HysplRI

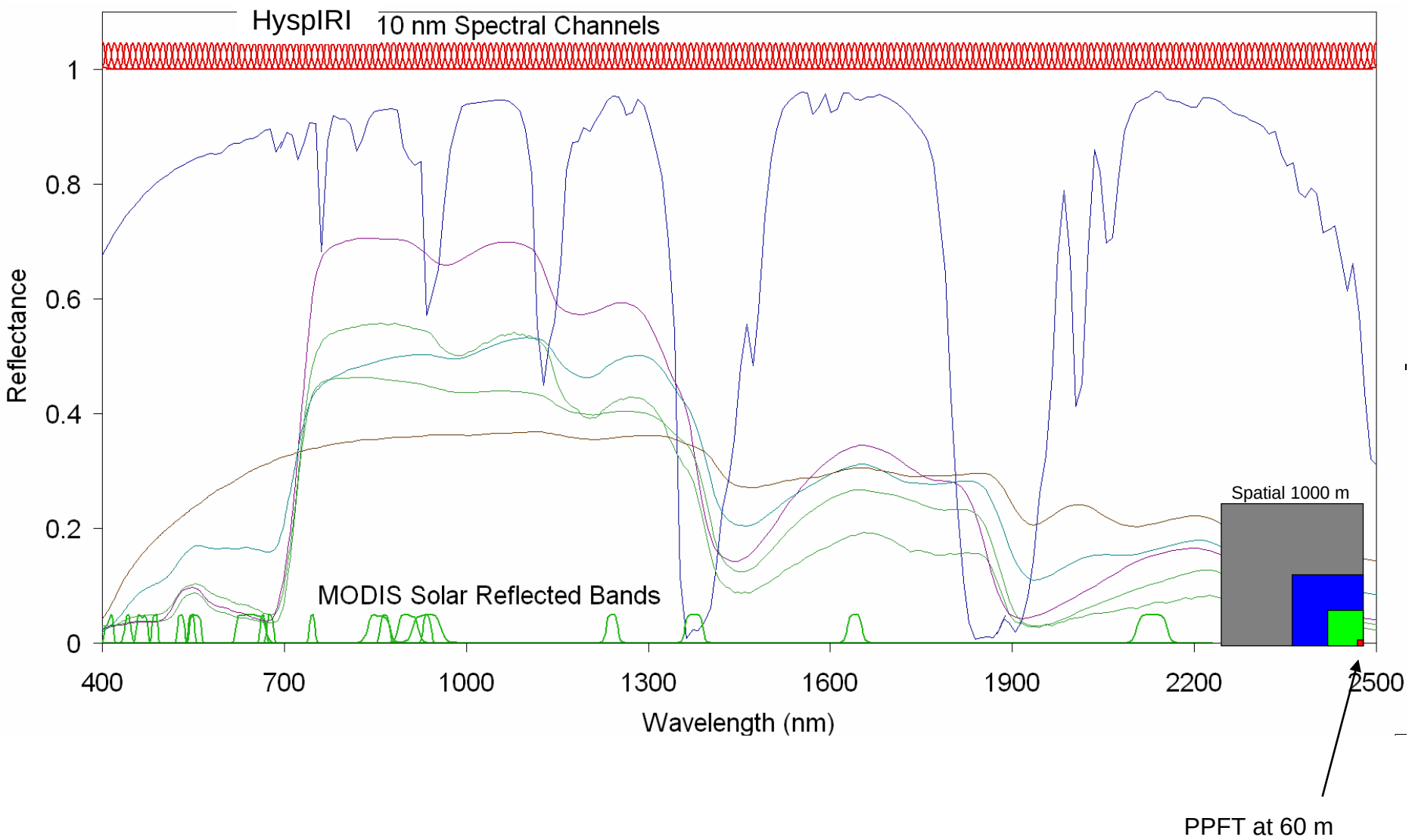
VSWIR Level 1 Calibration Approach and Traceability

