



DEVELOPMENT OF A SPACE IRRADIANCE SIMULATOR FOR ADVANCED STUDIES AND MATERIALS RESEARCH

Cryogenic Engineering Conference

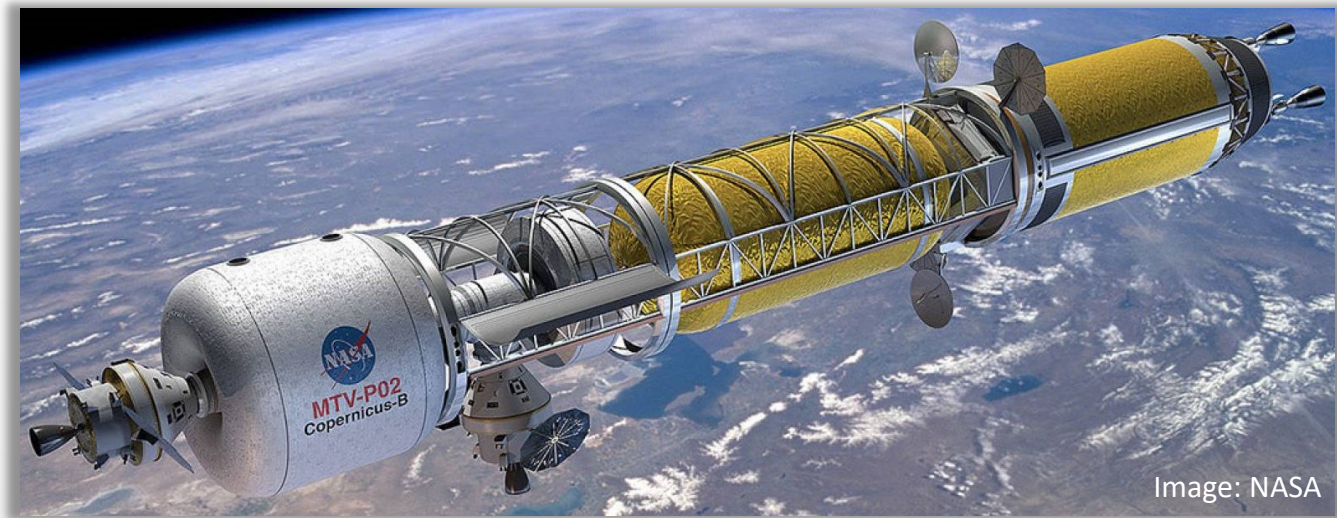
Virtual, Tuesday July 20th, 2021

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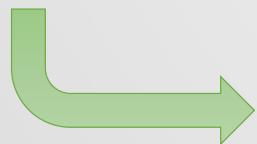
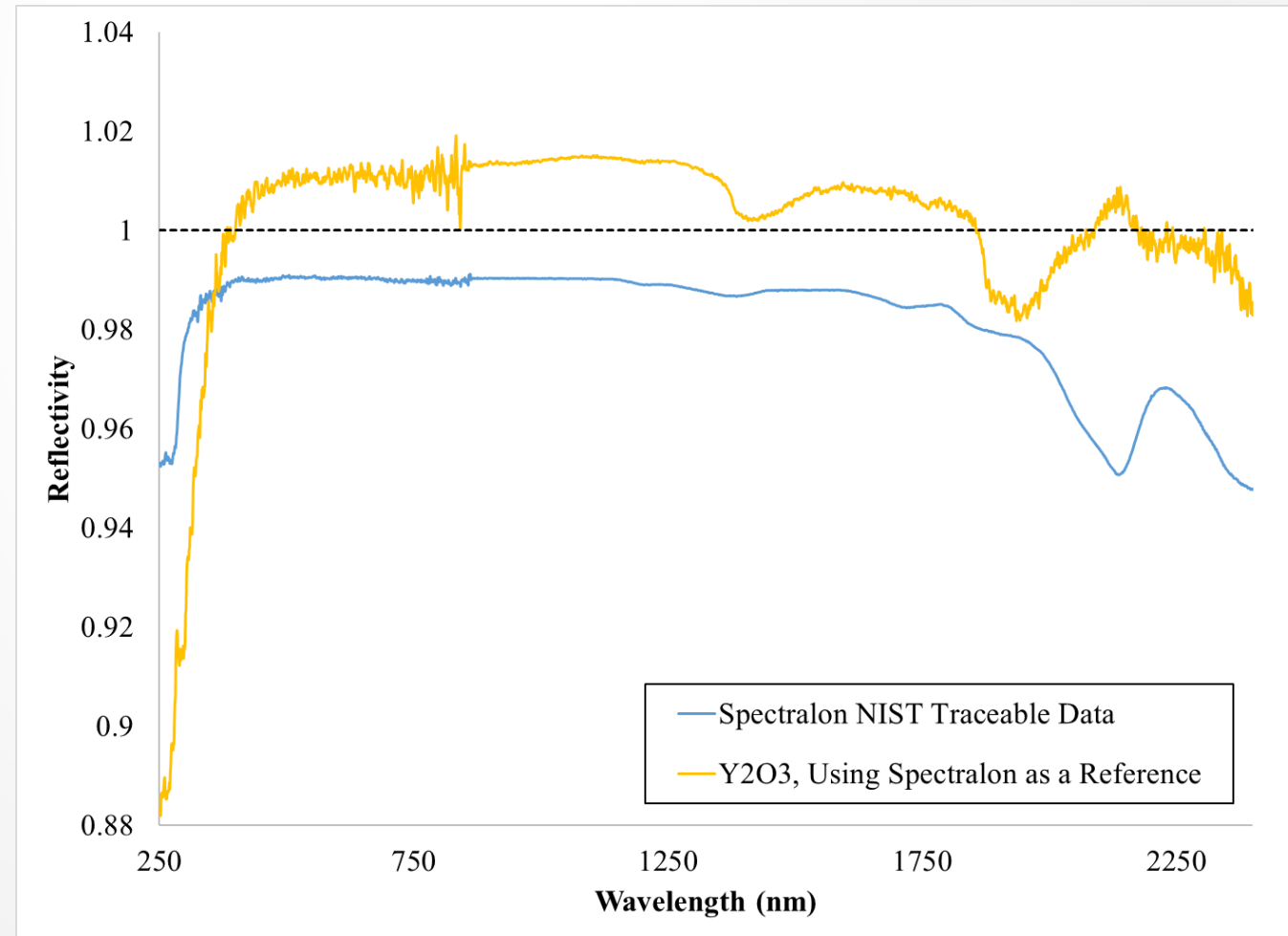
INTRODUCTION

