



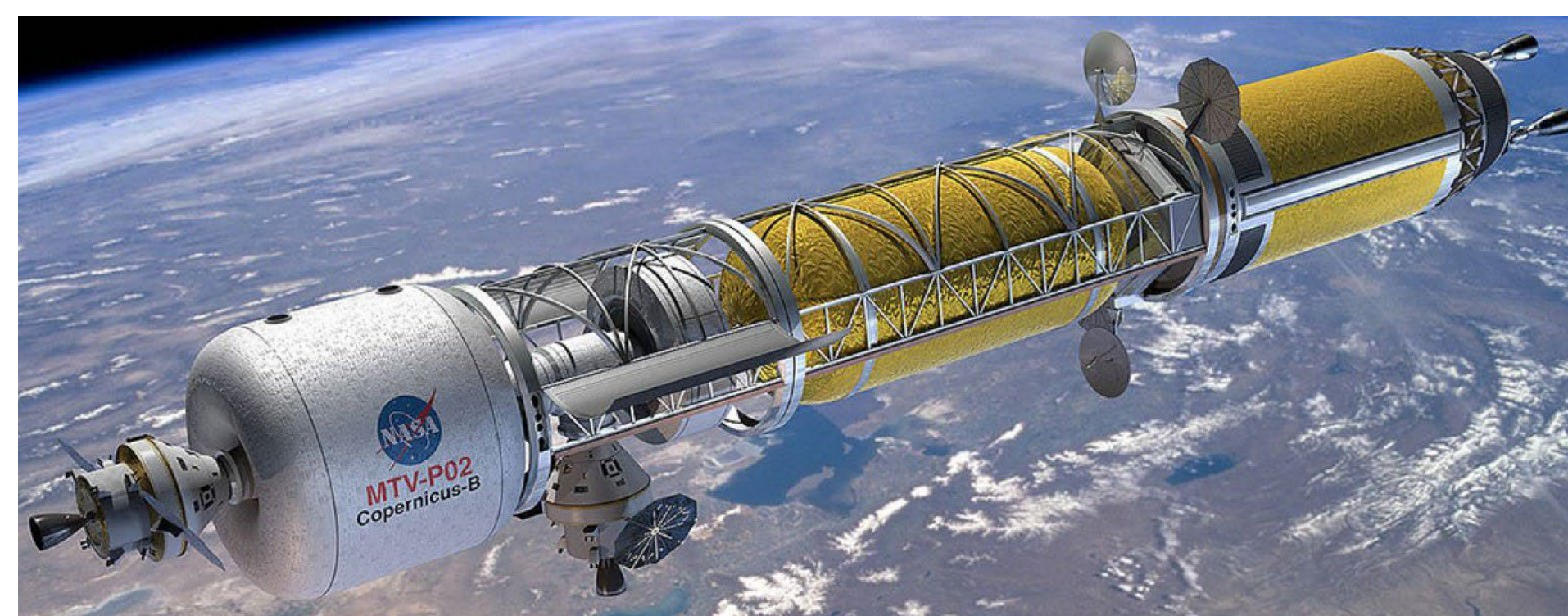
Development of a thermal control coating optimized for cryogenic space applications

A Krenn¹, R Youngquist, T Gibson², S Snyder³

¹Spaceport Technologies Office, NASA Kennedy Space Center, FL 32899 ²Southeastern Universities Research Association, Kennedy Space Center, FL 32899 ³Amentum, Kennedy Space Center, FL 32899

