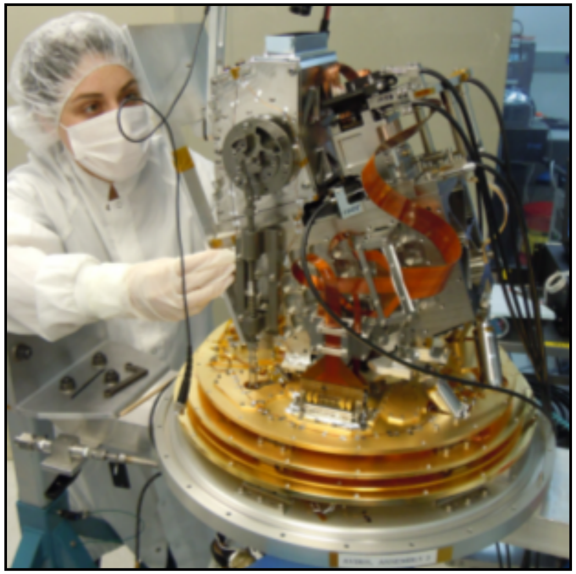
Initial Flights of the AVIRIS Next Generation Instrument and HyspIRI Concept Technology Validation



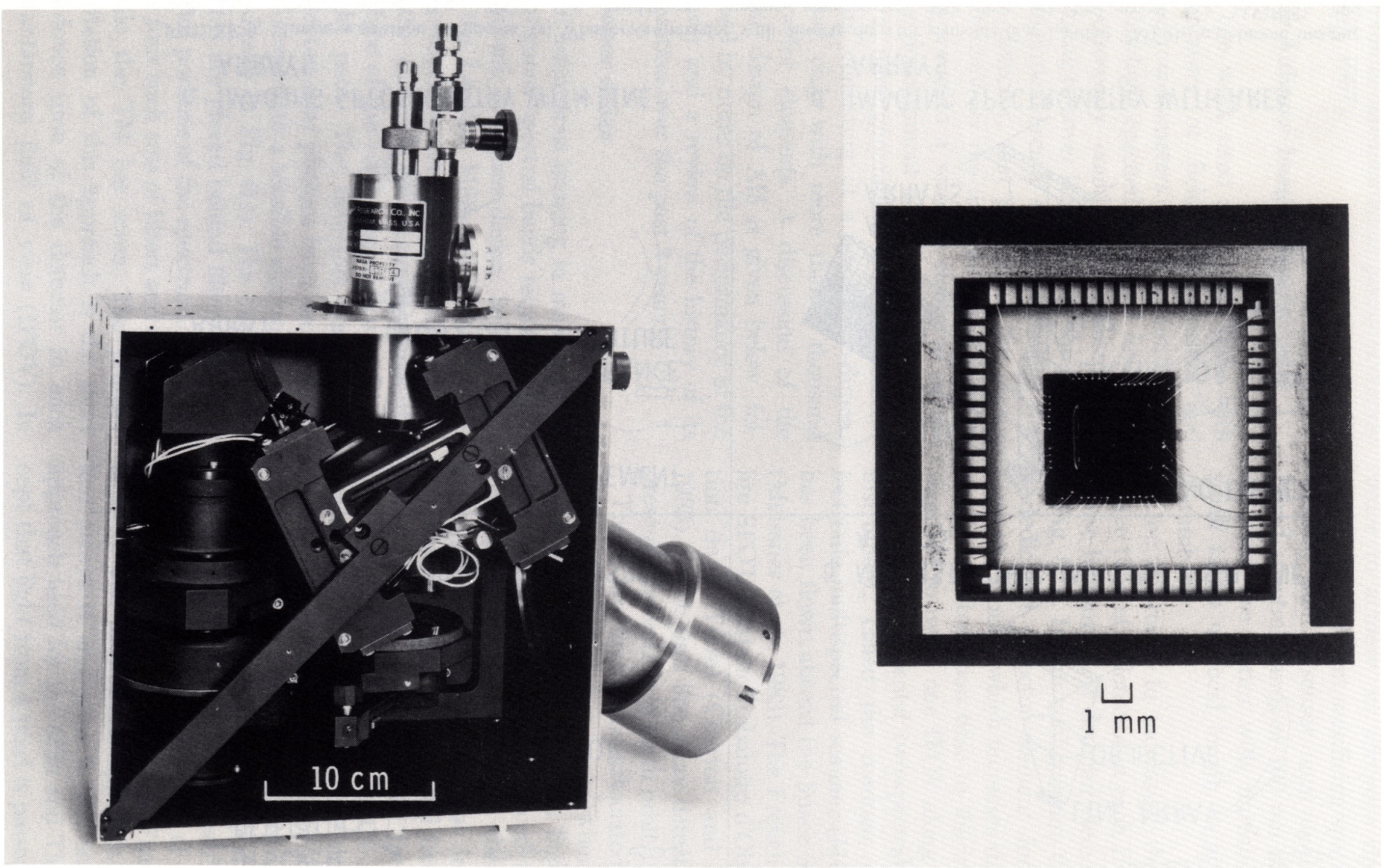
Robert O. Green and the AVIRIS-NG Team

Overview

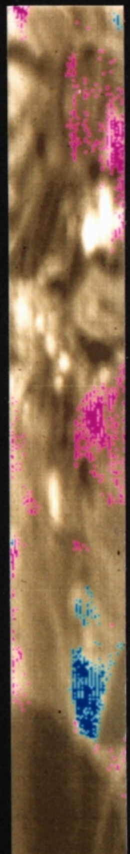
- Context Objective and Approach
- Development
- Laboratory Characterization and Calibration
- Inflight Calibration Validation
- HyspIRI Validation
- Summary and Conclusions

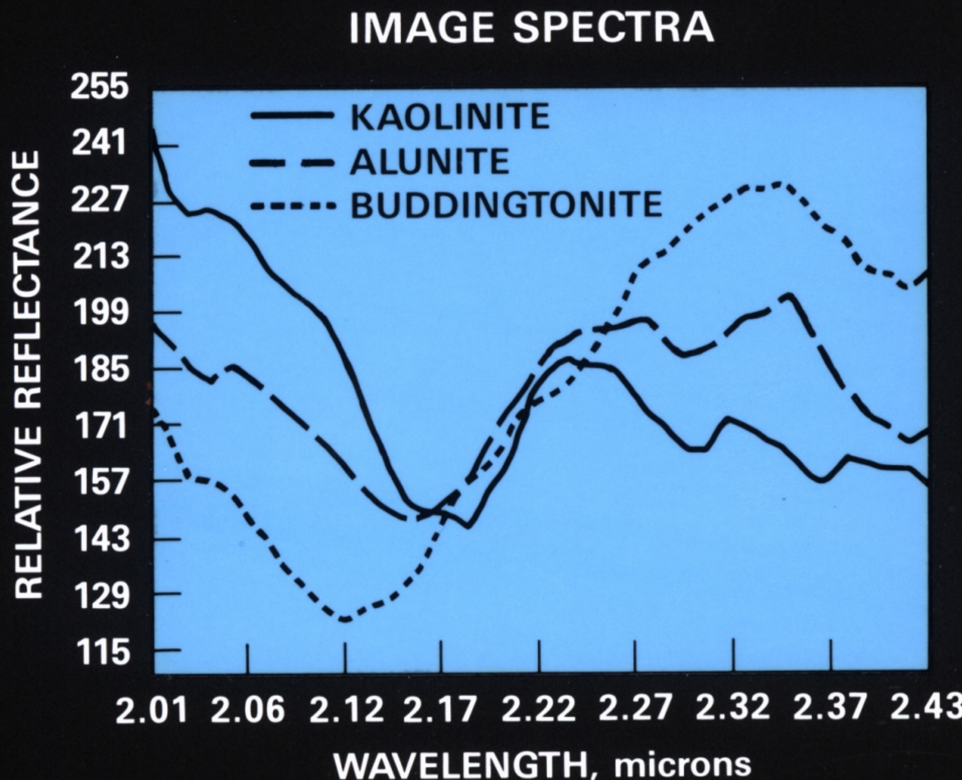
The Airborne Imaging Spectrometer (AIS)

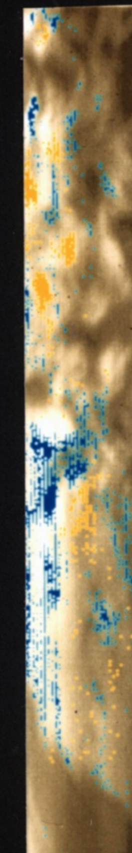
- Proposed in 1979. First flew in 1982.



AIS Measurements







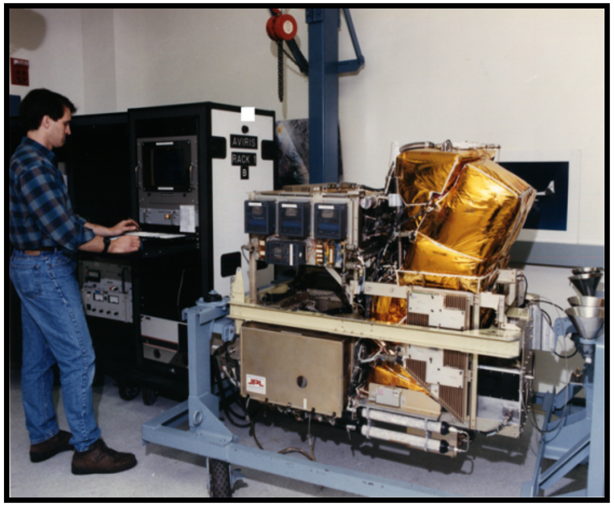
KAOLINITE
ALUNITE

BUDDINGTONITE
ALUNITE

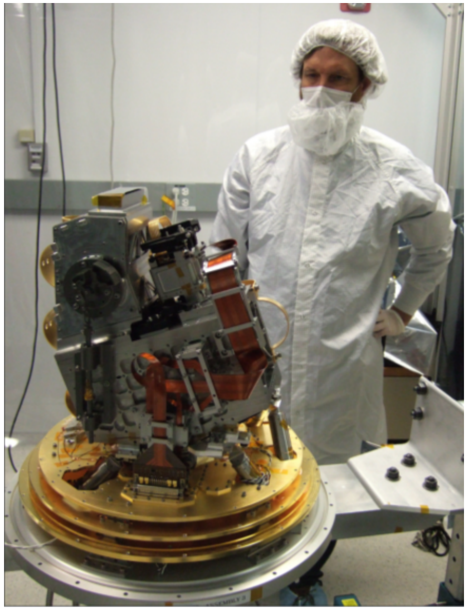
- IMAGE DATA HAVE BEEN FLAT FIELD CORRECTED
- SPECTRA ARE FOR 3 BY 3 PIXEL AREAS

Airborne Visible/Infrared Imaging Spectrometer

- AVIRIS-Classic (AVIRIS-C)



- AVIRIS-Next Generation (AVIRIS-NG)



Research and Applications

- Atmosphere: water vapor, clouds properties, aerosols, absorbing gases …
- Ecology: chlorophyll, leaf water, lignin, cellulose, pigments, structure, nonphotosynthetic constituents …
- Geology and soils: mineralogy, soil type …
- Coastal and Inland waters: chlorophyll, plankton, dissolved organics, sediments, bottom composition, bathymetry …
- Snow and Ice Hydrology: snow cover fraction, grainsize, impurities, melting …
- Biomass Burning: subpixel temperatures and extent, smoke, combustion products …
- Environmental hazards: contaminants directly and indirectly, geological substrate …
- Calibration: aircraft and satellite sensors, sensor simulation, standard validation …
- Modeling: radiative transfer model validation and constraint …
- Commercial: mineral exploration, agriculture and forest status …
- Algorithms: autonomous atmospheric correction, advance spectra derivation …
- Other: human infrastructure ...

Objective and Approach

- Objective: Pursue important next generation Earth science and science applications
- Secondary objective: Test imaging spectrometer elements that may be used in space instruments.
- Approach: Develop state-of-the-art imaging spectrometer with exceptional uniformity, signal-to-noise ratio and calibration

AVIRIS Next Generation Compared to AVIRIS

	AVIRIS-Next Generation	AVIRIS-Classic
SPECTRAL		
Range	380 to 2510 nm	380 to 2500 nm
Position	5 nm	10 nm
Response	1 to 1.5 X sampling	1 to 1.5 X sampling
Calibration	+-0.1 nm	+-0.1 nm
RADIOMETRIC		
Range	0 to max Lambertian	0 to max Lambertian
Precision (SNR)	>2000 @ 600 nm	>1000 @ 600 nm
	>1000 @ 2200 nm	>400 @ 2200 nm
Accuracy	95% (<5% uncertainty)	90% (<10% uncertainty)
Linearity	>=99% characterization	>=99% characterization
SPATIAL		
Range	34° field-of-view	34° field-of-view
Sampling	1 milliradian	1 milliradian
Response	1 to 1.5 X sampling	1 to 1.5 X sampling
Sample Distance	0.3 m to 20 m	4 m to 20 m
Geom Model	Full 3 Axes cosines	Full 3 Axes cosines
UNIFORMITY		
Spectral Cross-Track	>95% across FOV	>98% across FOV
Spectral-IFOV-Variation	>95% Spectral Direction	>98% Spectral Direction

