Determination of the Atmospheric Emitted Radiance Interferometer (AERI) Blackbody Emissivity and Radiance Using Multiple Techniques

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CALCON
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Topics

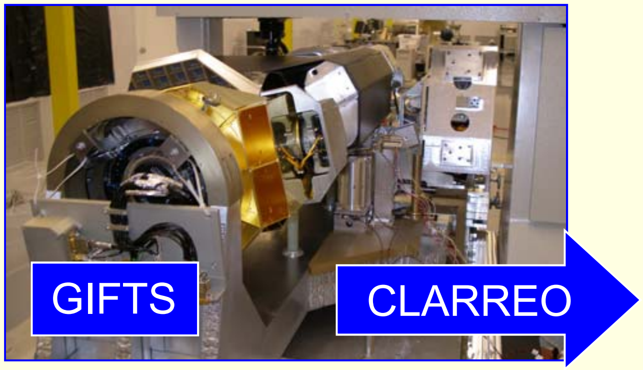
- UW-SSEC Blackbody design and heritage.
  - Cavity emisisivity determined using traditional approach.
  - NIST TXR measurements of emissivity and radiance.
  - UW Heated Halo demonstration (CLARREO)
  - NIST CHILR - Laser-based Reflectometer measurements.
  - NIST AIRI (Advanced Infrared Radiometry and Imaging) measurements of emissivity and radiance.
- Summary - comparison of measurements.

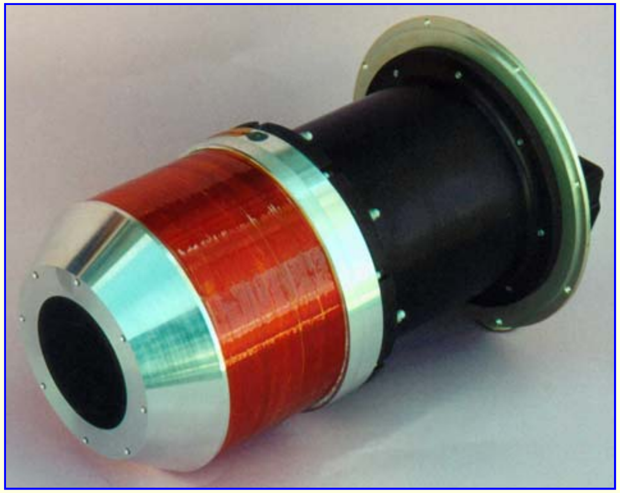
SSEC Blackbody Heritage

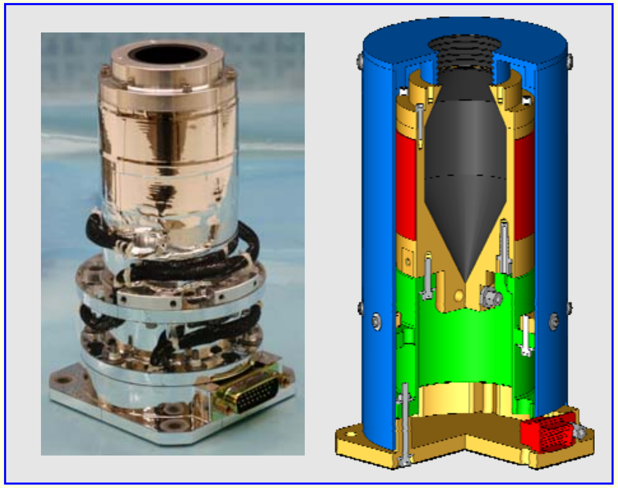
Ground-based

High-altitude Aircraft

Spaceflight

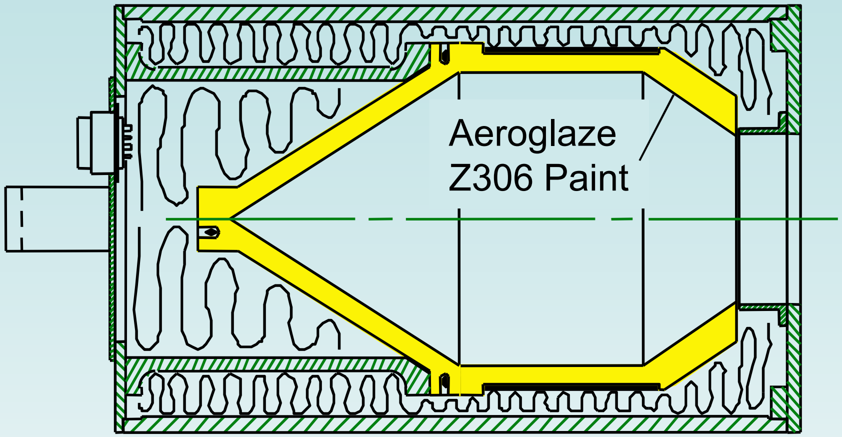


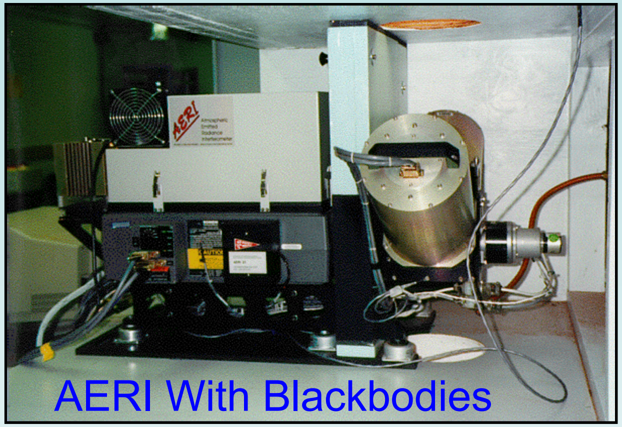




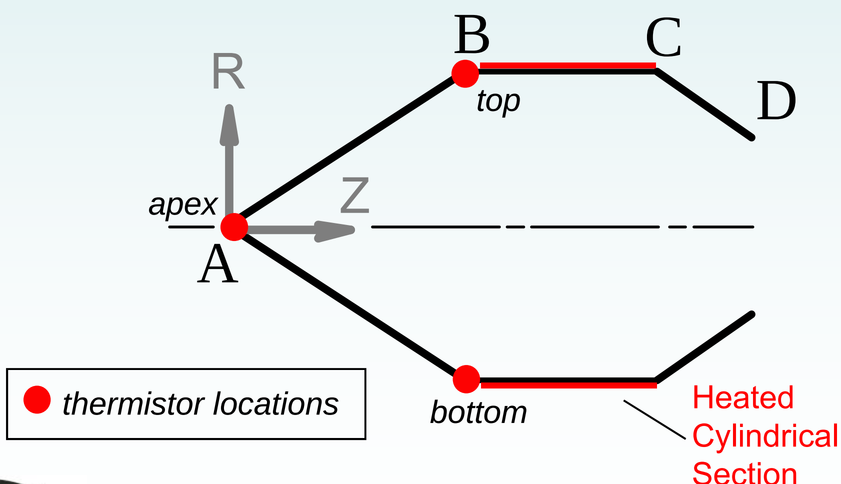
AERI Blackbody Cavity Characteristics

Requirement: $\varepsilon > 0.999$, $\Delta\varepsilon < 0.001$; $\Delta T < 0.10$





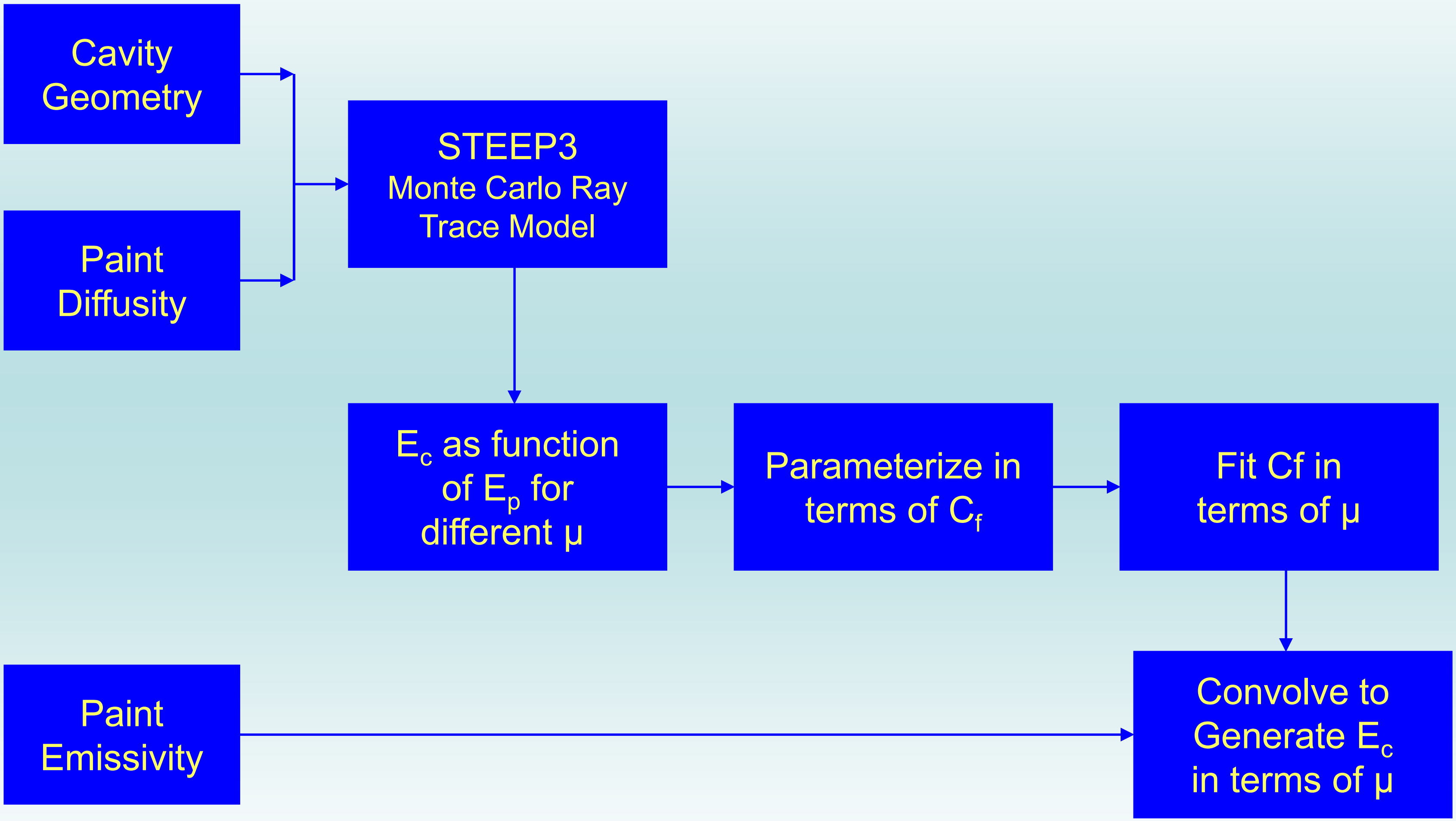
AERI blackbody internal cavity cross-section (dimensions in inches)



	Z	R
A	0	0.01
B	3.75	2.38
C	6.75	2.38
D	8.25	1.35 (Aperture)

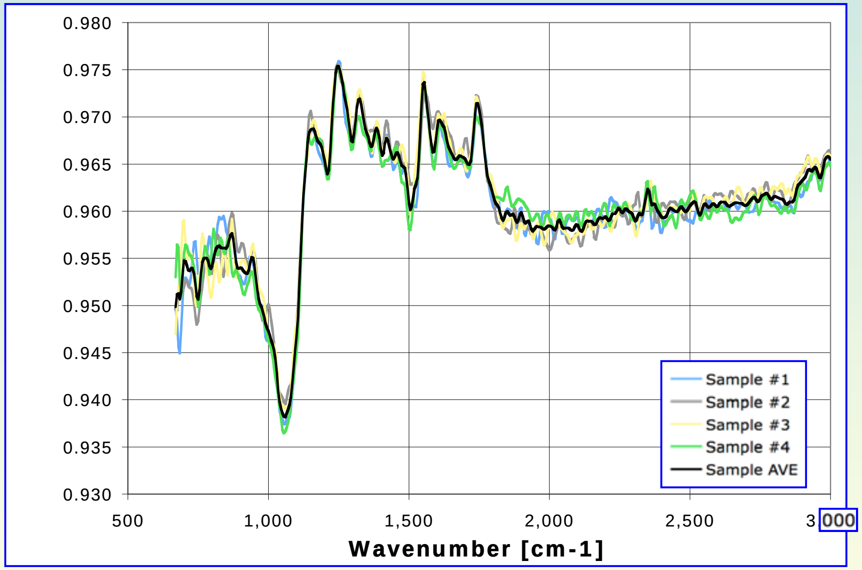
Traditional Approach

Cavity Emissivity - Traditional Approach

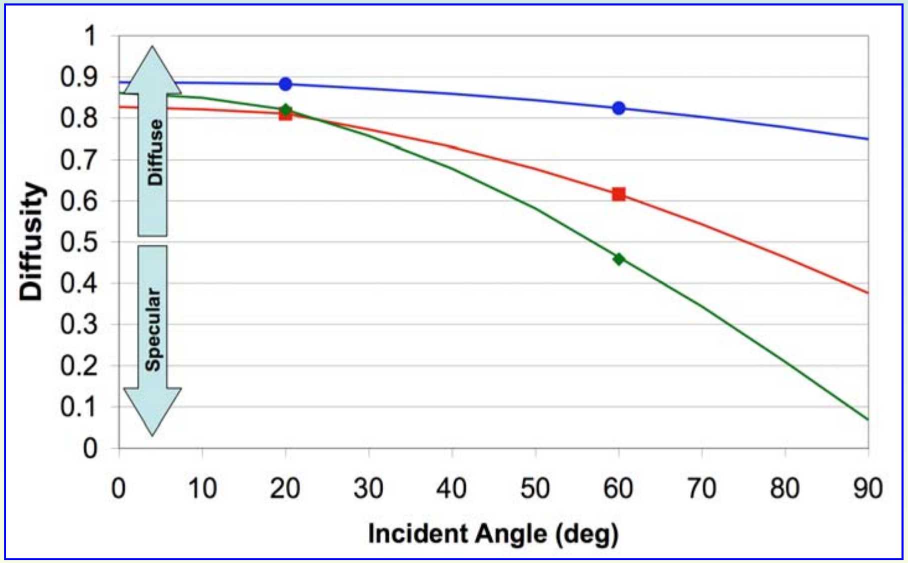


Paint Emissivity and Diffusity

Paint Emissivity Measured at Labsphere



Paint diffusity for Aeroglaze Z306 estimated from published values (Persky, Rev. Sci. Instrumentation)