- Need exists for highly reflective materials and coatings for in-space cryogenic propellant management
- Theory shows that a material with a solar absorptivity of 1%, and an IR emissivity of 90% could facilitate **passive storage of LOX indefinitely** at 1 AU from the Sun.



INTRODUCTION

- KSC currently developing ultra-reflective, broadband Yttrium-Oxide (Y_2O_3) materials
- Challenge of properly testing performance of Y_2O_3
 - ASTM E903 standard using a Jasco V-670 reflectance spectrometer with an ISN-723 integrating sphere
 - Y_2O_3 showed a reflectance >1 , which is impossible

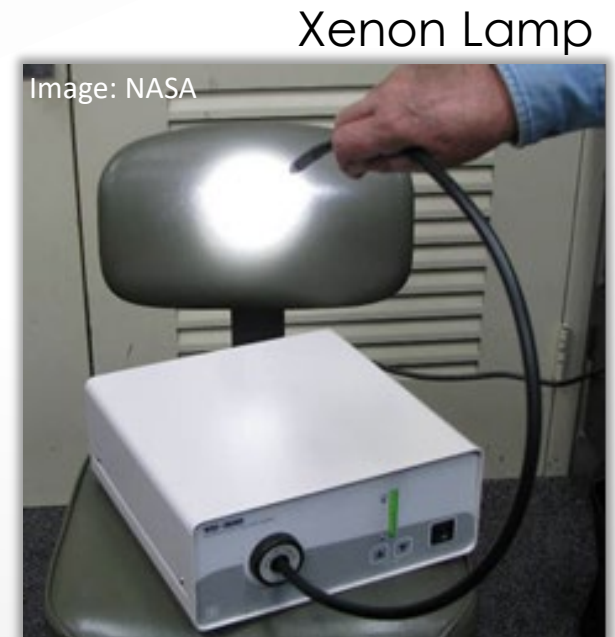
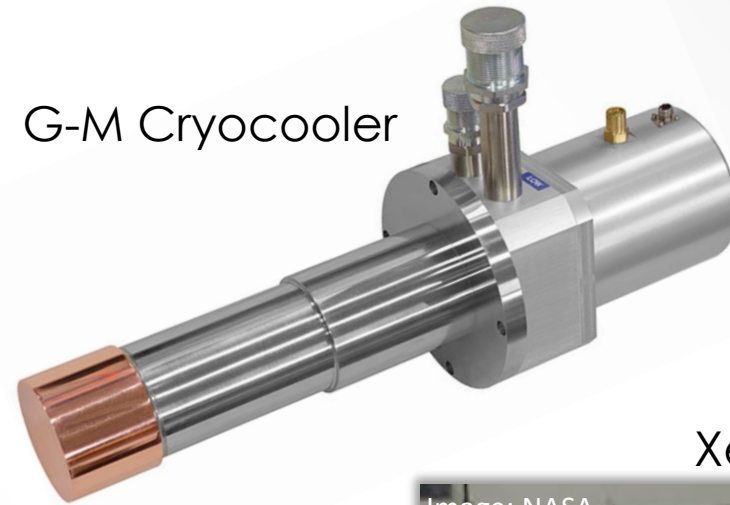


A new test method was necessary!

