Characterization of the VIIRS Blackbody Emittance

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Abstract

High emissivity is a key performance parameter for blackbody calibrators, reducing calibration sensitivity to the thermal background and blackbody emittance non-uniformity. The Visible Infrared Imaging Radiometer Suite (VIIRS) blackbody element on the Suomi National Polar-orbiting Partnership (NPP) satellite and the upcoming Joint Polar-orbiting Satellite System (JPSS) have an emittance requirement greater than 0.996. In order to achieve a high value over a large aperture (~12.5 cm diameter), we combine a low reflectance specular coating with an innovative repeating v-groove cavity design. The emittance is then characterized with a custom laser test station that measures the Total Integrated Reflectance (TIR) from the blackbody. Measurements show that the resulting emissivity is greater than 0.997 at 3.39 µm. Details on the experimental setup and data analysis and results are presented herein and discuss the drivers and uncertainties that go into testing a high emittance design.

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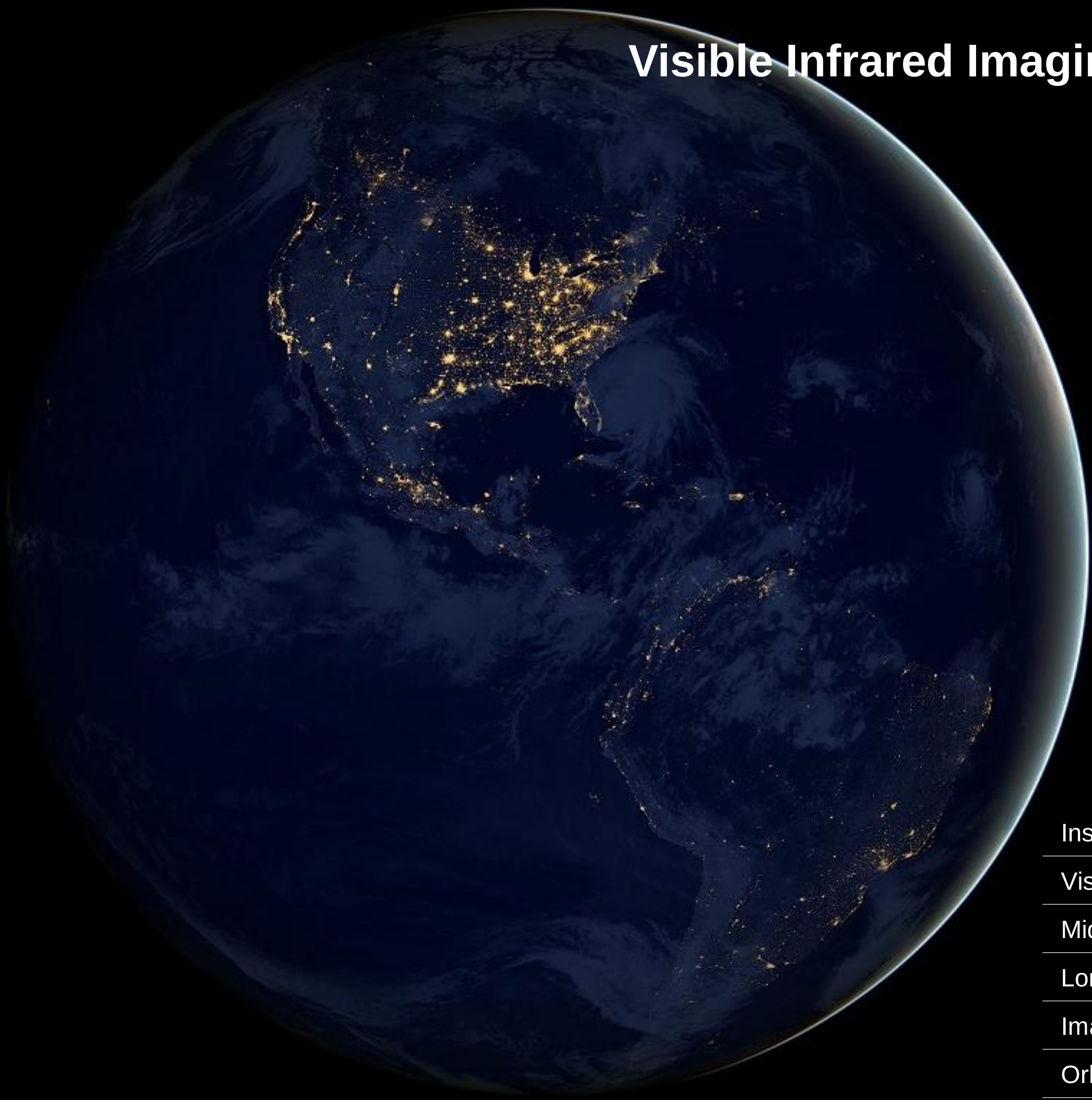
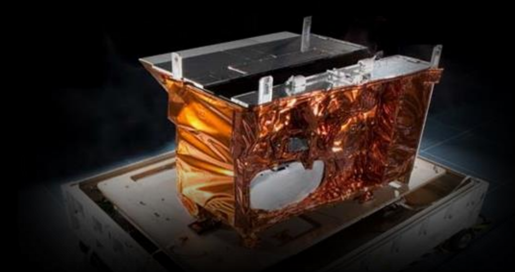
Visible Infrared Imaging Radiometer Suite (VIIRS)





