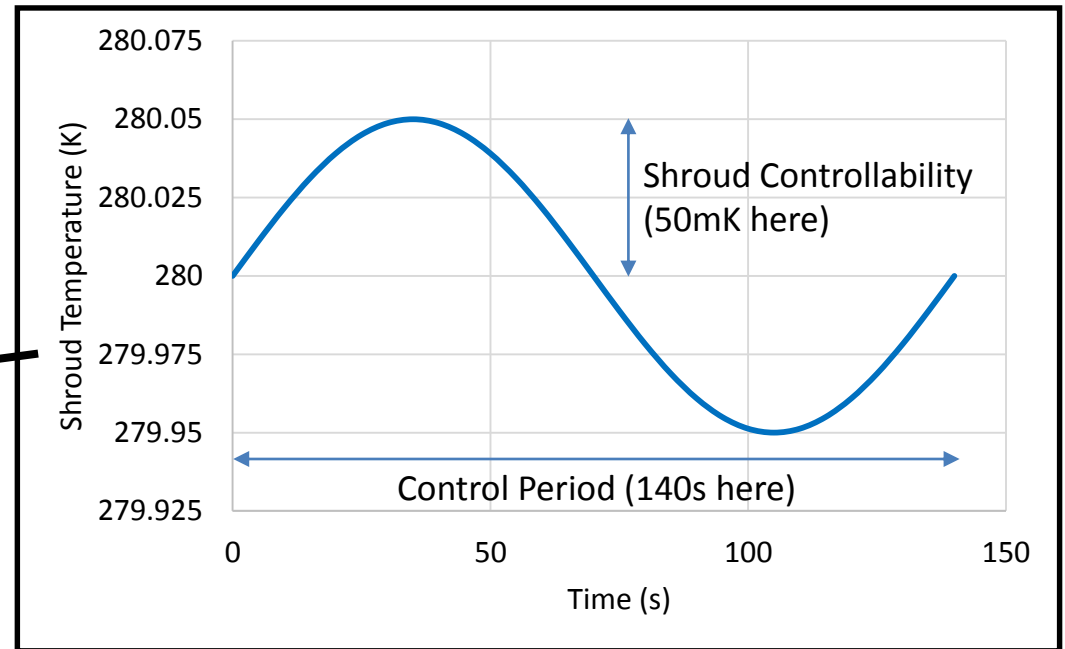
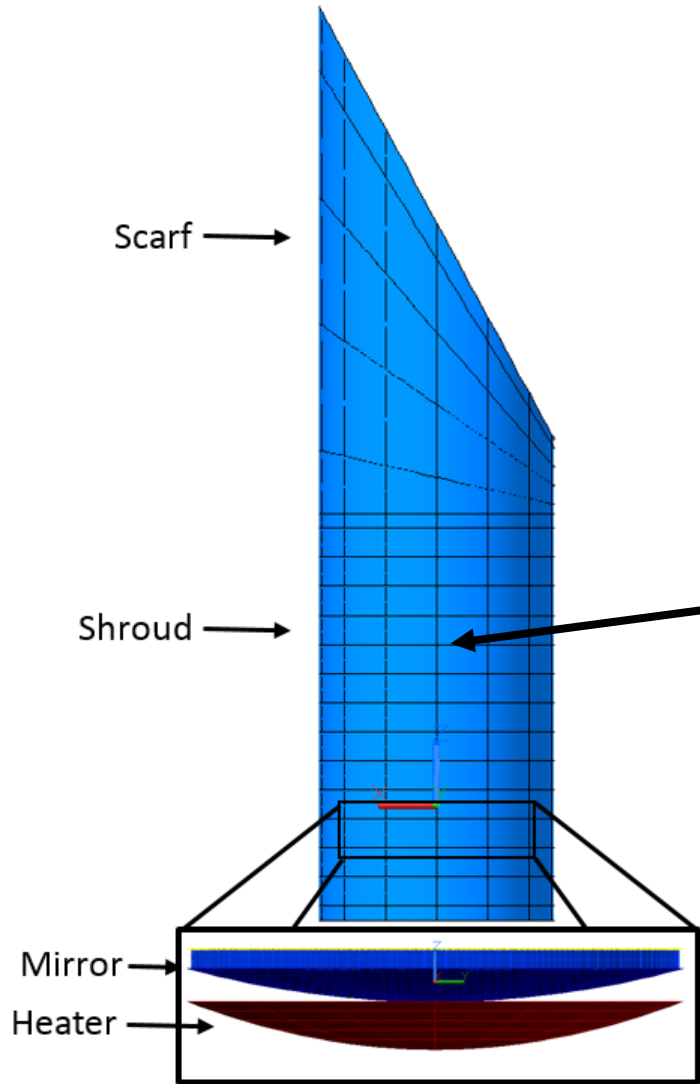
Biosignatures.^[2]

