Far-Infrared Blackbody Emissivity Measurements with the Heated Halo Method

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Overview

- Introduction
  - Traceability of infrared blackbody radiance
  - Paint degradation in space
  - On-orbit Absolute Radiance Standard
- Heated Halo Emissivity Monitor
  - Test configuration
  - Emissivity results and uncertainty
  - Comparison between S-HIS, ARI and NIST measurements
- Summary

Traceable Blackbody Radiance

- Planck function:

$$B_{\tilde{\nu}}(T) = \frac{2hc^2\nu^3}{\exp(h\nu c / k_B T) - 1}$$

- Blackbody radiance:

$$I_{\tilde{\nu}}(\varepsilon_{\tilde{\nu}}, T) = \varepsilon_{\tilde{\nu}} B(T_{BB}) + (1 - \varepsilon_{\tilde{\nu}}) B(T_{eff})$$

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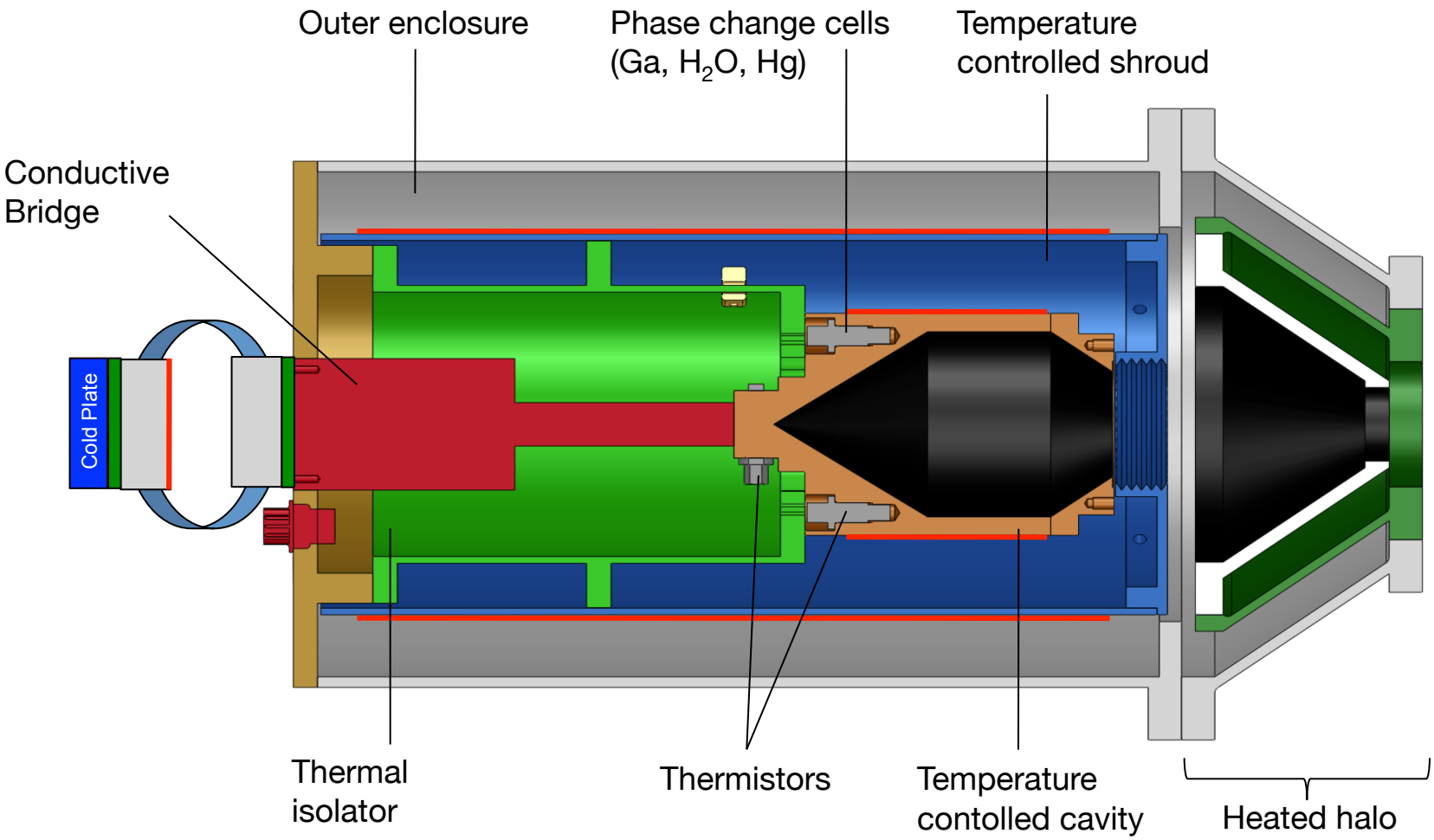
- Both temperature and emissivity of a blackbody must be known — on-orbit — throughout the lifetime of the instrument

On-orbit Absolute Radiance Standard



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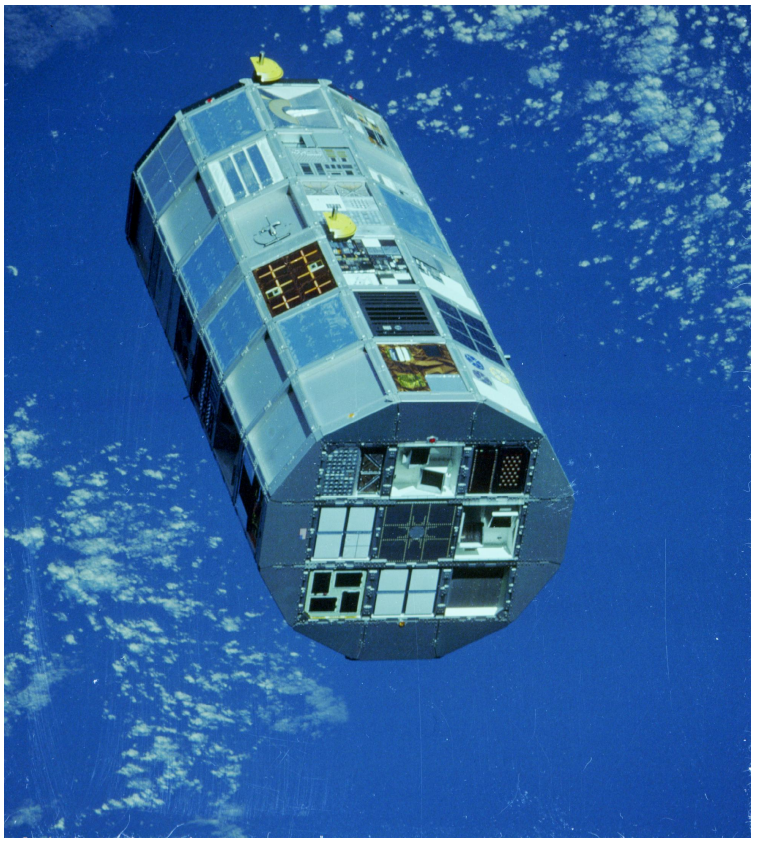
Paint Degradation in Space