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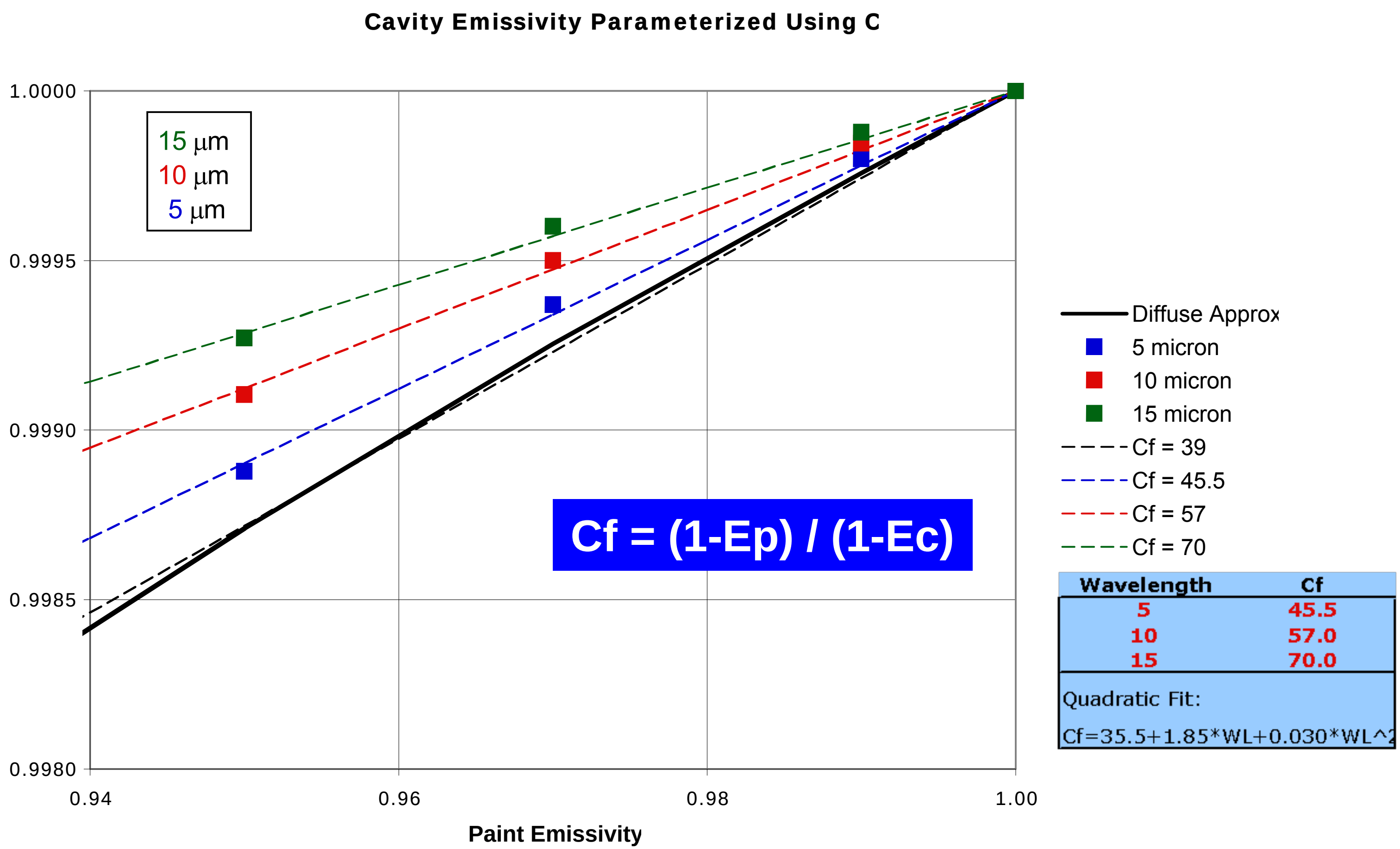
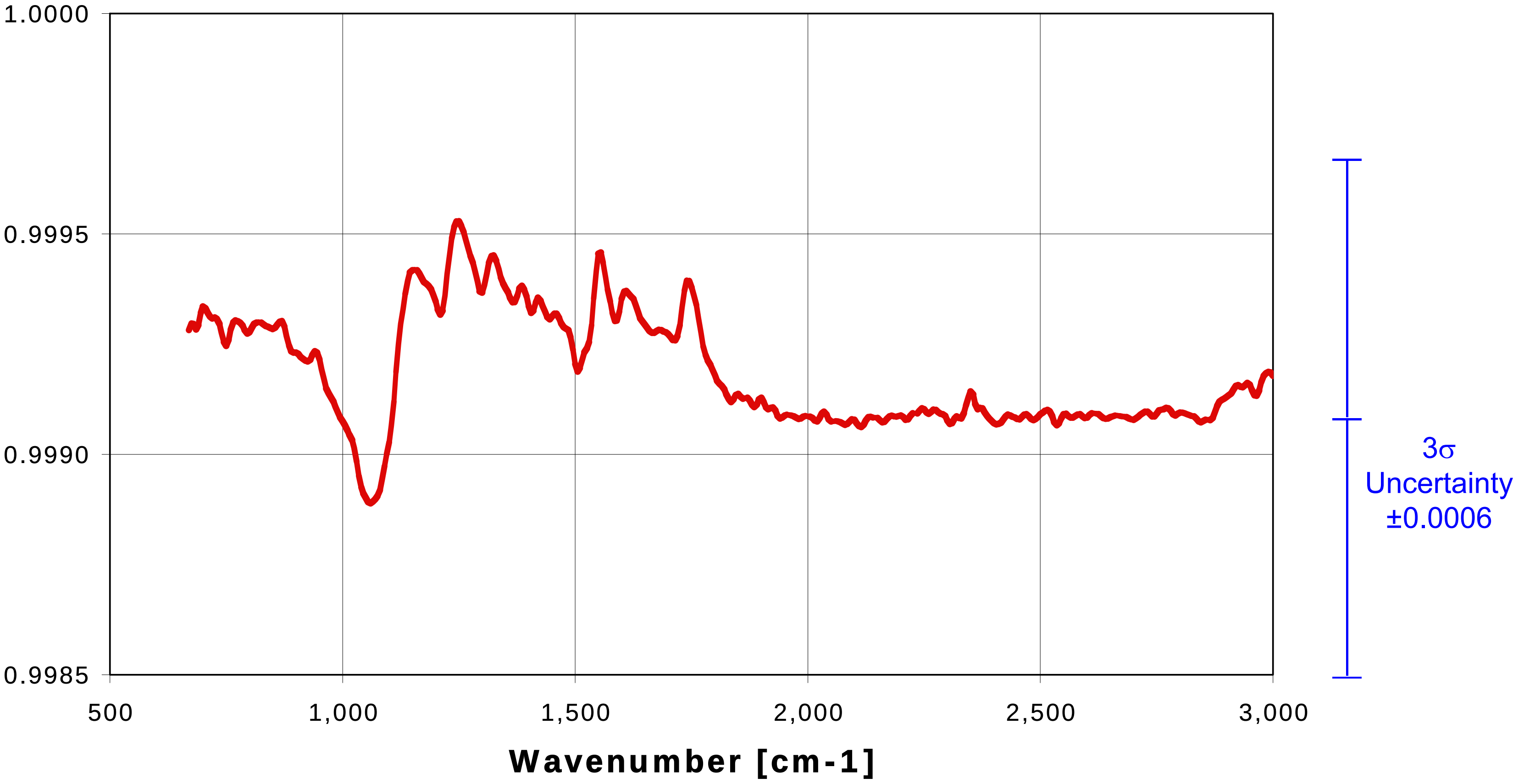
Monte Carlo Results Parameterized Using Cavity Factor, Cf

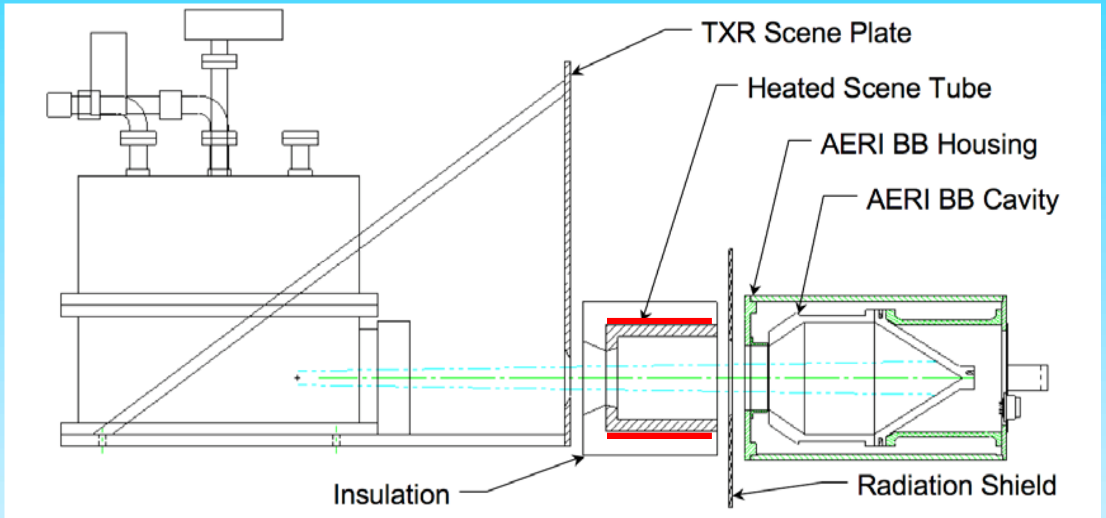


AERI BB S/N 041 Cavity Emissivity

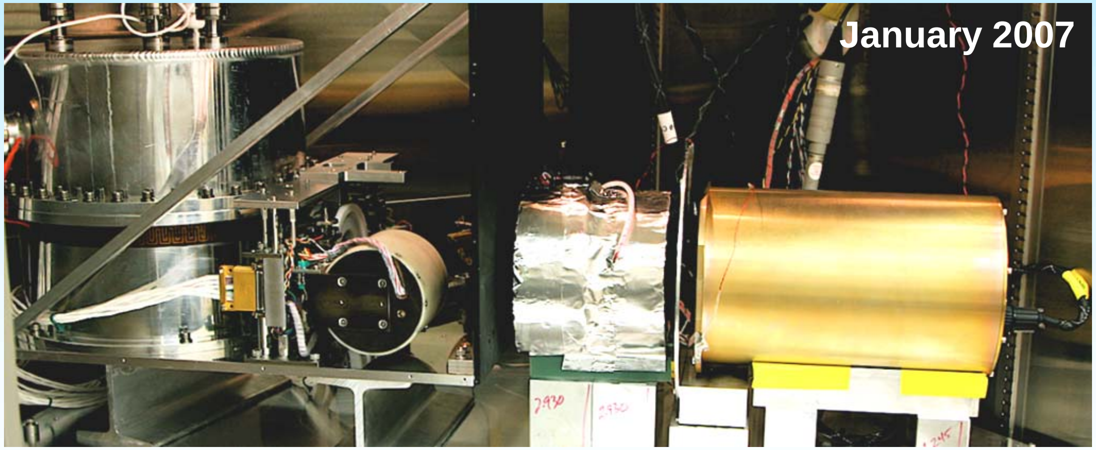


NIST Thermal-Infrared Transfer Radiometer (TXR)