Engineering Requirements

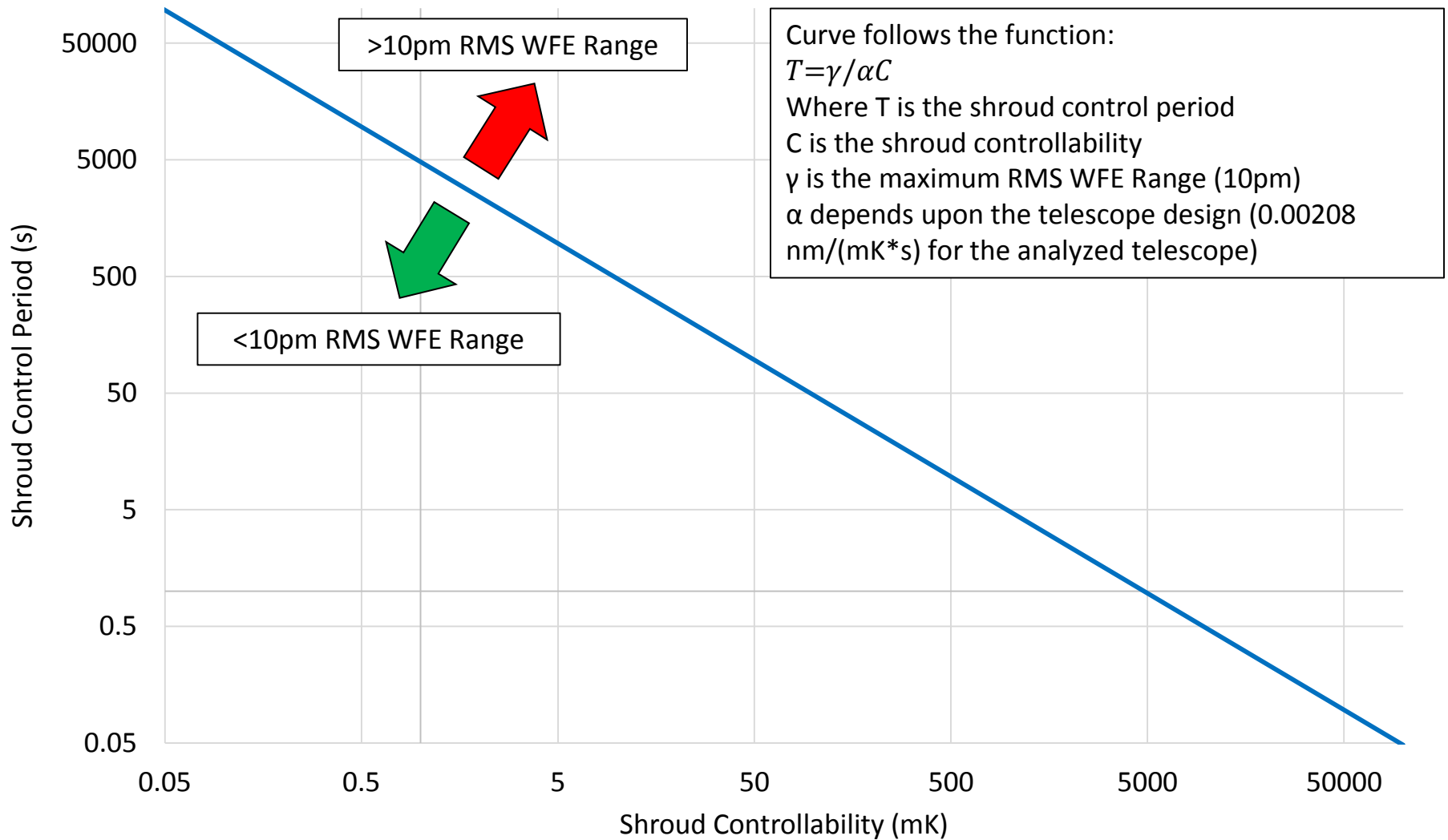


SFE may not change by more than 10pm in 10 minutes
Position may not move by more than ~2nm per 10 minutes