Introduction/Background

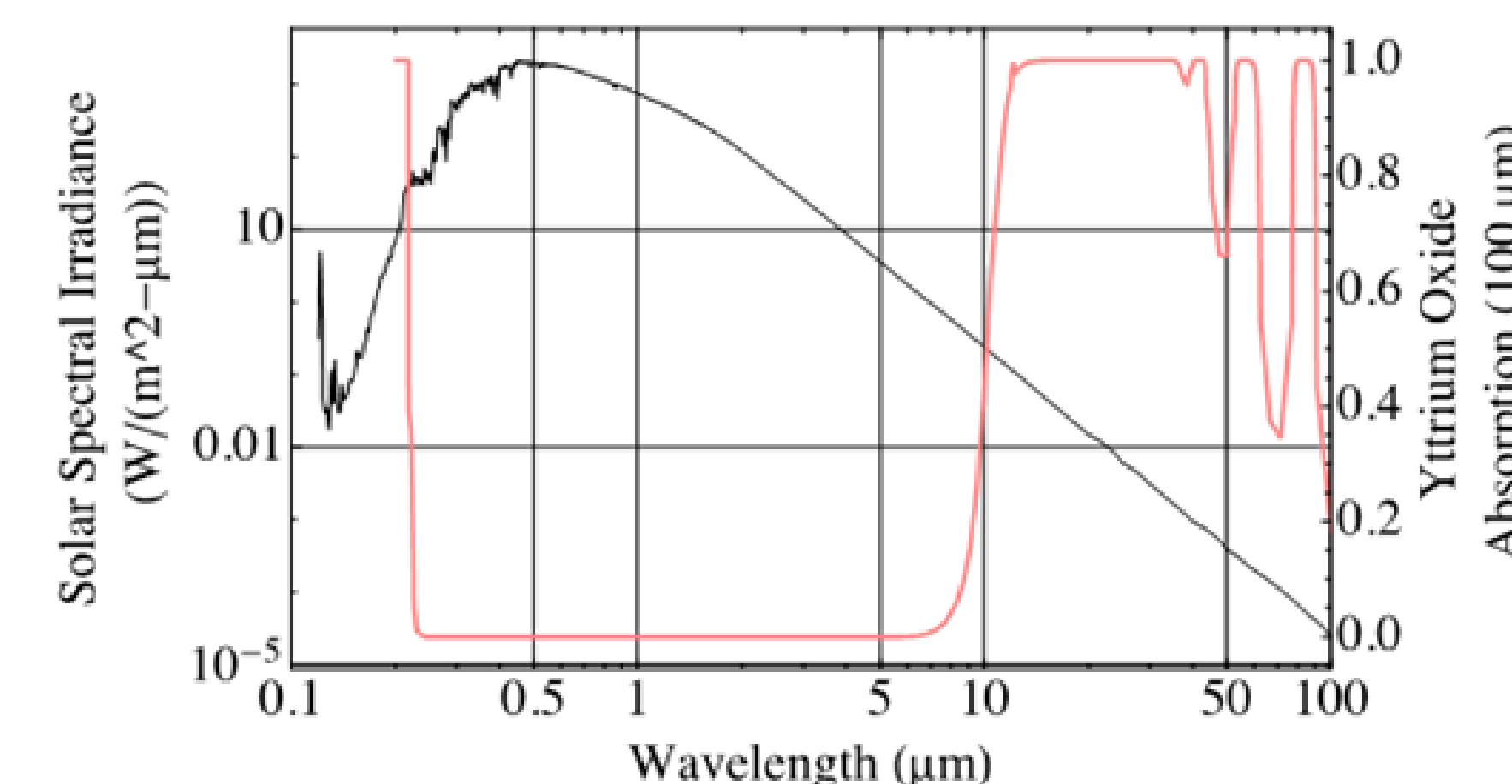
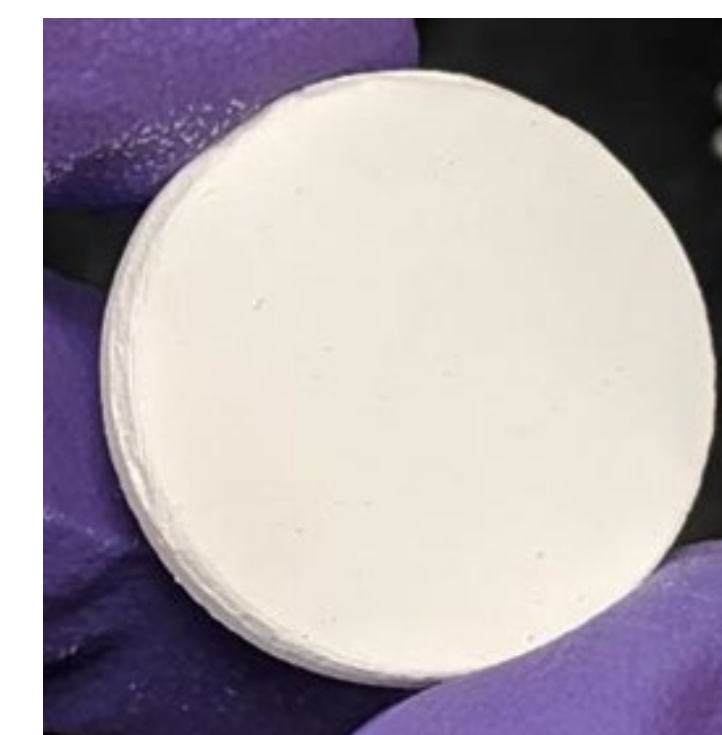
- Long-term storage of cryogens in space is required to enable NASA missions
- Thermal control coatings (TCC) that reflect most solar irradiance while simultaneously emitting infra-red radiation may enable passive cryogenic storage, if no other heat sources are present
- A high performance TCC tile has been fabricated
- A paint-like coating has been developed with significant performance improvements over current state-of-the-art paints