AERI Blackbody Reflectivity Test Using NIST TXR

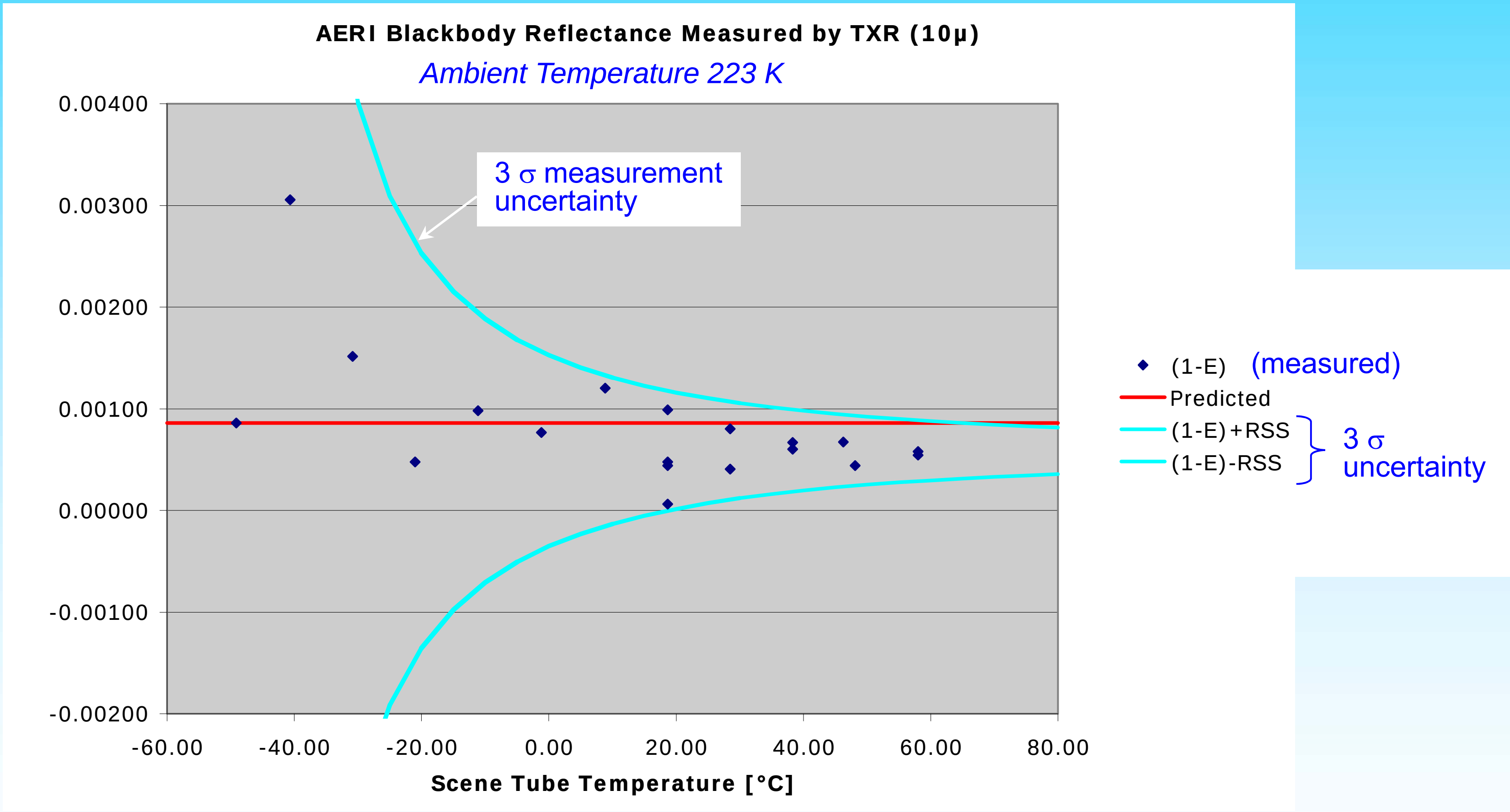


NIST Transfer Radiometer (TXR) used to detect reflection from heated tube (up to background +100 ºC) surrounding direct FOV



$$M_{txr} = \underbrace{\varepsilon \bullet B(T_{bb})}_{\text{direct radiance from BB}} + \underbrace{(1-\varepsilon) \bullet [F \bullet B(T_{tube}) + (1-F) \bullet B(T_{bg})]}_{\text{reflected radiance from BB}}$$

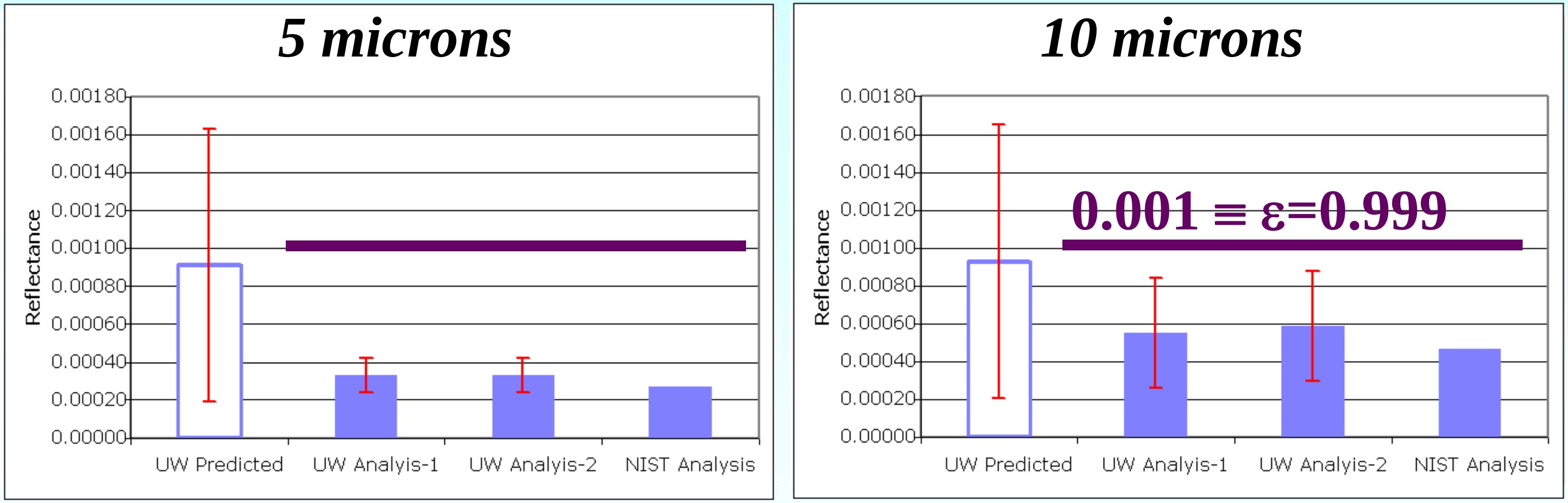
AERI BB Reflectance at 10μ (TXR)



TXR Results Summary

AERI Blackbody Reflectance

Updated August 07

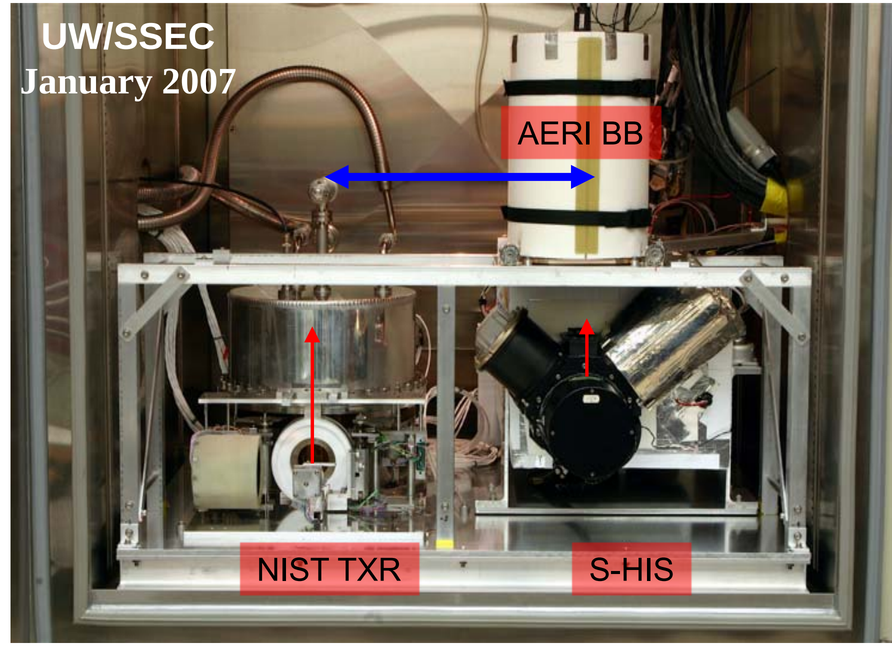


Measurements confirm estimated emissivity within uncertainty (3-sigma estimates)

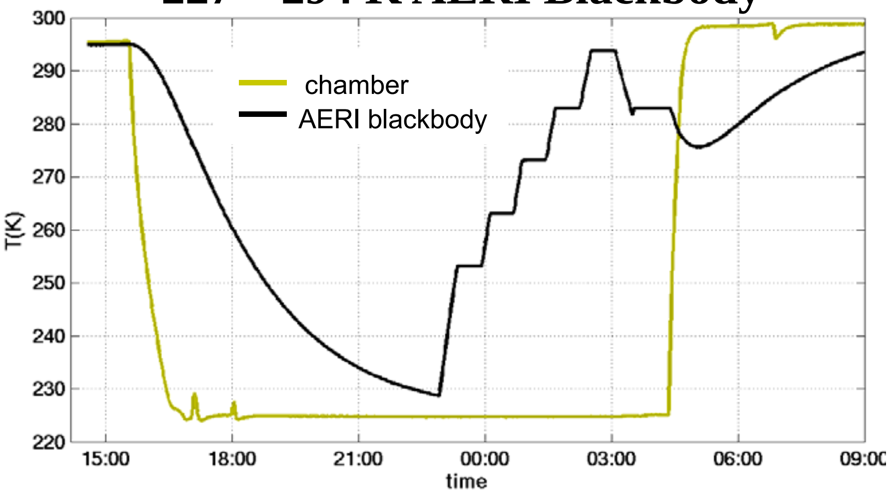
**NIST analysis still being conducted*

UW S-HIS & AERI Blackbody Absolute Accuracy: The NIST Connection for SI Traceability

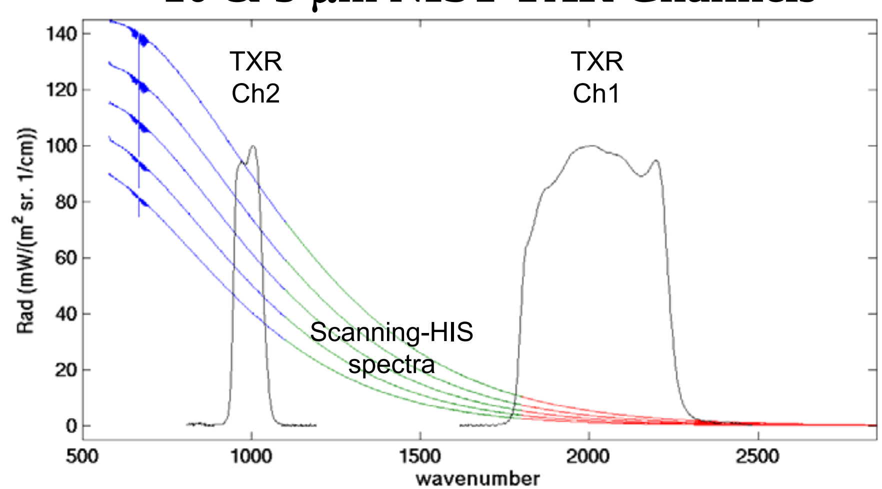
End-to-end radiance evaluations conducted under S-HIS flight-like conditions with NIST transfer sensor (TXR) such that S-HIS satellite validation & AERI observations are traceable to the NIST radiance scale