SPACE IRRADIANCE SIMULATOR (SIRS)

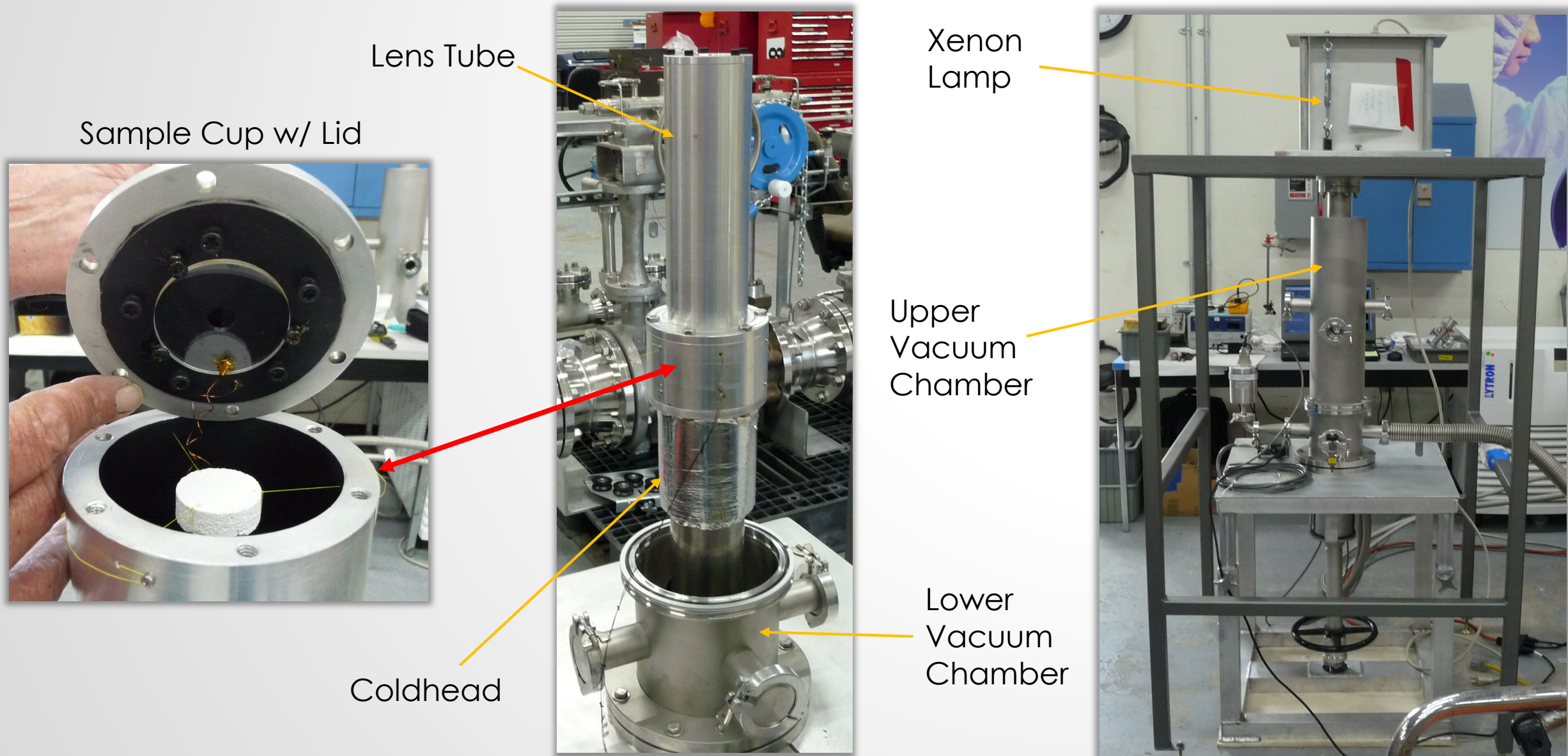
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- Needed to create an environment similar to that of deep space
 - High vacuum ($<10^{-5}$ torr)
 - Access to a deep cryogenic background temperature with optical properties that closely imitate a blackbody
 - A “point-like” light source providing a spectral irradiance like that of the Sun
- Three different iterations of SIRS configurations were explored beginning in 2016



SPACE IRRADIANCE SIMULATOR #1 (SIRS-1)

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SPACE IRRADIANCE SIMULATOR #1 (SIRS-1)

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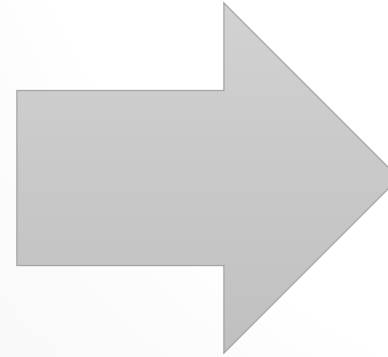
SIRS-1 Take-Aways