Materials

Yttrium Oxide (Y₂O₃)

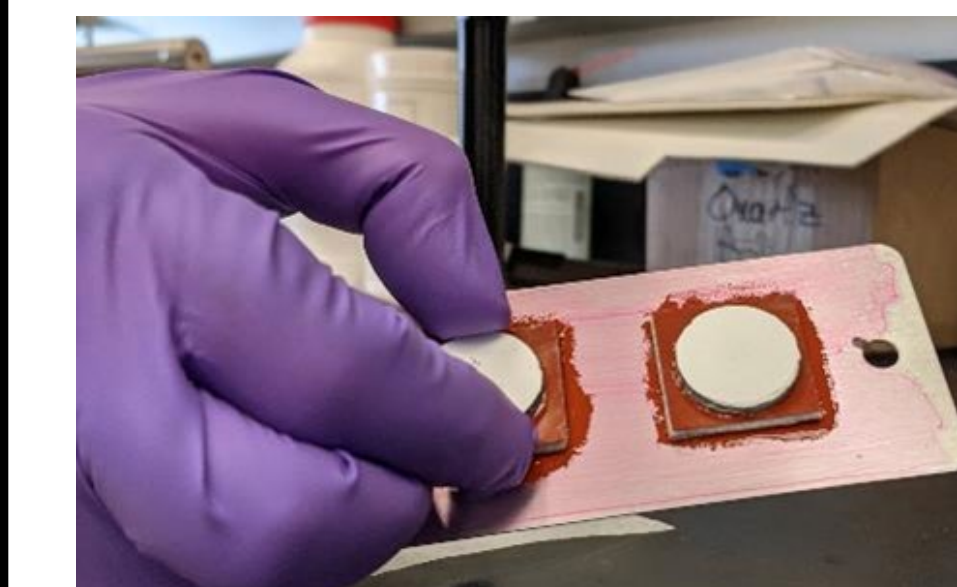
- Reflects all wavelengths between 0.235 and 8 microns
- Hydrophobic
- Chemically stable
- 1-inch diameter tile (right)