Long Duration Exposure Facility

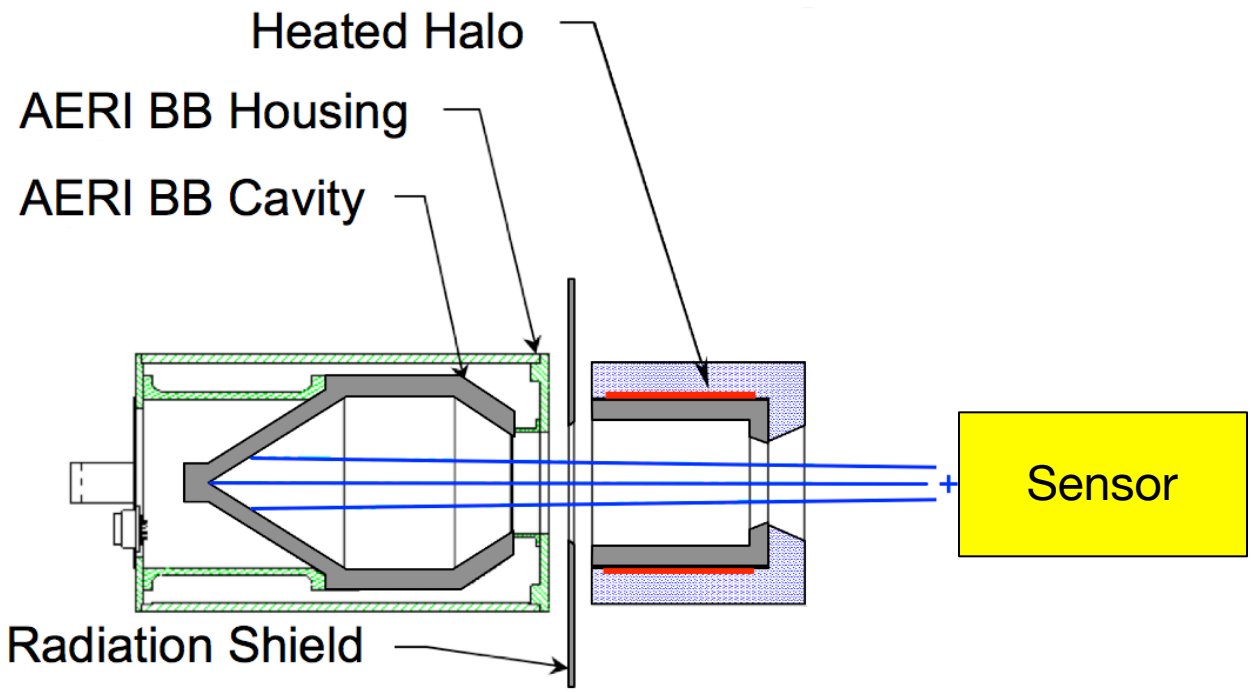
- Study effects of LEO exposure on various materials
- In LEO 1984-1990 (5.7 years)
- Samples of Z306 on Aluminum

Results

- Evidence of oxidation, erosion, removal of resins, appearance of silicate residues, cracking
- Quantitative changes in optical properties



Heated Halo Concept



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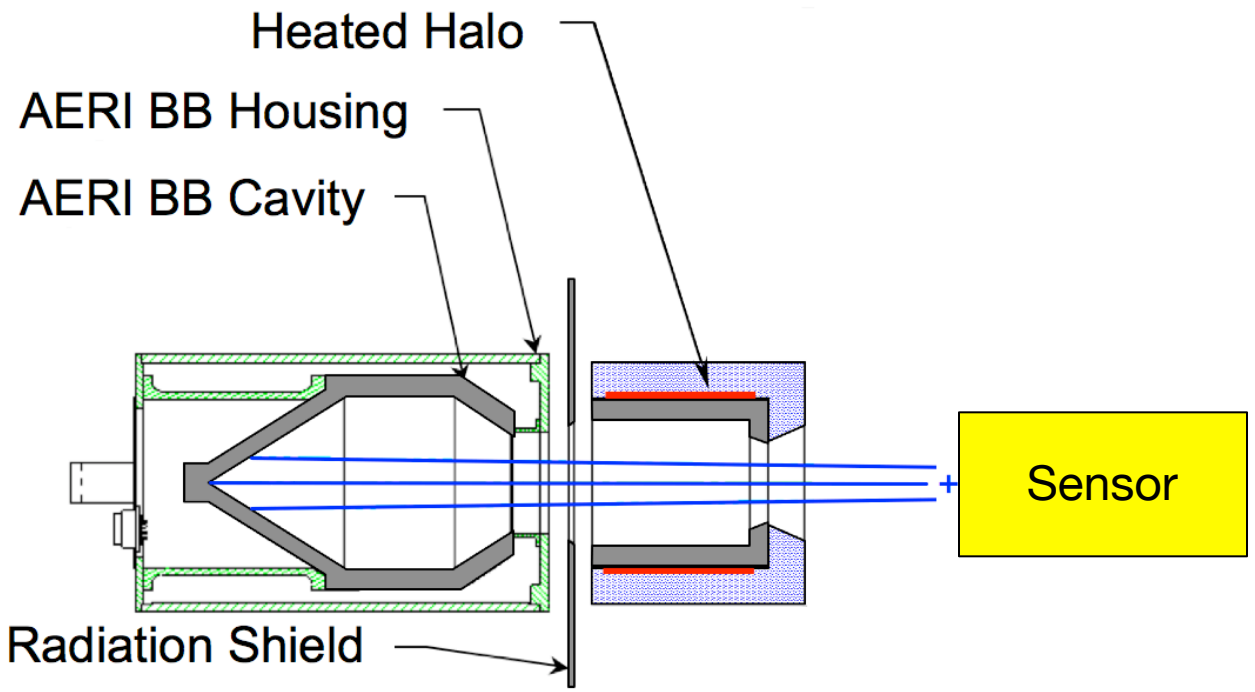

$$R_{obs} = \varepsilon \bullet B(T_{bb}) + (1-\varepsilon) \bullet [F \bullet B(T_{halo}) + (1-F) \bullet B(T_{room})]$$

Direct radiance from BB

Reflected radiance from BB

Emissivity Calculation

Observed radiance:

$$R_{\text{obs}} = \varepsilon \bullet B(T_{\text{bb}}) + (1 - \varepsilon) \bullet R_{\text{bg}},$$

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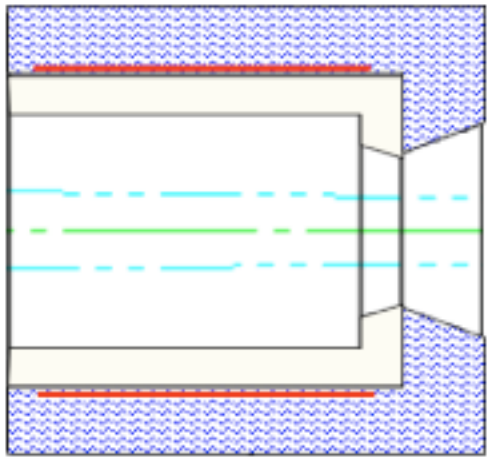
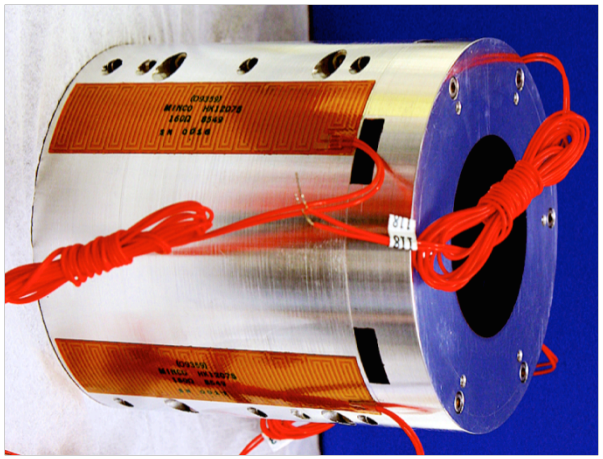
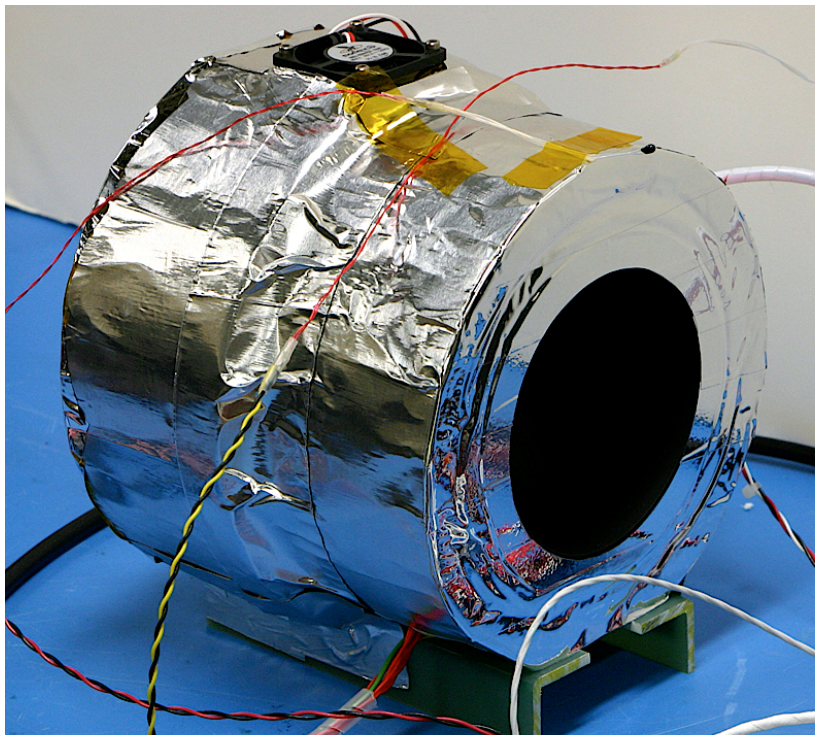
Emissivity/reflectivity measurement:

$$\langle 1 - \varepsilon(t) \rangle_t = \left\langle \frac{R_{\text{obs}}(t) - B[T_{\text{bb}}(t)]}{R_{\text{bg}}(t) - B[T_{\text{bb}}(t)]} \right\rangle_t$$

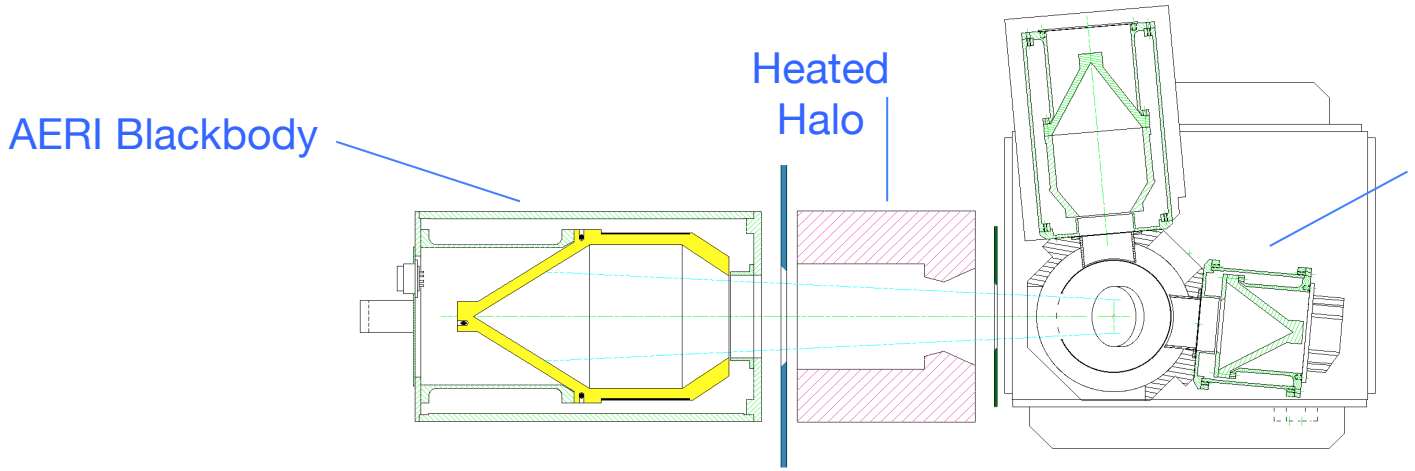
Heated Halo Gen. 1

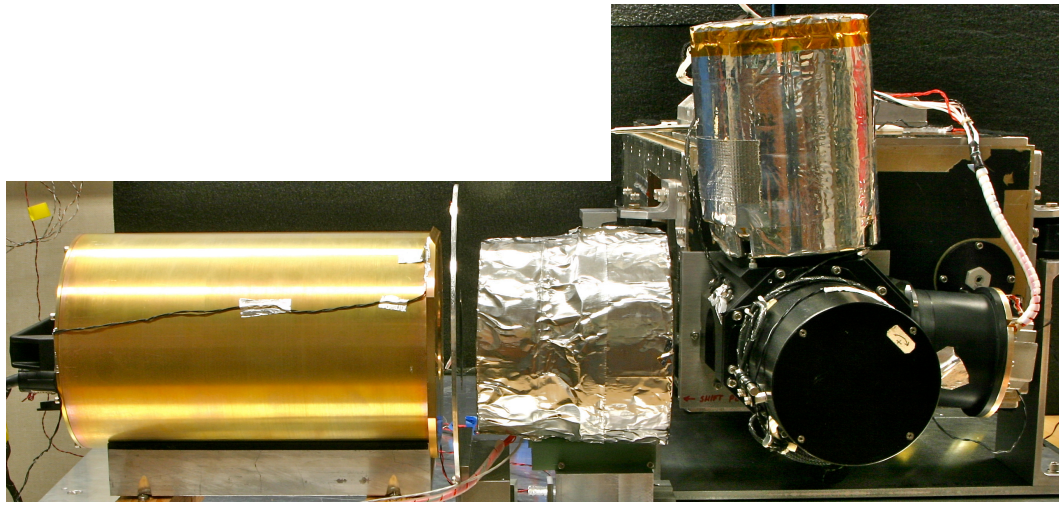






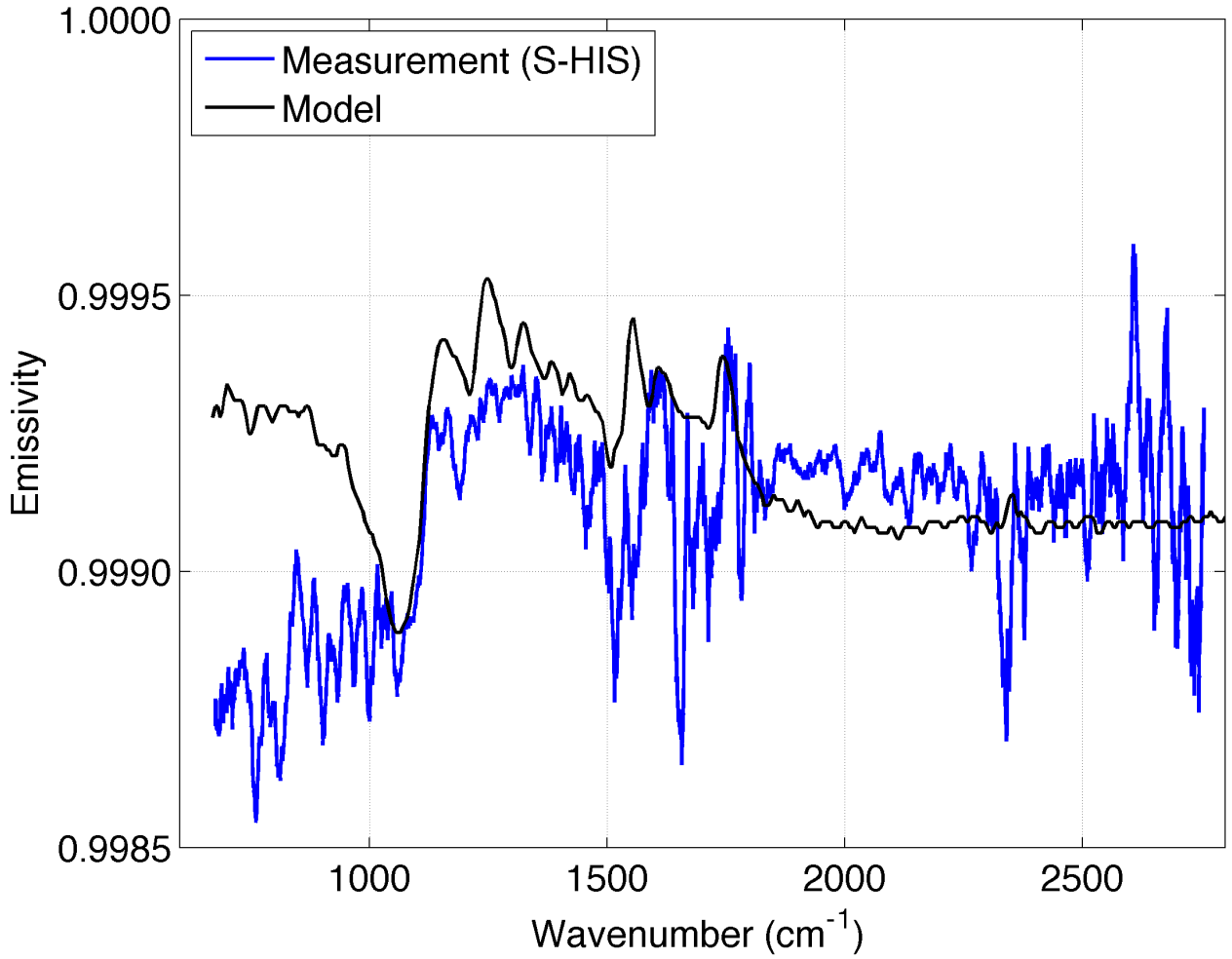
Heated Halo Gen. 1 Test Configuration (S-HIS)