Thermal Analysis Approach



Thermal Stability Requirement



1-D Rod Closed-Form Model



Rod with a mass, specific heat, thermal energy, temperature and coefficient of thermal expansion of m , c_p , Q , T , and CTE respectfully

Length of rod, L

- Equation 1 describes heat storage in the rod
- Equation 3 describes linear thermal expansion
- Algebra and calculus then Equation 5
- Equation 5 shows variables that affect thermal strain rate
 - Geometry dependent: L , V , dQ/dt (surface area)
 - Material dependent: CTE, ρ , c_p , and dQ/dt (emissivity and absorptivity)

$$Q = \rho V c_p T \quad \text{Equation 1}$$

$$\frac{dQ}{dt} = \rho V c_p \frac{dT}{dt} \quad \text{Equation 2}$$

$$(\text{CTE})L\Delta T = \Delta L \quad \text{Equation 3}$$

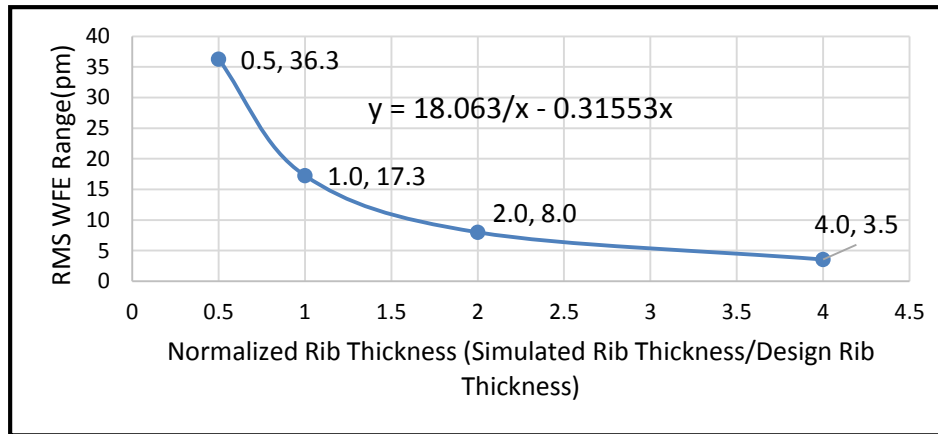
$$\frac{dT}{dt} (\text{CTE})L = \frac{dL}{dt} \quad \text{Equation 4}$$

$$\frac{dL}{dt} = \frac{(\text{CTE})L}{\rho V c_p} \frac{dQ}{dt} \quad \text{Equation 5}$$

Passive Design Figures of Merit



- Numerical and analytical models agree that heat capacity and CTE have very strong effects on thermal deformation rates.