- *Pros*

- ✓ Simple, effective vacuum sealing methods

- *Cons*

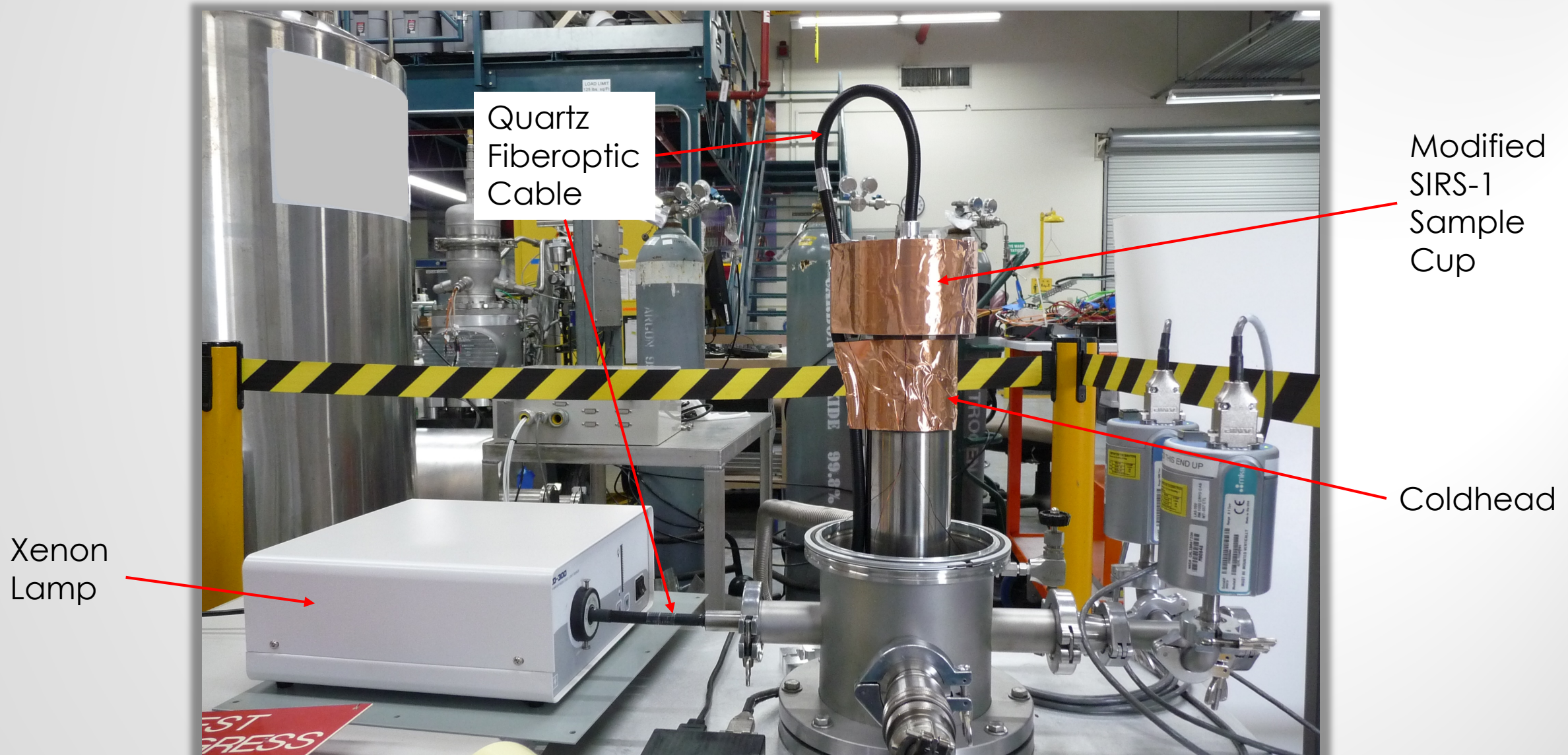
- x Complex system of lenses to focus light on sample
- x Possible infrared radiation from lenses contaminating test results
- x Lens tube desired to cool lenses, but no way to directly monitor their temperatures



Beam light through the chamber using a quartz fiberoptic cable!

SPACE IRRADIANCE SIMULATOR #2 (SIRS-2)

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SPACE IRRADIANCE SIMULATOR #2 (SIRS-2)

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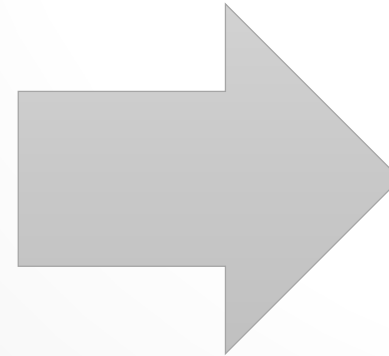
SIRS-2 Take-Aways

- *Pros*

- ✓ Design flexibility
- ✓ Positive initial test results validated concept

- *Cons*

- x Vacuum leaks from epoxy-based fiberoptic feedthrough
- x Sharp bends in the fiberoptic cable
- x Difficult thermal coupling of the quartz fibers and coldhead led to lingering IR contamination concerns