227 – 294 K AERI Blackbody

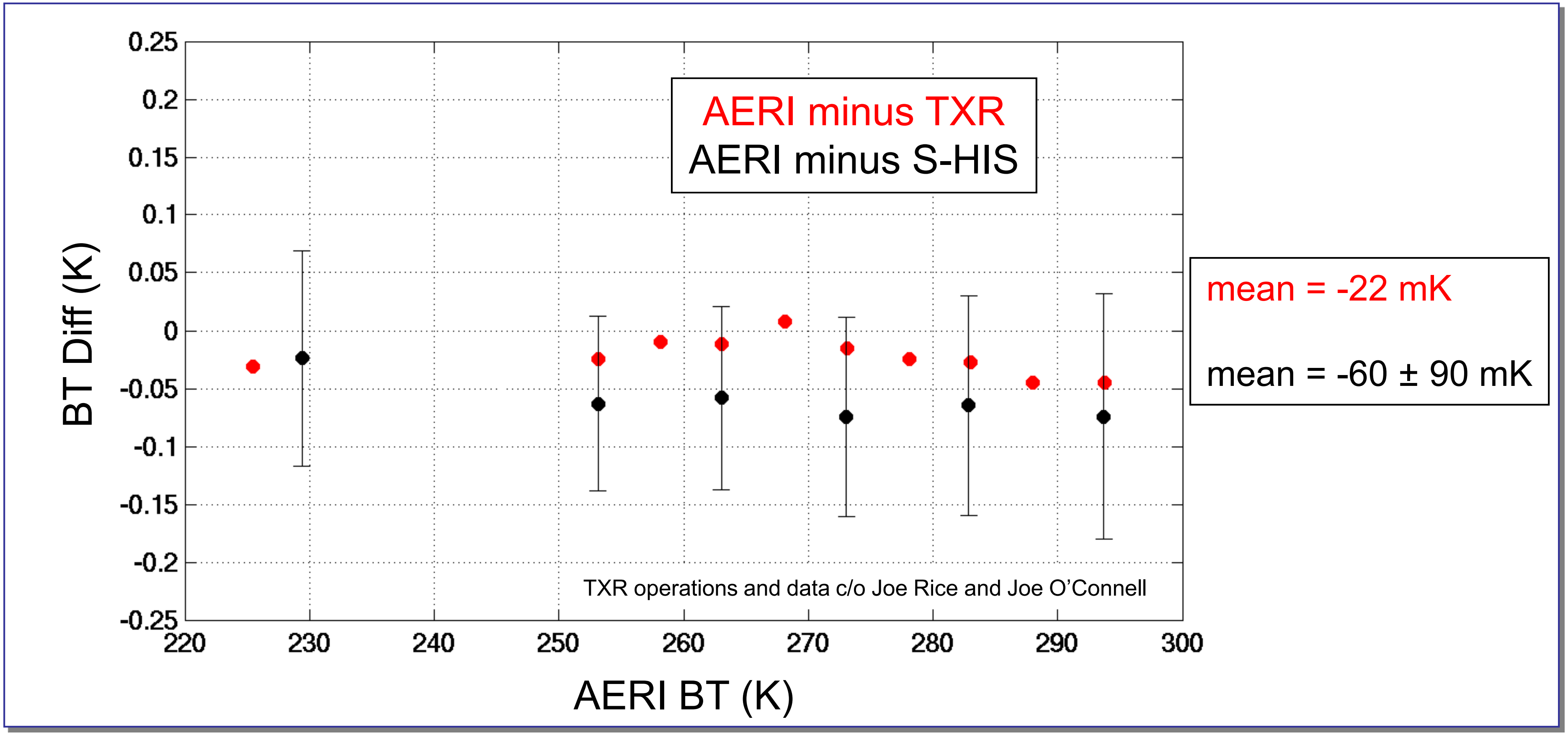


10 & 5 μm NIST TXR Channels



NIST TXR Validation of S-HIS Radiances

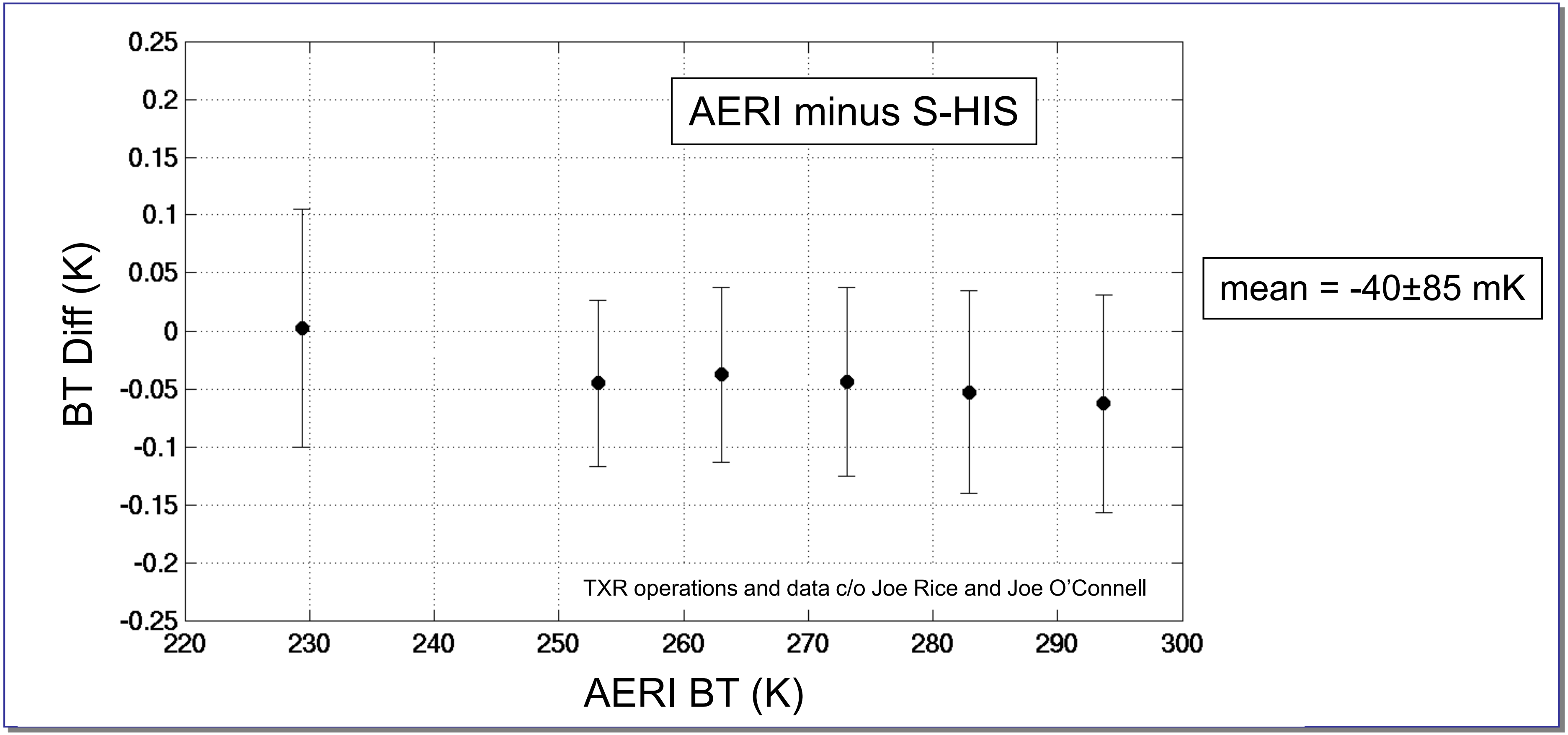
NIST TXR Channel 2 (10μm)



- **mean difference between TXR & S-HIS = 38 mK, well less than propagated 3-sigma uncertainties**

NIST TXR Validation of S-HIS Radiances

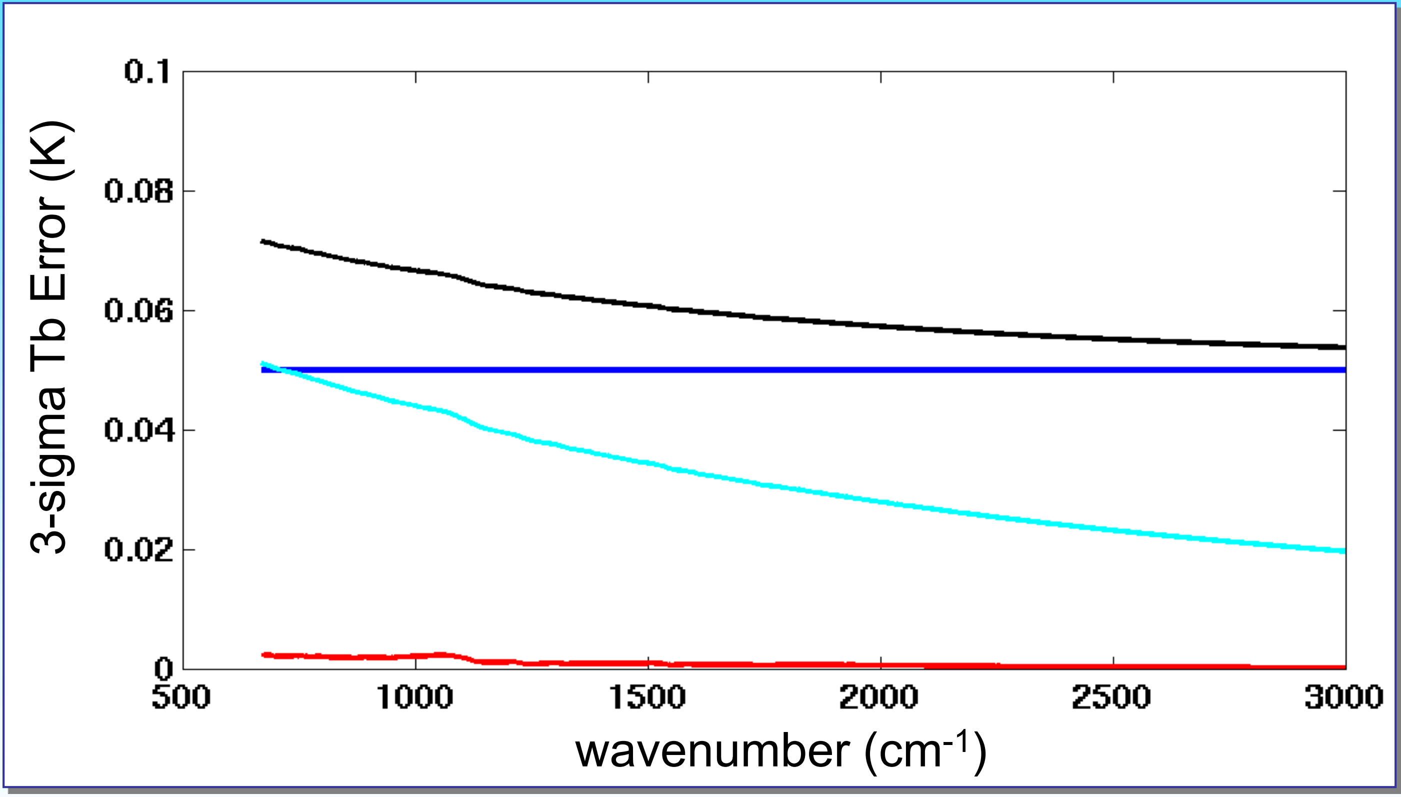
NIST TXR Channel 1 (5μm)



- **mean difference between AERI BB & S-HIS = 40 mK**
- **TXR Ch1 analysis requires refinement at this time**