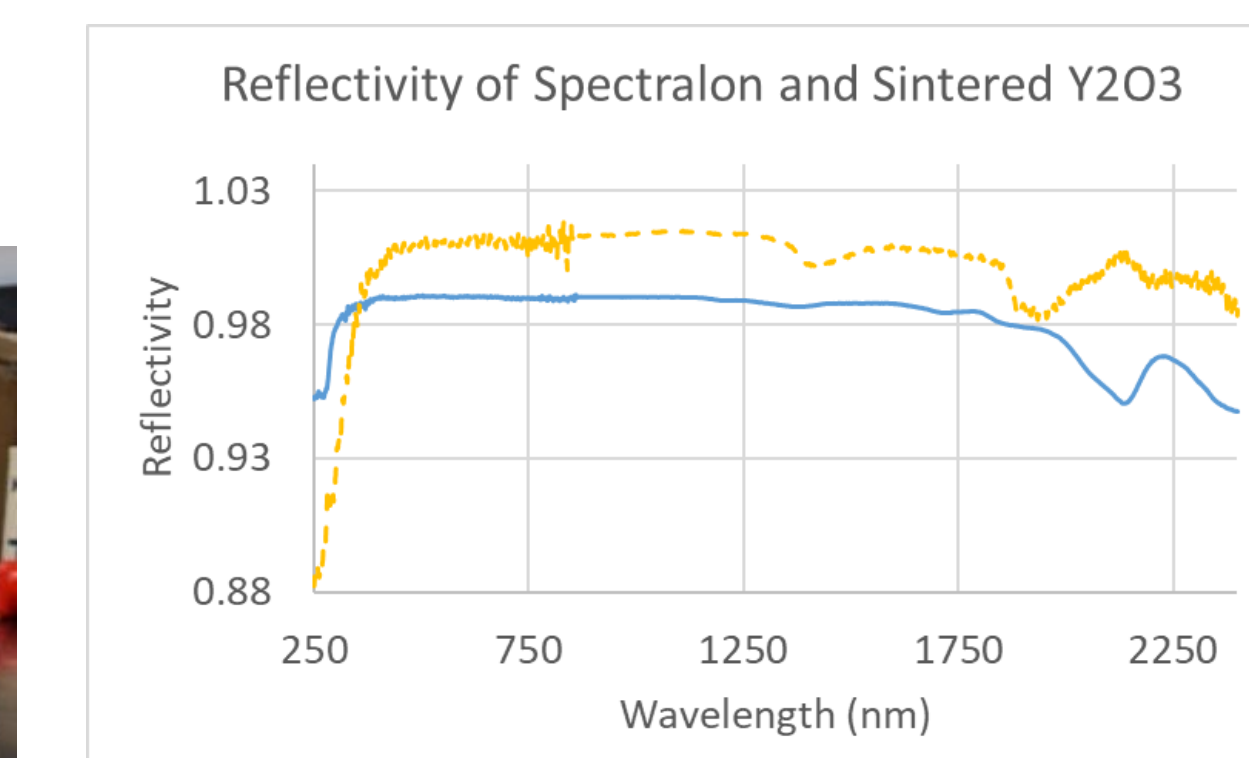
The transmission spectrum of a 100-micron window of yttrium oxide overlaid on the solar spectral irradiance (left)

Tiles

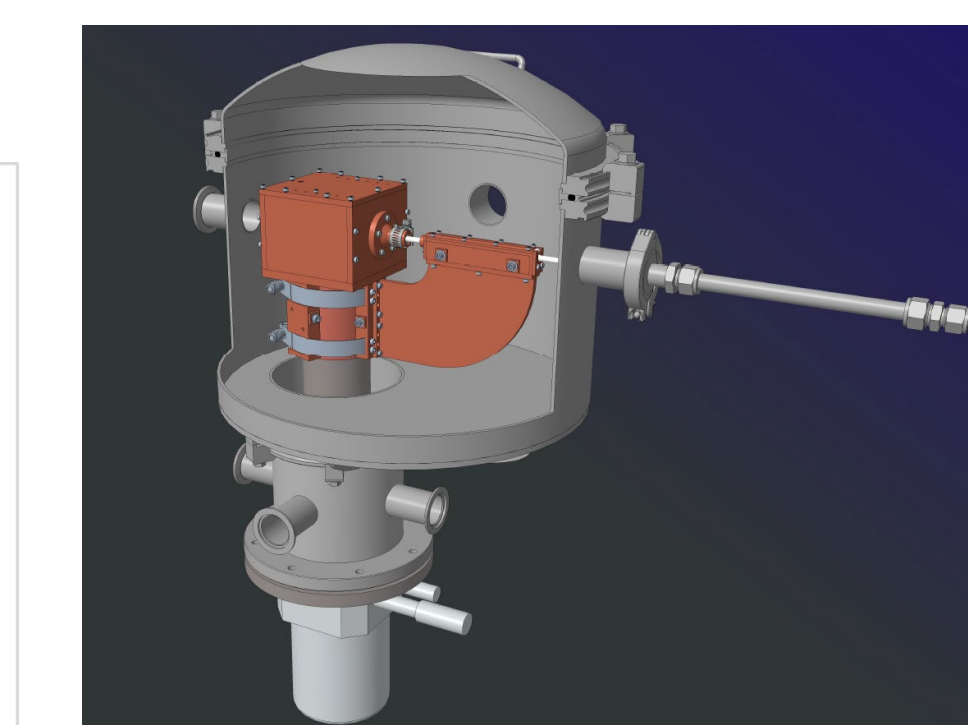
- 10 parts yttrium oxide
- 1 part high purity water
- Compact mixture in mold (~ 5 million Pa – varies with size)
- Sinter in oven
- Vapor deposition of aluminium on one side to facilitate tile application
- 3 mm total thickness