AVIRIS-NG Uniformity

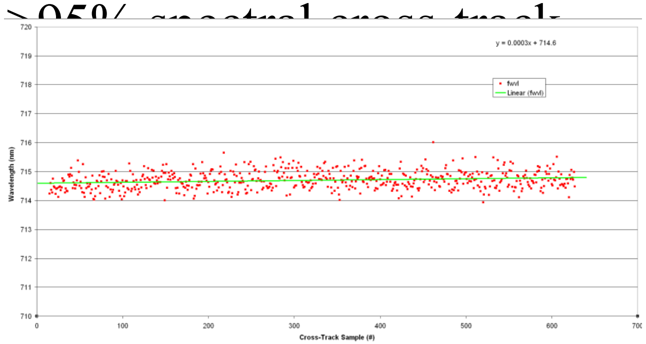
Depiction

-Grids are the detectors

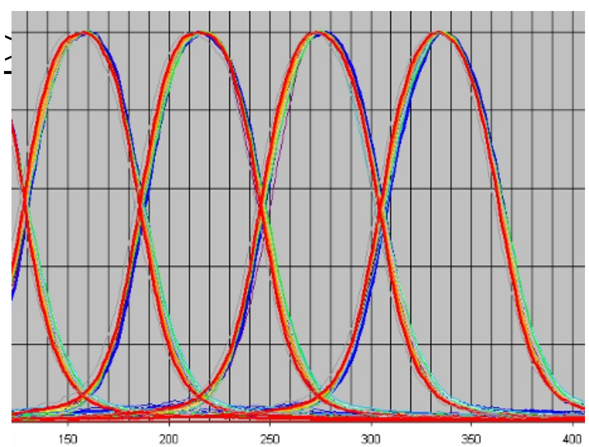
-Spots are the IFOV centers

-Colors are the wavelengths

>95% spectral cross-track



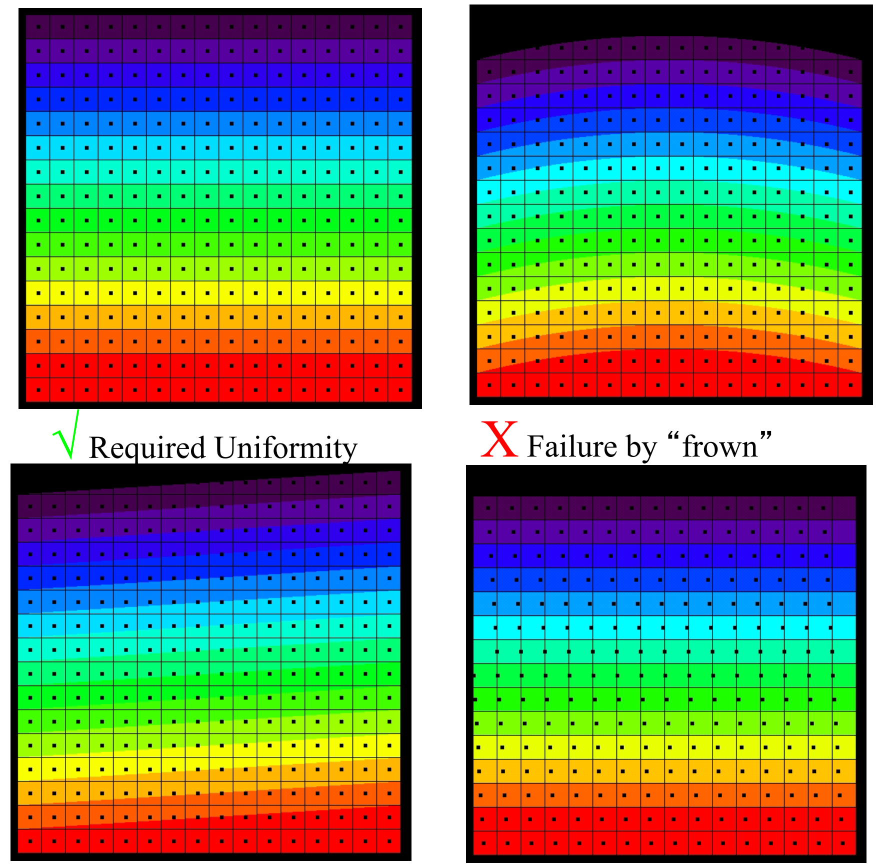
M3



M3

Cross-Track

Wavelength (nm)



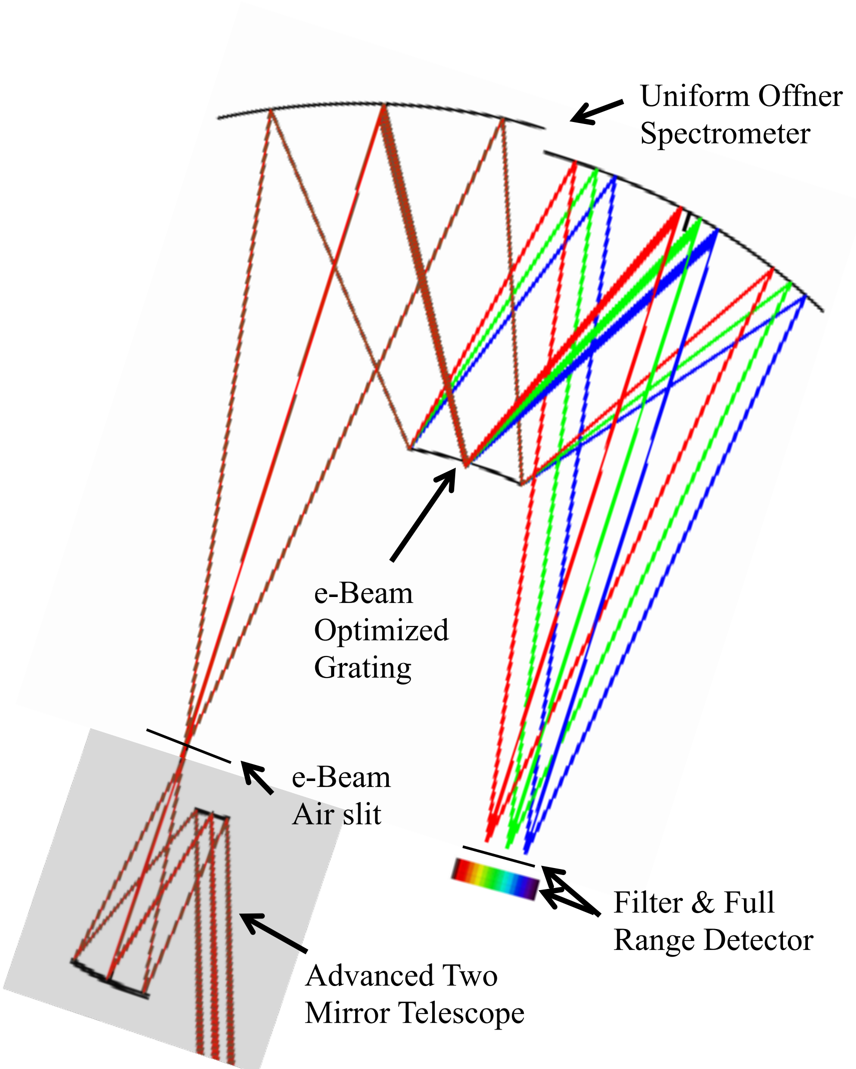
√ Required Uniformity

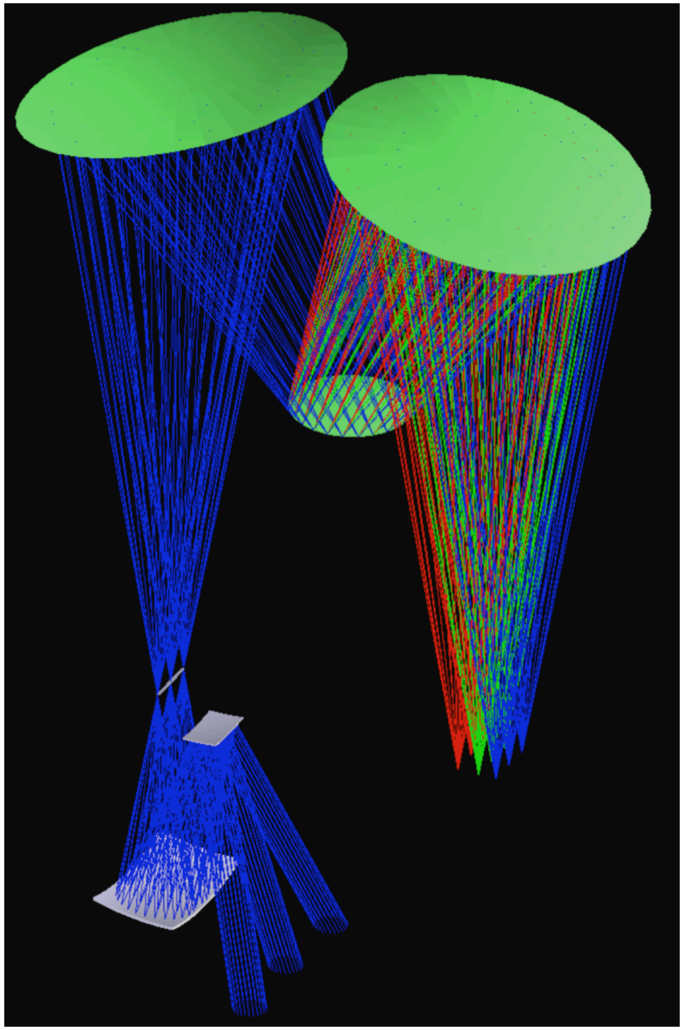
X Failure by "frown"

X Failure by twist

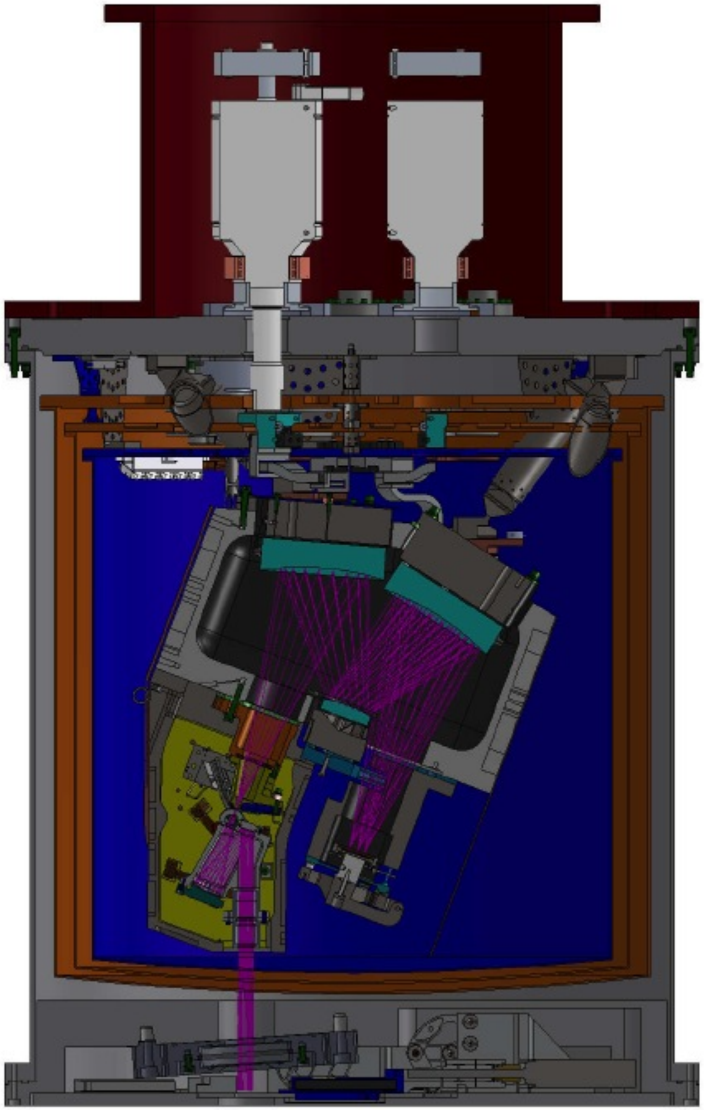
X Failure by Spectral-IFOV-shift

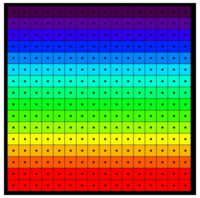
AVIRIS Next Generation Optical Concept



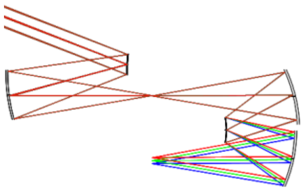


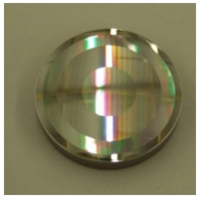
Enabling Elements



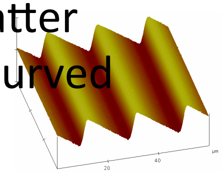


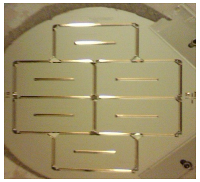
High SNR and high uniformity imaging spectrometer designs (Mouroulis et al., 2000)*



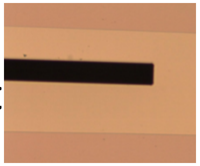


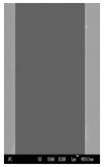
Electron-beam lithography low-scatter tuned-high-efficiency gratings on curved surfaces for space

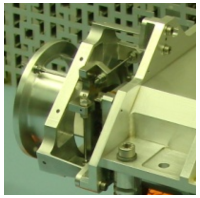




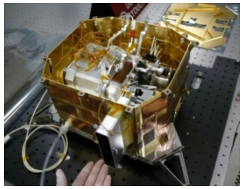
Ultra uniform 27 µm x 20 mm electron-beam lithography slit space flight

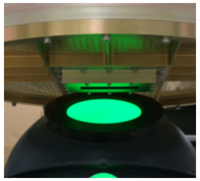




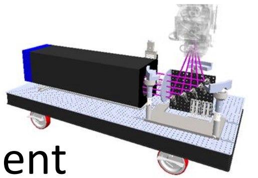


Component mounts with 0.25 micron feedback adjustment that are lockable for space flight



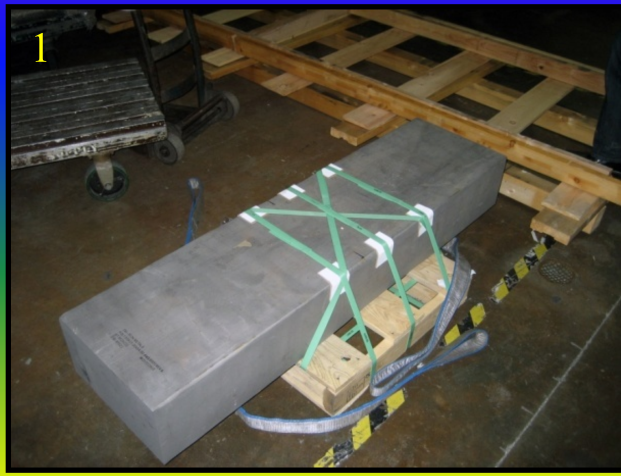


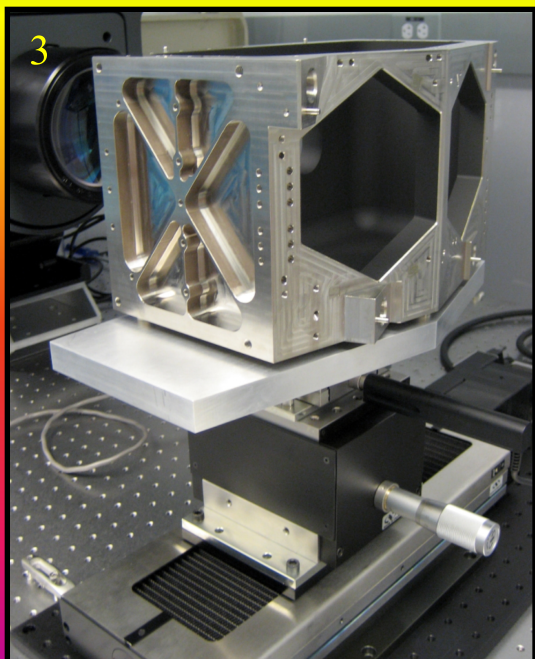
Unique set of alignment and calibration sources and tools for imaging spectrometer development