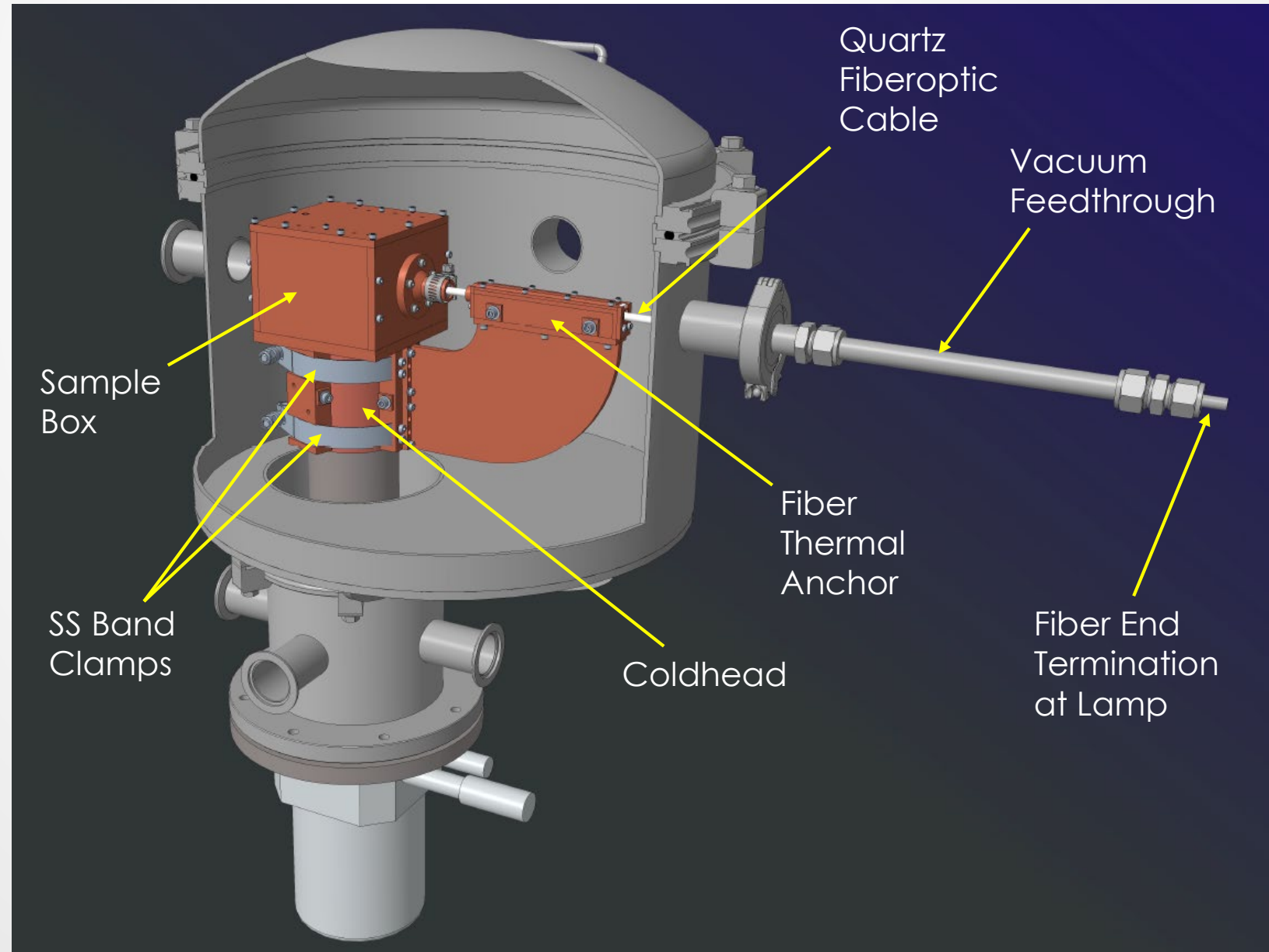


1. Improve thermal mounting of quartz fibers
2. Reduce or eliminate bends in fiberoptic cable
3. Update vacuum feedthrough to eliminate leaks

SPACE IRRADIANCE SIMULATOR #3 (SIRS-3)

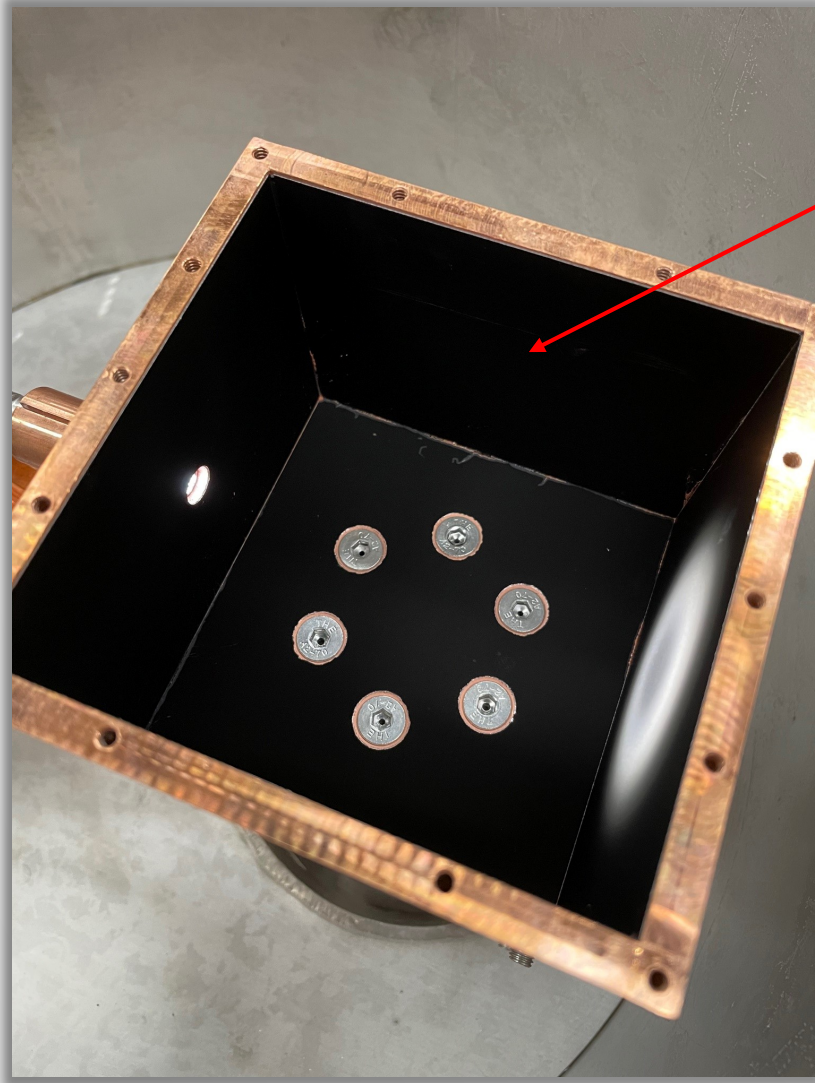
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- New, larger, 3-piece vacuum chamber
- Horizontally oriented, fiber w/o bends
- Large fiber thermal anchor
- Updated vacuum feedthrough for the fiber