MCT, InSb
detectors

AERI Blackbody Emissivity (Halo 1, S-HIS)



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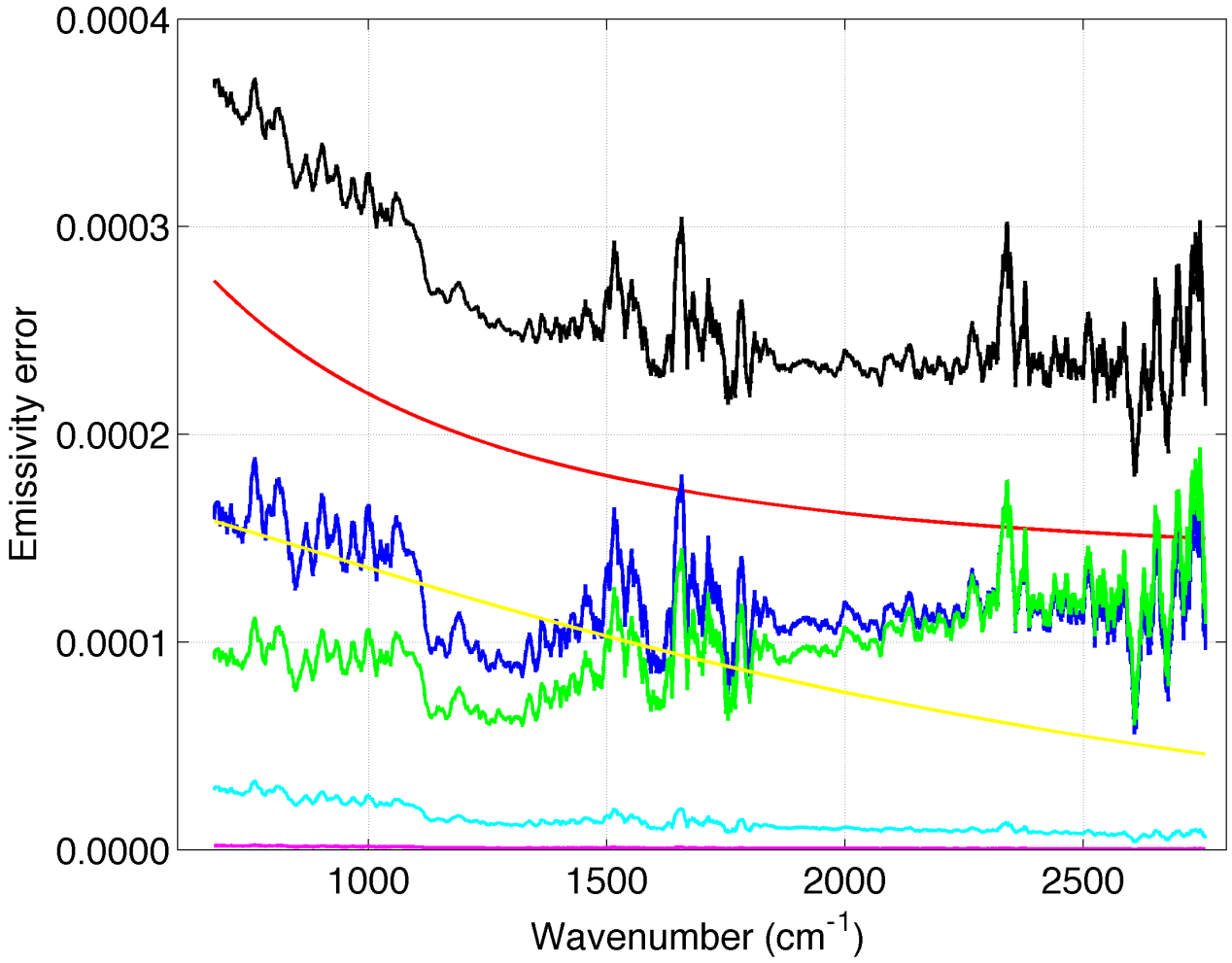
Emissivity Uncertainty (Halo 1, S-HIS)



Type B measurement uncertainty (k = 3)

- u_c
- f_{stray}=0.01 %
- ΔF=0.1
- ΔT_{ha}=5 K
- ΔT_{cal}=0.01 K
- ΔT_{rm}=5 K
- ΔT_{bb}=0.1 K

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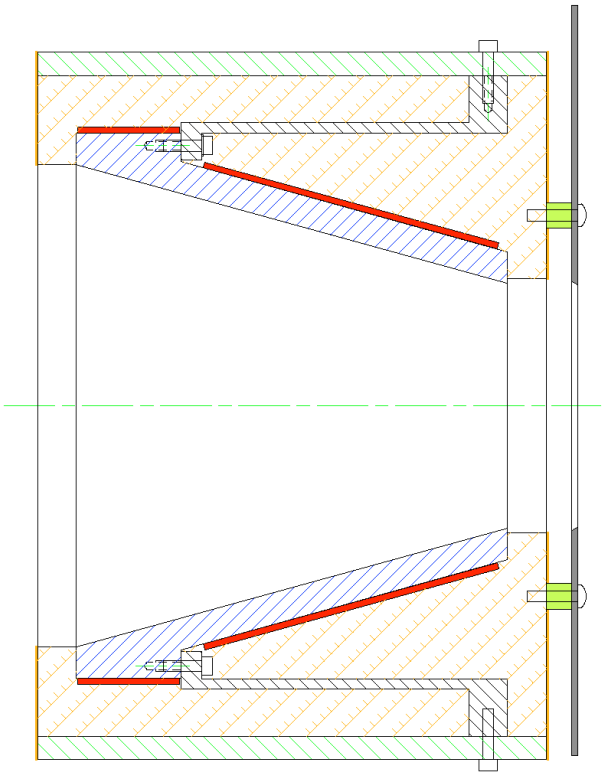
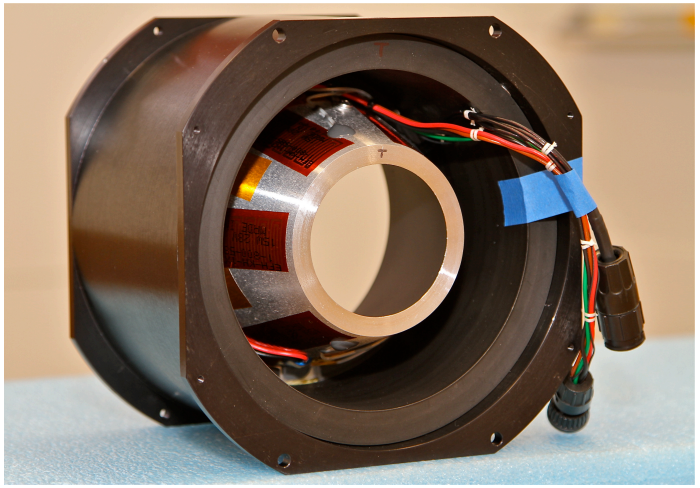
Heated Halo Gen. 2