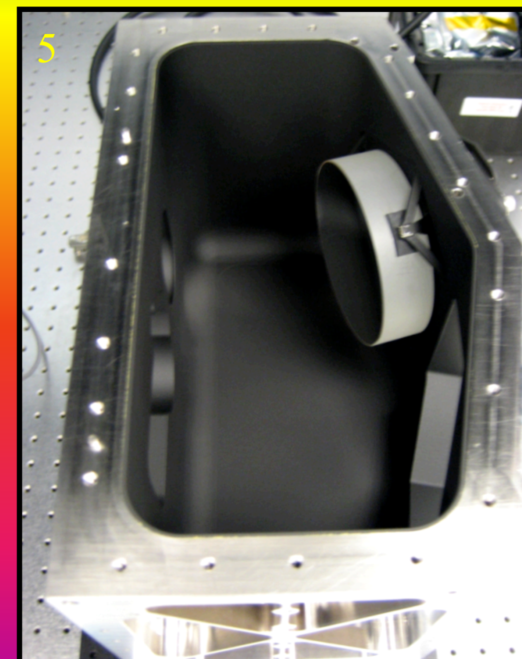


*Mouroulis P., Green R. O., Chrien T. G., "Design of pushbroom imaging spectrometers for optimum recovery of spectroscopic and spatial information," APPL OPTICS 39: (13) 2210-2220 MAY 1 2000

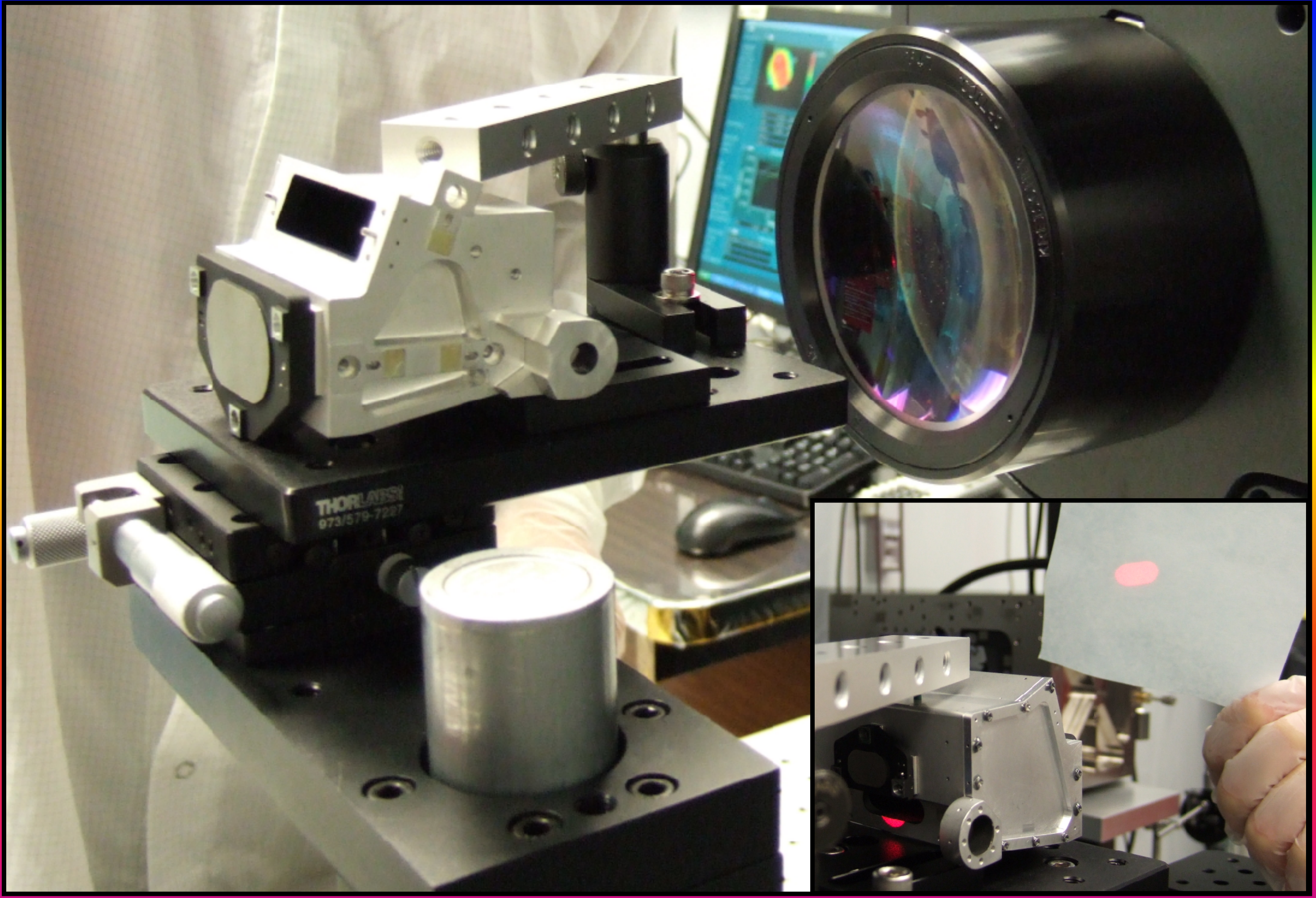
AVIRIS Next Generation Spectrometer
Installation of First Mirror





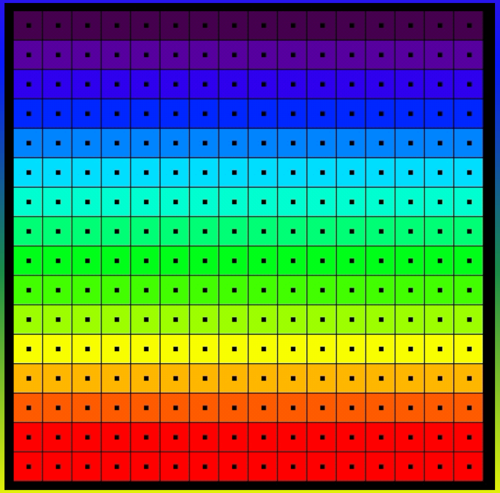


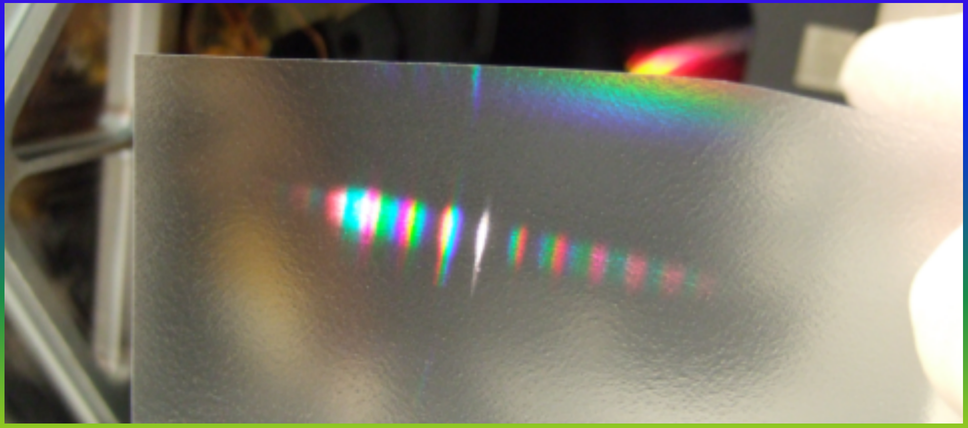
AVIRIS Next Generation Telescope Fully Aligned

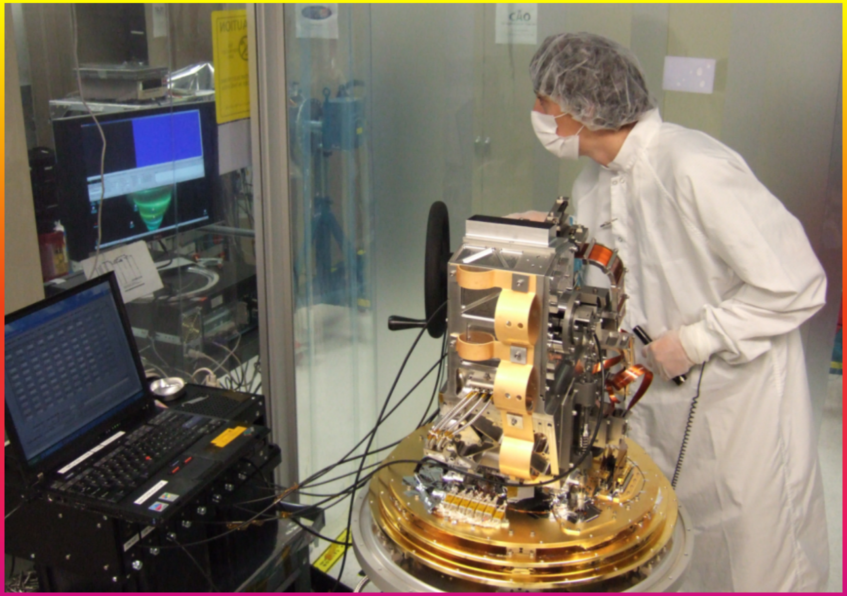


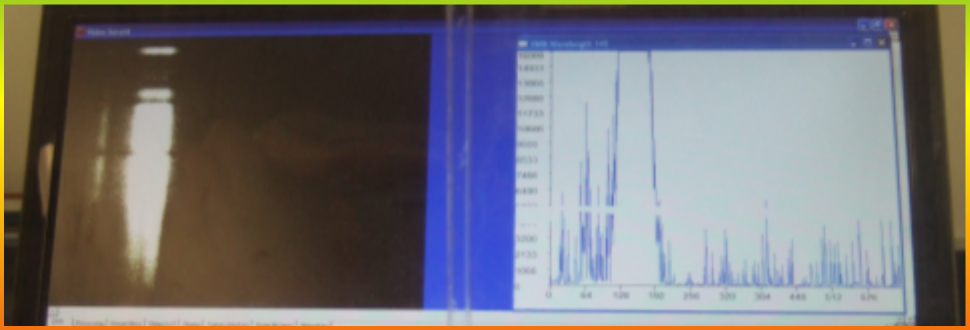
Spectrometer toThermal Shields

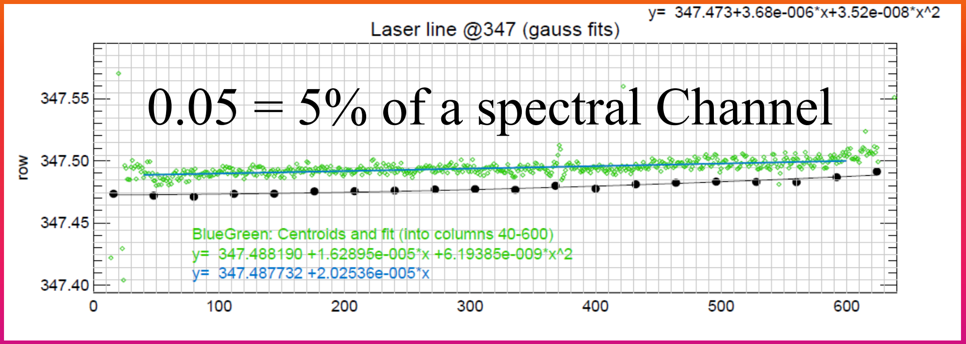
AVIRIS Next Generation Instrument in the Laboratory and First Light 14 Months from Funding Start







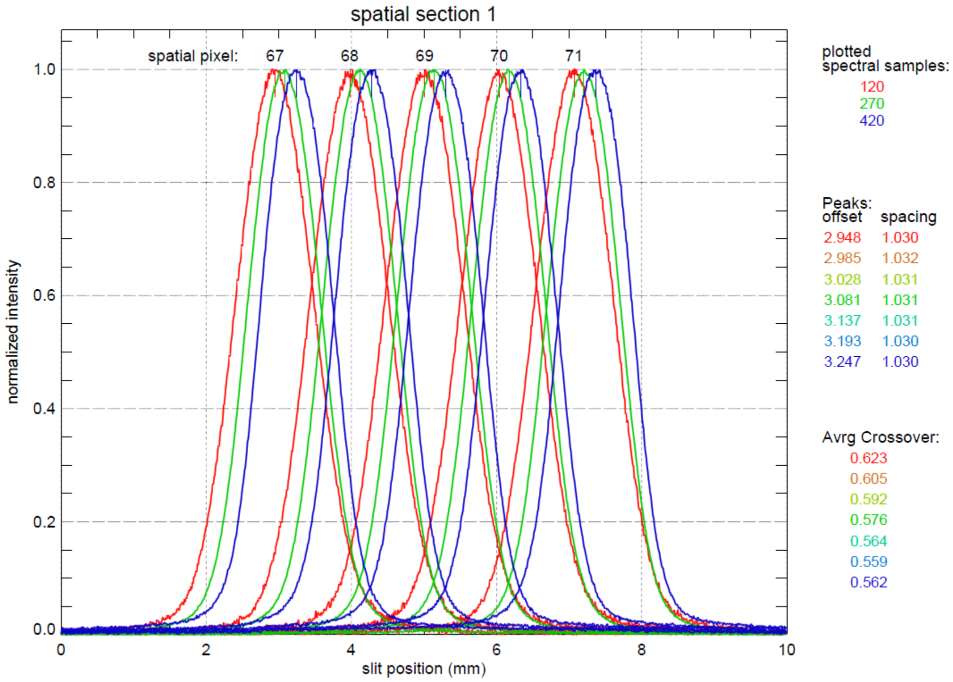




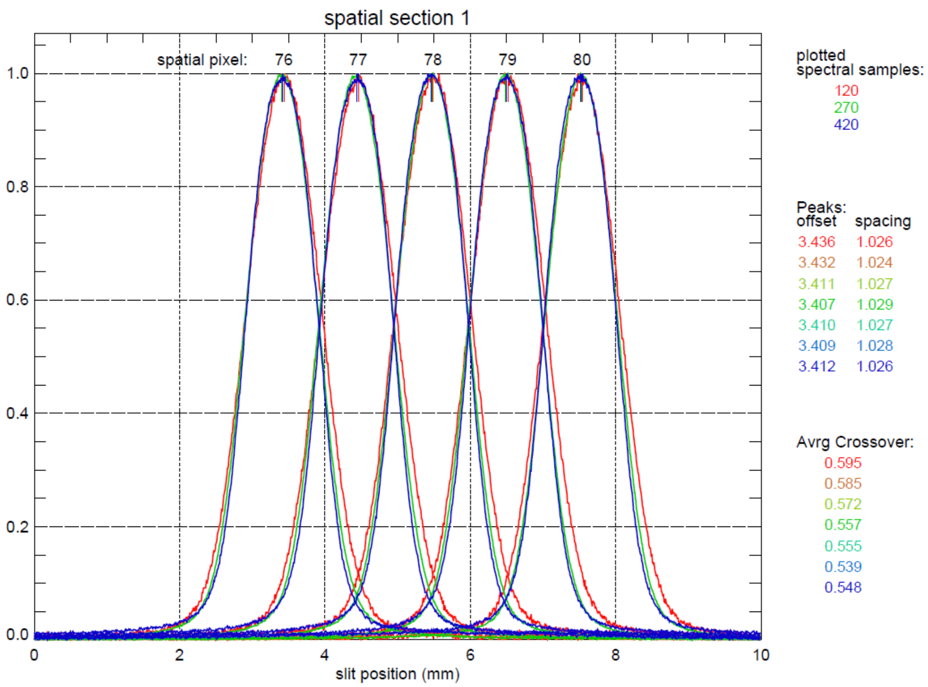
AVIRIS-NG Alignment Cycle #2 and #3

- 22 March 2012
- Alignment from thermal vacuum #2 to #3.
- IFOV uniformity brought from 60% to requirement of ≥95%.