NASA Earth Science and Applications Decadal Survey

Michael Eastwood and HysplRI Team

HyspIRI VSWIR – PPFT
Imaging Spectrometer
Measurement Characteristics

HyspIRI VSWIR
Key Science Measurements
Characteristics

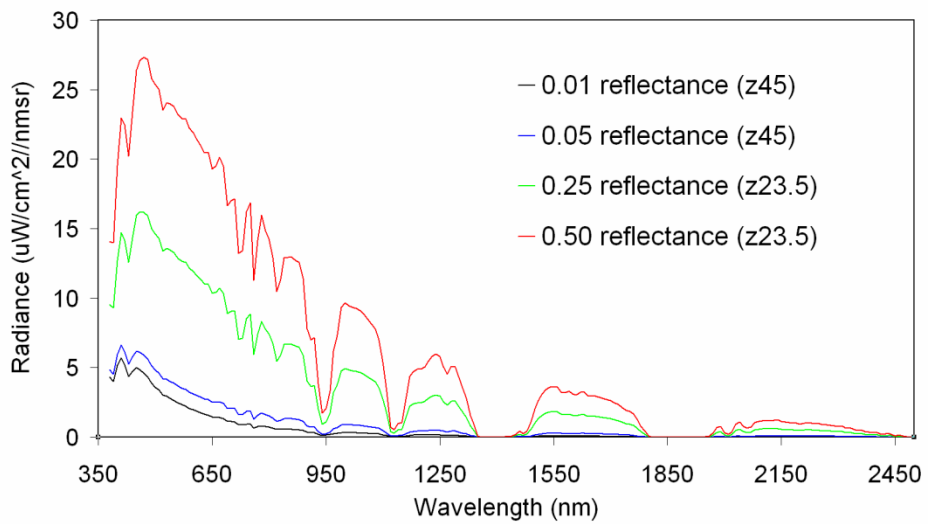


HyspIRI VSWIR
Science Measurement Characteristics

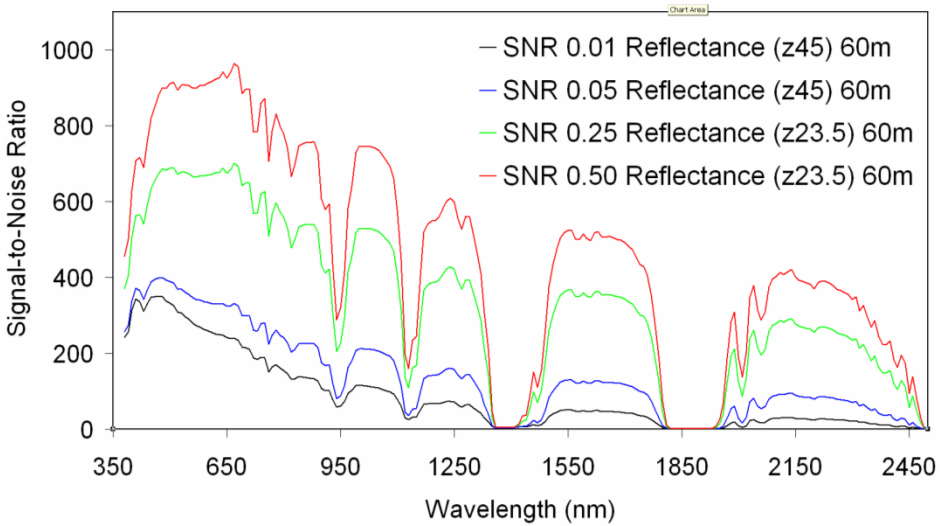
Spectral	
Range	380 to 2500 nm in the solar reflected spectrum
Sampling	<= 10 nm {uniform over range}
Response	<= 1.2 X sampling (FWHM) {uniform over range}
Accuracy	<0.5 nm
Radiometric	
Range & Sampling	0 to 1.5 X max benchmark radiance, 14 bits measured
Accuracy	>95% absolute radiometric, 98% on-orbit reflectance, 99.5% stability
Precision (SNR)	See spectral plots at benchmark radiances
Linearity	>99% characterized to 0.1 %
Polarization	<2% sensitivity, characterized to 0.5 %
Scattered Light	<1:200 characterized to 0.1%
Spatial	
Range	>150 km (12 degrees at 700 km altitude)
Cross-Track Samples	>2500
Sampling	<=60 m
Response	<=1.2 X sampling (FWHM)
Uniformity	
Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

HysplRI VSWIR Science Measurements
Key SNR and Uniformity Requirements

Benchmark Radiances

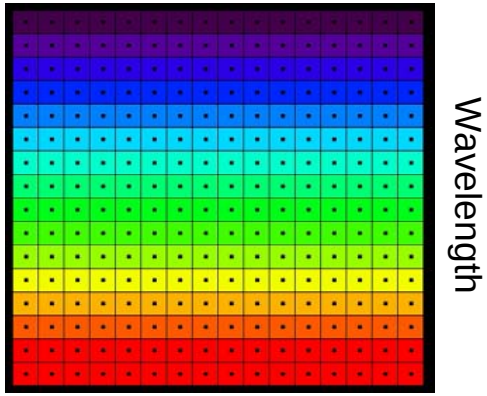


Required SNR



Uniformity Requirement

Cross Track Sample



Depiction

-Grids are the detectors
-dots are the IFOV centers
-Colors are the wavelengths

Requirement

Spectral Cross-Track	>95% cross-track uniformity {<0.5 nm min-max over swath}
Spectral-IFOV-Variation	>95% spectral IFOV uniformity {<5% variation over spectral range}

Recent Imaging Spectrometer Calibration Experience

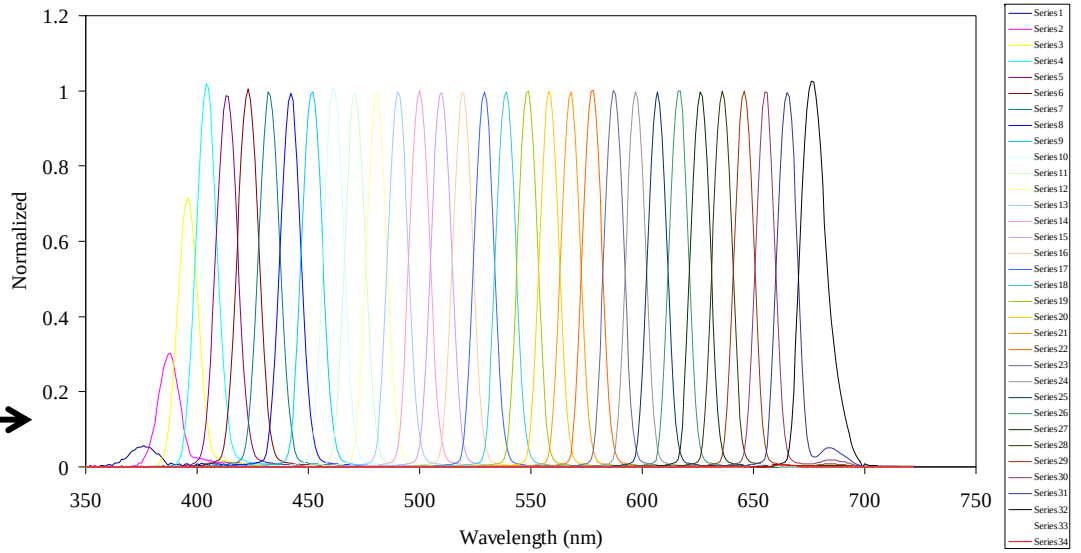
- Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
  - Spectral Range 360 to 2510 nm
  - Year involved in calibration: 1987 to present
- NASA EO-1 Hyperion Imaging spectrometer
  - Spectral range: 450 to 2430 nm
  - Years Involved in calibration: 1999 to 2003
- Compact Reconnaissance Imaging Spectrometer (CRISM)
  - Spectral range: 400 to 4000 nm
  - Years Involved in calibration: 2002 to 2005
  - On-orbit calibration validation ongoing
- Airborne Pushbroom Imaging Spectrometer (Airborne-IS)
  - Spectral range: 380 to 2515 nm
  - Years Involved in calibration: 2005 to present