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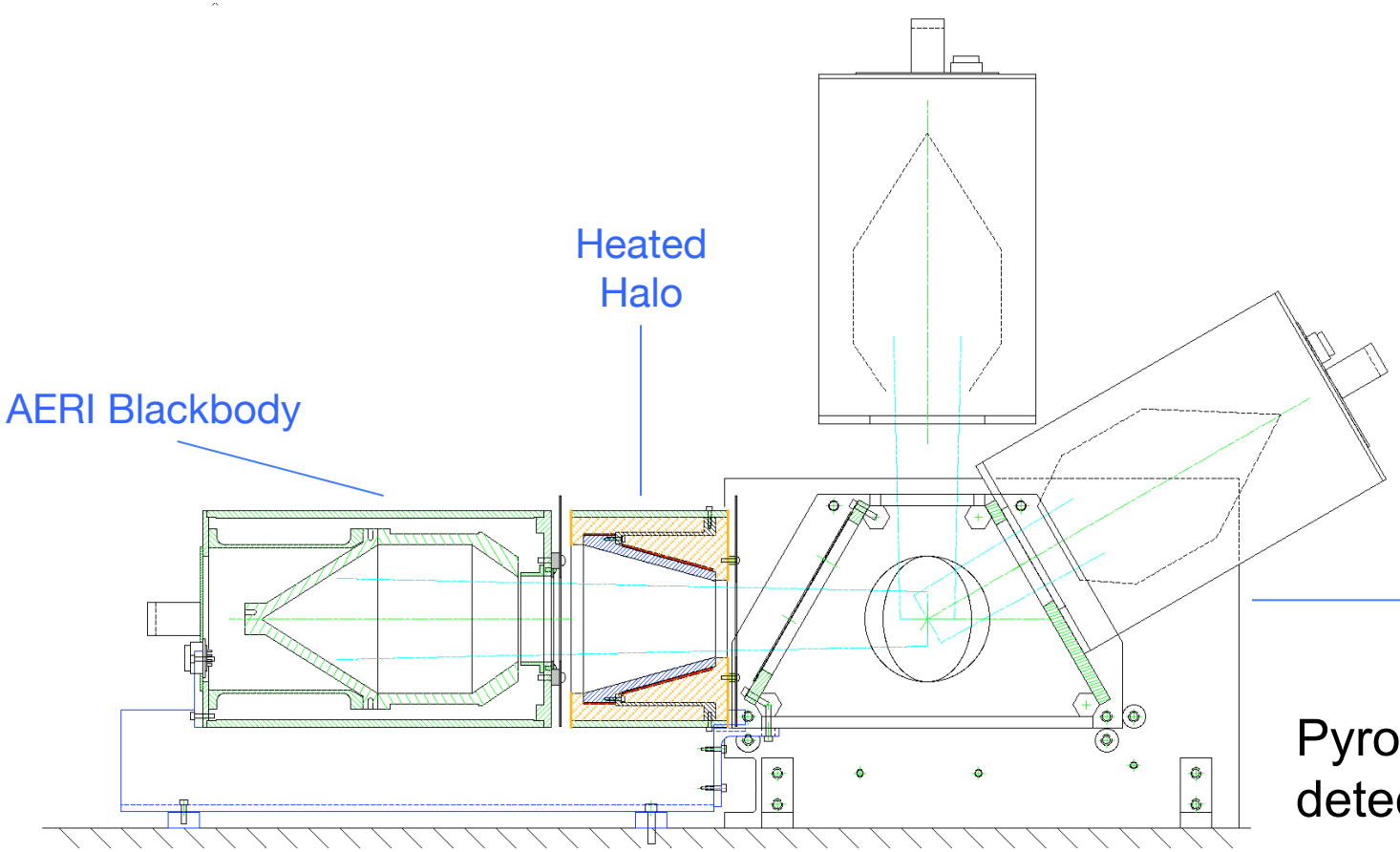
Heated Halo Gen. 2 Test Configuration (ARI)



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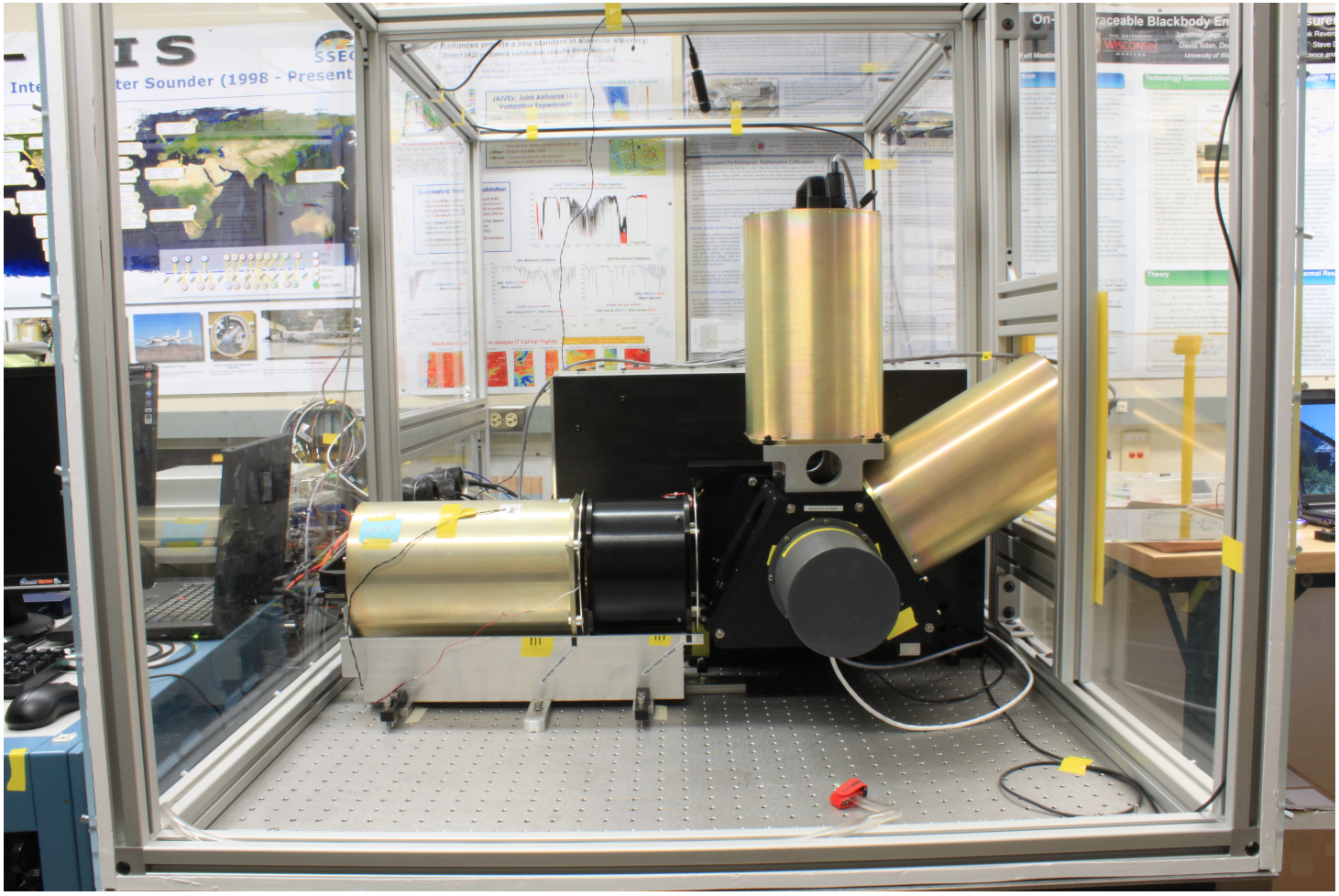