TV#2

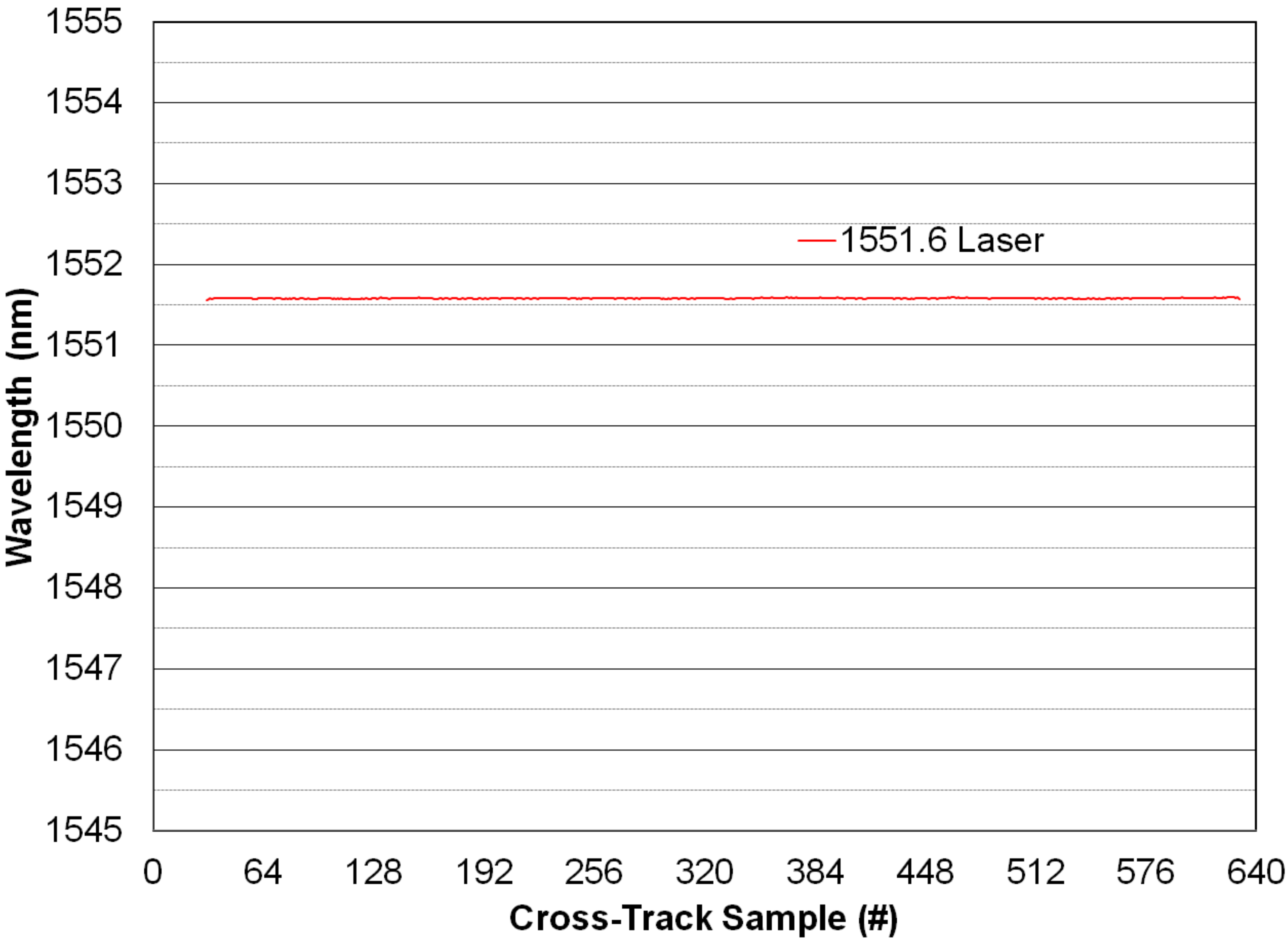


TV#3

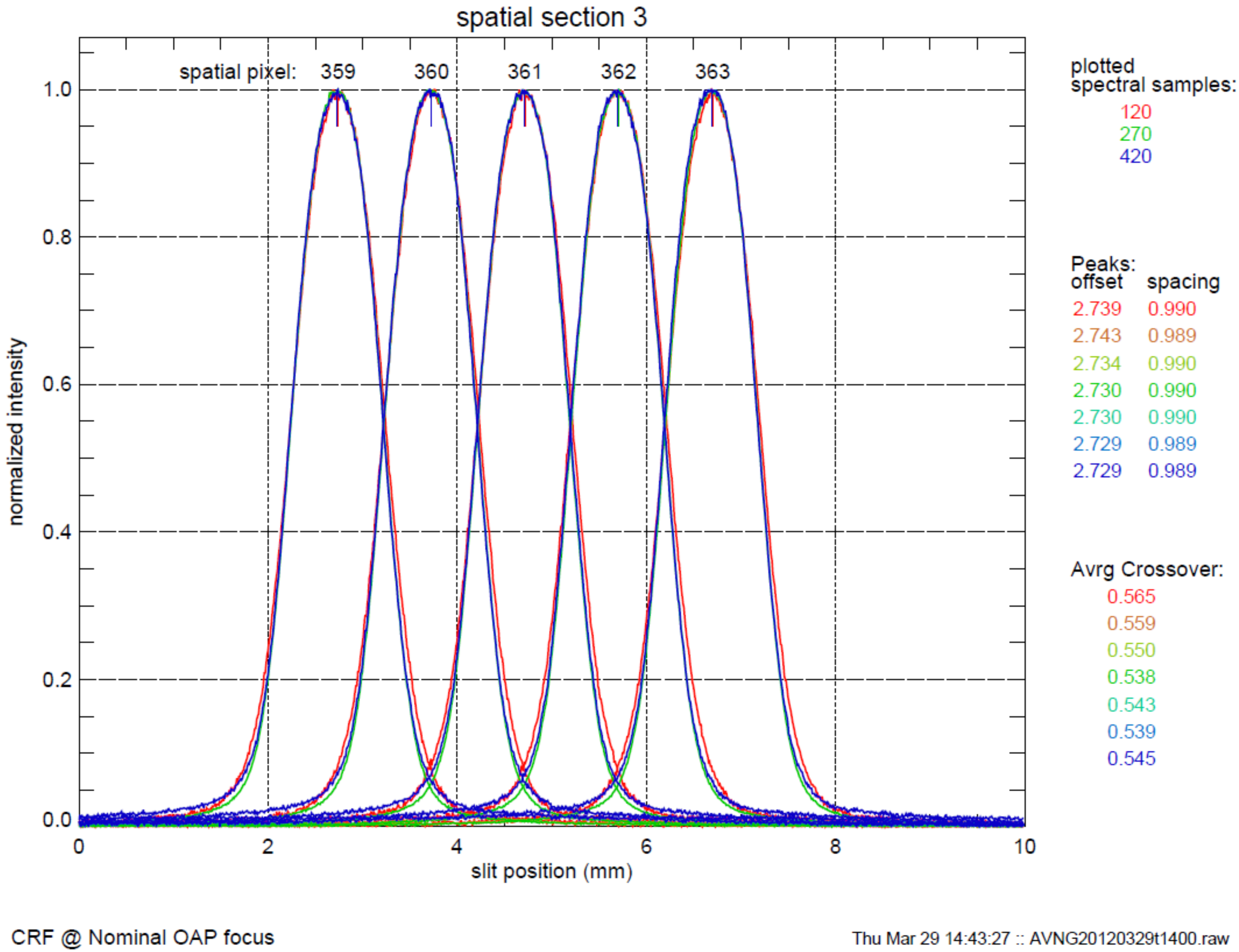


AVIRIS-NG Alignment Team

AVIRIS-NG Cross-Track Uniformity > 95%



AVIRIS-NG Spectral IFOV Uniformity > 95%

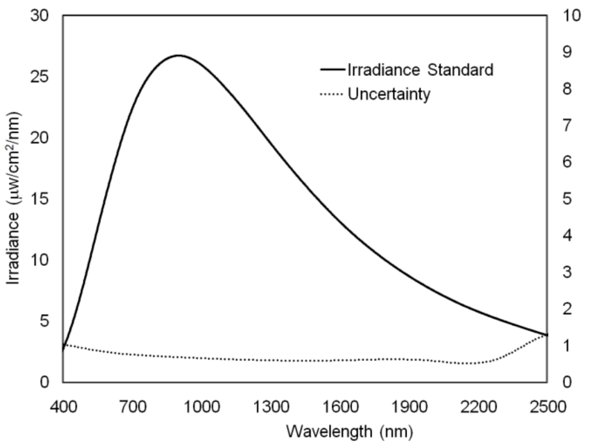


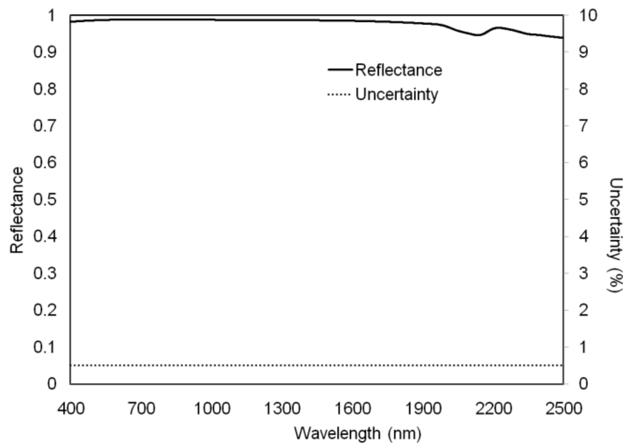
Radiometric Calibration

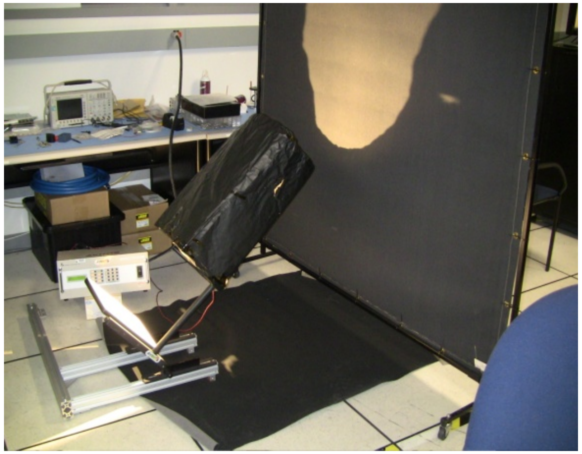
Standards and Equipment

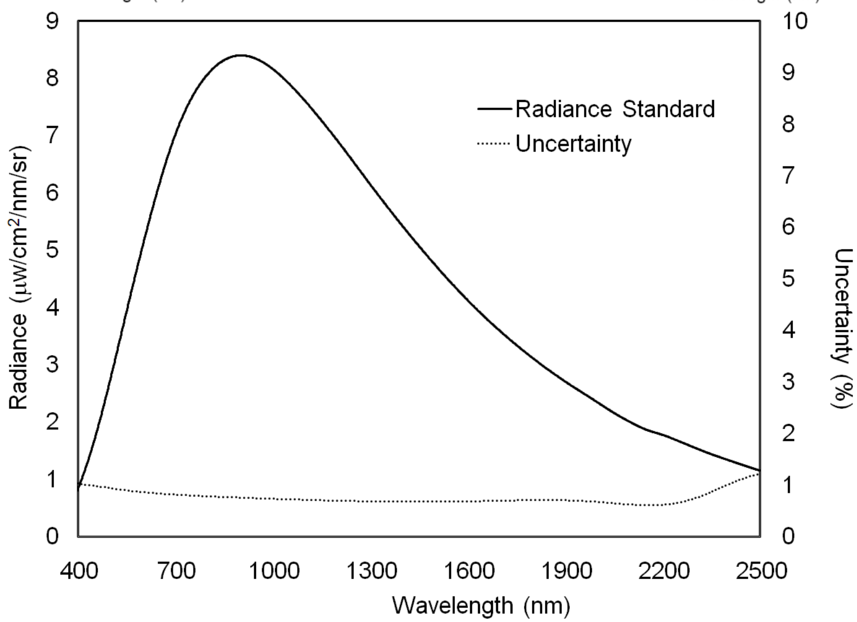
NIST traced lamp panel 350-2500 nm

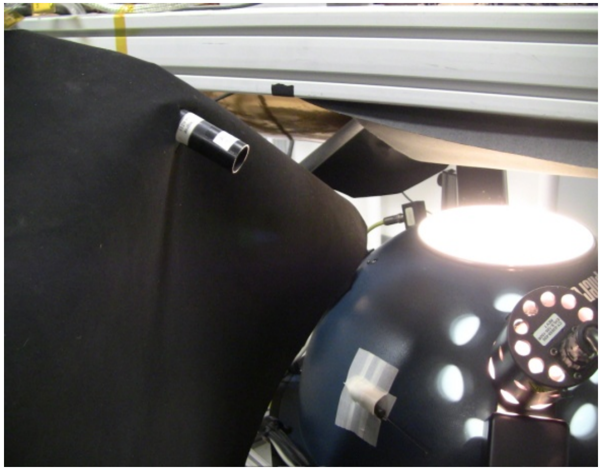
Stable variable intensity integrating sphere



