# The Goddard Laser for Absolute Measurement of Radiance (GLAMR) Facility

Joel McCorkel[1], Brendan McAndrew[2], Julia Barsi[1,3]

[1]NASA's Goddard Space Flight Center, Biospheric Sciences Laboratory (618), USA
[2]NASA's Goddard Space Flight Center, Instrument Systems and Technology (550), USA
[3]SSAI, Inc., USA

# GLAMR Facility

- The Goddard Laser for Absolute Measurement of Radiance (GLAMR) is a travel-capable facility for spectral-radiometric characterization.
- Laser-based, tunable, and narrow linewidth sources provide higher signal and dynamic range, improved wavelength and radiance accuracy over traditional broadband (white light) lamp-based techniques
- More straightforward measurement and data interpretation –
  - flat field,
  - full signal level,
  - unpolarized
- Enables increased understanding of the instrument to enable new and better science.

*GLAMR deployed for JPSS VIIRS characterization*

# Instruments are getting better; science can advance with improved instrument characterization

Higher SNR →

- better spectroscopy, more dynamic range, etc.

Higher spatial resolution →

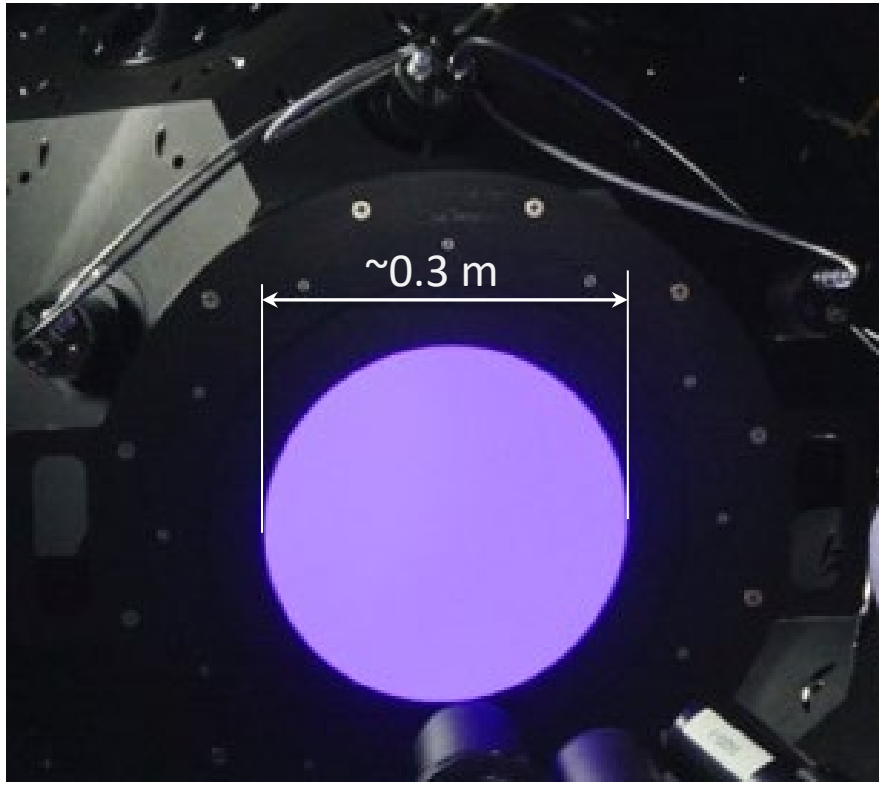
- more spectrally pure samples

Increasing number of instruments →

- more temporal sampling and more stringent interoperability requirements

More advanced, physically-based, algorithms and retrievals →

- Increased dependance on knowledge of what the sensor is actually measuring, i.e. spectral sensitivity