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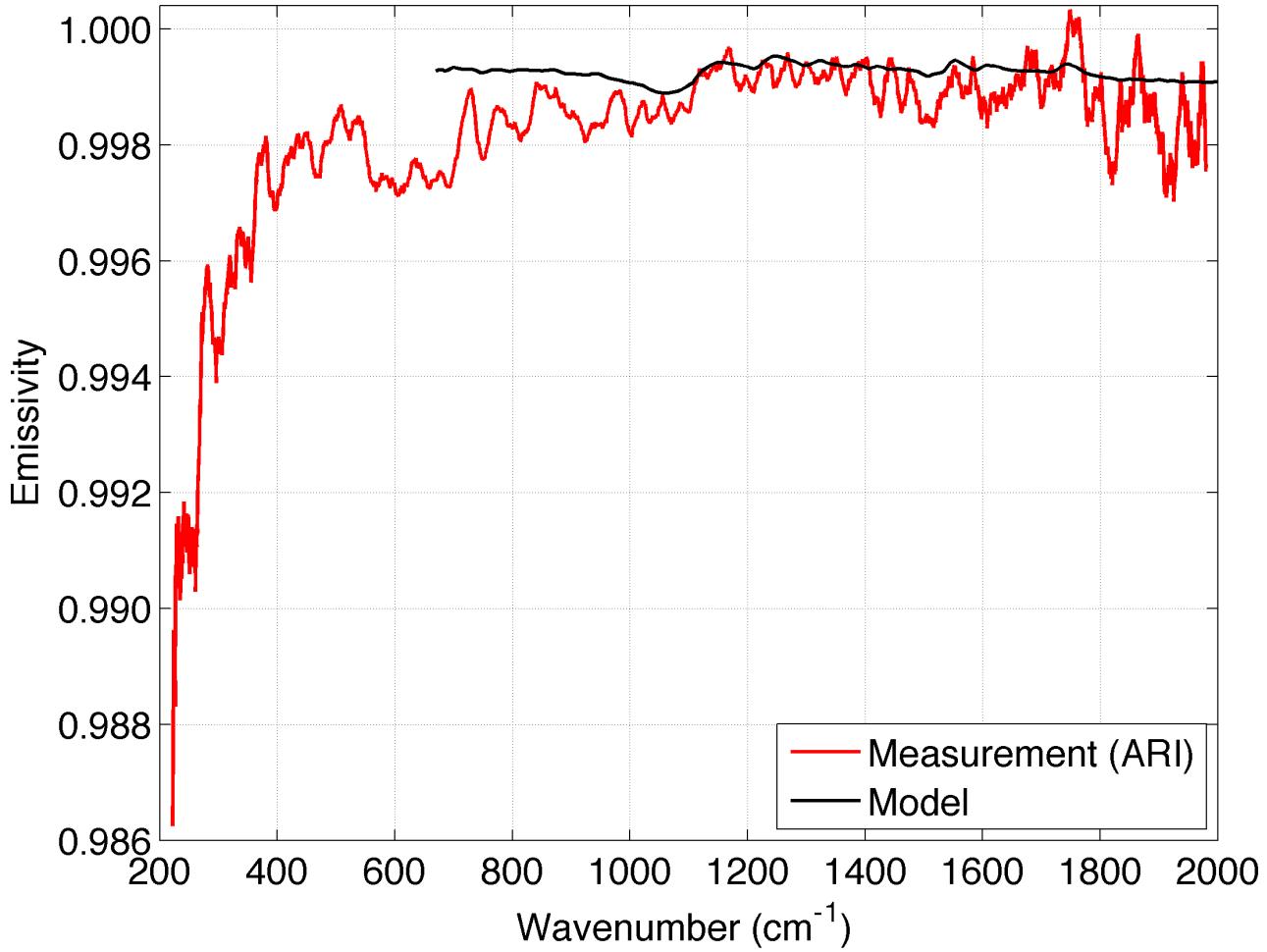
AERI Blackbody Emissivity (Halo 2, ARI)



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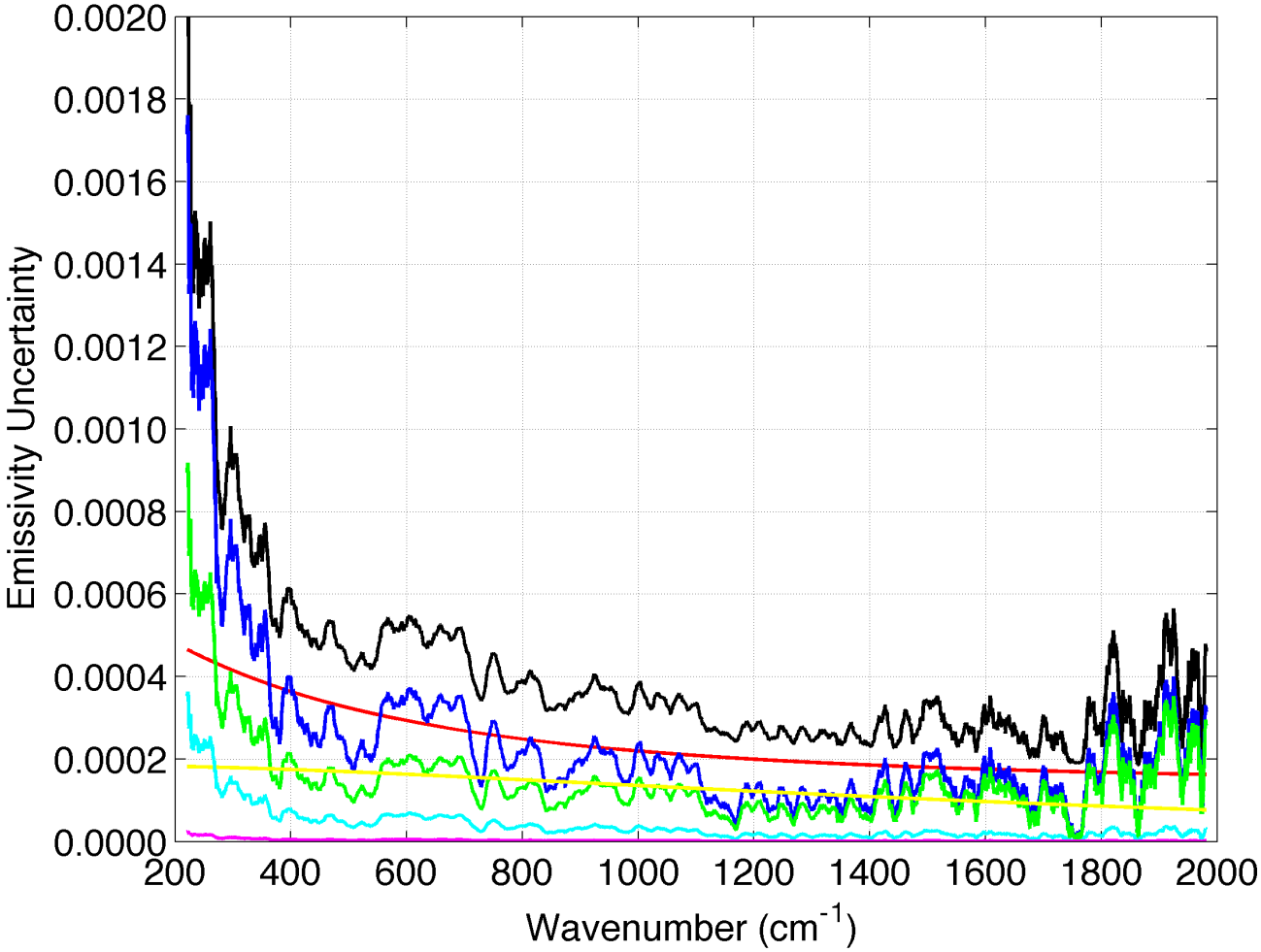
Emissivity Uncertainty (Halo 2, ARI)