UW-SSEC AERI Blackbody Predicted Radiance Uncertainty

Uncertainty for T_{BB} = 293K, T_{Refl} = 230K

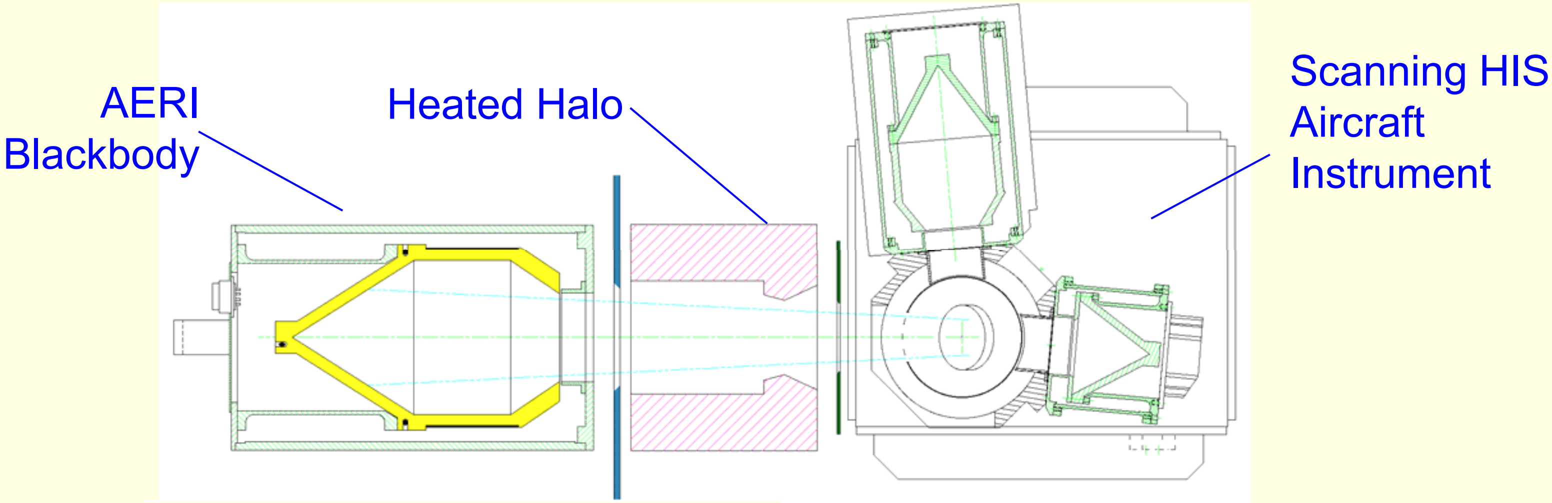


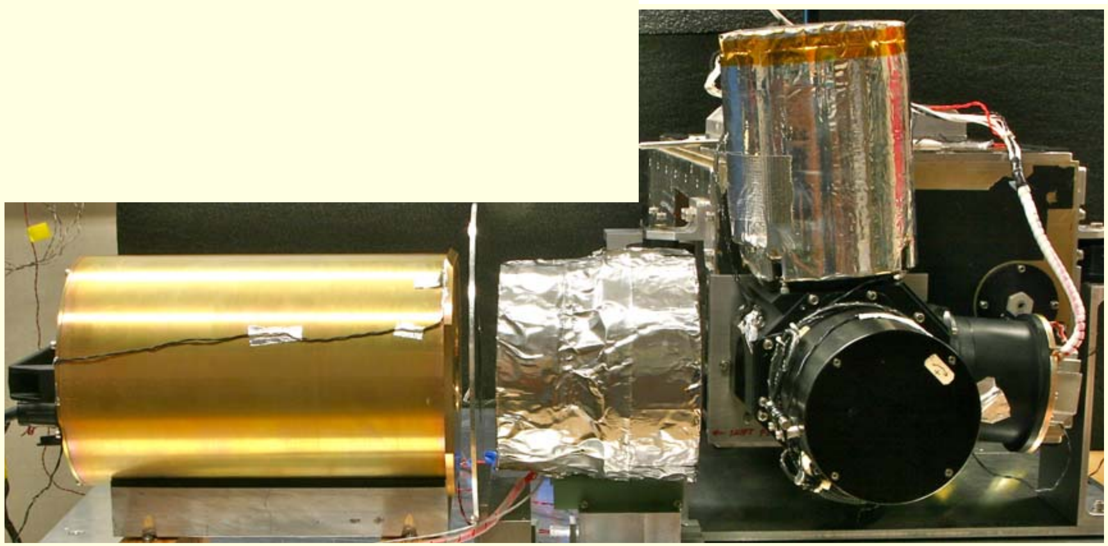
3σ Uncertainties: $3\sigma T_{BB}$ = 0.05 K $3\sigma T_{Refl}$ = 5 K $3\sigma \varepsilon_{BB}$ = 0.001 **Total (RSS)**

Heated Halo Using Scanning-HIS

A Demonstration For CLARREO

Heated Halo Test Configuration





Emissivity Calculation

Observed radiance

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

$$R_{\text{bg}} = [F \bullet B(T_{\text{halo}}) + (1-F) \bullet B(T_{\text{room}})]$$

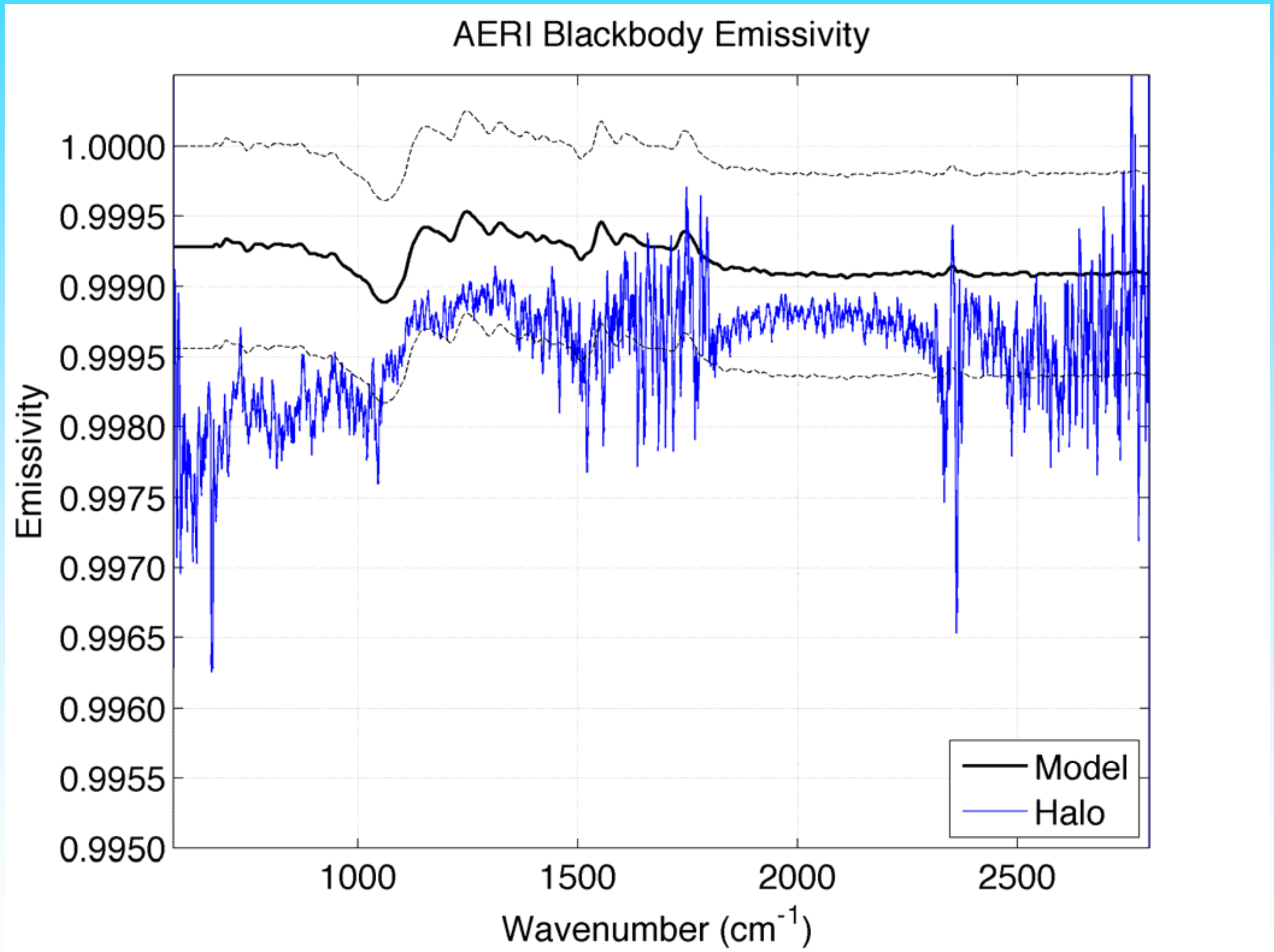
Bias correction with halo out

$$\delta R = R_{\text{AERI model}} - R_{\text{S-HIS}}$$

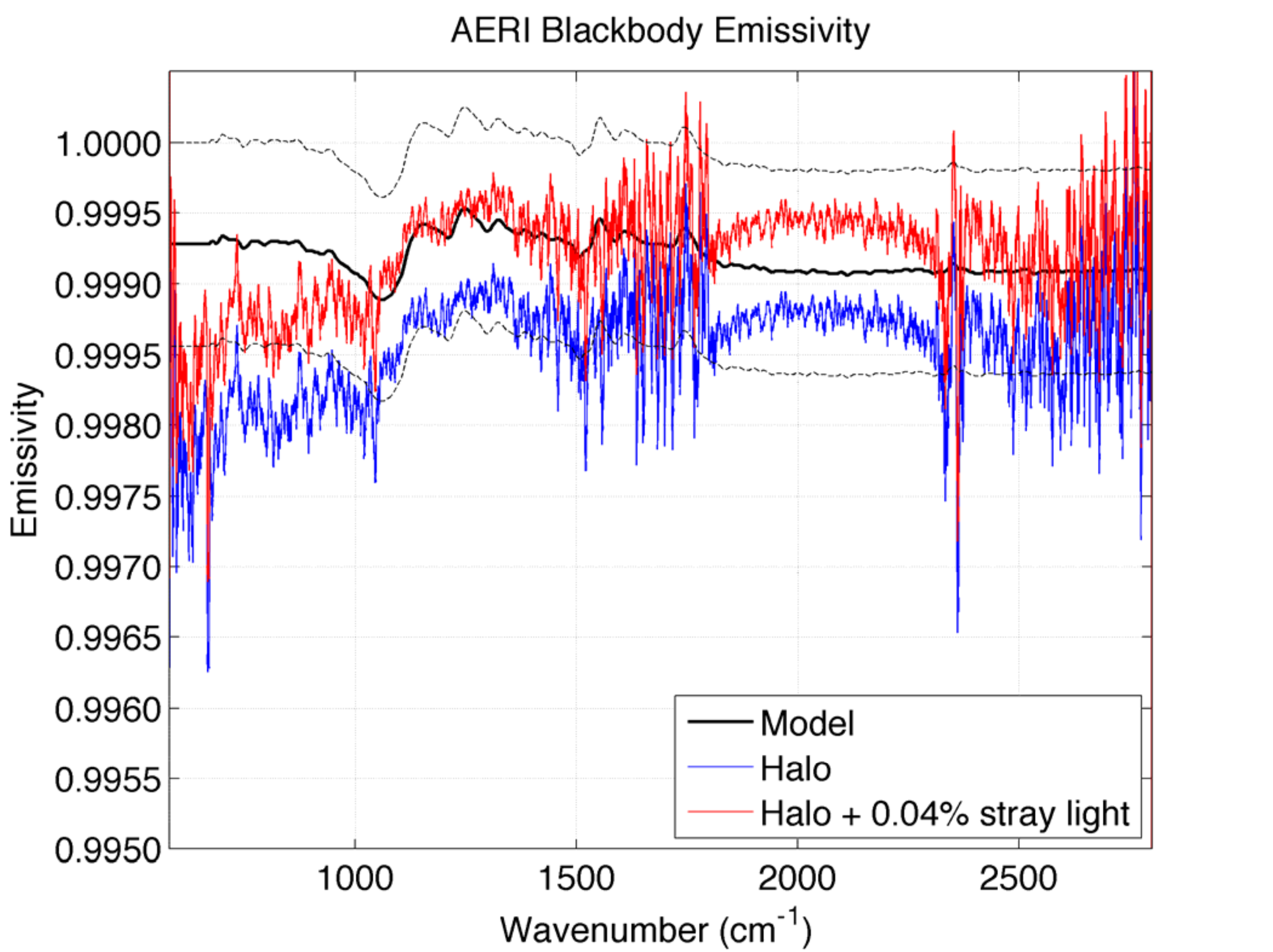
Emissivity/reflectivity measurement with halo in

$$\overline{1-\varepsilon(t)} = \frac{\overline{[R_{S-HIS}(t) + \delta R] - B[T_{bb}(t)]}}{R_{bg}(t) - B[T_{bb}(t)]}$$