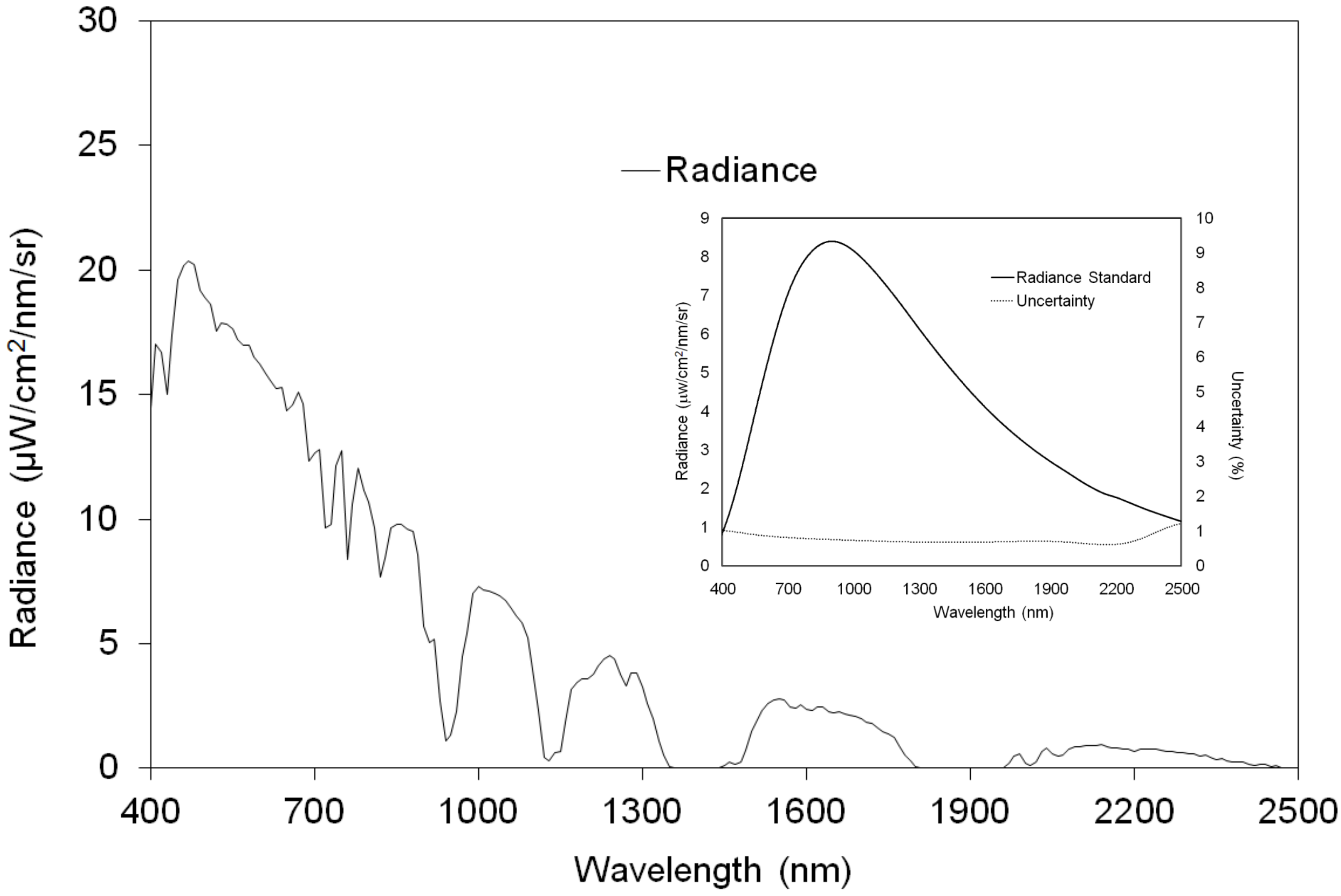




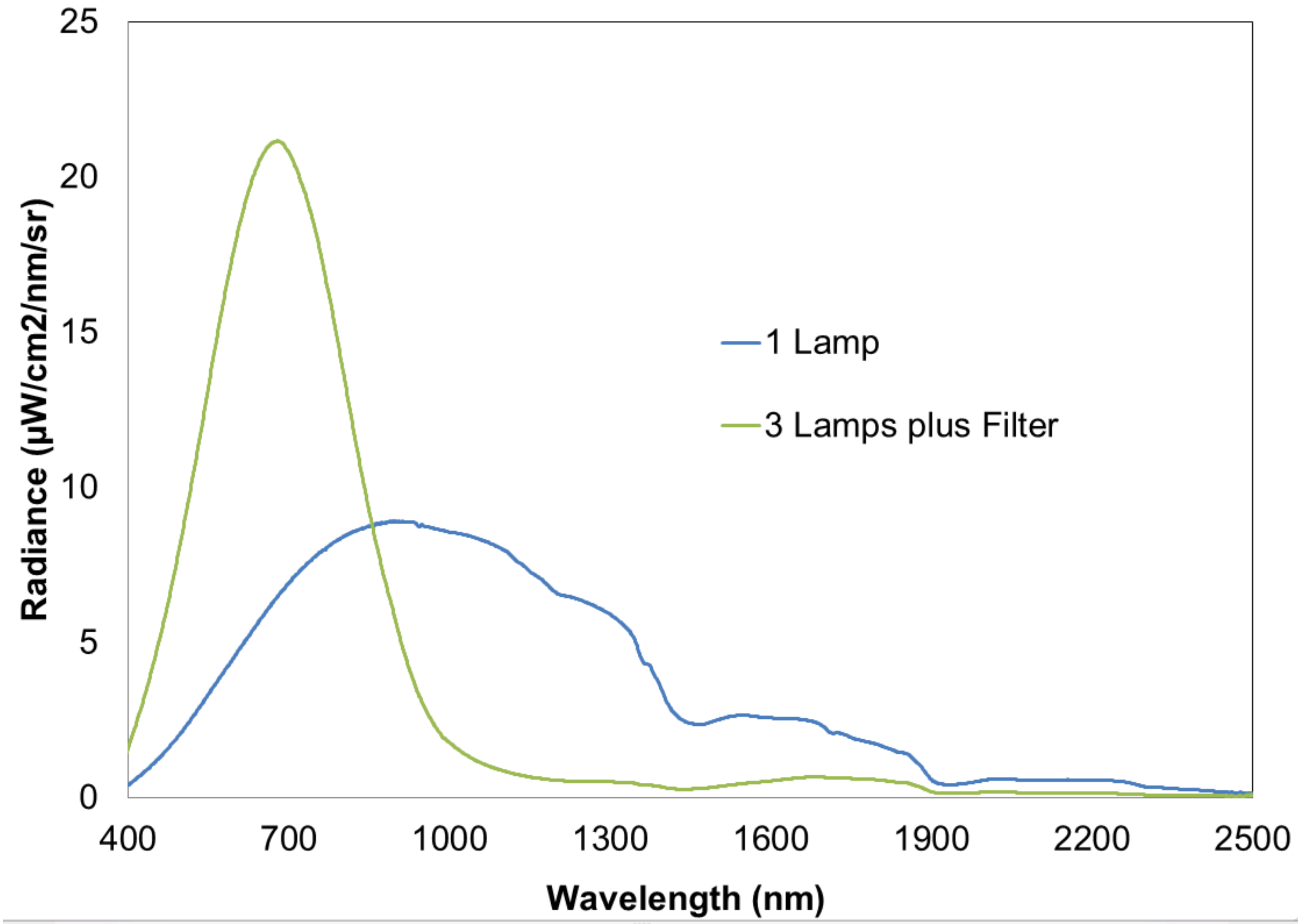




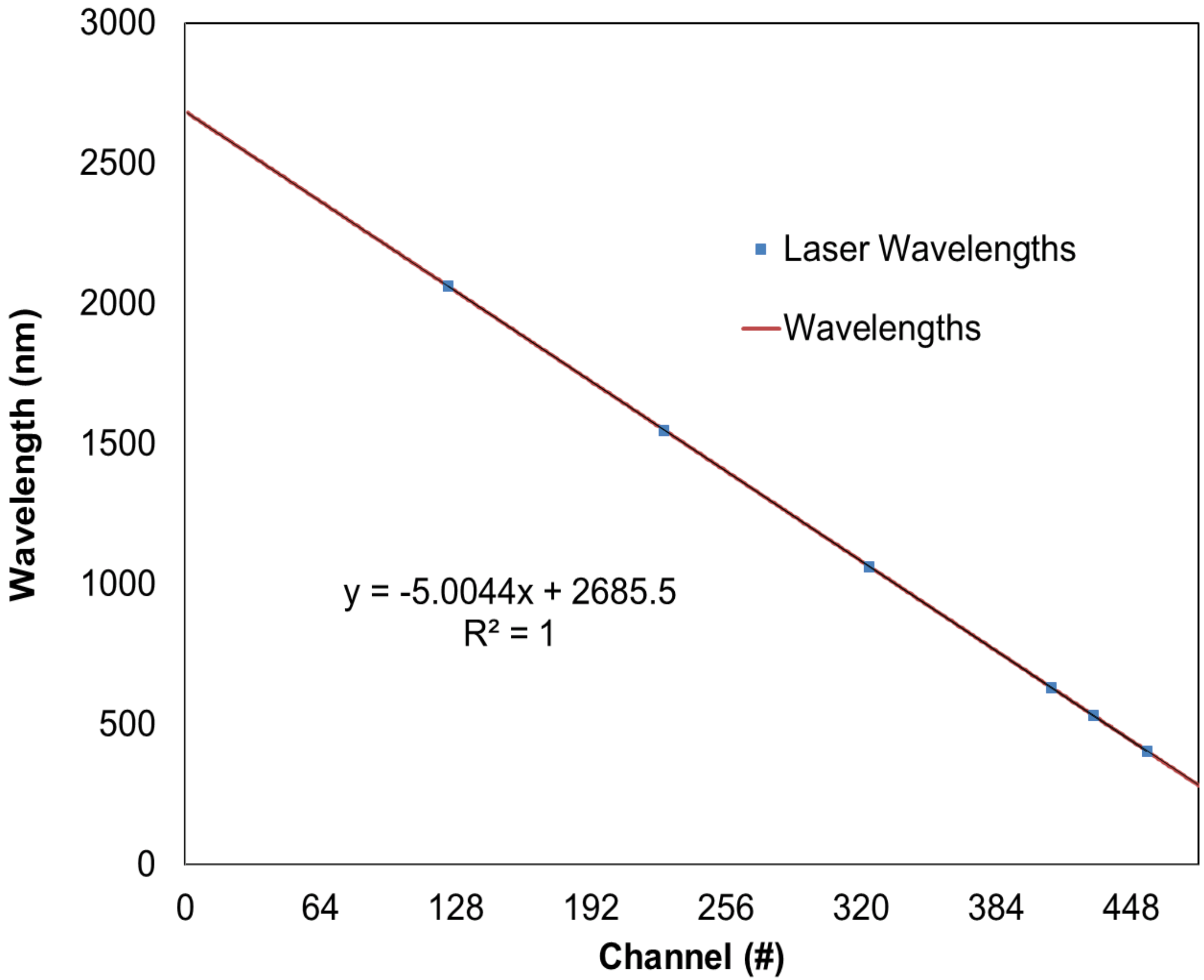
Upwelling Radiance



Evolution of Laboratory Calibration Source



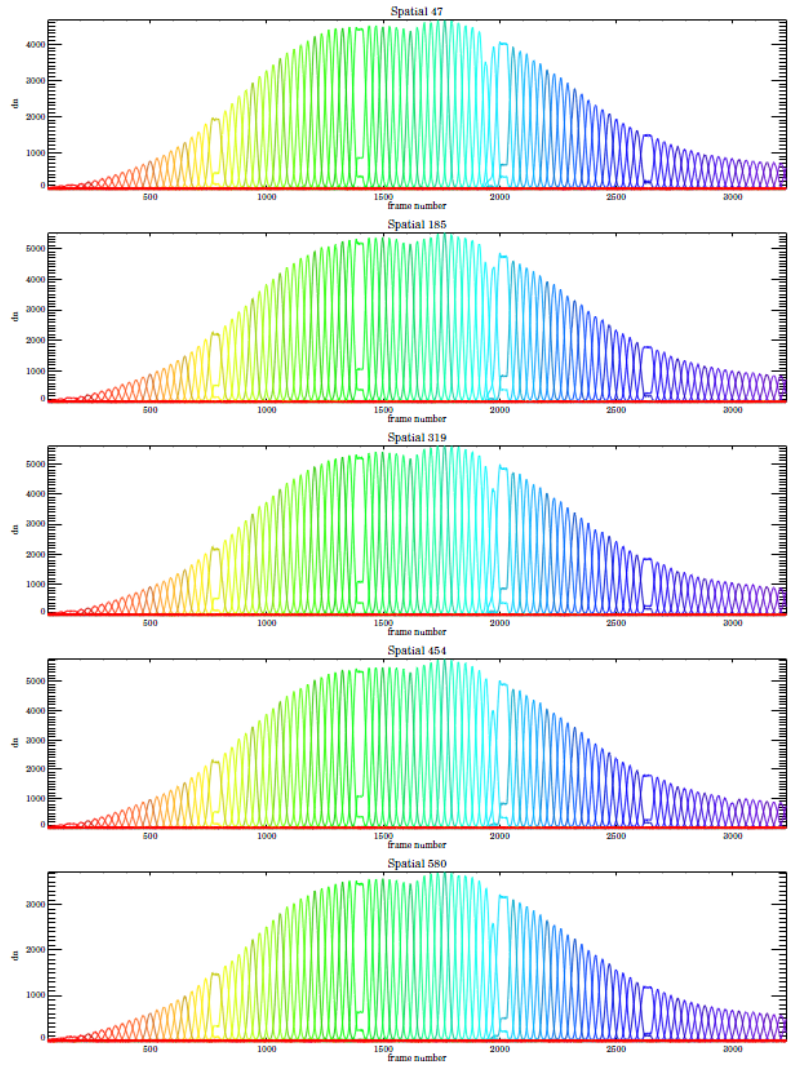
AVIRIS-NG 380 to 2510 nm

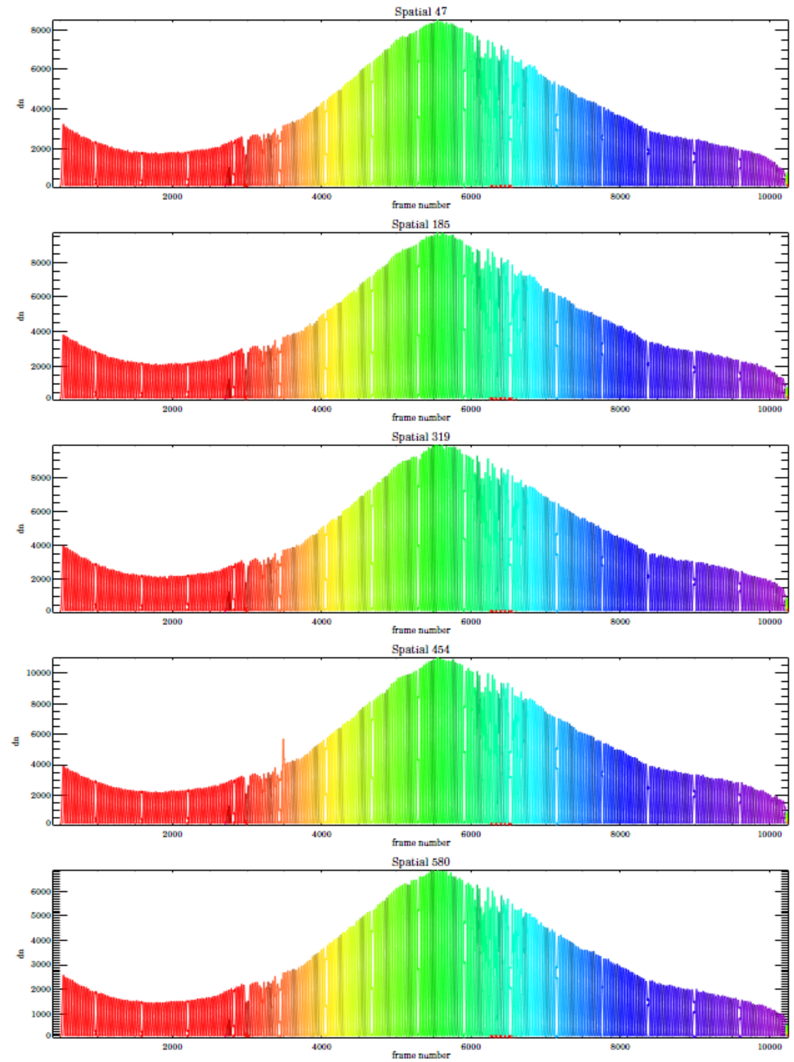


Example NGIS Spectral Response Functions

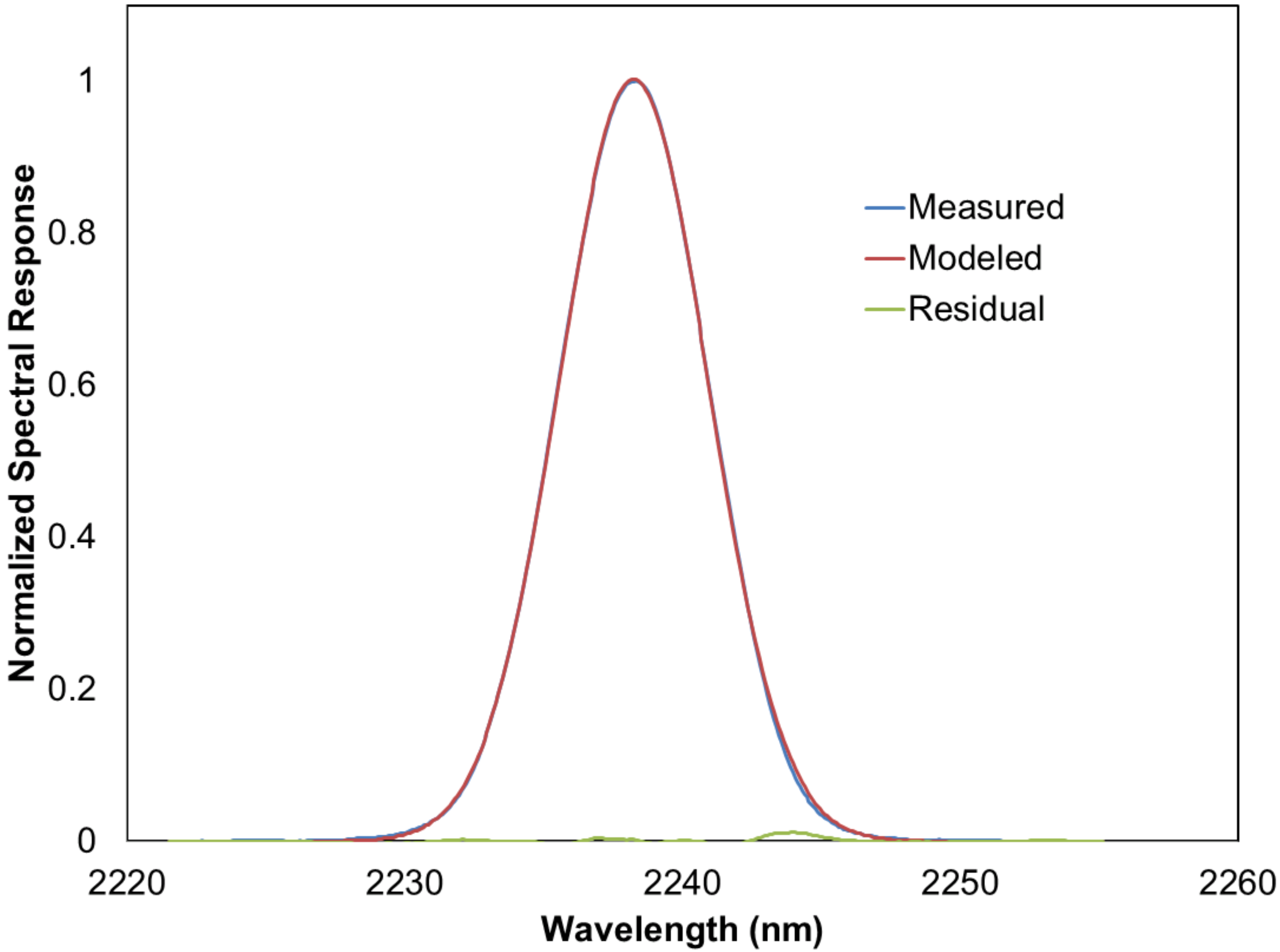