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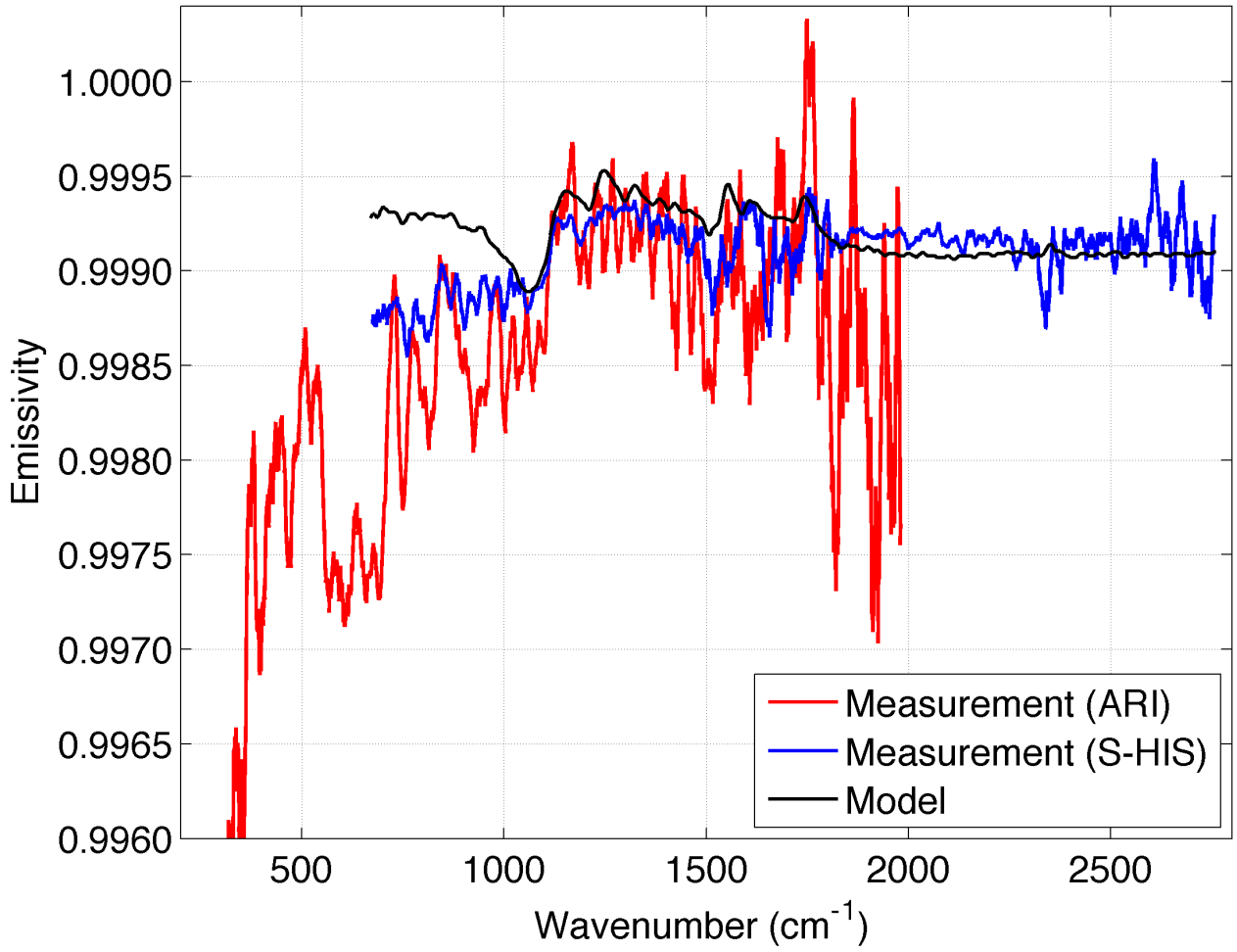
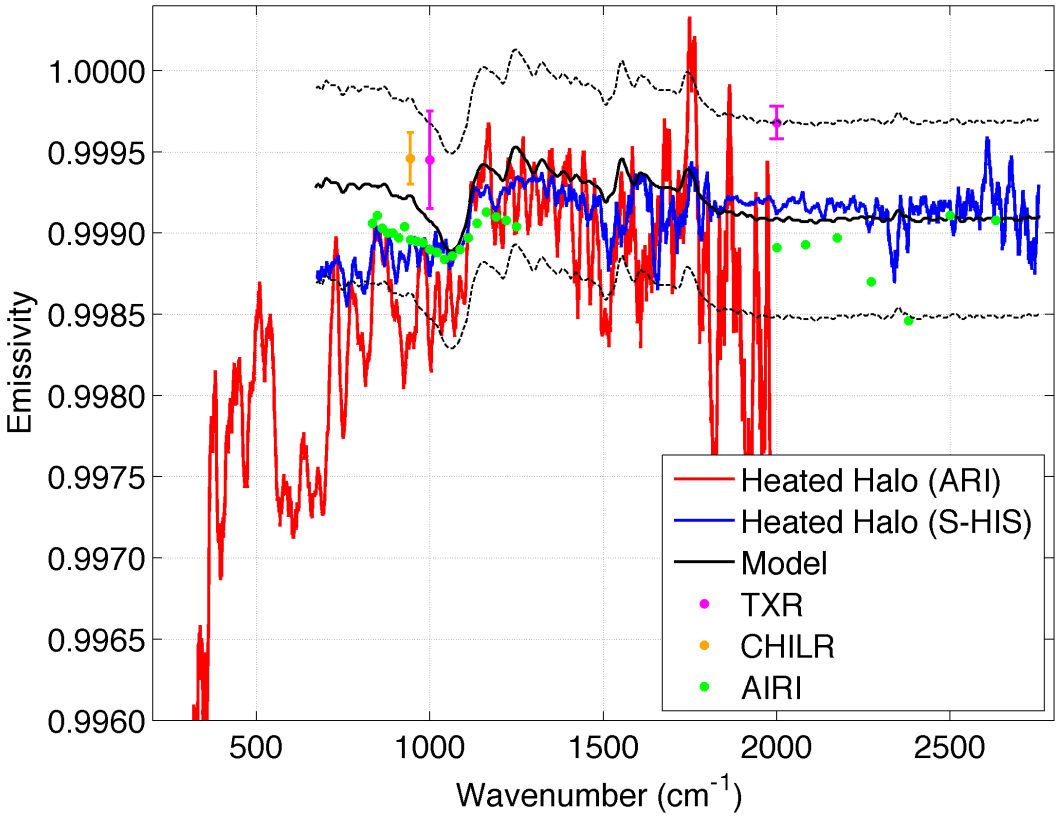
AERI Blackbody Emissivity (Halo 1, Halo 2)