SPACE IRRADIANCE SIMULATOR #3 (SIRS-3)

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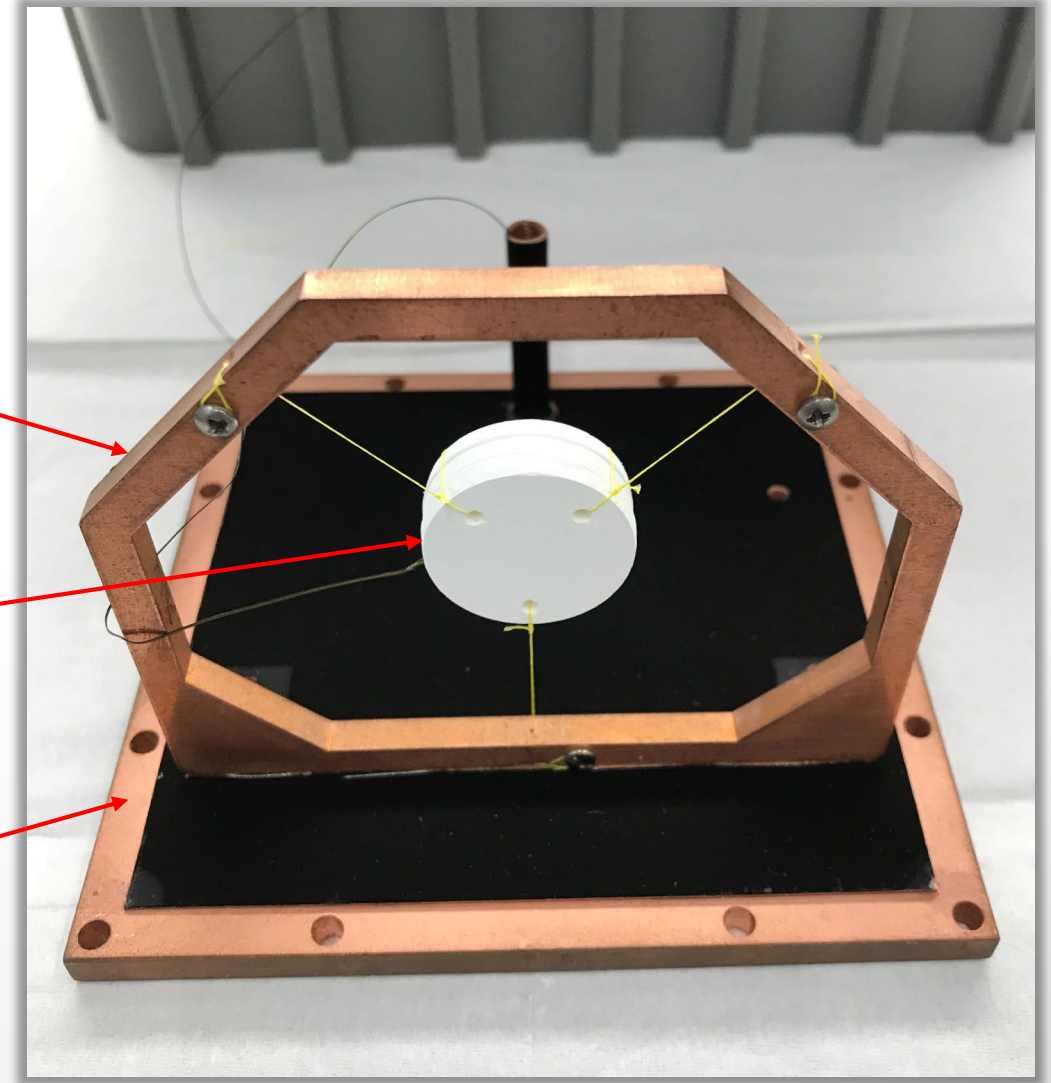