Laboratory Calibration

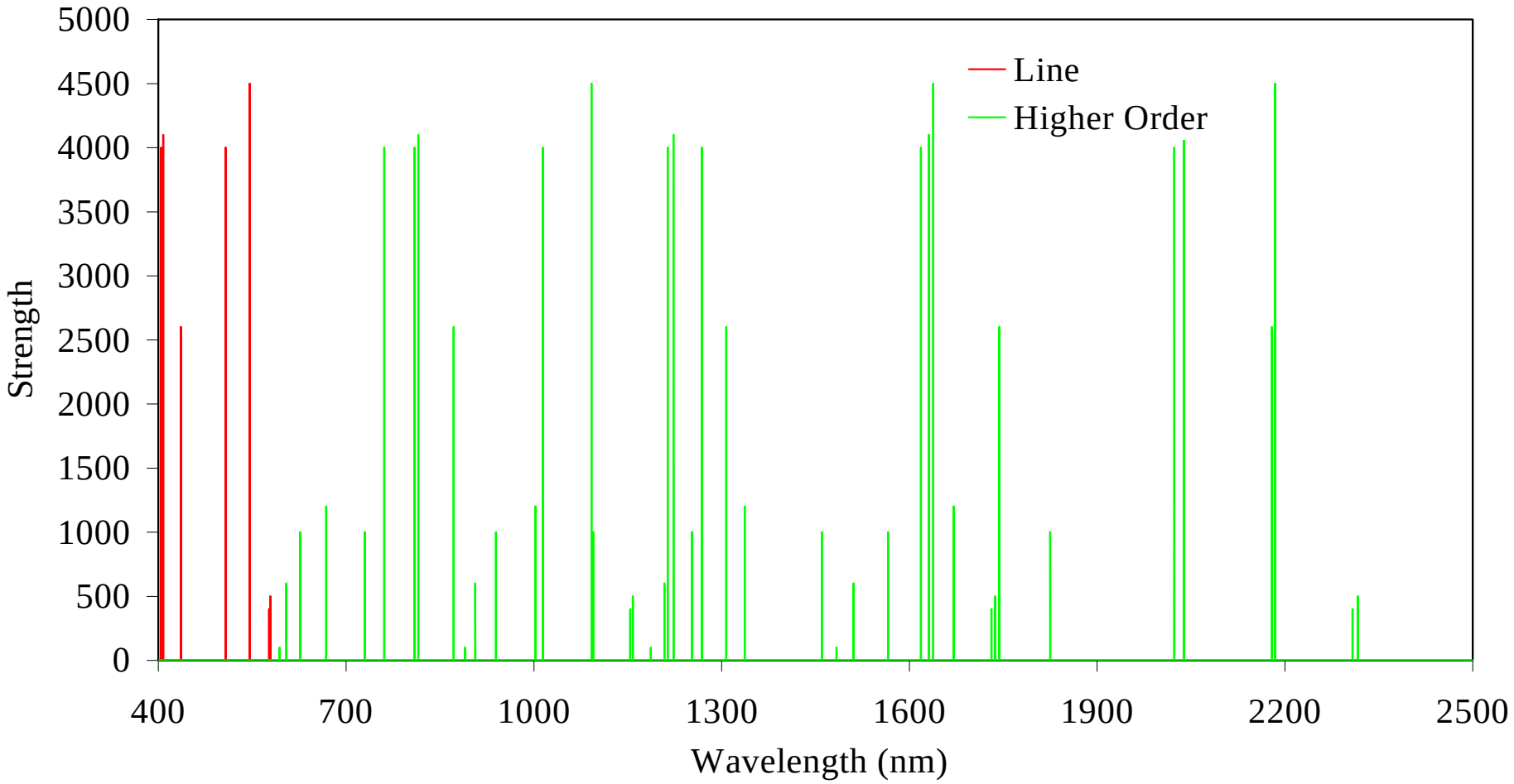
- Imaging Spectrometers have unique spectral, radiometric, and spatial characteristics
- Each calibration characteristic has response, range, and corresponding uncertainty factors
- With 100s of spectral channels, imaging spectrometers present special challenges for calibration

M3 Spectral Calibration

- Standards (in-house)
  - Emission lamps, lasers and rare-earth target
- Approach
  - Collimator fed by scanned monochromator
  - Laser fed integrating sphere
  - Illuminated neodymium panel
- Calibration Analysis Output
  - 2D spectral calibration file with uncertainties for Global and Target modes
- Example
  - AVIRIS Spectral Response Functions (from ~2001)