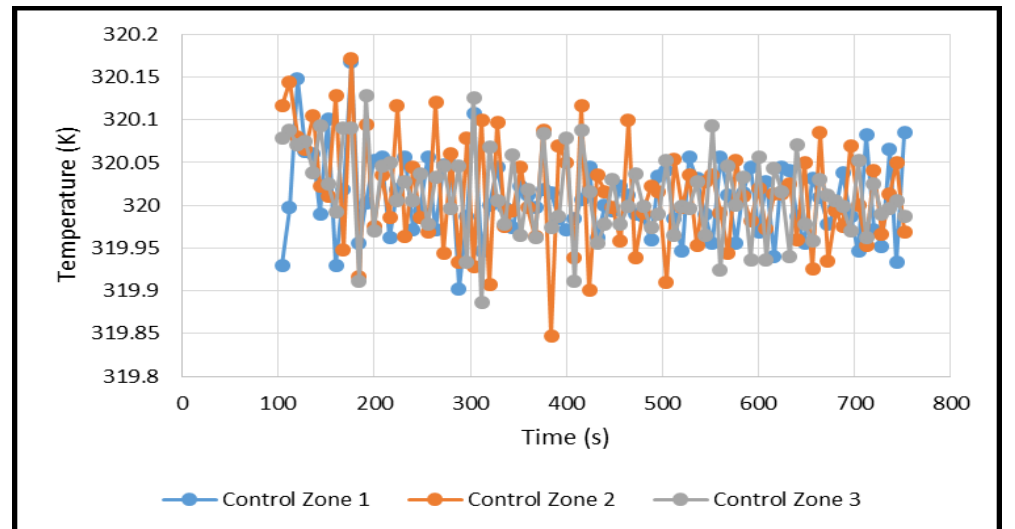
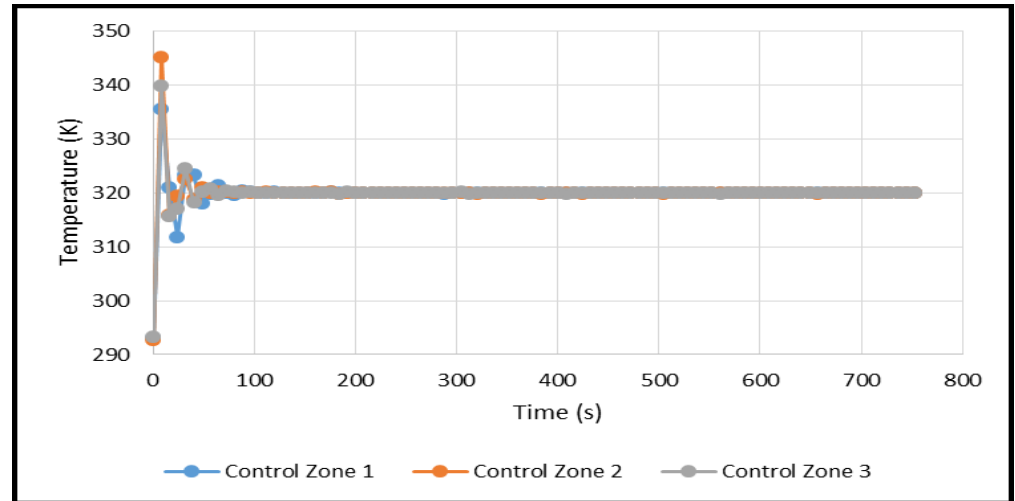
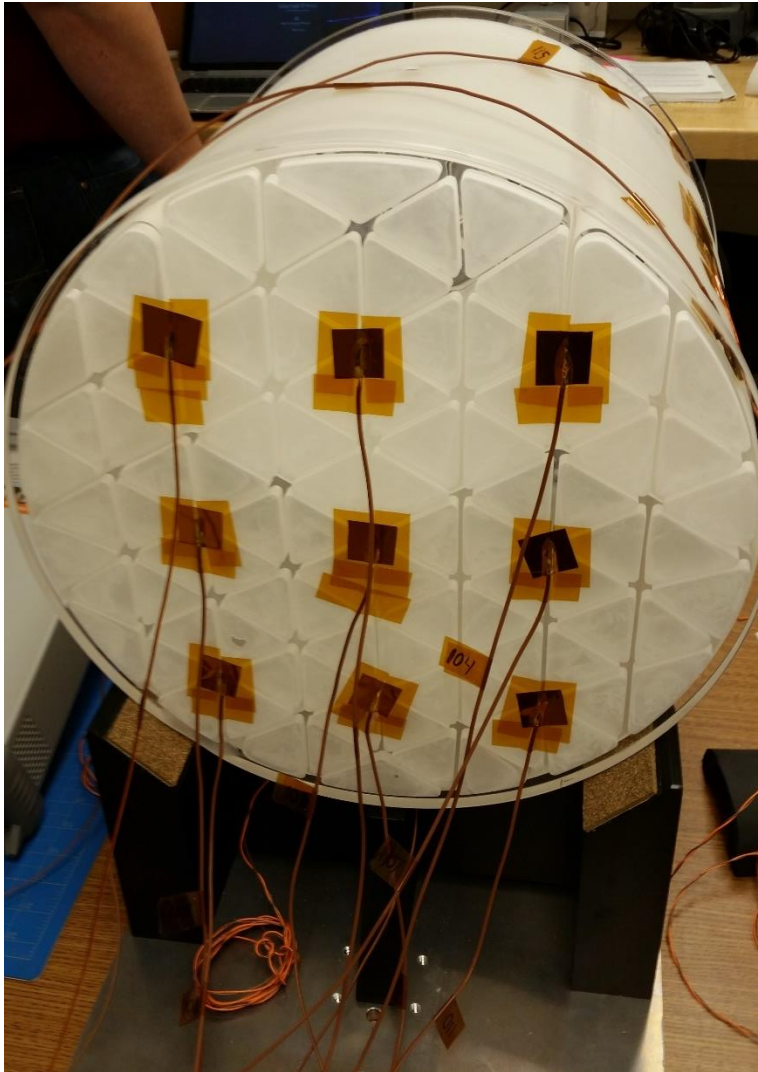
$$\frac{dL}{dt} = \frac{(CTE)L}{\rho V c_p} \frac{dQ}{dt}$$