VNIR

SWIR

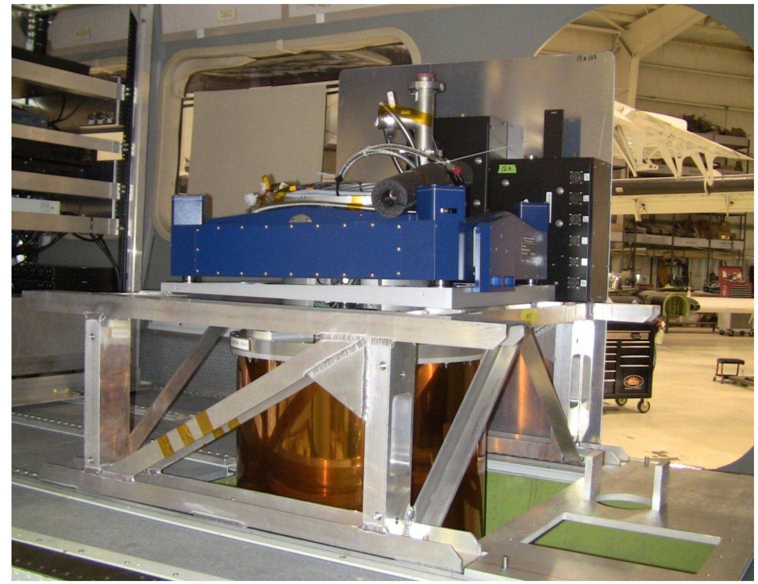


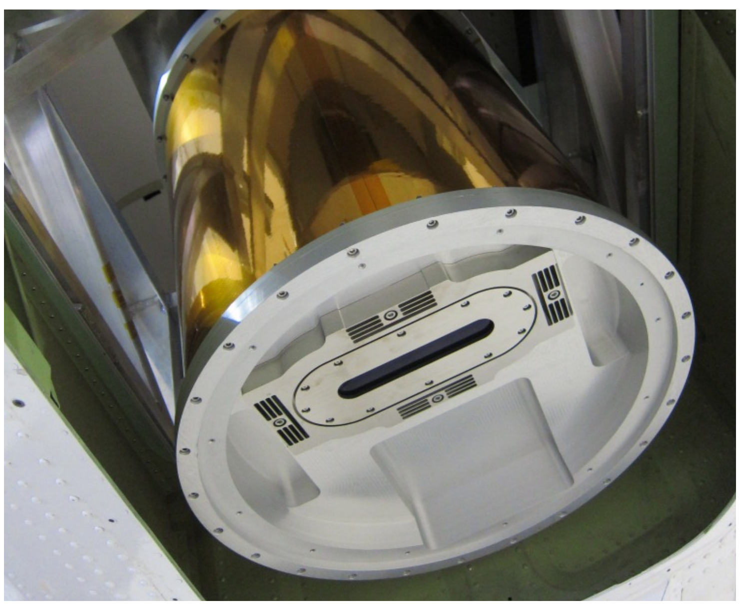


Example Spectral Response Function

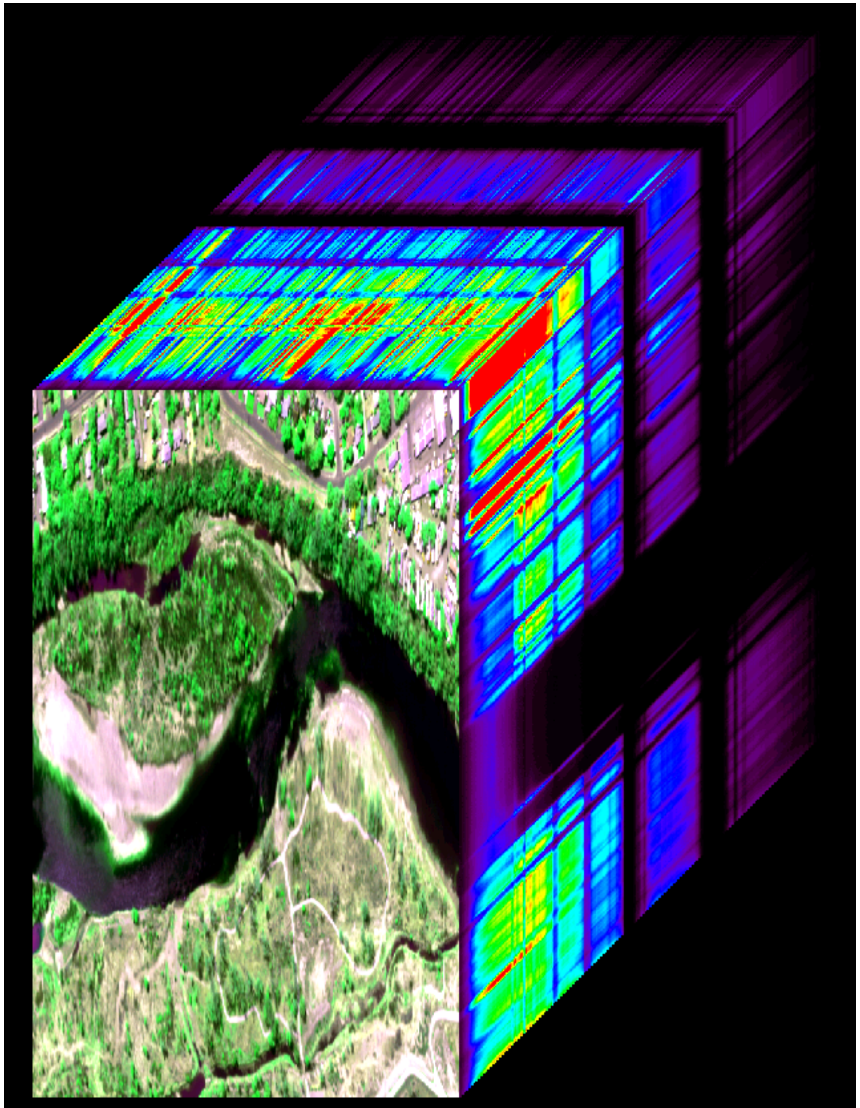


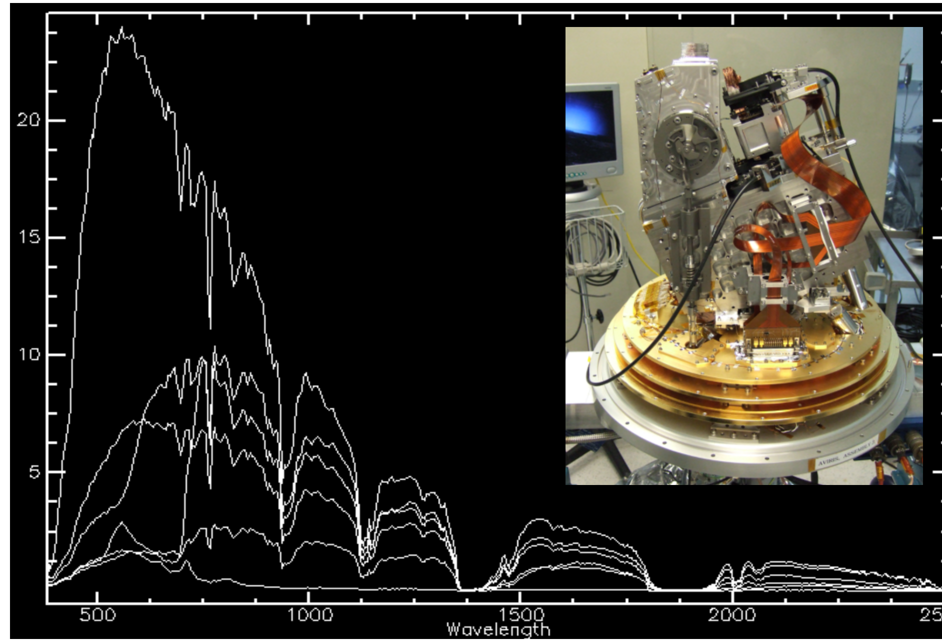
AVIRIS-Next Generation Installation
17 April 2012





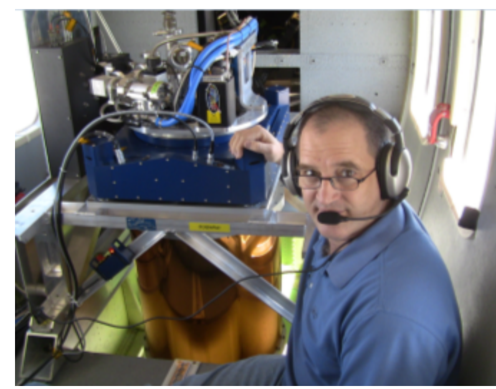
AVIRIS Next Generation First Spectra 120422