Instrument Specifications	
Visible/Near IR Bands	9 plus day/night pan band
Mid-Wave IR Bands	8
Long-Wave IR Bands	4
Imaging Optics	19.1 cm aperture, 114 cm f.l.
Orbit Average Power	200 Watts
Weight	275 kg
Scanned Swath	±56°, 3000 km
Ground Sample Distance	<1.6 km @ end of scan

VIIRS Blackbody

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Blackbody Optical Requirements

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Requirement	Description	Compliance
Emittance	The design of the Blackbody source shall have an effective emittance greater than 0.996 for the MWIR and LWIR spectral bands.	Pass
Emittance Characterization	The emittance shall be characterized to an uncertainty less than ± 0.002.	Pass
Particulate Contamination	The minimum emittance and emittance knowledge requirement shall be met over a cleanliness level of CL400 and cleaner.	Pass
Directional Reflectance Characterization	The directional illumination to integrated scatter shall be characterized at 5 collecting solid angles corresponding to 1/2 cone angles of 90, 70, 55, 40, and 20 degrees.	Pass

Blackbody Emittance Determined from Reflectance of Gold Standard

- Equations:

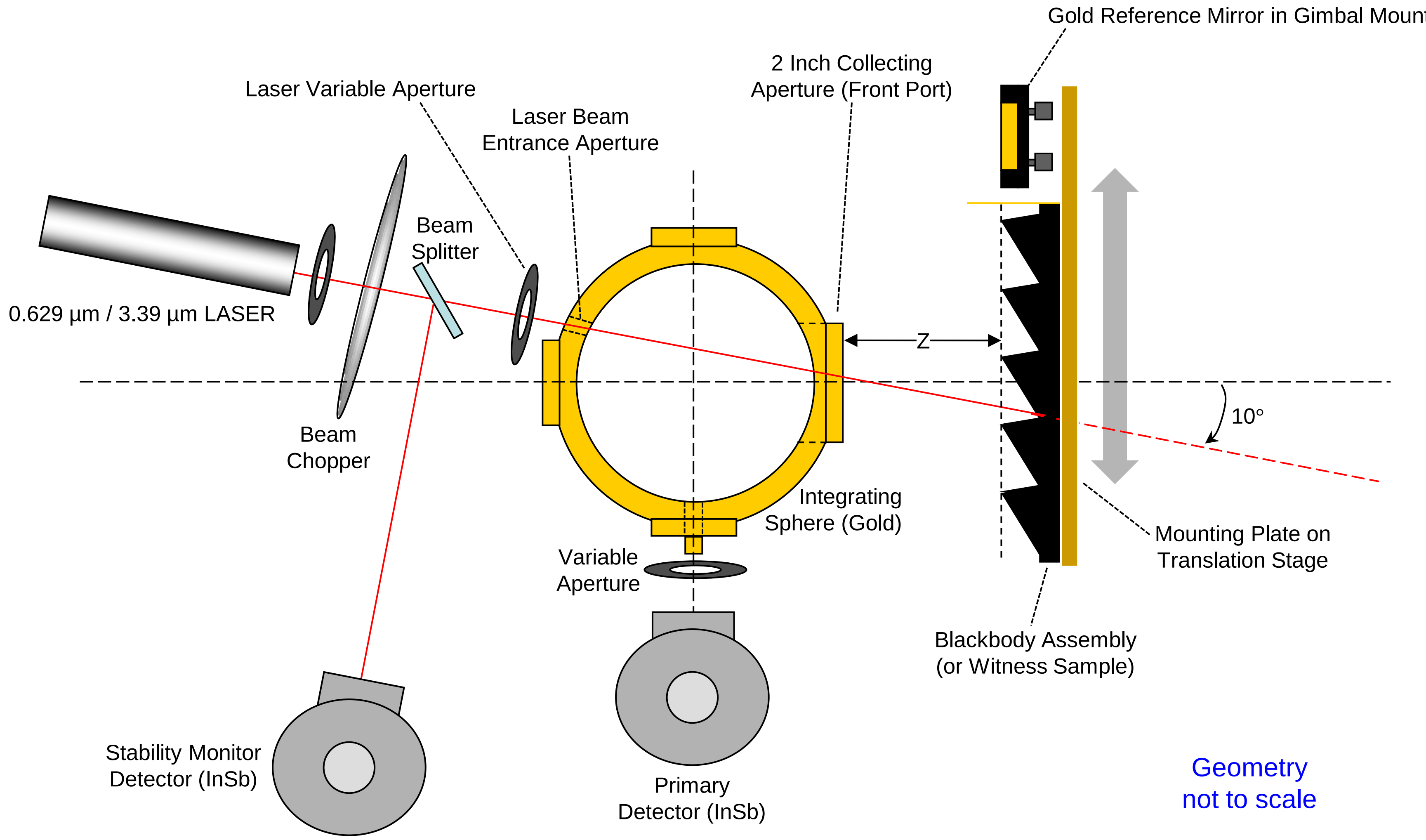
$$E_{BB} = 1 - R_{BB}$$

$$R_{BB} = V_{BB}\left(\frac{R_{Au}}{V_{Au}}\right)$$

$$\sigma_{R_{BB}} = R_{BB}\sqrt{\left(\frac{\sigma_{V_{BB}}}{V_{BB}}\right)^2 + \left(\frac{\sigma_{R_{Au}}}{R_{Au}}\right)^2 + \left(\frac{\sigma_{V_{Au}}}{V_{Au}}\right)^2}$$