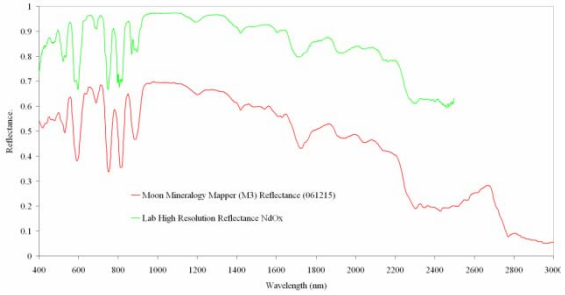


Mercury Vapor Lamp
Spectral Calibration Standard



Spectral Equipment

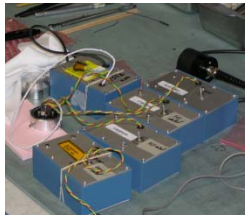
Illuminated Nd Panel



Custom Scanning Monochromator with Collimator

Laser-fed Integrating Sphere

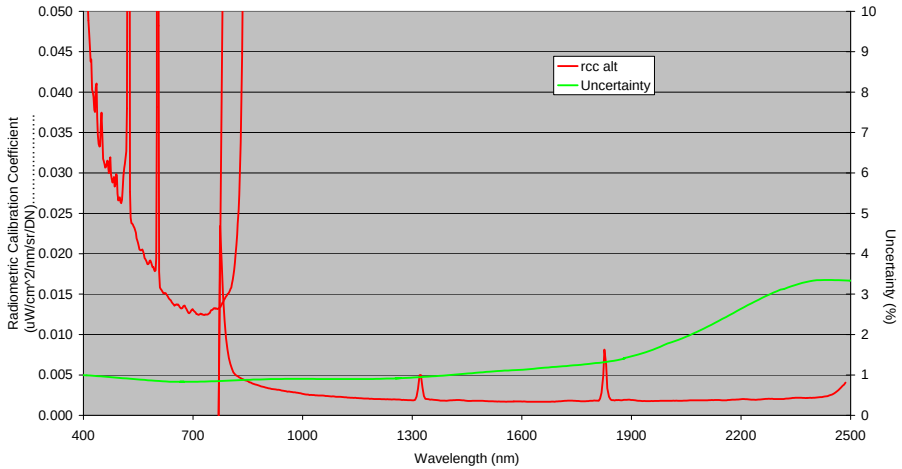
407 nm
532 nm
632 nm
780 nm
830 nm
1064 nm
1a550 nm
2050 nm



Sphere In Use

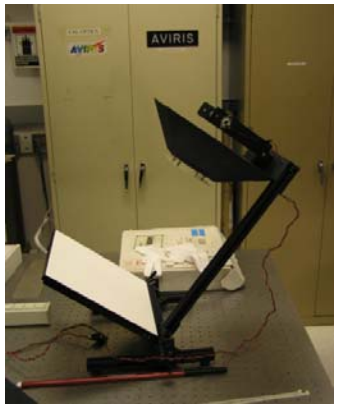
M3 Radiometric Calibration

- Standards
  - NIST traced lamp panel 400 to 2500 nm
  - Blackbody (BB) 1500 to 3000 nm
  - Stable integrating sphere
- Approach
  - Direct view of NIST lamp panel, integrating sphere, and BB
- Calibration Analysis Output
  - 2D radiometric calibration coefficients and uncertainties
- Example
  - Airborne-IS : 321000 radiometric calibration coefficients and uncertainty

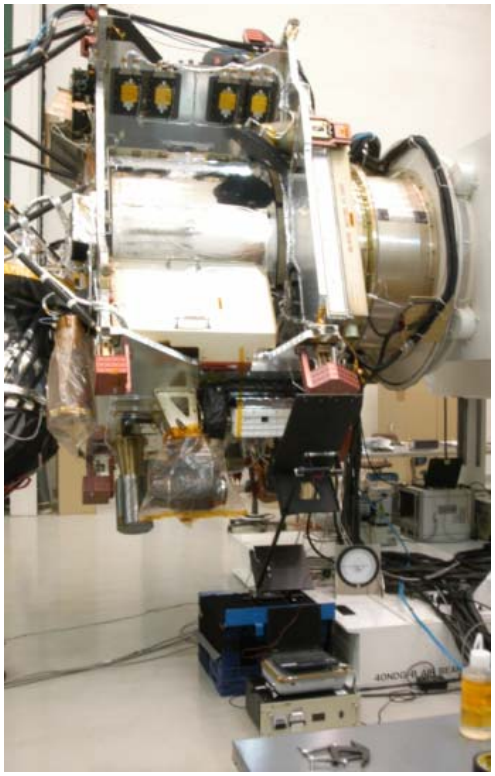


Radiometric Equipment

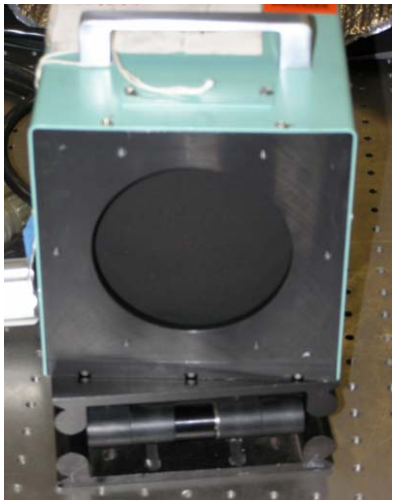
NIST Traced Lamp-Panel
400 to 2500 nm



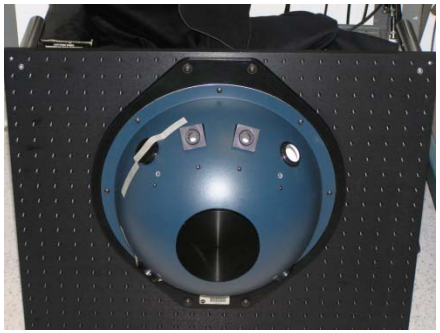
NIST Traced Lamp-Panel
used for CRISM Check