- For an actively controlled substrate, the following figures of merit are proposed:

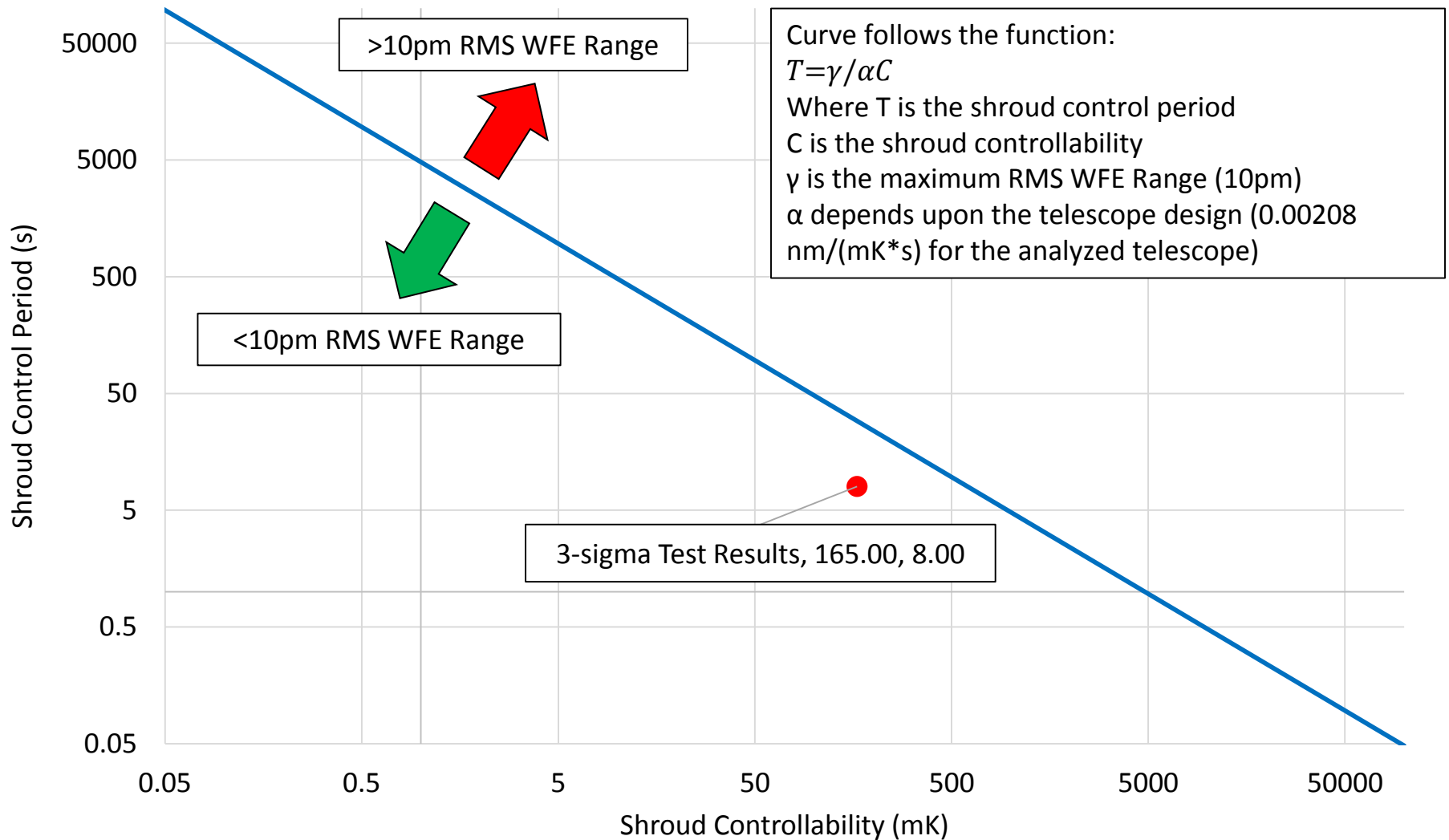
$$\text{Massive Active Optothermal Stability, MAOS} = \frac{\rho c_p}{CTE}$$

$$\text{Active Optothermal Stability, AOS} = \frac{c_p}{CTE}$$

Subscale Test



Test Compared to Requirement



Questions or Comments?



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