Edmunds
Optics, Metal
Velvet black foil

Sample Cradle

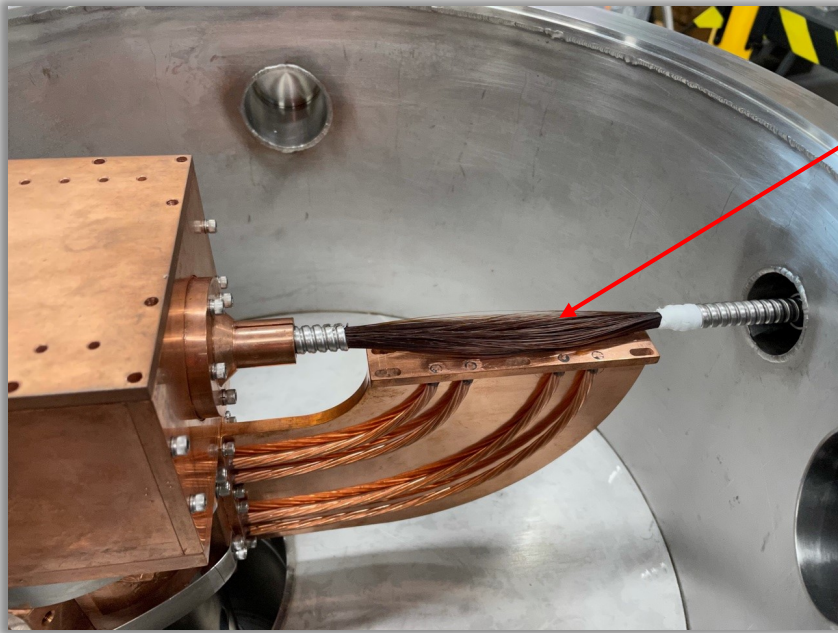
Y2O3 Test
Specimen

Box Lid



SPACE IRRADIANCE SIMULATOR #3 (SIRS-3)

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Exposed Quartz
Fiber Bundle

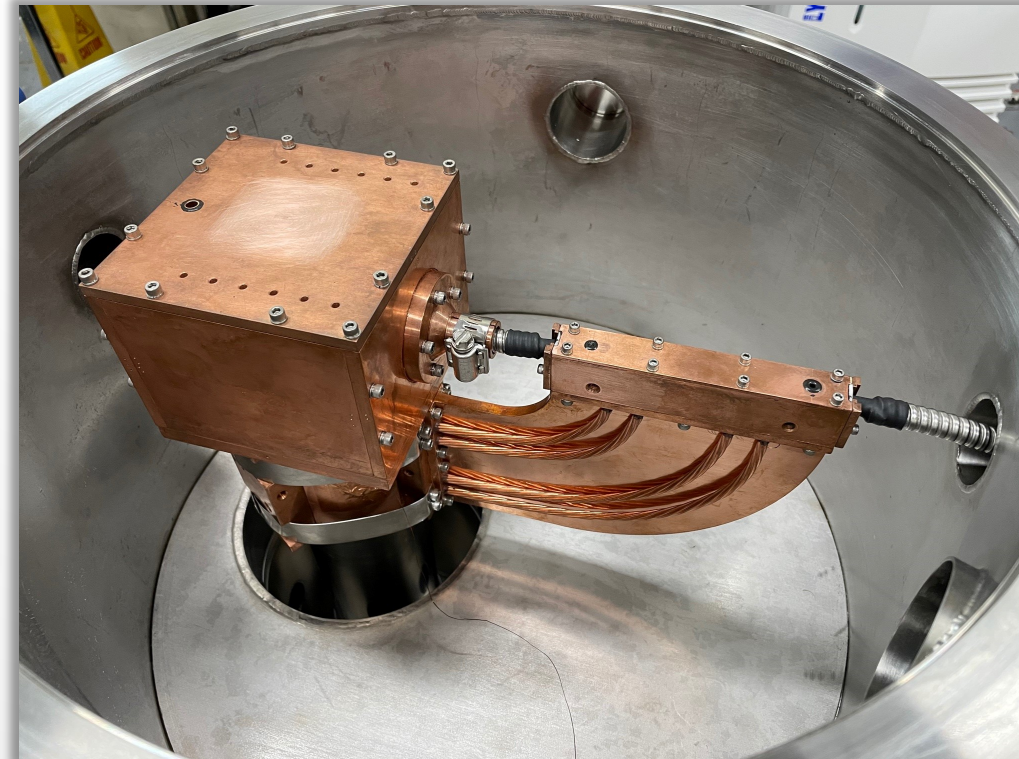
Quartz Fiber Bundle
In Thermal Anchor
Prior to Epoxy Filling



End Termination of
Fiberoptic Cable

Vacuum
Feedthrough

Completed Assembly



SPACE IRRADIANCE SIMULATOR #3 (SIRS-3)