Extended Area Blackbody
1500 to 3000 nm

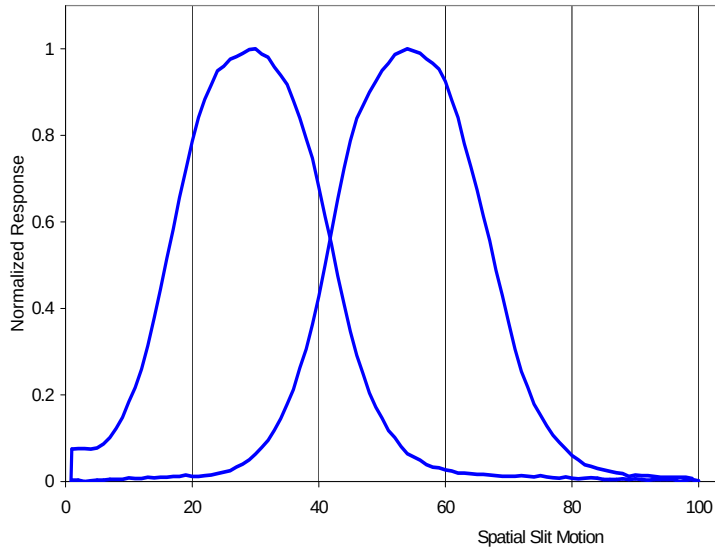


White-light Integrating Sphere
for Vignetting and Flat Field



M3 Spatial Calibration

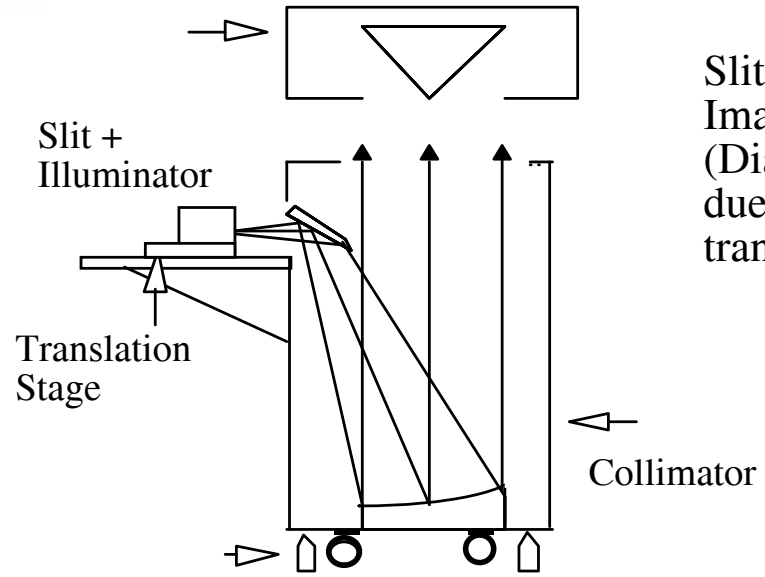
- Standards
  - White light illuminated slit
- Approach
  - Collimator fed by scanned white light slit
- Calibration Analysis Output
  - 2D spatial response functions and uncertainties
- Example
  - Airborne-IS spatial response functions