A yttrium oxide tile with aluminium backing attached to an aluminium plate



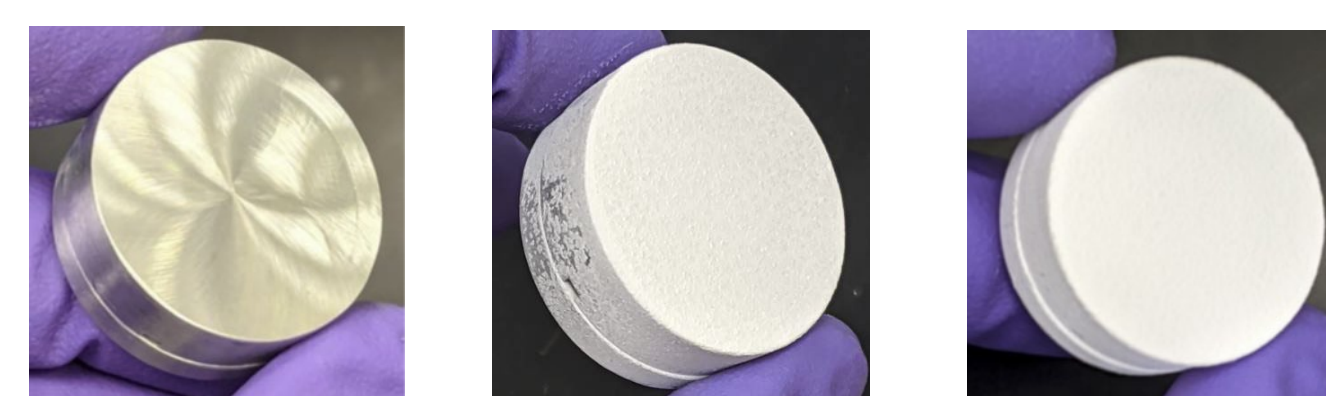
Reflection spectra of Spectralon (solid blue) and a sintered yttrium oxide tile (dashed yellow) demonstrating limitations of ASTM E903 measurement method



Space Irradiance Simulator #3 (SIRS-3) developed to obtain absolute performance data: Ref Swanger, et al., "Development of a Space Irradiance Simulator for Advanced Studies and Materials Research," presented at the 2021 CEC.

Spray-on Coating

- Yttrium Oxide Scattering Powder
- Potassium Bromide Binder
- Water and Alcohol
- Approximately 10 thinly applied layers
- 5 mils total thickness
- Easily applied to large surfaces
- Solar absorption measured using industry standard, ASTM E903
- Solar absorption dependant on substrate
- Significant improvement over SOA (AZW/LA-II $\alpha = 9\% \pm 2\%$ at 10 mils thick)



7075 aluminium disk with, from left to right, no coating ($\alpha = 31\%$), 3 spray layers ($\alpha = 10\%$), and 10 spray layers ($\alpha = 4\%$) (above)

Solar absorption values on various substrates quantifying the improvement obtained by applying multiple layers of spray-on coating (right)