Heated Halo Preliminary Results



Heated Halo Preliminary Results

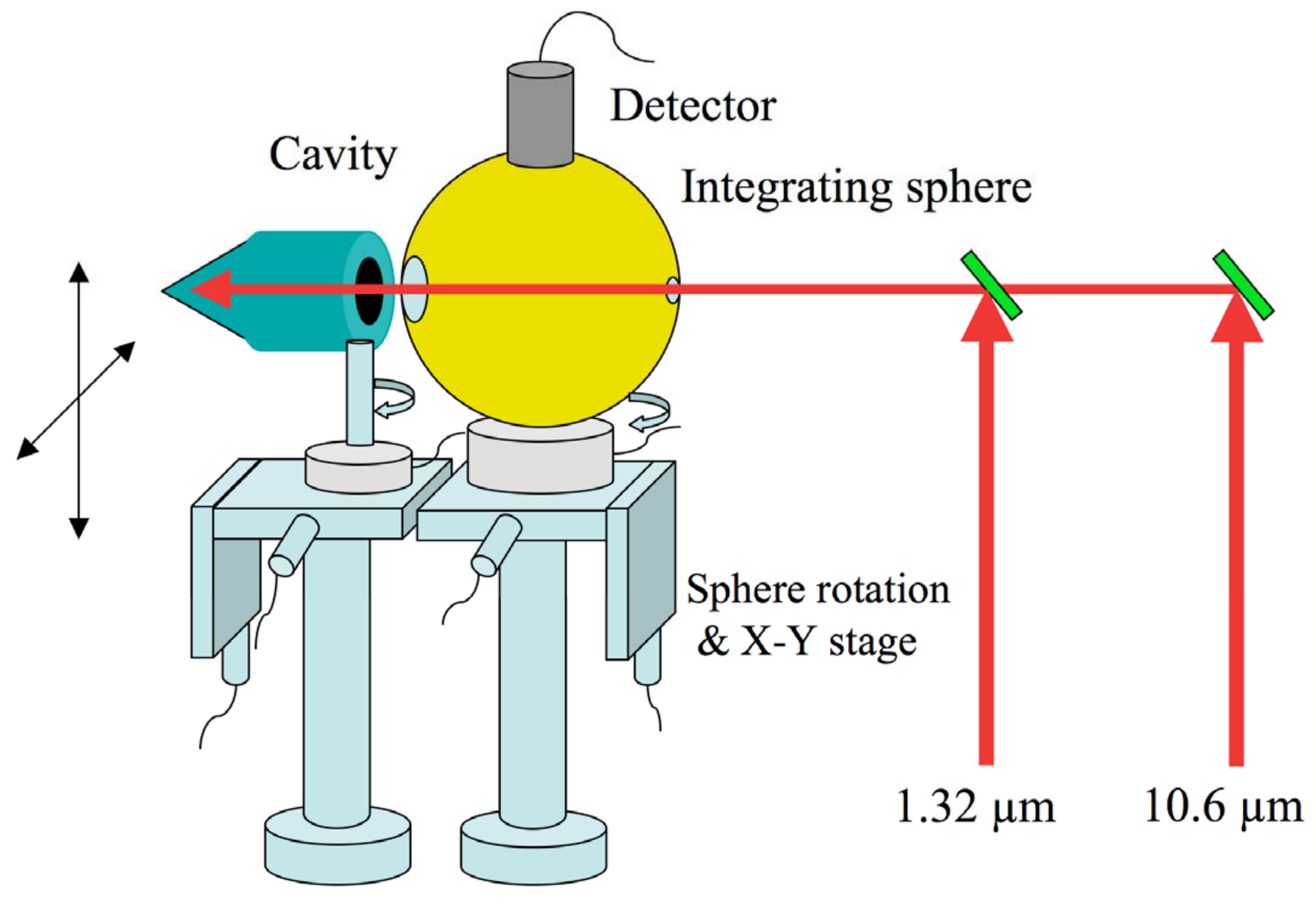


Results are sensitive to out-of-field stray light contributions

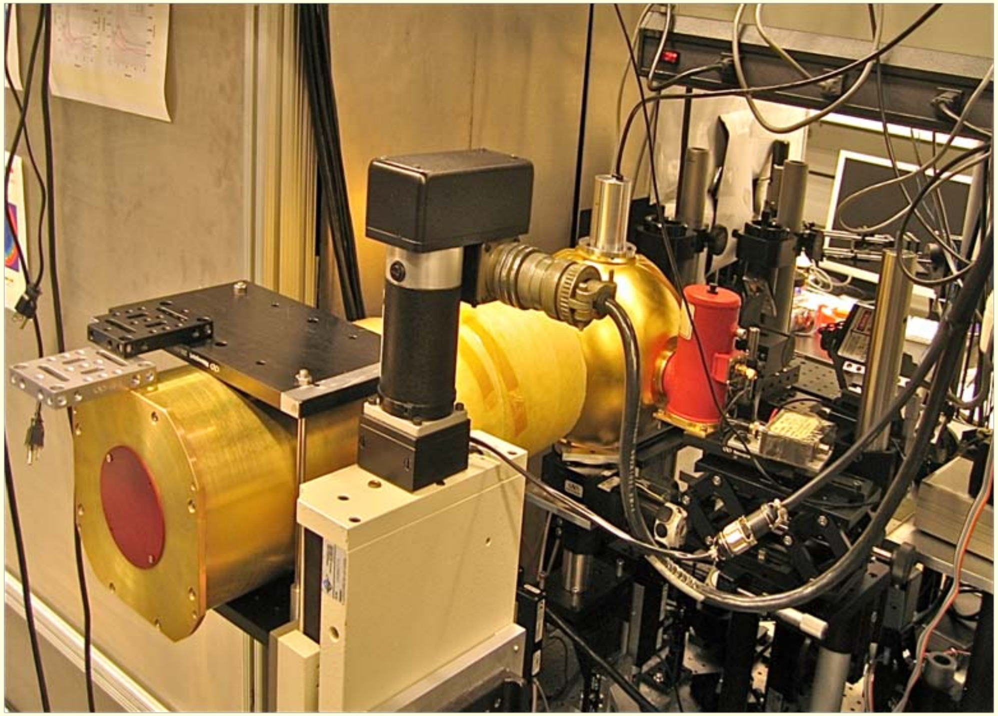
This issue is still being investigated

NIST Complete Hemispherical Laser-based Reflectometer (CHILR)

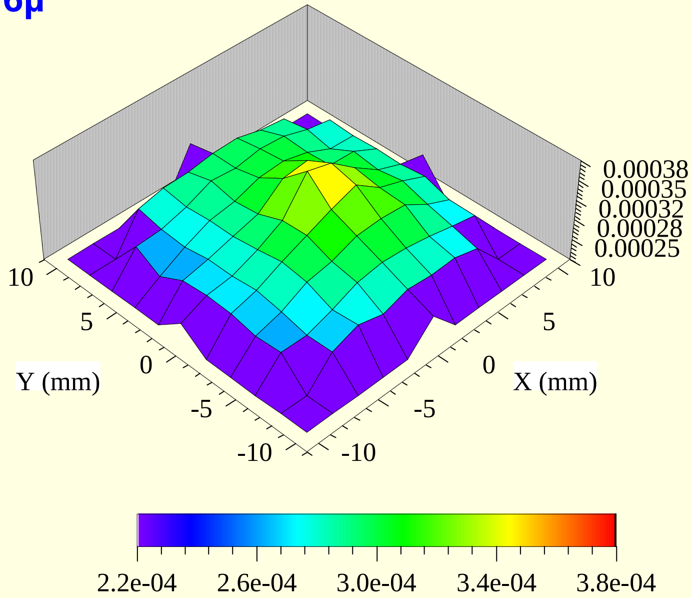
Cavity Reflectance Measurements w/ Complete Hemispherical Laser-based Reflectometer (CHILR)



Blackbody in Reflectance Setup

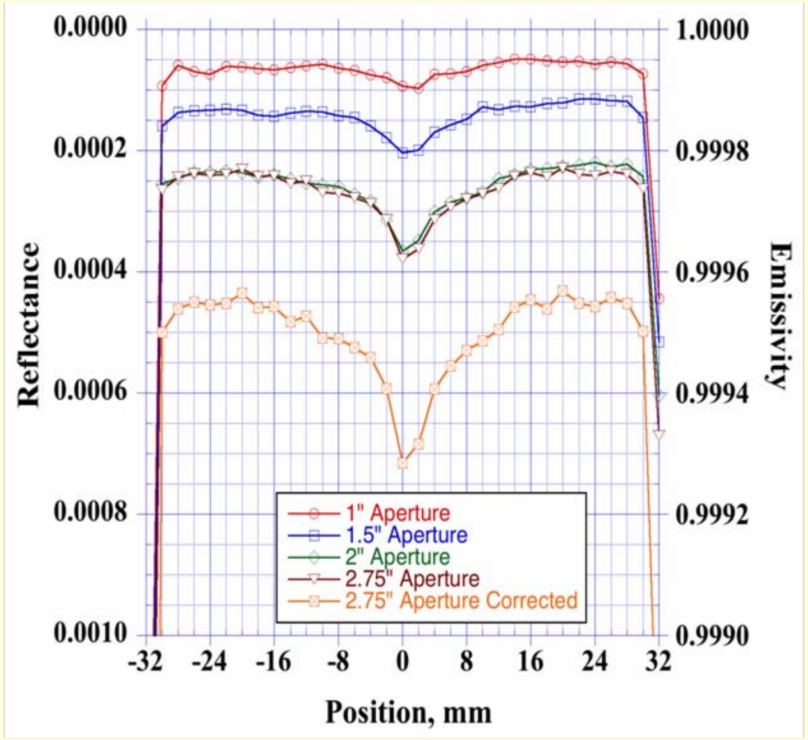


AERI Cavity Reflectance Measurements w/Complete Hemispherical Laser-based Reflectometer (CHILR), with 2" aperture - 10.6µ

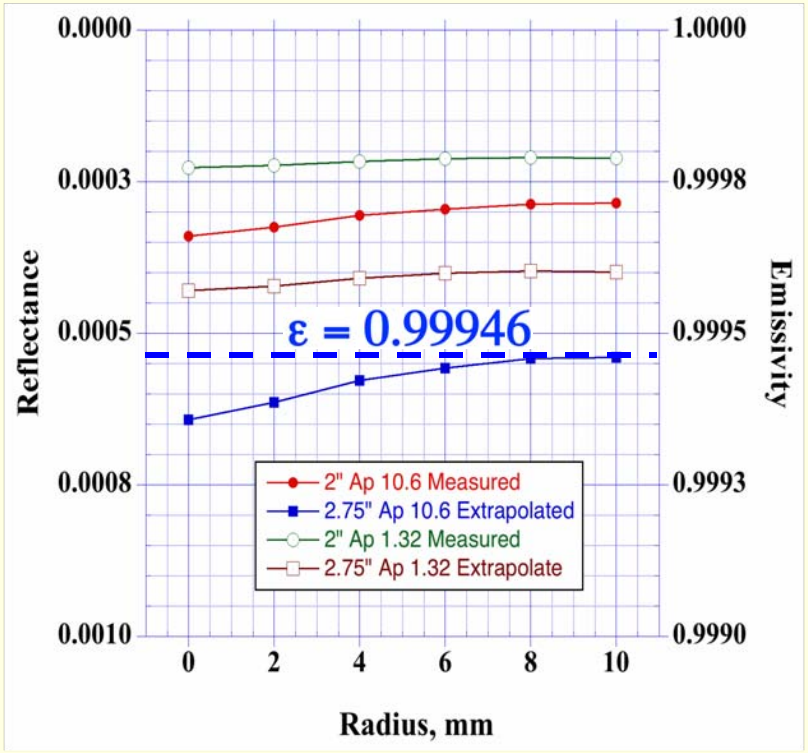


CHILR Results For AERI BB - 10.6μ

Scan vs. Aperture Size



Viewed Area Dependence

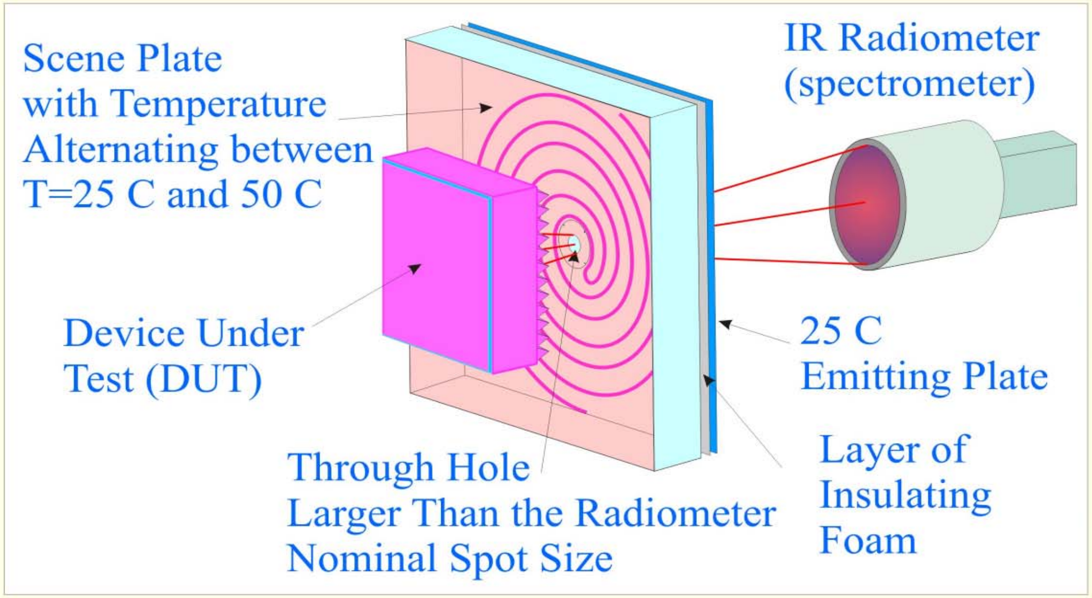


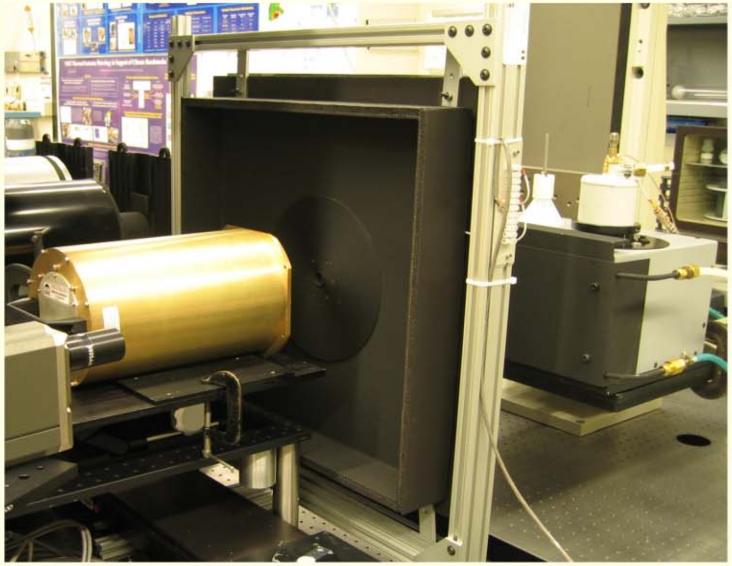
NIST

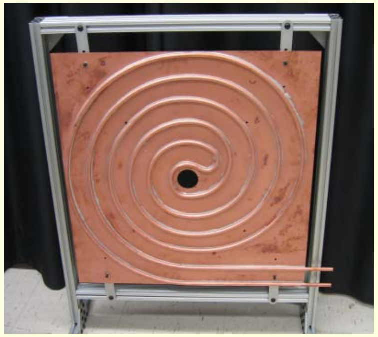
NIST AIRI (Advanced Infrared Radiometry and Imaging)