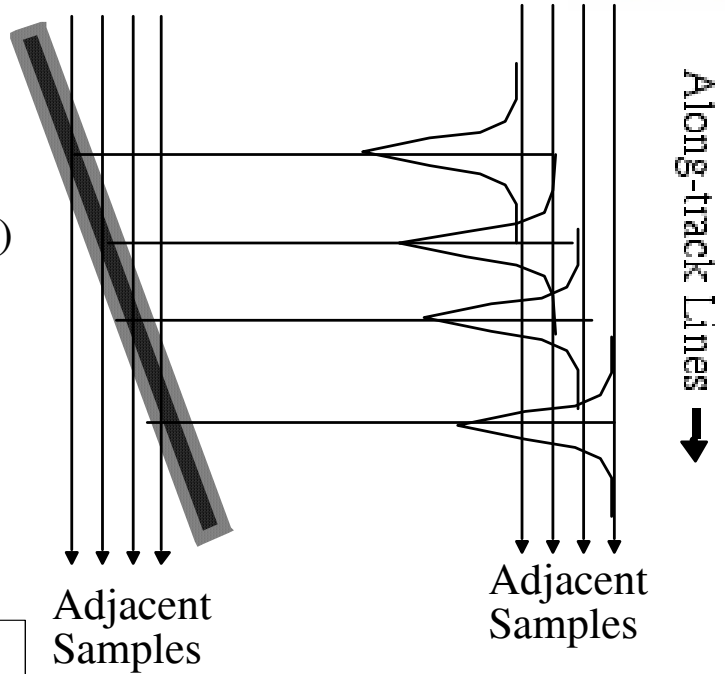


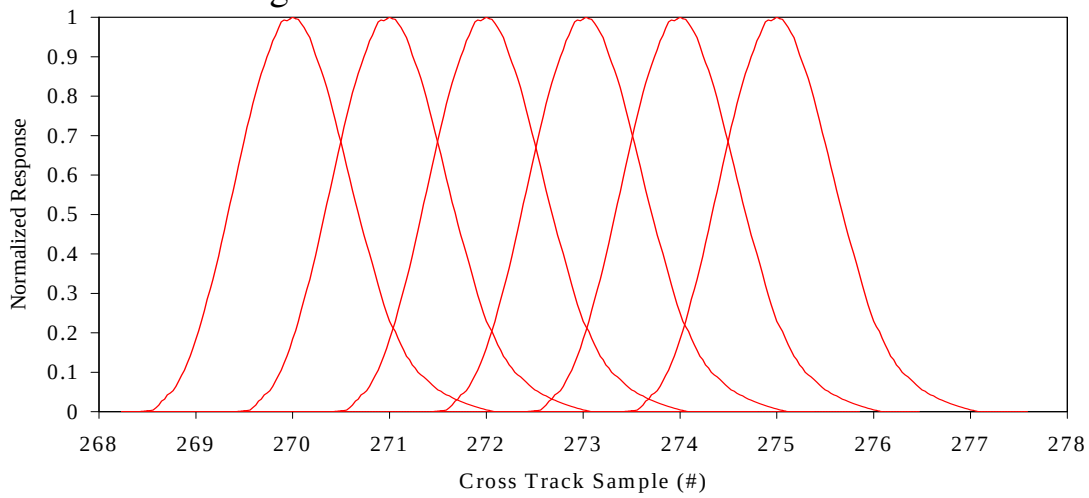
Spatial Equipment

Custom Scanning Collimator with White Light Slit

Slit Response Function Measurement





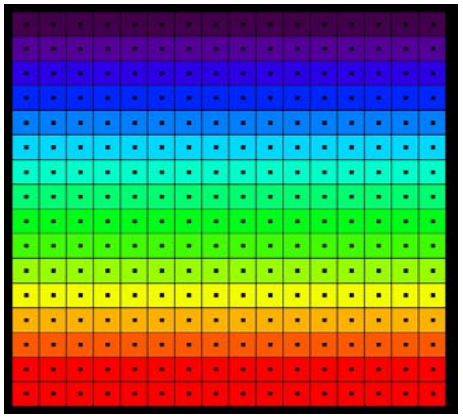


M3 Geometric Calibration

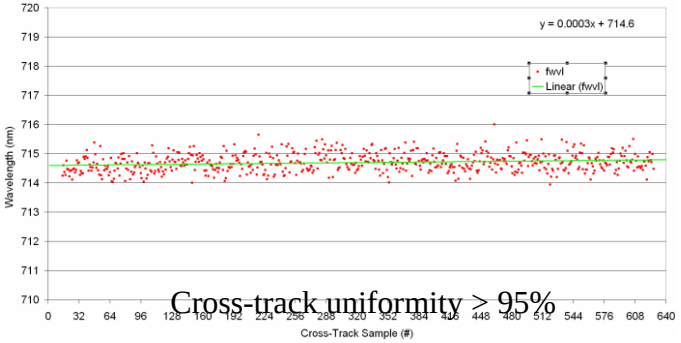
- Standards
  - Spatial targets plus validated optical design
- Approach
  - Use optical design plus selected lab collimator fed spatial targets
  - Theodolite measurements of telescope projected slit
- Calibration Analysis Output
  - Camera model cosines
- Example
  - Airborne-IS georectification

Uniformity

HyspIRI Uniformity Calibration



- Standards
  - Laser-fed integrating sphere
  - Neodymium panel
  - Scanning monochromator
  - Scanning white light slit
- Approach
  - Use optical design plus selected collimator-fed spatial targets
  - Use Laser-fed integrating sphere to cover FOV
- Calibration Analysis Output
  - Spectral cross-track uniformity
  - Spectral IFOV uniformity
- Example
  - M3 cross-track uniformity



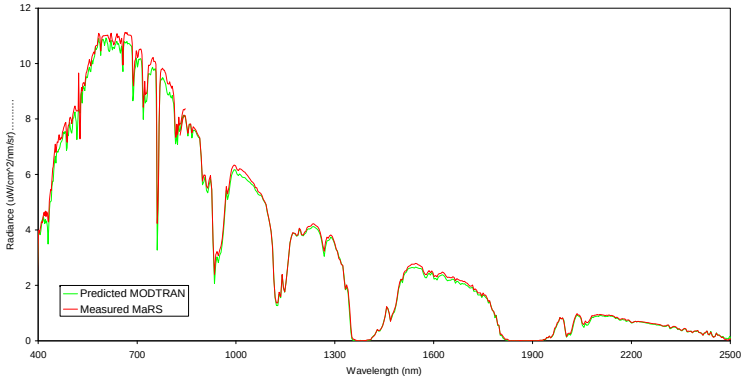
Cross-track uniformity > 95%

HyspIRI Calibration Files and Equation

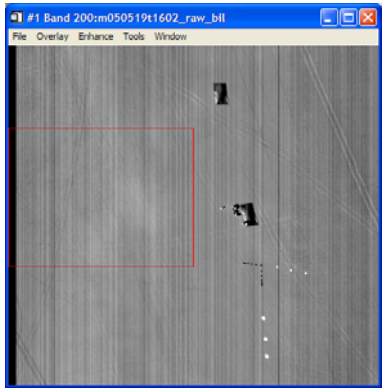
- HyspIRI Calibration Files
  - Radiometric, Spectral, Spatial, Uniformity
- Basic HyspIRI Calibration Equation
  - L(c,s) = RCC(c,s) * (DN(c,s)-DS(c,s))
    - (c,s) per spectral channel and cross-track sample
    - L = radiance
    - RCC(c,s) = radiometric calibration coefficient (uW/cm^2/nm/sr/DN)
    - DN(c,s) is the measured signal from the detector
    - DS(c,s) is the dark signal measured from un-illuminated portion of the orbit

HyspIRI Example from Airborne-IS 2005

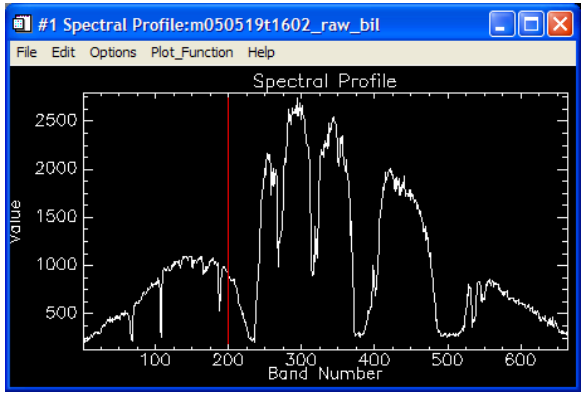
- Airborne-IS example from Ivanpah Playa
- Solar reflected spectrum
- Offner spectrometer
- TCM6604a detector array
- HyspIRI calibration standards and approach



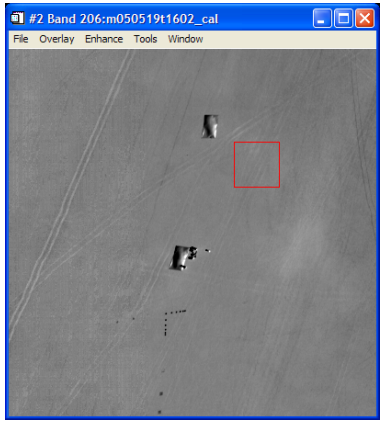
Level O



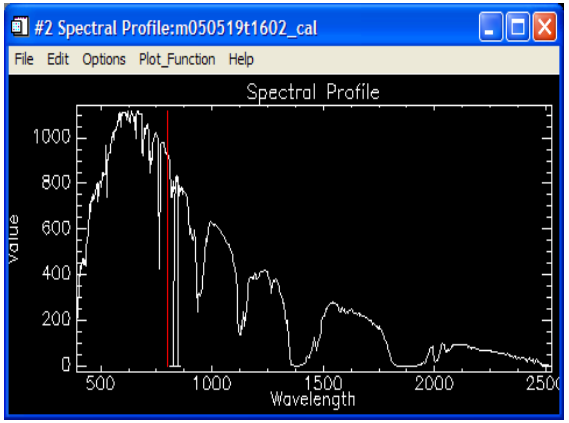
DN versus Band



Level 1



Radiance versus Wavelength



HyspIRI Calibration Summary

- The imaging spectrometer calibration history for HyspIRI is strong.
  - AVIRIS, WarFighter, Hyperion, CRISM, Airborne-IS, M3, etc.