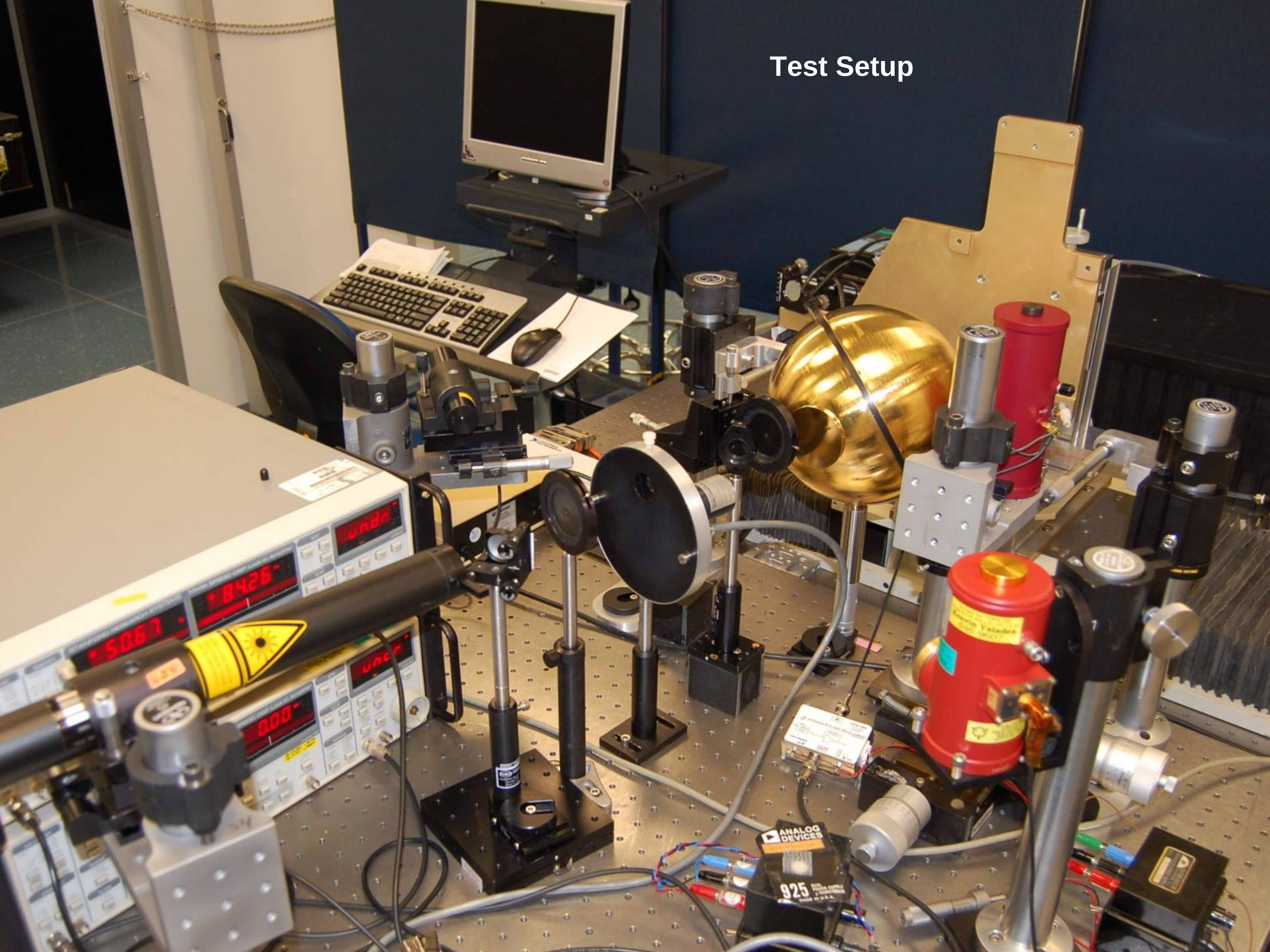
- Parameters:
  - E_{BB} blackbody emittance
  - R_{BB} blackbody reflectance
  - R_{Au} Au mirror reflectance from spectrophotometer tests
  - V_{BB} blackbody signal from TIR test (in volts)
  - V_{Au} Au mirror reference signal from TIR test (in volts)
  - σ one sigma standard deviation (measurement uncertainty)