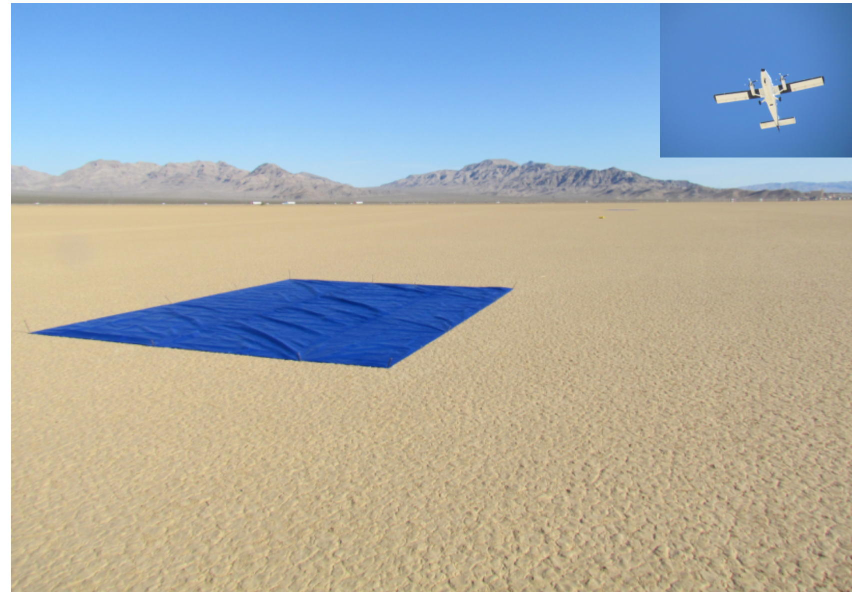


Scrolling Display

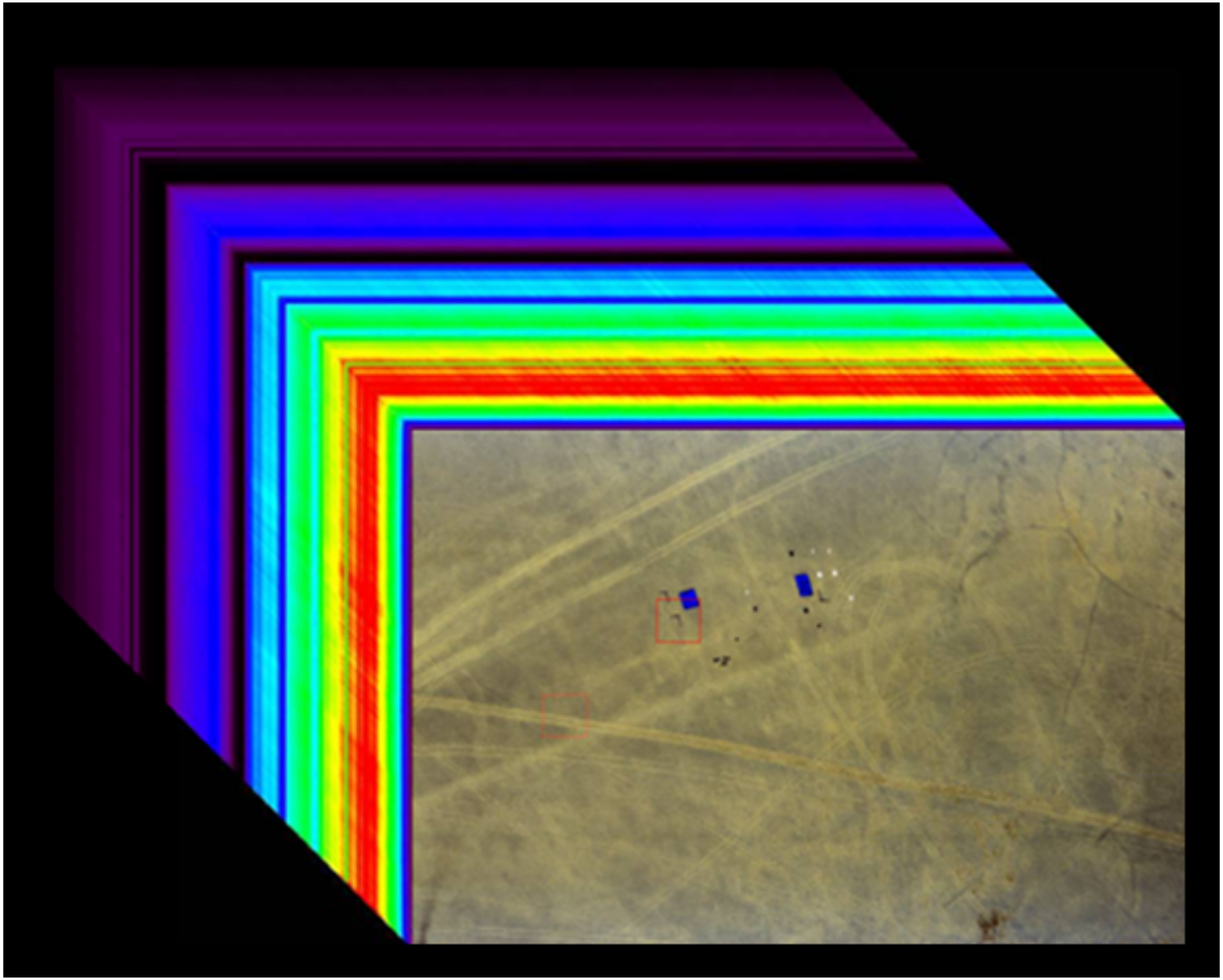
Michael Eastwood



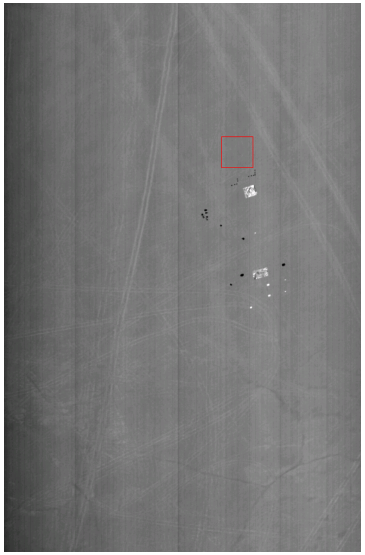
AVIRIS-NG Calibration Validation
Ivanpah Playa Calibration Site 2012

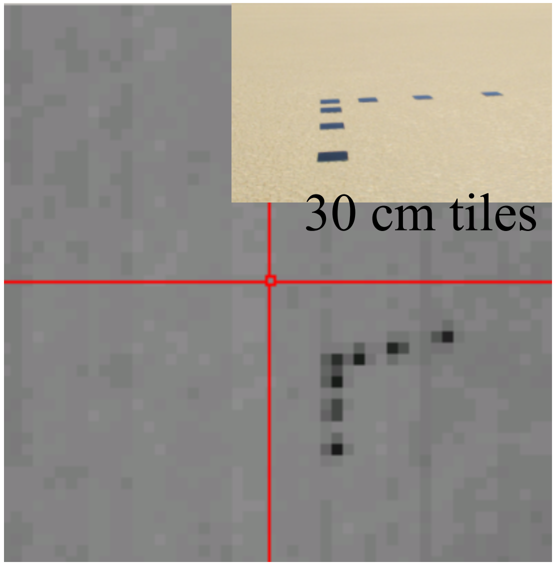


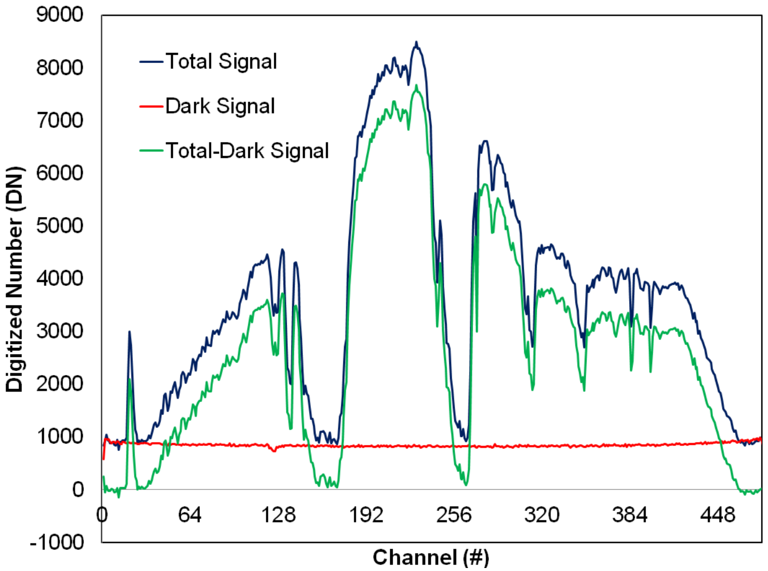
AVIRIS-NG Cube 427 Spectral Channels

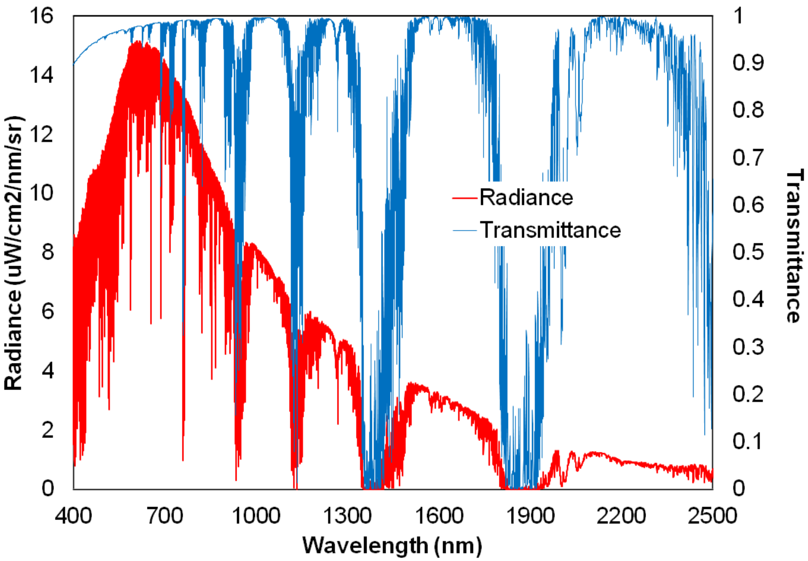


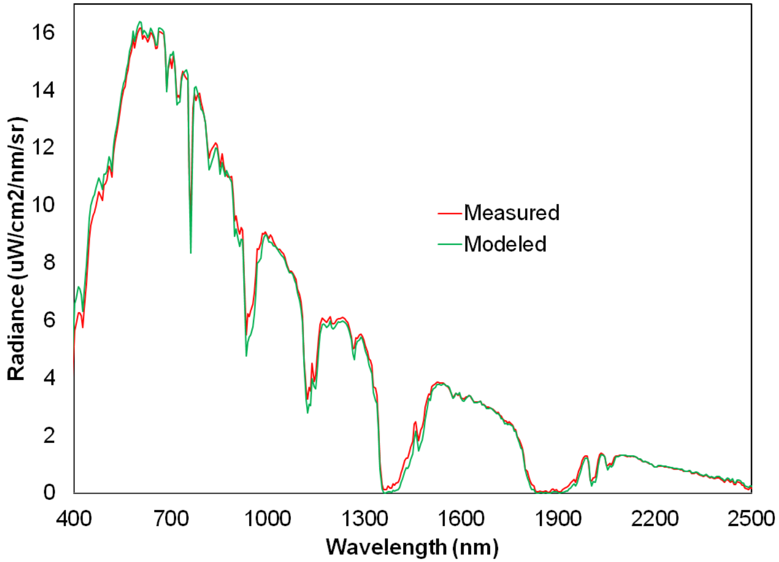
AVIRIS-NG Calibration Validation Experiment Results