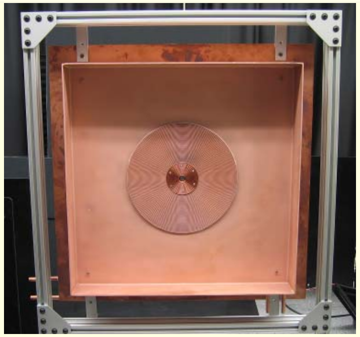
Blackbody Emissivity Measurements With Two Temperature Background Method

$$\varepsilon_{dut} = 1 - \frac{(\varepsilon_1^{dut\_apparent} - \varepsilon_2^{dut\_apparent})}{Planck(T_1^{scene\_plate}) - Planck(T_2^{scene\_plate})} \cdot \frac{Planck(T_{dut})}{\varepsilon_{scene}}$$



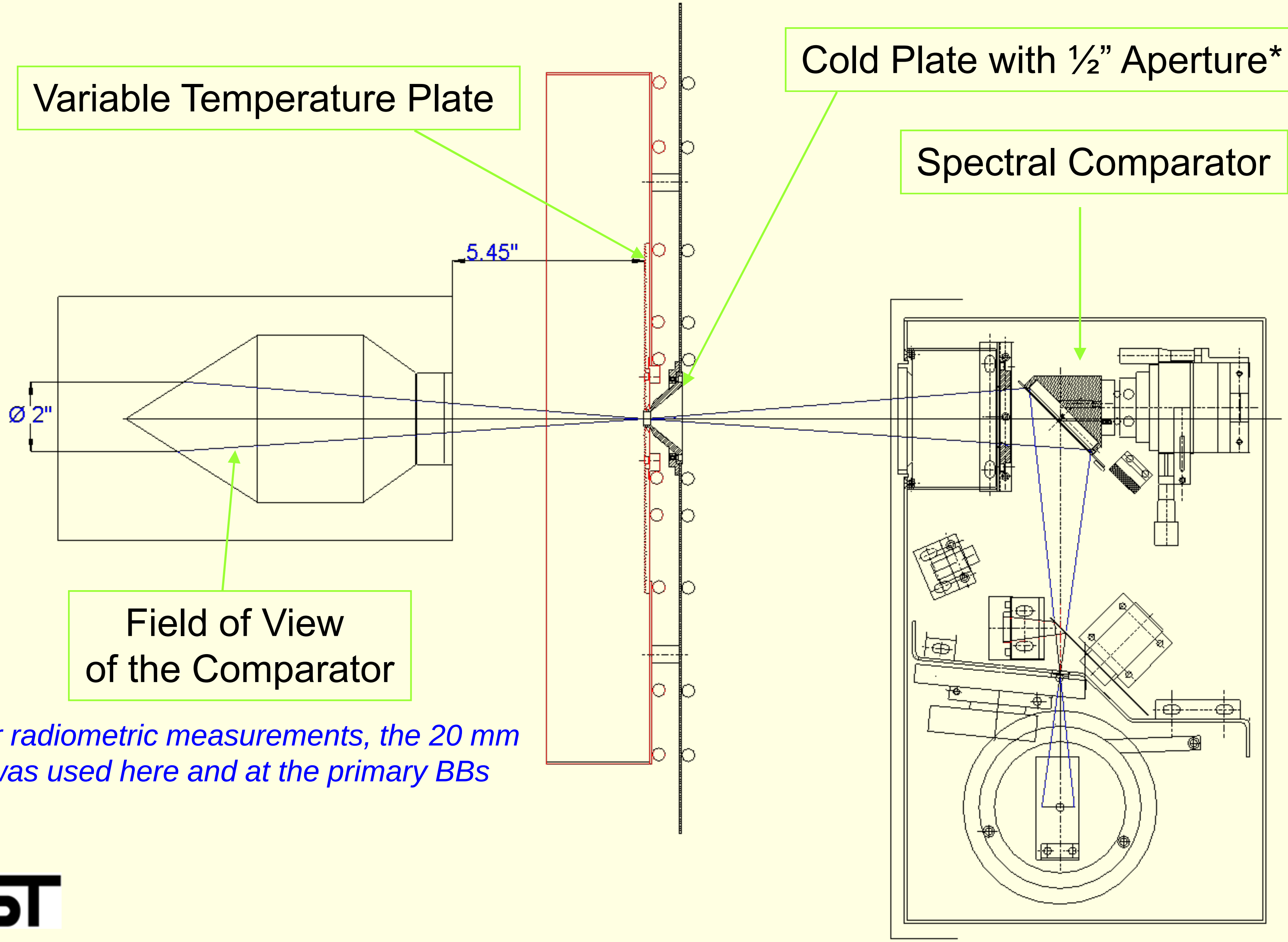






NIST

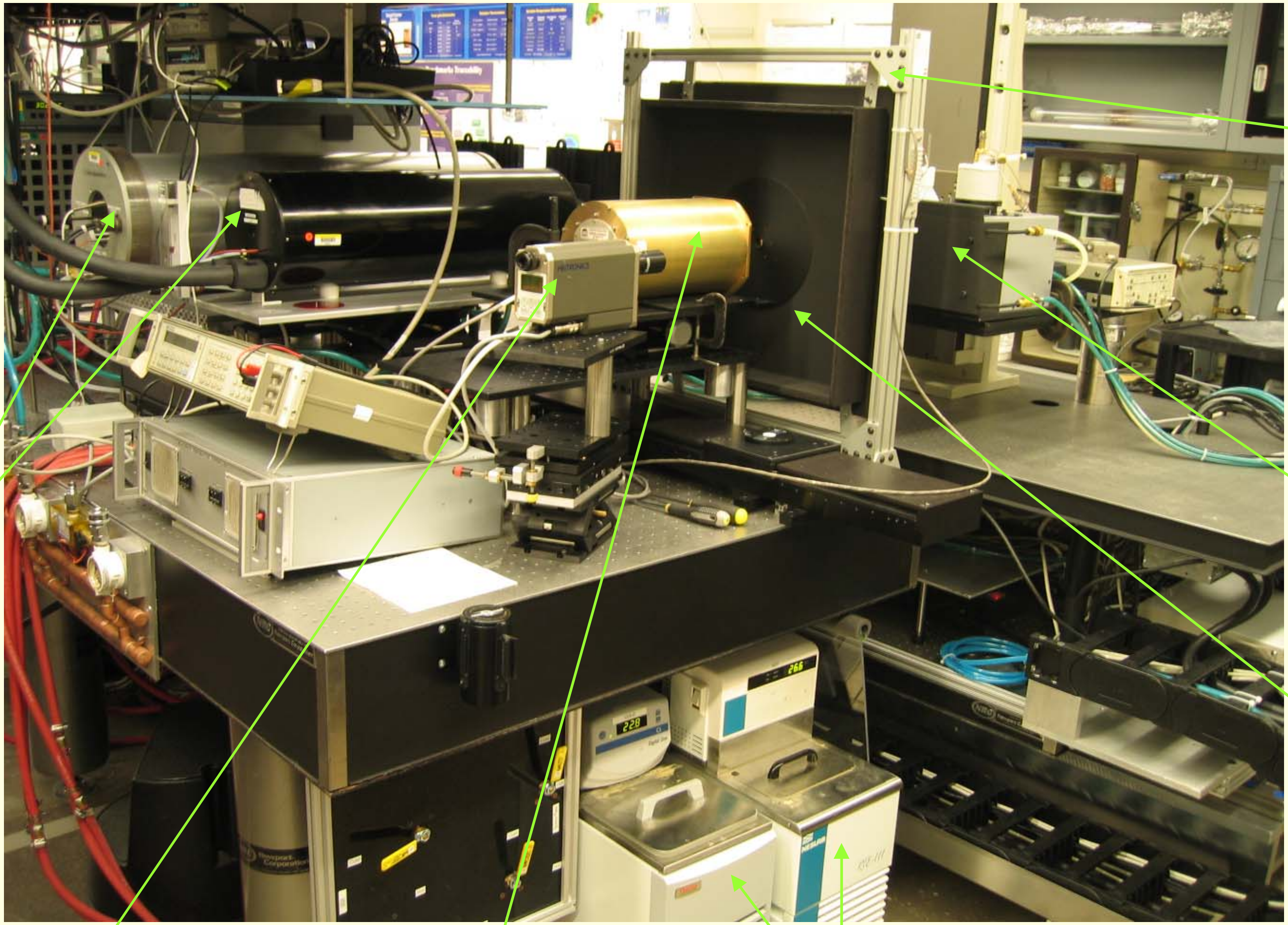
AERI BB Emissivity Measurements with the Variable Background Temperature Method: Experiment Geometry



*Note: *For radiometric measurements, the 20 mm aperture was used here and at the primary BBs*