- We understand the HsypIRI calibration requirements.

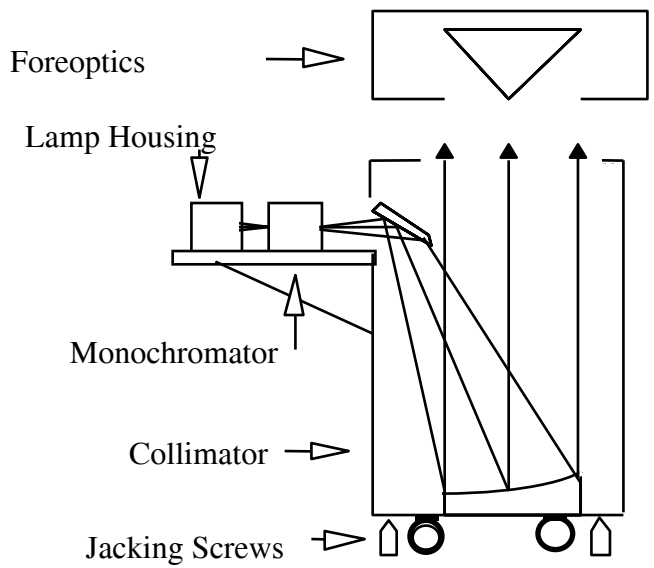
- To a large degree, the approach, baseline equipment and procedures have been tested with previous effort.

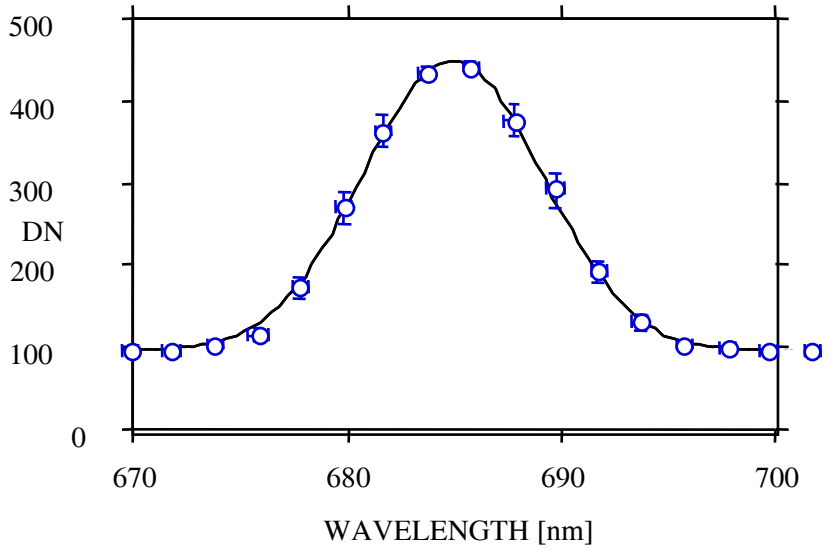
- It is predicted the HyspIRI calibration schedule will be tight, but sufficient because of deep previous experience.

- The on-orbit calibration validation approach is well understood.
  - Moon, Solar cover, Ground-Calibration-Experiments