Substrate	Number of Layers	Solar Absorption α
Unfinished Aluminum Panel	bare	31%
	4 spray-on layers	15%
	10 spray-on layers	6%
Unfinished Stainless-Steel Panel	bare	53%
	4 spray-on layers	18%
	10 spray-on layers	8.5%
Silver Foil (smooth)	bare	16%
	10 spray-on layers	5%
Silver Foil (scuffed)	bare	25%
	10 spray-on layers	5.5%
Multi-Layer Insulation (MLI) Substrate	bare	11%
	10 coats	5.5%
7075 machined Aluminum Substrate	bare	35%
	10 coats	4%

Space Environment Testing

Glen Research Center Planned Testing

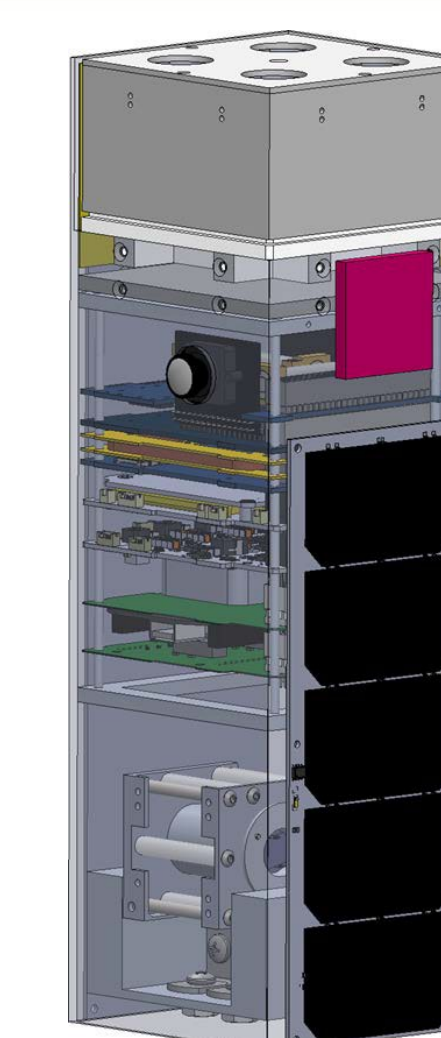
- Atomic oxygen exposure
- Ultraviolet radiation exposure