NIST

Rear View of the Measurement Setup



Front Plate

Spectral Comparator on a Stage

Rear Plate

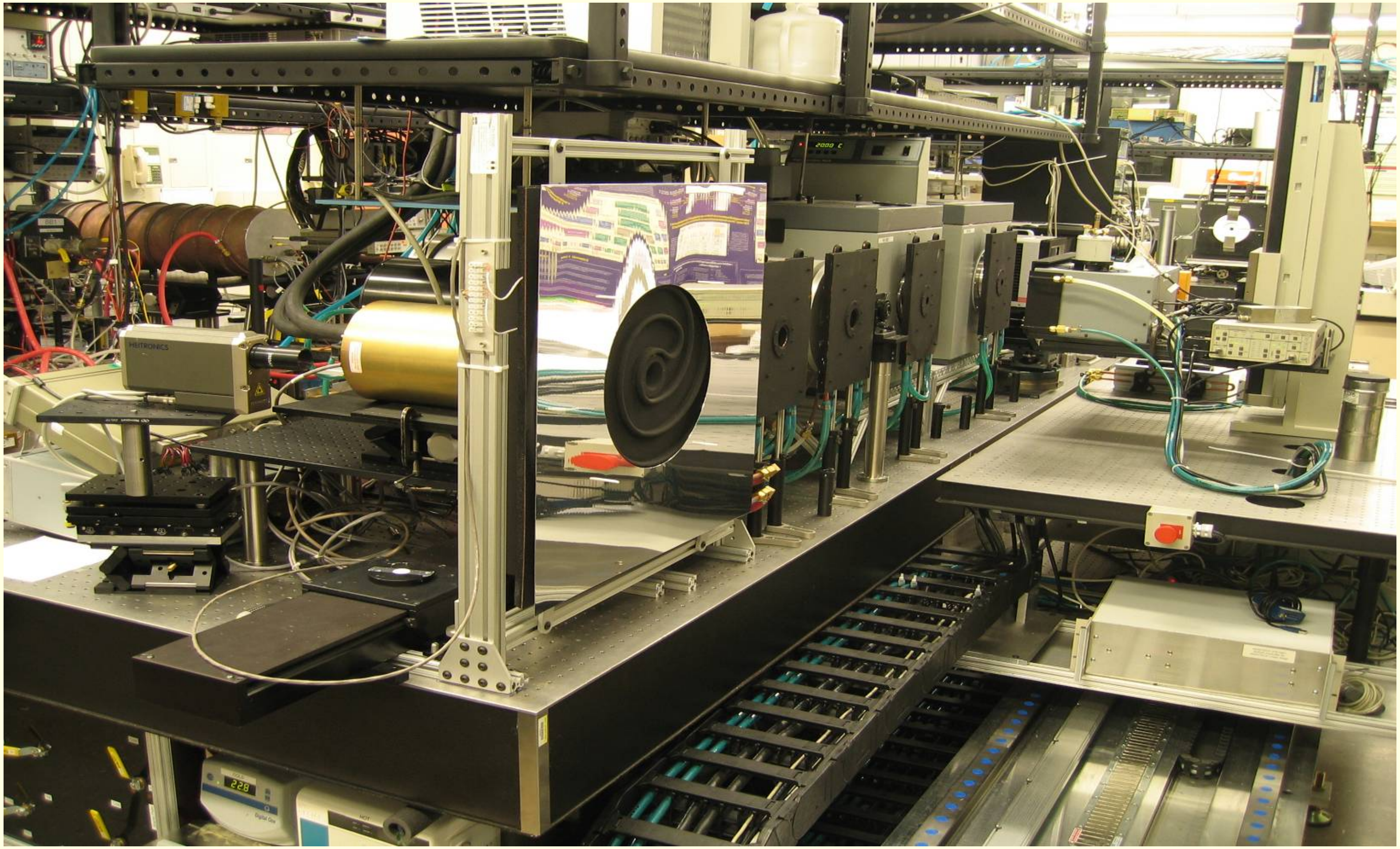
Primary Standard BBs

LWIR Pyrometer for Reading Background Temperature

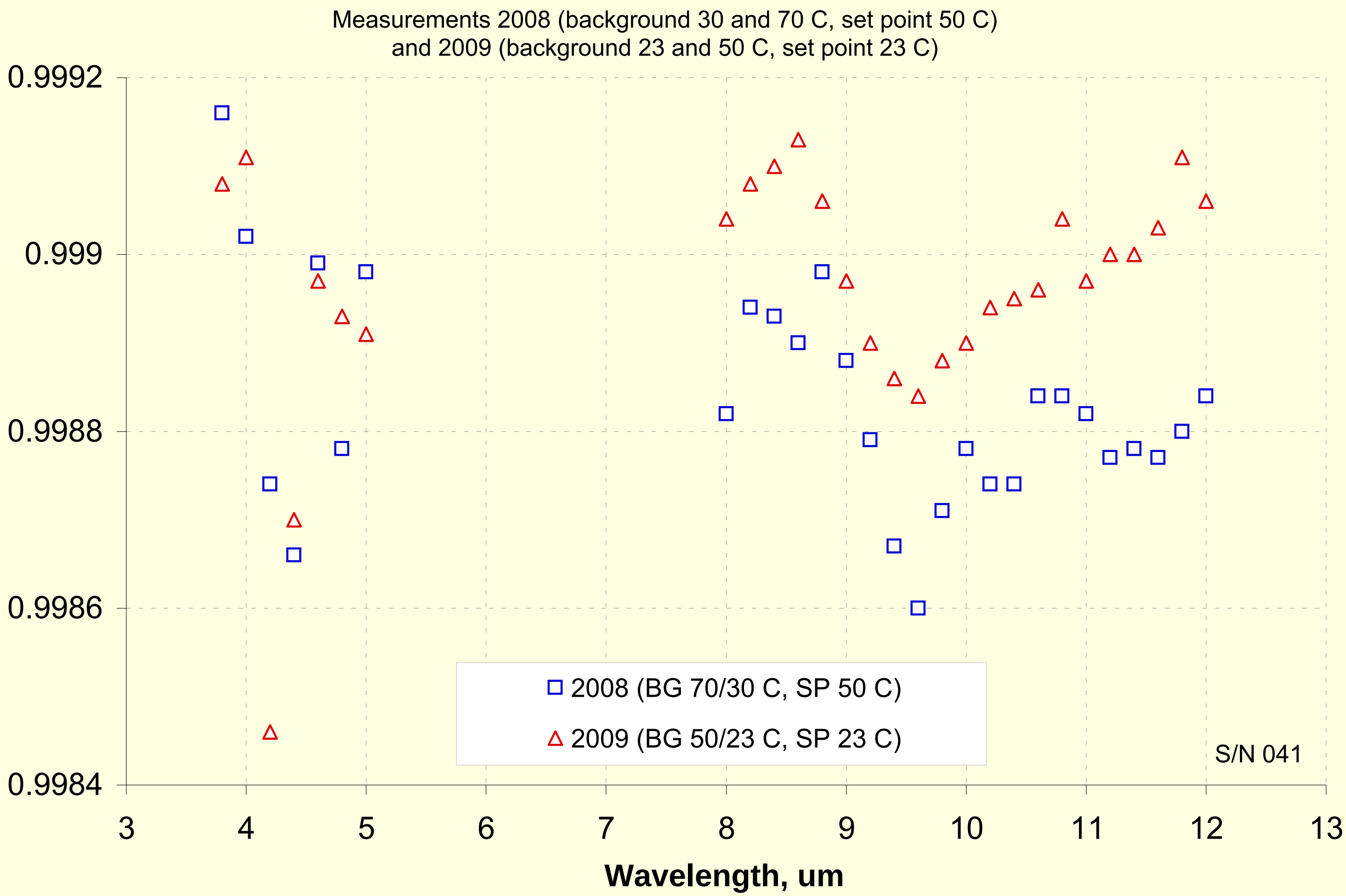
AERI BB Under Calibration

Circulating Baths For Front and Rear Plate Temperature Control

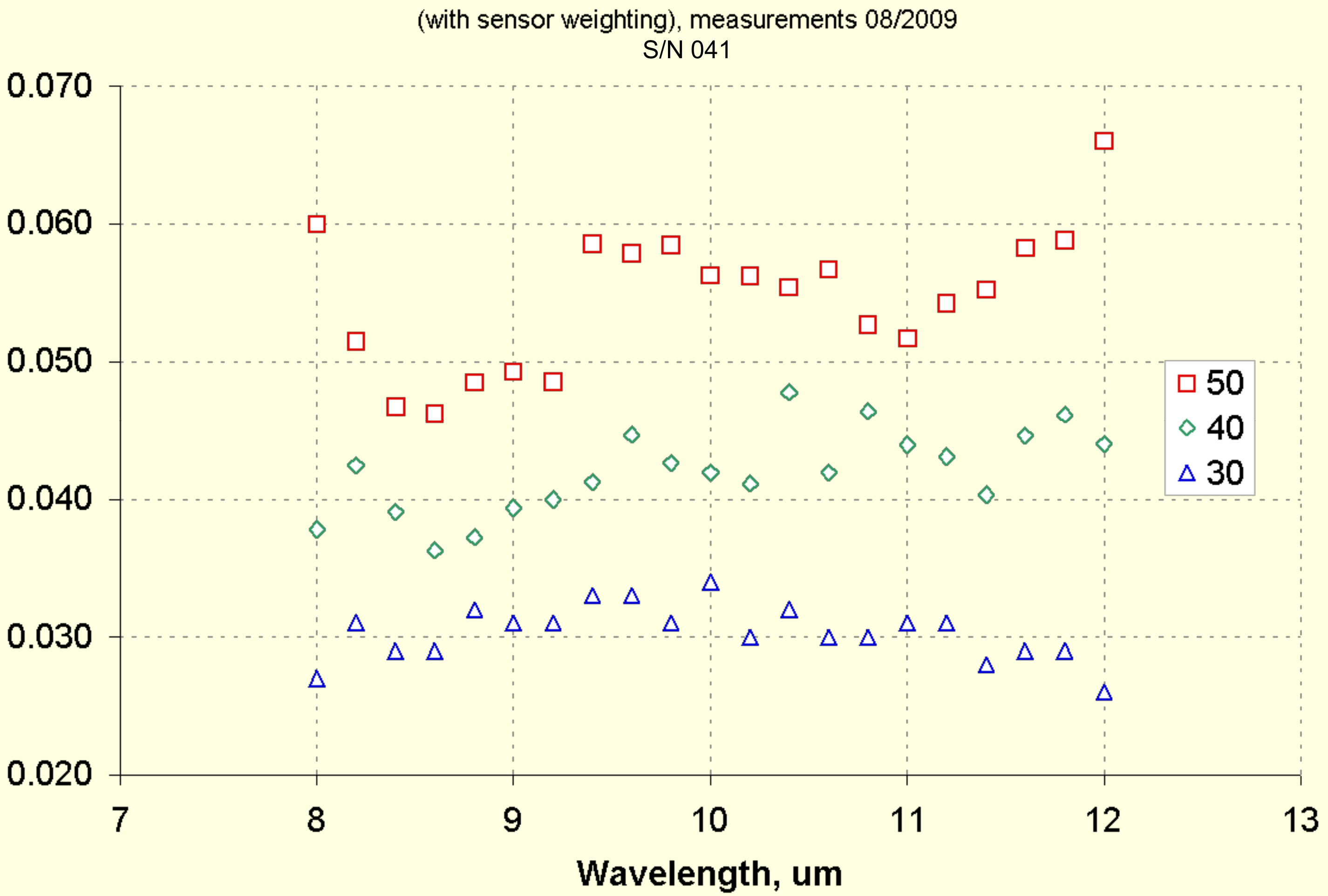
Front View of the Measurement Setup



Emissivity From Scene Plate Measurements



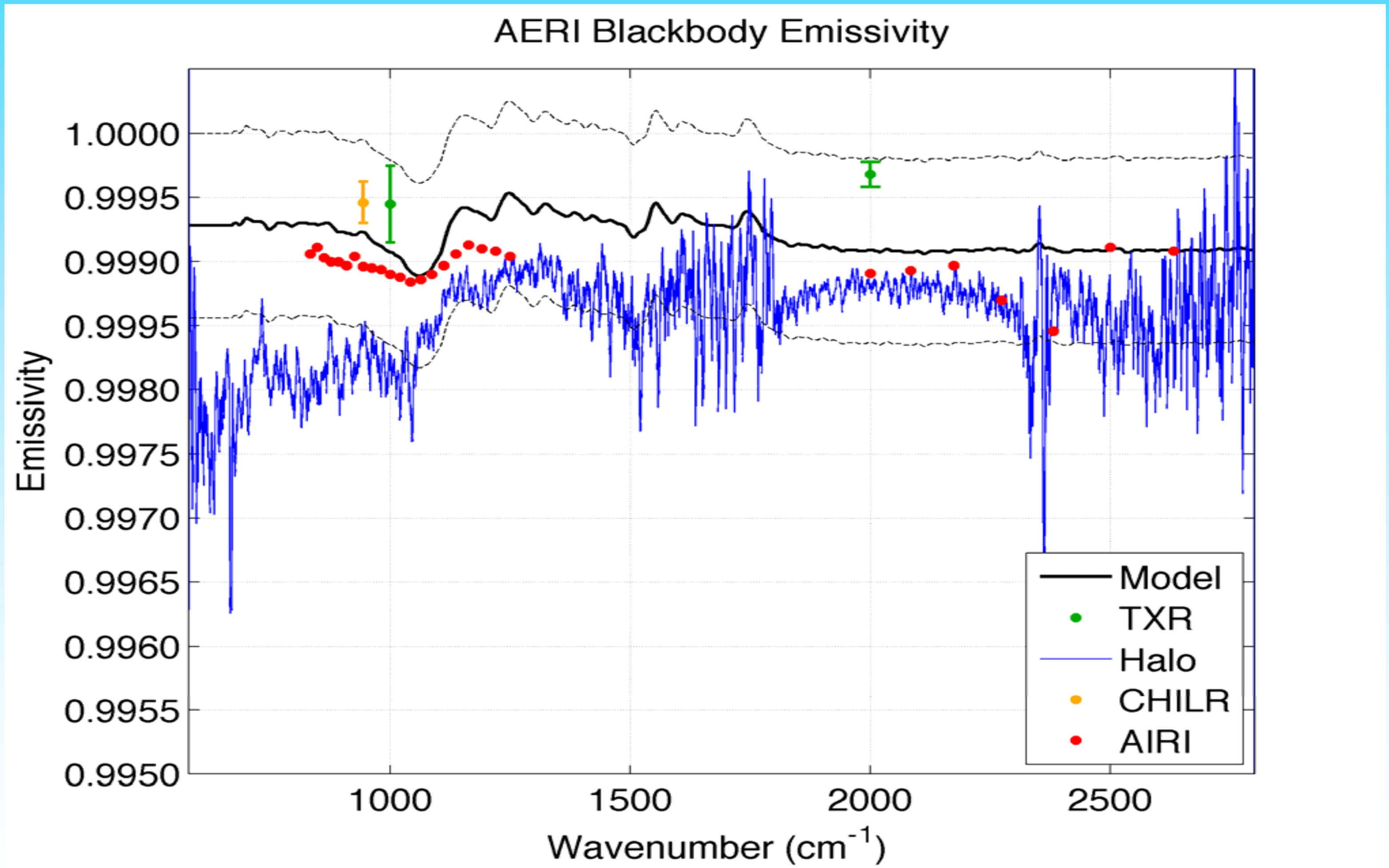
AERI BB Radiance Temperature



Emissivity Measurement Comparison Shows Excellent Agreement

Method	ε (5μ)	ε (10μ)	Note
Traditional	0.9991 ±0.00006	0.9991±0.0006	*Measured Intrinsic paint emissivity & diffusity with MC ray-trace modeling.*
NIST TXR	0.9991±0.0001	0.9995±0.0003	*Tests conducted at UW-SSEC.*
UW Heated Halo	0.9987±0.0006	0.9981±0.0006	*Results thought to be low. Stray light investigation underway at UW.*
NIST CHILR	No Measurement	0.9995±0.0002	*Test done at NIST using 10.6μ laser.*
NIST AIRI	0.9989	0.9989	*Uncertainty under investigation at NIST.*

Emissivity Measurement Comparison Shows Excellent Agreement



Final Thoughts

- UW is working closely with NIST to refine multiple techniques that will aid in the establishment of SI traceable measurements for NPOESS (using Scanning-HIS). These techniques are also directly applicable for NASA's upcoming CLARREO benchmark mission.
- Preliminary results confirm theoretical expectations for the Wisconsin cavity design within assumed uncertainties.
- Further analysis is underway to establish uncertainty estimates for the new laboratory methods being developed, in part, under the NASA CLARREO IIP.