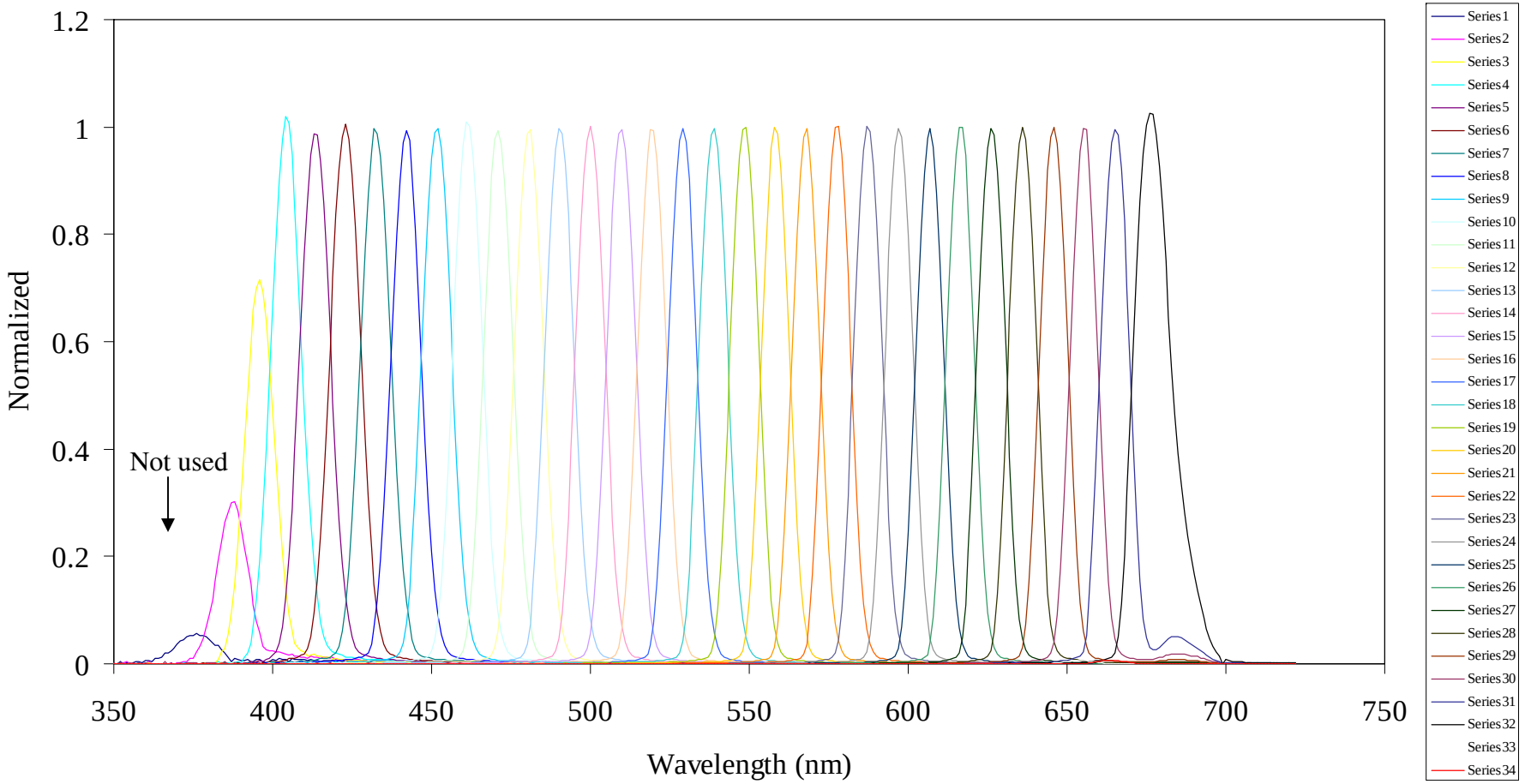
Backup

Spectral Calibration Apparatus and Result

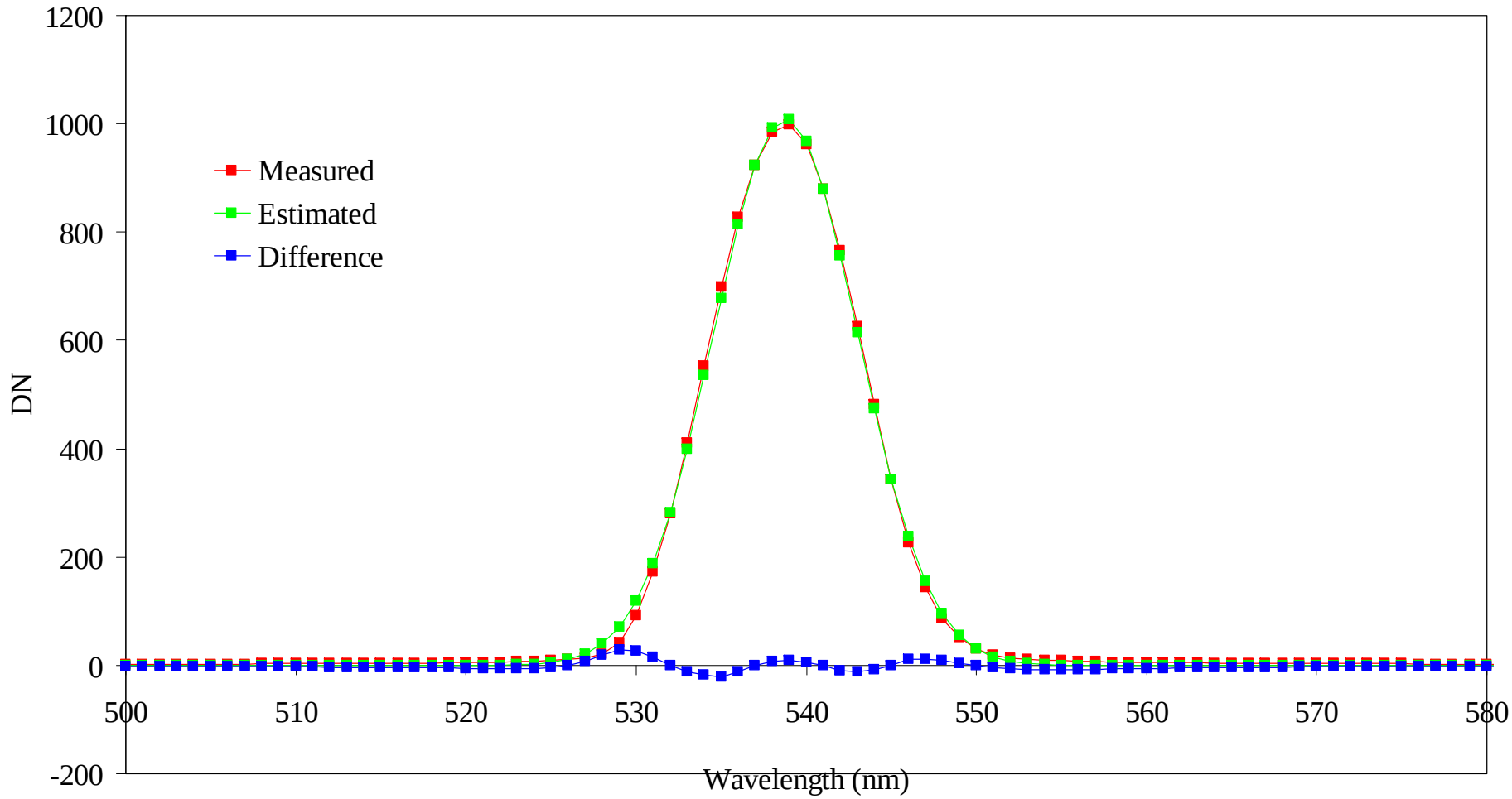




A Spectrometer Spectral Response Function after Spectral Flat Field



Spectral Fit for Determination of Best Gaussian Function



Radiance Source