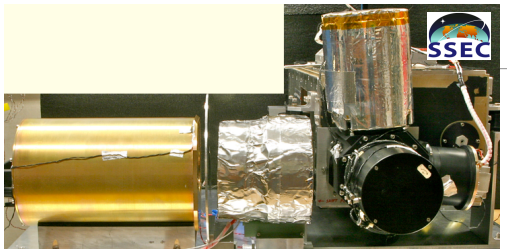
AERI Blackbody Emissivity Comparison



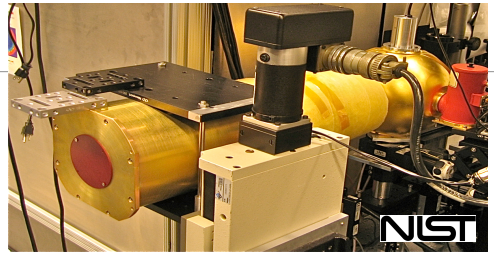
Comparison with NIST measurements

Continued work corroborates earlier results and helps reduce uncertainty

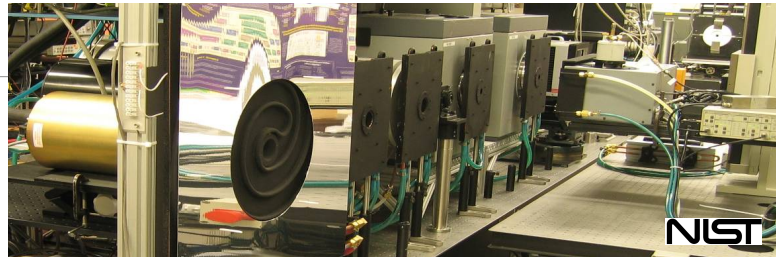
UW Heated Halo



NIST CHILR

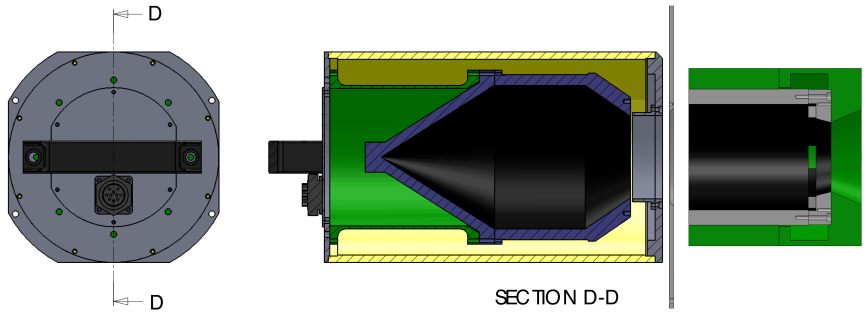


NIST AIRI



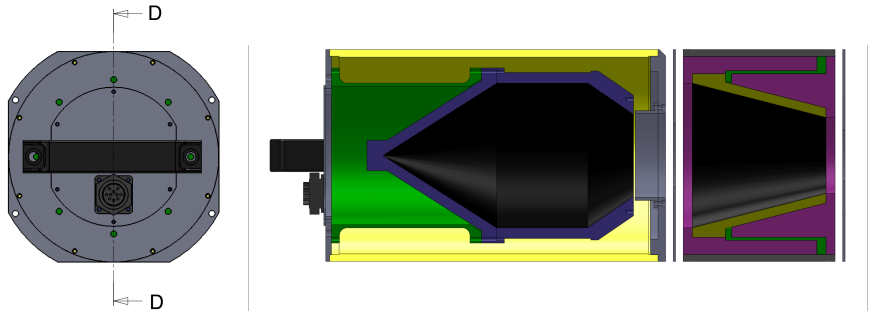
Next Generation Heated Halo

Gen. 1



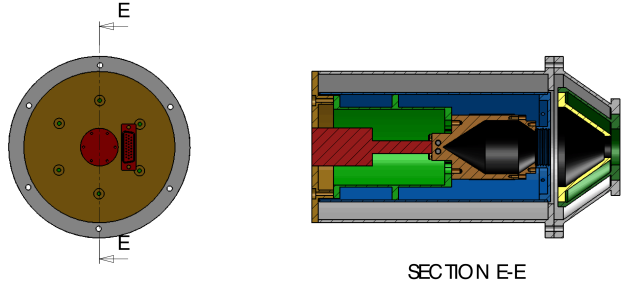
TRL 4

Gen. 2



TRL 5

Gen. 3

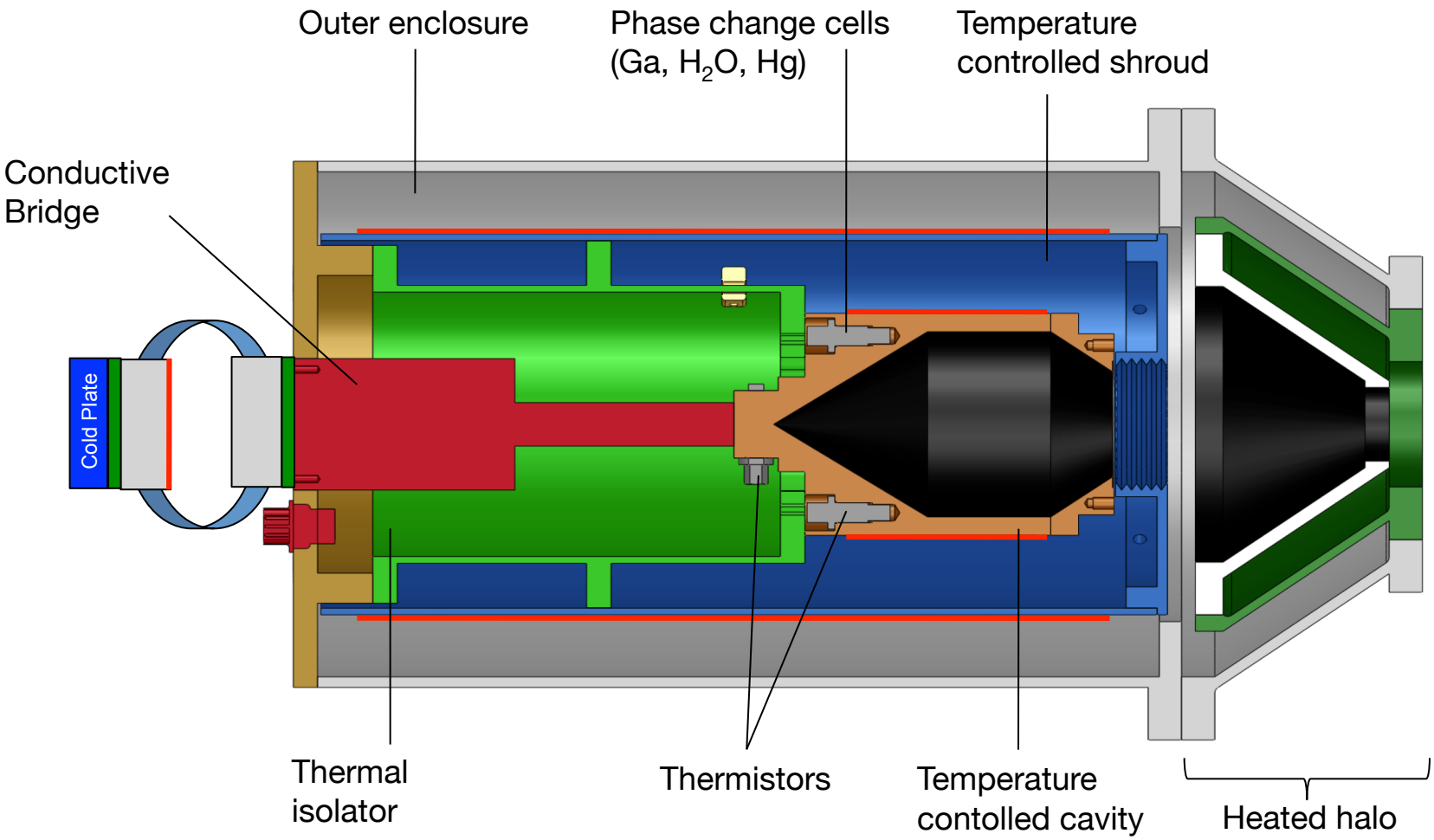


TRL 6

Summary

- Spectral emissivity measurement has been demonstrated with the Heated Halo configured with both the S-HIS and the ARI, using an AERI blackbody as the target
- 0.0006 measurement uncertainty achievable across most of the thermal infrared
- Primary “lesson learned” is the importance of controlling stray light contributions
- Agreement between observations using two different instruments validates the process for emissivity measurement with the Heated Halo

On-orbit Absolute Radiance Standard



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