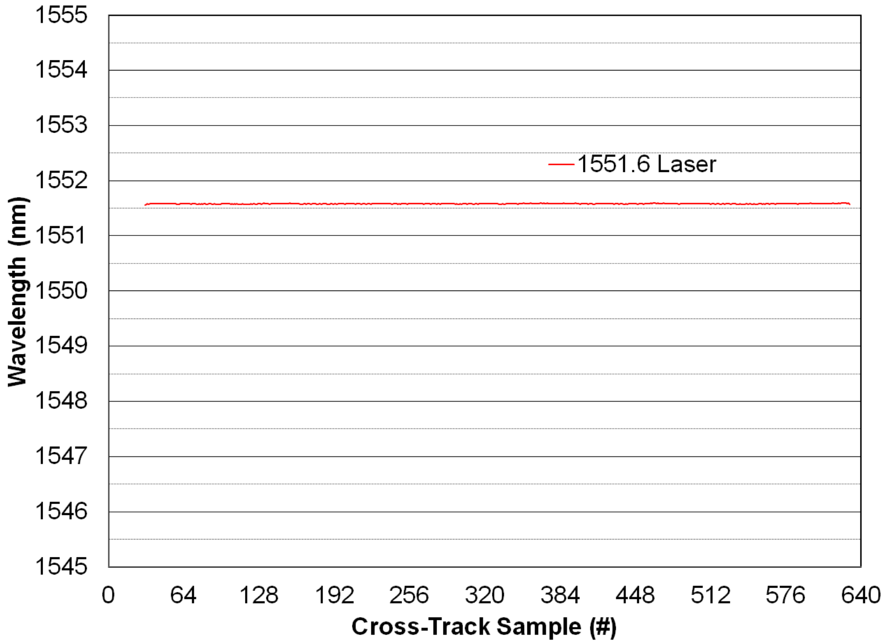




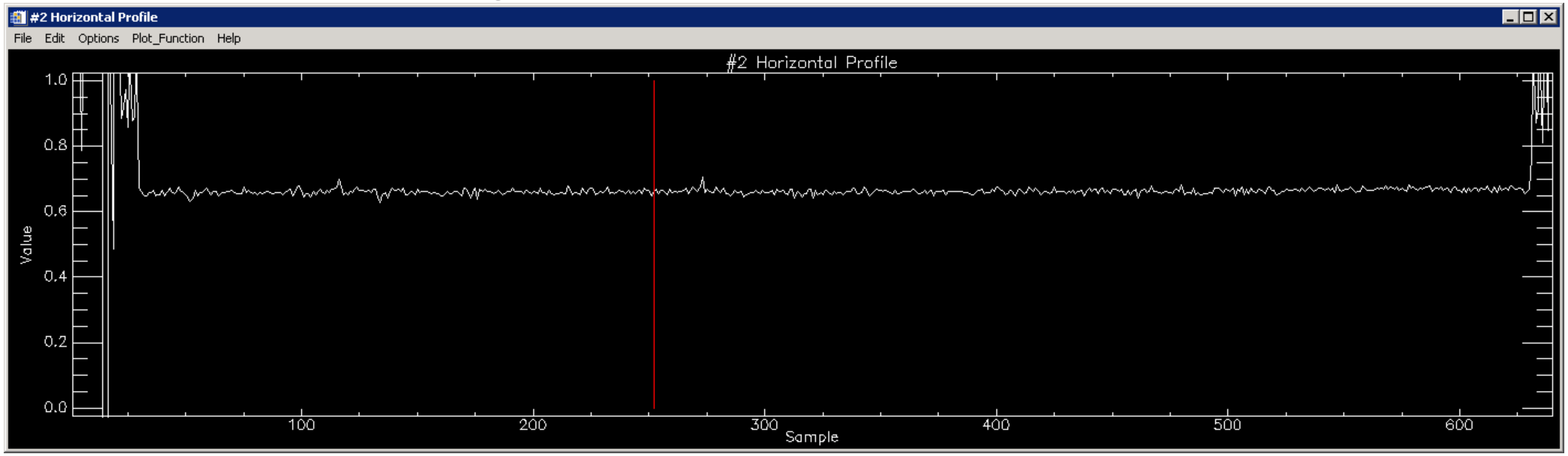




Cross-Track Spectral Uniformity

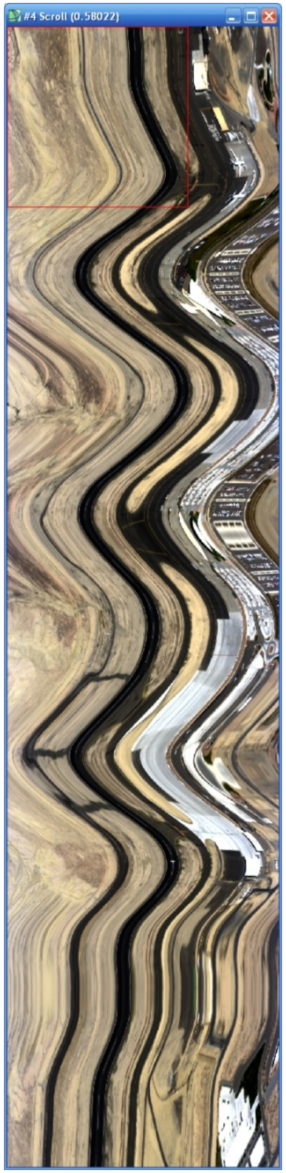


>95% uniform in the flight environment



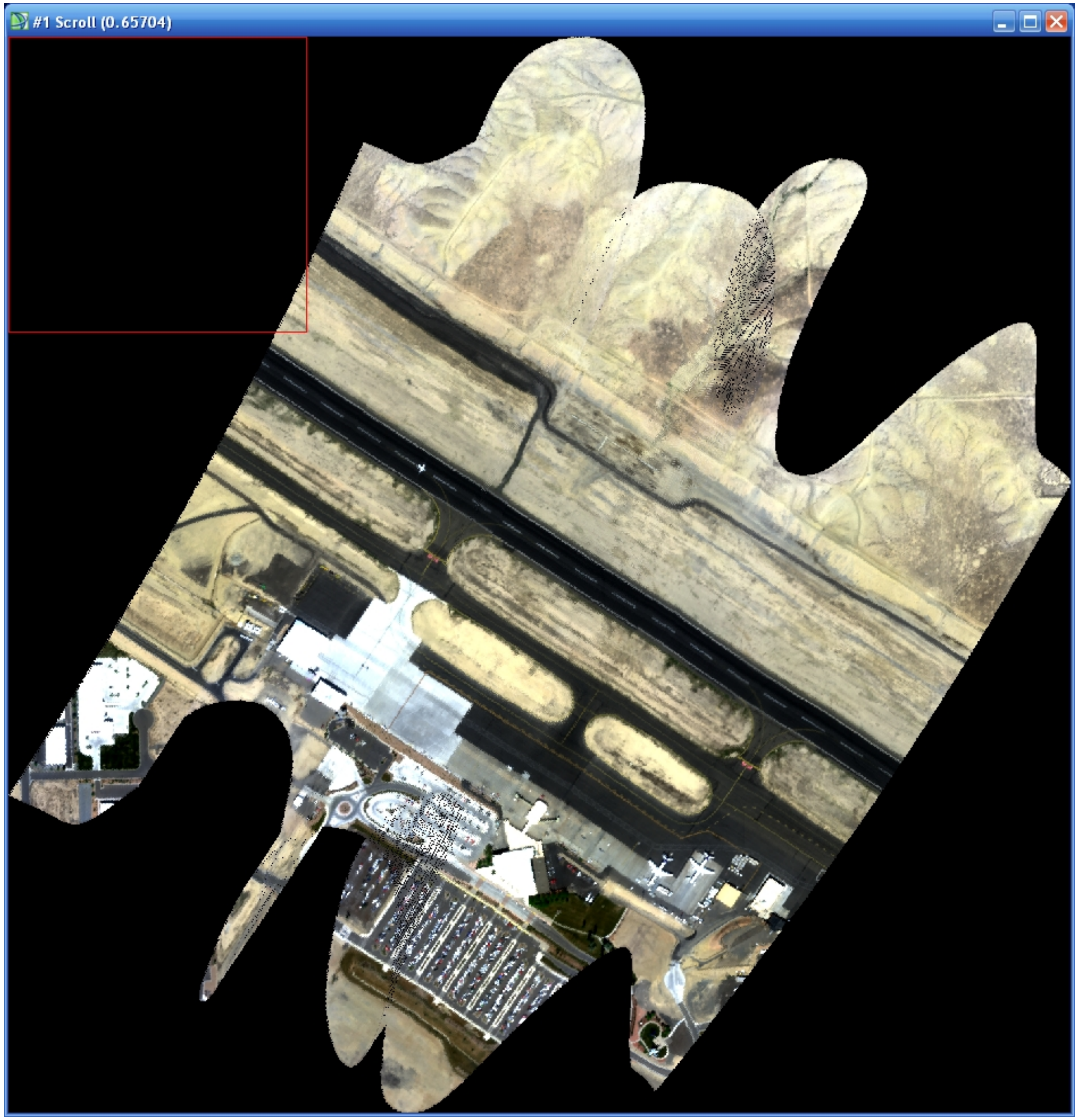
AVIRIS-NG Orthorectification Test

Raw Data



AVIRIS-NG Orthorectified

Successful Orthorectification

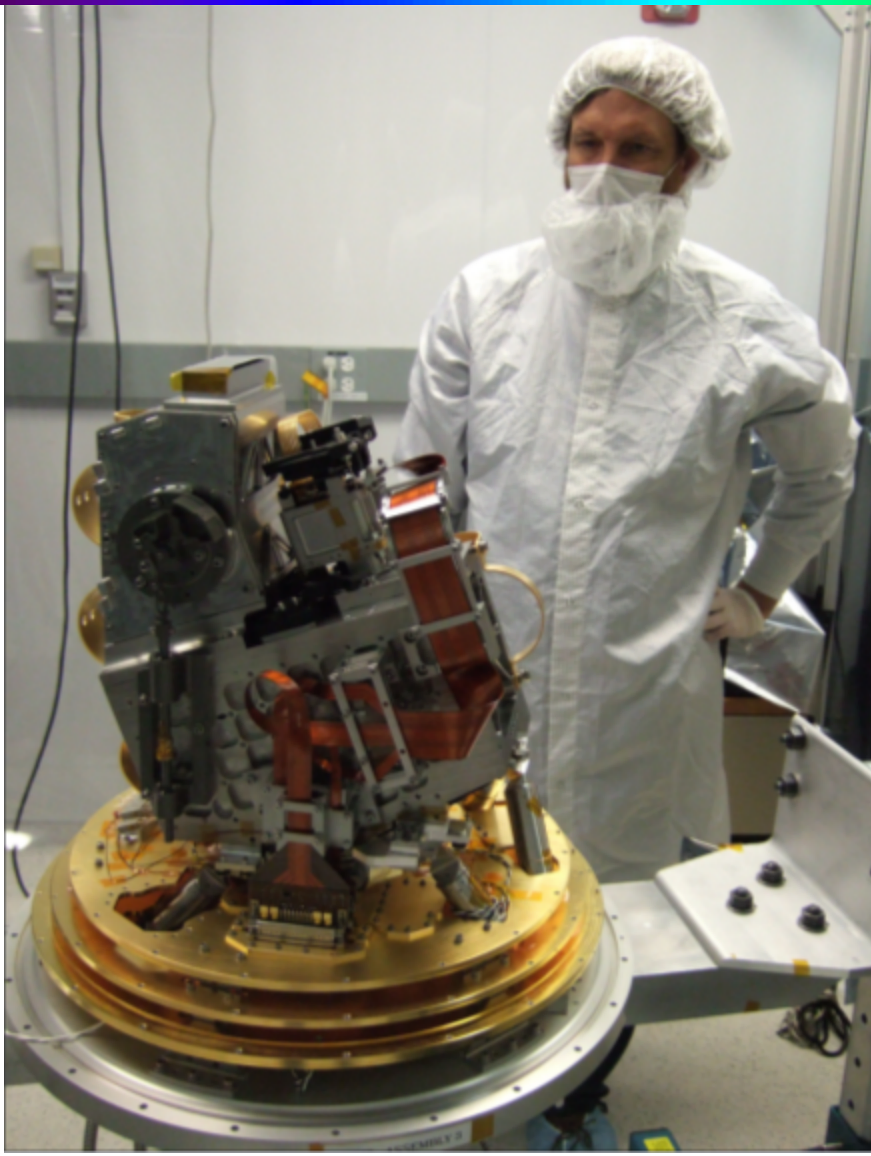


AVIRIS Next Generation Flown with LIDAR
31 July 2012

AVIRIS Next Generation Data Subsystem

- AVIRIS Next Generation computer in place
- ANG calibration modules testing
  - Spectral radiometric
  - Orthorectification
- ANG flight lines in AVIRIS website
- Plans for automated distribution of ANG data from website

AVIRIS-NG and HyspIRI VSWIR Concept



- Two mirror telescope
- Offner spectrometer
- Uniform SiN slit (eBL)
- Convex grating (eBL)
- Alignment mounts
- Alignment process
- All aluminum telescope
- Full range detector
- Order sorting filter
- Uniformity requirements
- Vacuum operation
- 140 K operation

Summary and Conclusion

- The science enabled by a high uniformity and high signal-to-noise ratio imaging spectrometer is well established
  - AVIRIS referred to in > 700 journal articles in the refereed literature

- A set of instruments requirements flowing from the science objectives and experience with AVIRIS-Classic were established

- ARRA funding became available 2009 AVIRIS-NG. The first spectra were acquired with 14 Months of funding start.

- The first flight was on the 22nd of April 2012

- AVIRIS-NG validates a wide range of technology and implementation elements of the HyspIRI VSWIR concept

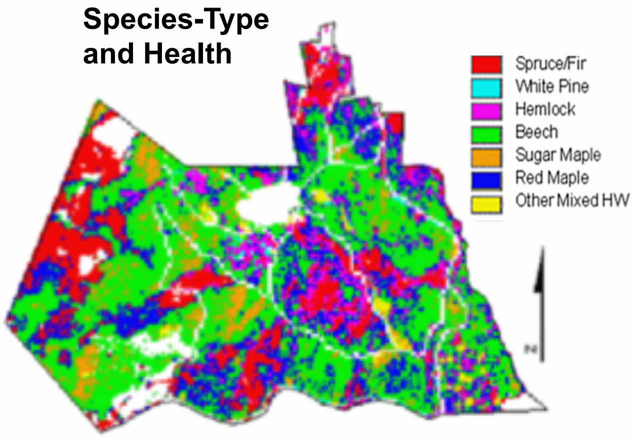
- AVIRIS-NG is expected to be available for science validation, research and application data acquisition in 2013

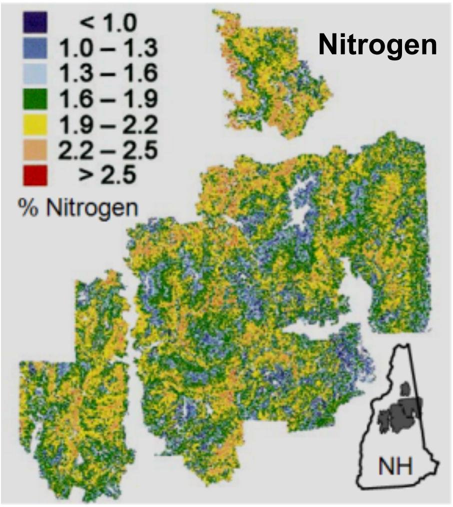
Earth Imaging Spectroscopy

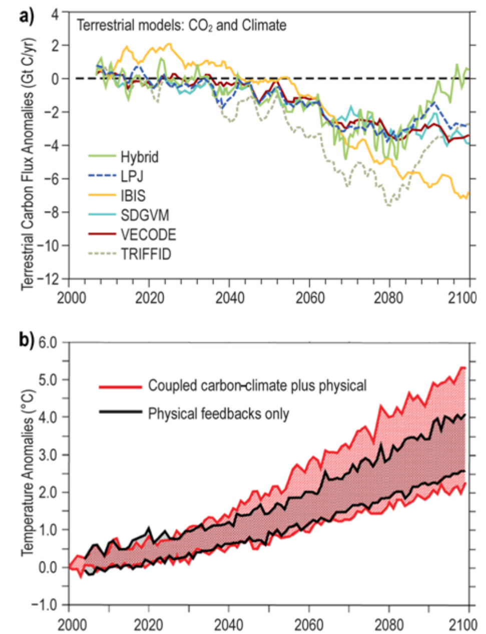
Global Science

Ecosystems: Global climate feedback, biochemistry, plant functional-type, and physiological condition, including agricultural lands.

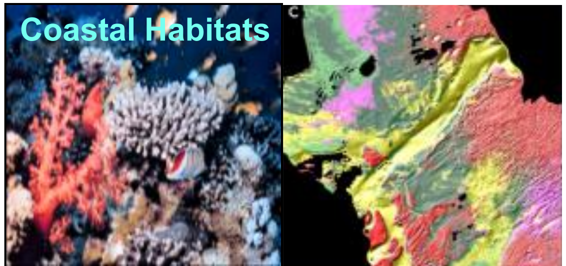
Ecosystems

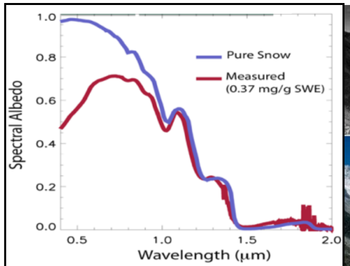






Fires: Fuel status, burn severity, and patterns of recovery globally.
Coral reef and coastal habitats: Global composition and status.
Snow and Ice: Spectral albedo; black carbon/dust on snow/Ice including arctic.





Backup