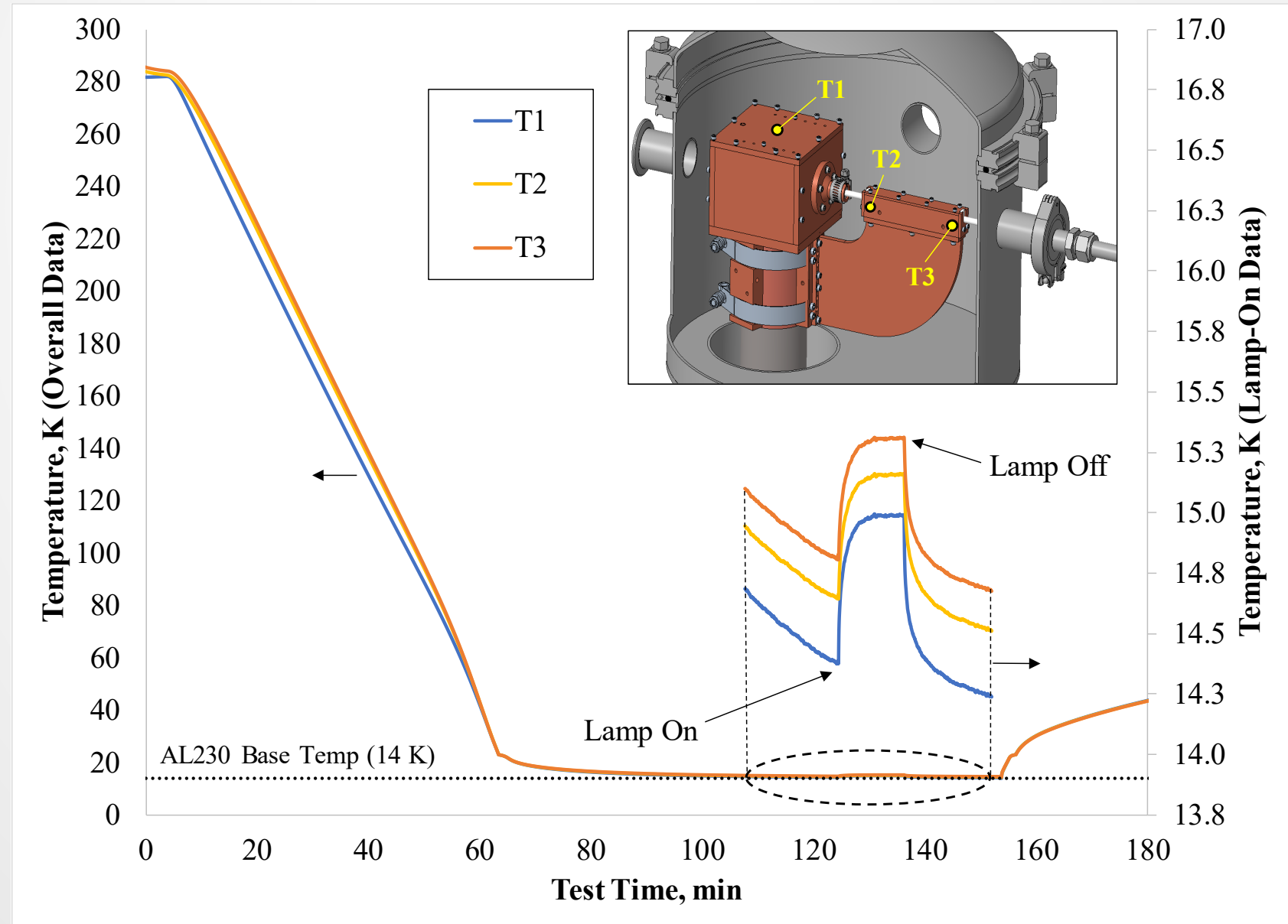
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SIRS-3 CHECKOUT TESTING

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- Silicon diode temperature sensors
- No sample
- Cooldown close to base temp. of cryocooler
- Very little ΔT across sensors (0.44 K avg.) at steady state
- Lamp on at 124 min
 - Fast stabilization
 - Small rise in temperatures (0.5-0.6 K)



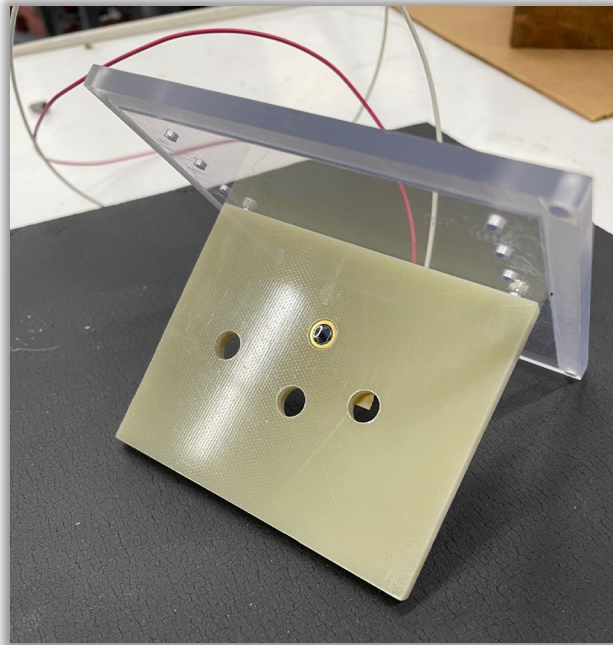
SIRS-3 ATTENUATION TESTING

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- Power output of lamp ≈ 1.11 W at ambient
- Measured with a Thor Labs PM100D digital power meter & broadband sensor

What is the emitted power when the fiber is cold?

- Array of four Thor Labs FDS100 photodiodes
- Measurements taken at ambient and cold
- Results
 - Avg. 15.9% reduction when cold
 - ≈ 0.93 W cold



CONCLUSION

- A series of Space Irradiance Simulators (SIRS) have been **designed, built, and tested in-house** at NASA Kennedy Space Center
- The current, most advanced version, SIRS-3, hosts a variety of **unique design features** including:
 - A custom vacuum feedthrough for the fiberoptic cable
 - Efficient thermal anchoring of the quartz fiber bundle using cryogenic epoxy filling
- SIRS-3 has been thermally cycled numerous times to-date without issue
- Currently in operation evaluating super-reflective materials and coatings for NASA



THANK YOU FOR
YOUR ATTENTION!

QUESTIONS?