Test Setup



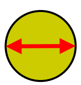
Geometry
not to scale

Test Setup

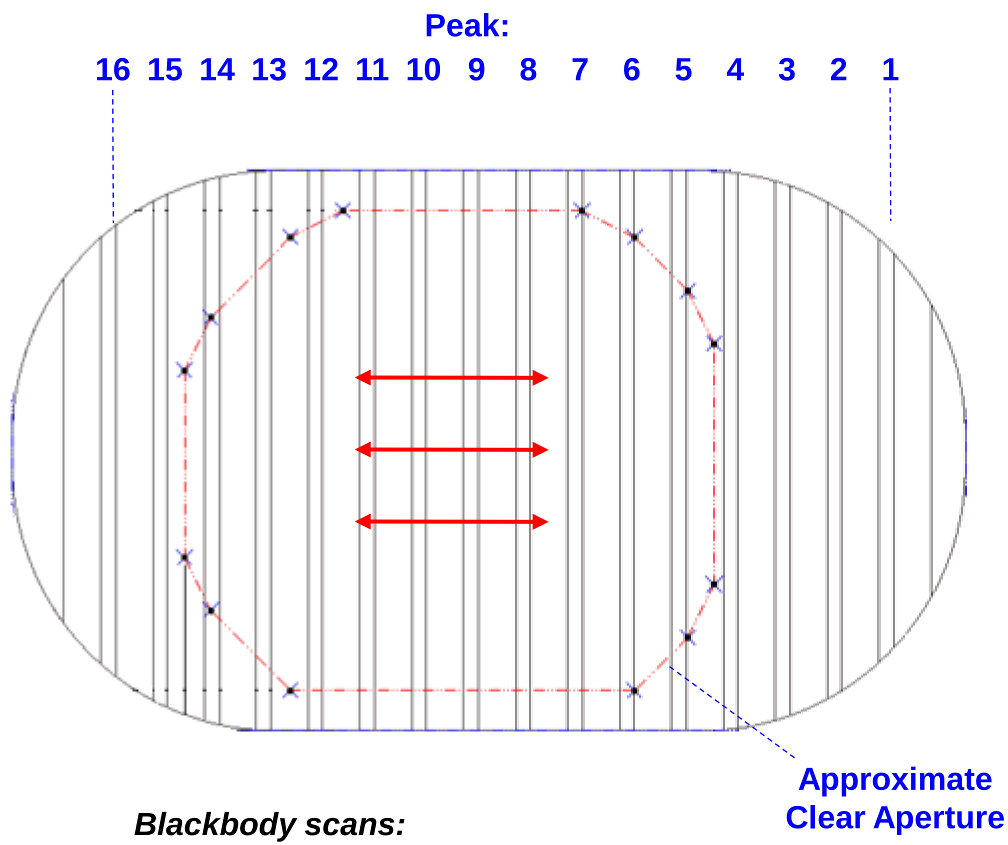


Measurement Locations

Au Mirror Reference Scan:



Background Scan:

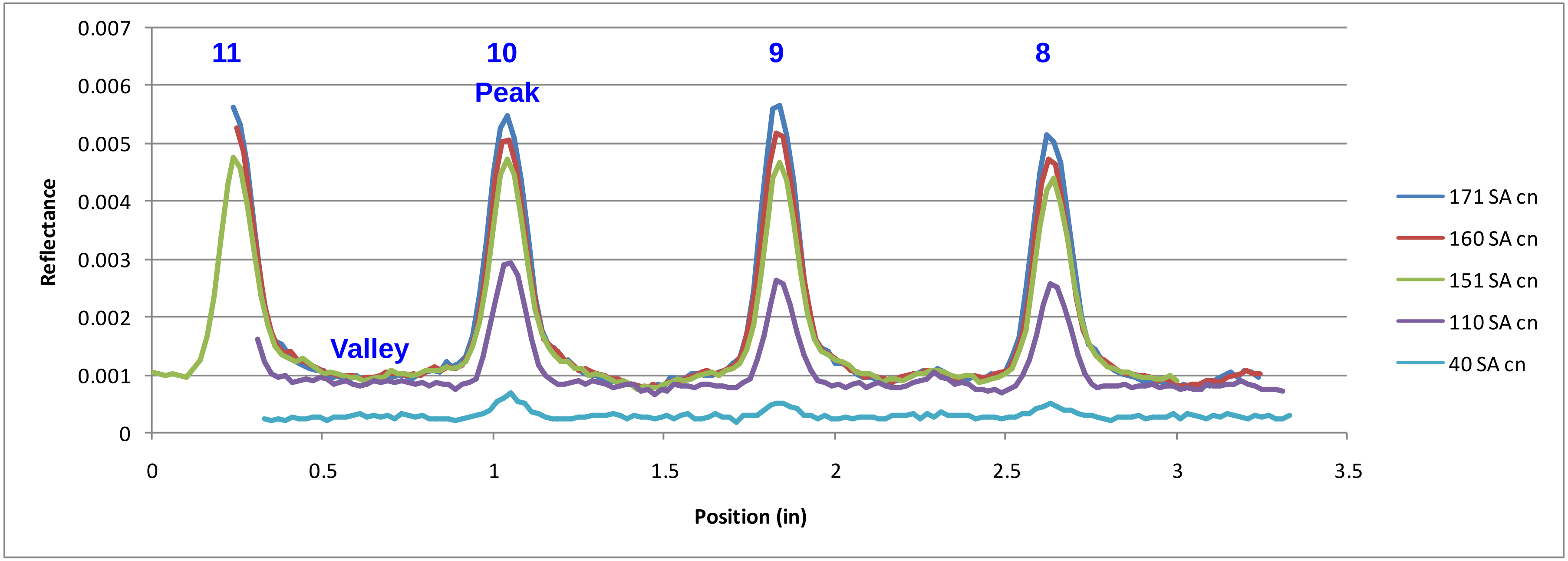


Au reference scans
- ***At a set Z distance***
- ***Made during test***

Background scans
- ***Made at start and end of test***

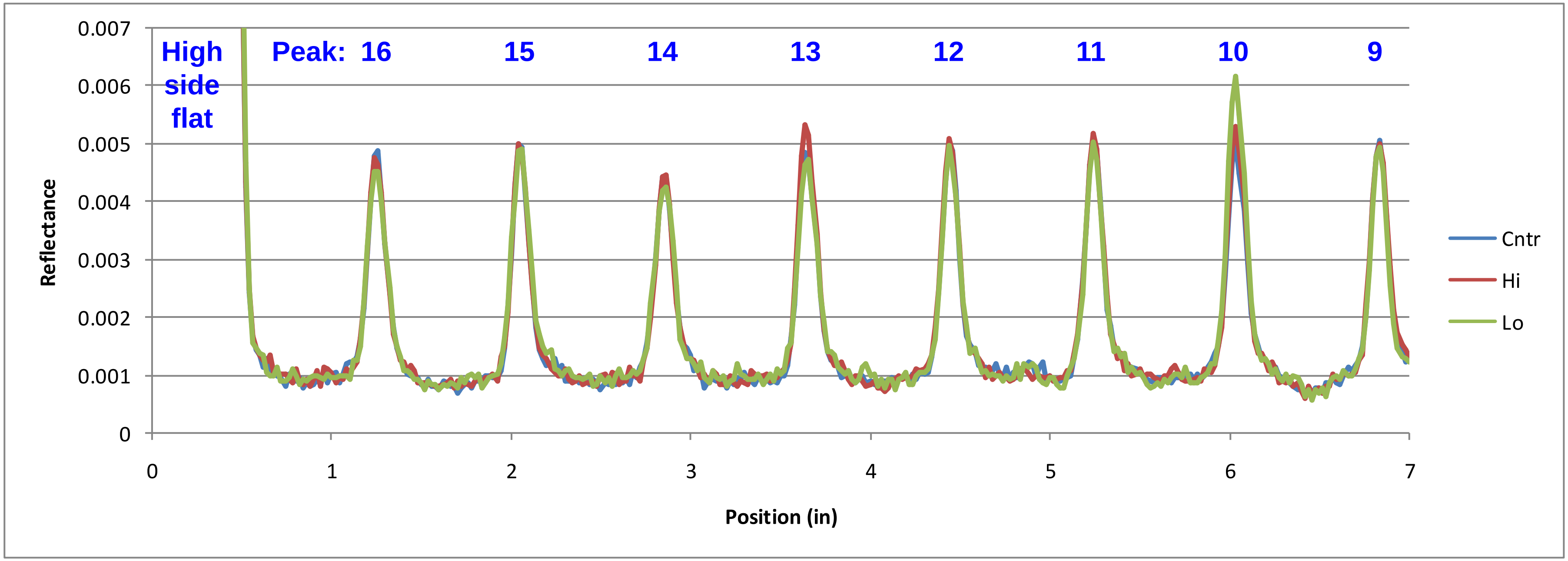
Blackbody scans:
- ***3 elevations, forward and reverse***
- ***5 Z distances***

Measurement Data Results for Several Solid Angles