Goddard Space Flight Center Planned Testing

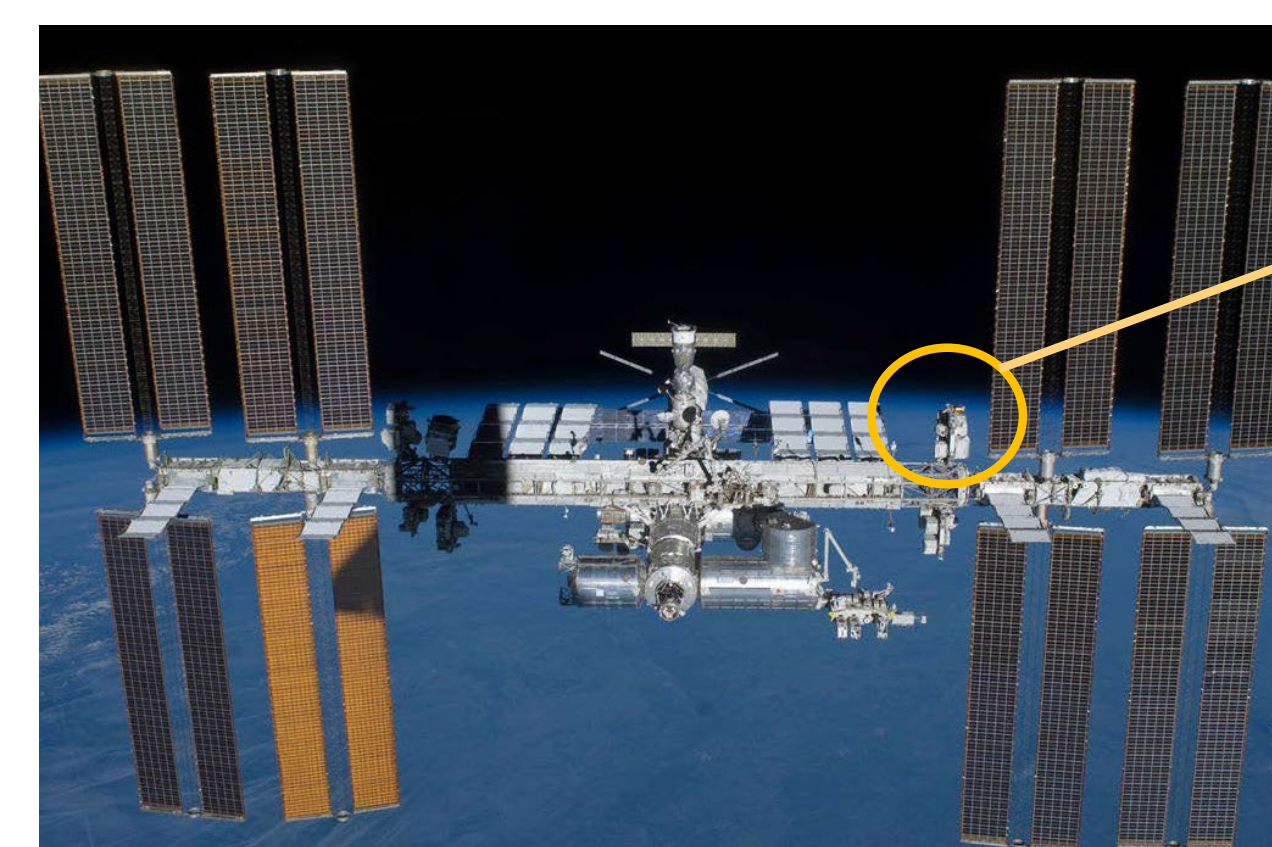
- Solar wind exposure

United Launch Alliance Planned Testing

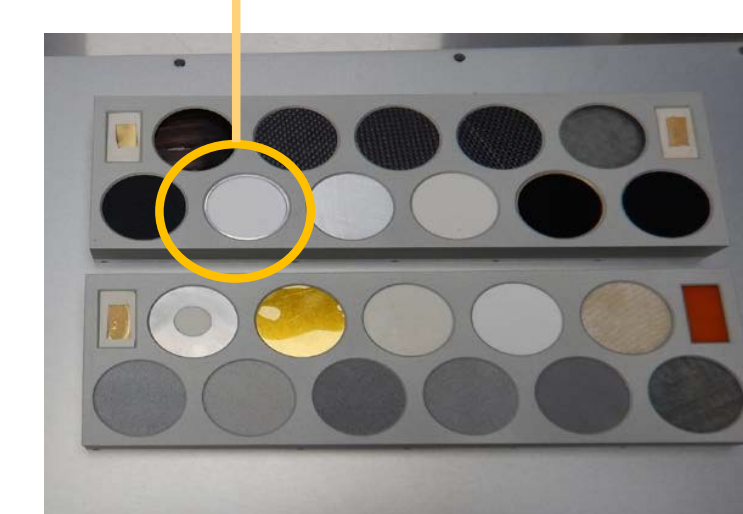
- Tipping Point demonstration - Cryogenic (H₂-O₂) Smart Prolusion Flight Demonstration



CubeSat design to provide a direct comparison between AZ-93 and the spray-on yttrium oxide coating



Yttrium oxide tile tested on the Materials International Space Station Experiment (MISSE)



Conclusions

- Lots of NASA interest (NASA Innovative Advanced Concepts, Game Changing Development, Technology Demonstration, Launch Services Program)
- Commercial interest as well (Northrup Grumman, Blue Origin, United Launch Alliance)
- Large-scale manufacturing process development in work with the Thermal Protection System Facility at Kennedy Space Center
- Pressed and sintered yttrium oxide tiles perform better than NIST standard reference material, imposing the need to develop a new absolute test capability
- Spray-on mixture of yttrium oxide and potassium bromide offer performance improvement over state-of-the-art
- More space environment testing required – and in work or planned