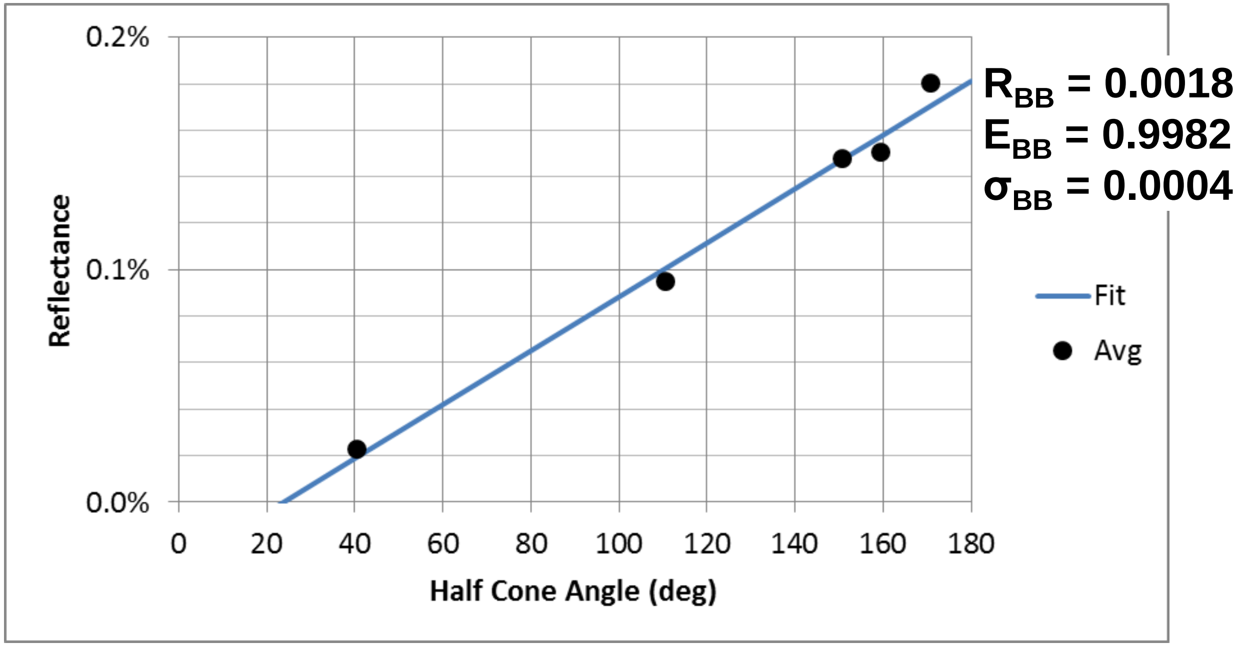
- Plot of calculated blackbody total integrated reflectance versus position
- Each line an average of 6 scans at different solid angle collects
- Light poorly trapped at tops of peaks so reflectance spikes
- Expected fall off in signal at smaller solid angles

Measurement Data Reflectance Uniformity



- Plot of calculated blackbody total integrated reflectance versus position
- Each line collected at same solid angle but different location
- Very good signal uniformity across entire blackbody

Emittance Results



- Estimated blackbody emittance is 0.9982 at 3.39 µm
- Based on a fit of the average total integrated reflectance at each SA
- Uncertainty a roll-up of several test uncertainties including:
  - Blackbody signal variation
  - Au signal variation and reflectance knowledge
  - Test station alignment uncertainties that reduce half cone angle knowledge

Emittance at Other Wavelengths

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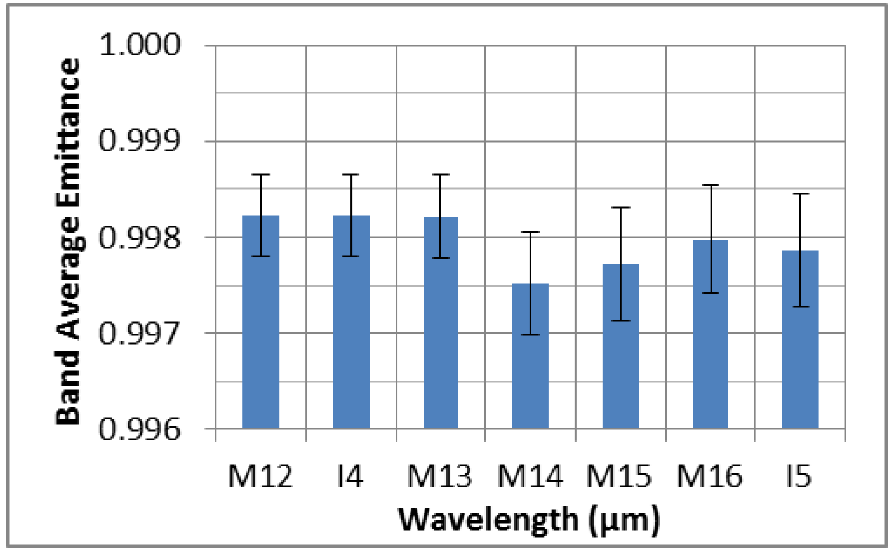
Band	Center λ (µm)
M12	3.7
I4	3.74
M13	4.05
M14	8.55
M15	10.8
M16	12
I5	11.45



- Detailed optical raytrace model was constructed to calculate the emittance at other wavelengths and lower cleanliness levels
  - Model was correlated with specular and total reflectance and scatter measurements at other wavelengths to ground and optimize predictions
- Results show emittance >0.997 across all bands of interest
- At 8.55 µm, the wavelength with lowest emittance, CL400 contamination drops the emittance to 0.9968

Summary

- VIIRS on-board blackbody calibrator requires emittance >0.996
- A custom laser test station was constructed to measure the total integrated reflectance at 3.39 µm
- Measurements show uniform emittance exceeding 0.998 across the blackbody
- Simulated emittance at other wavelengths >0.997