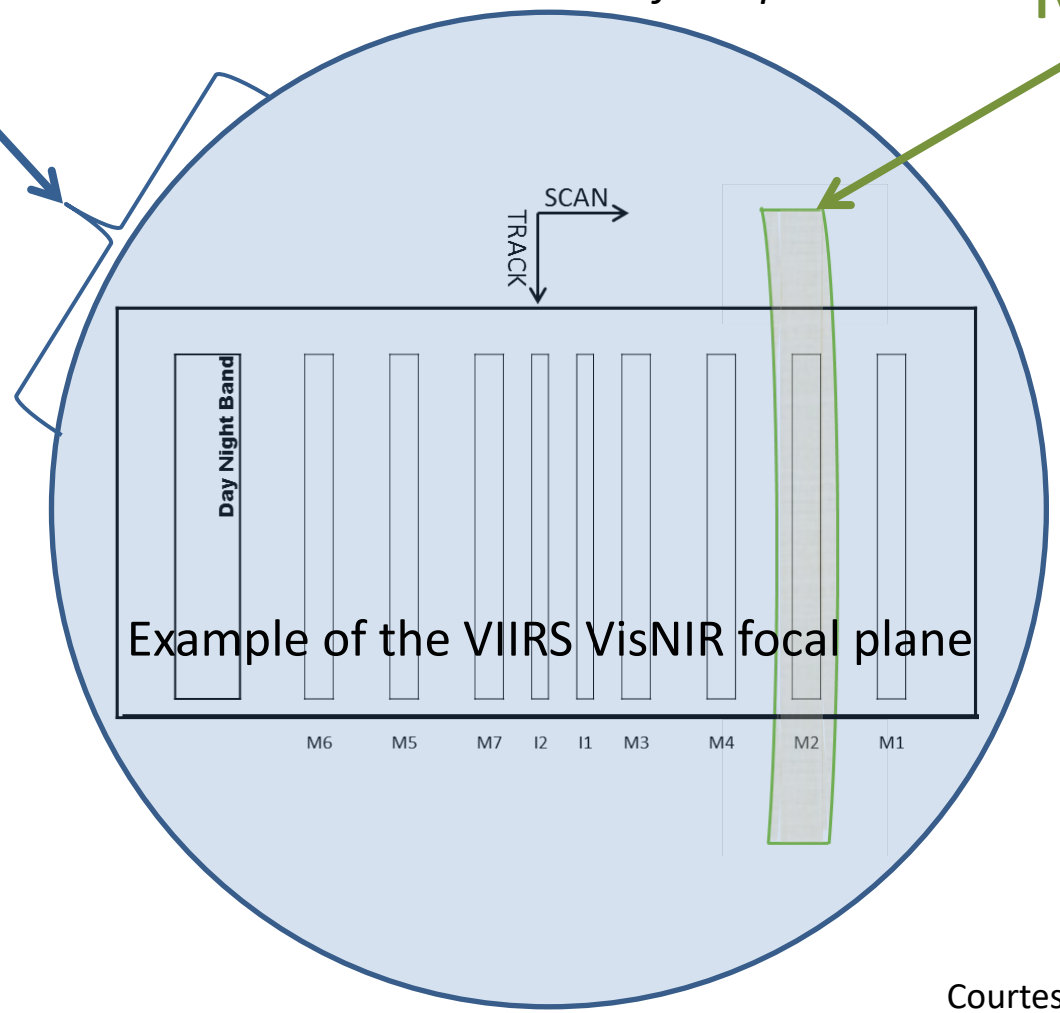

*Example output of GLAMR (410 nm)*

# GLAMR vs. Traditional characterization techniques

## GLAMR light

- √ Flood illumination (overfilled focal plane)
- √ Unpolarized
- √ Spectrally flat/uniform
- √ <10% source non-uniformity along-track
- √ Realtime source monitoring
- 4 to 5 decades of response (refl solar)
- "Picket-fence" spectral sampling
- √ Nominal spectral interval 0.1–1 nm

*Source illumination at focal plane*

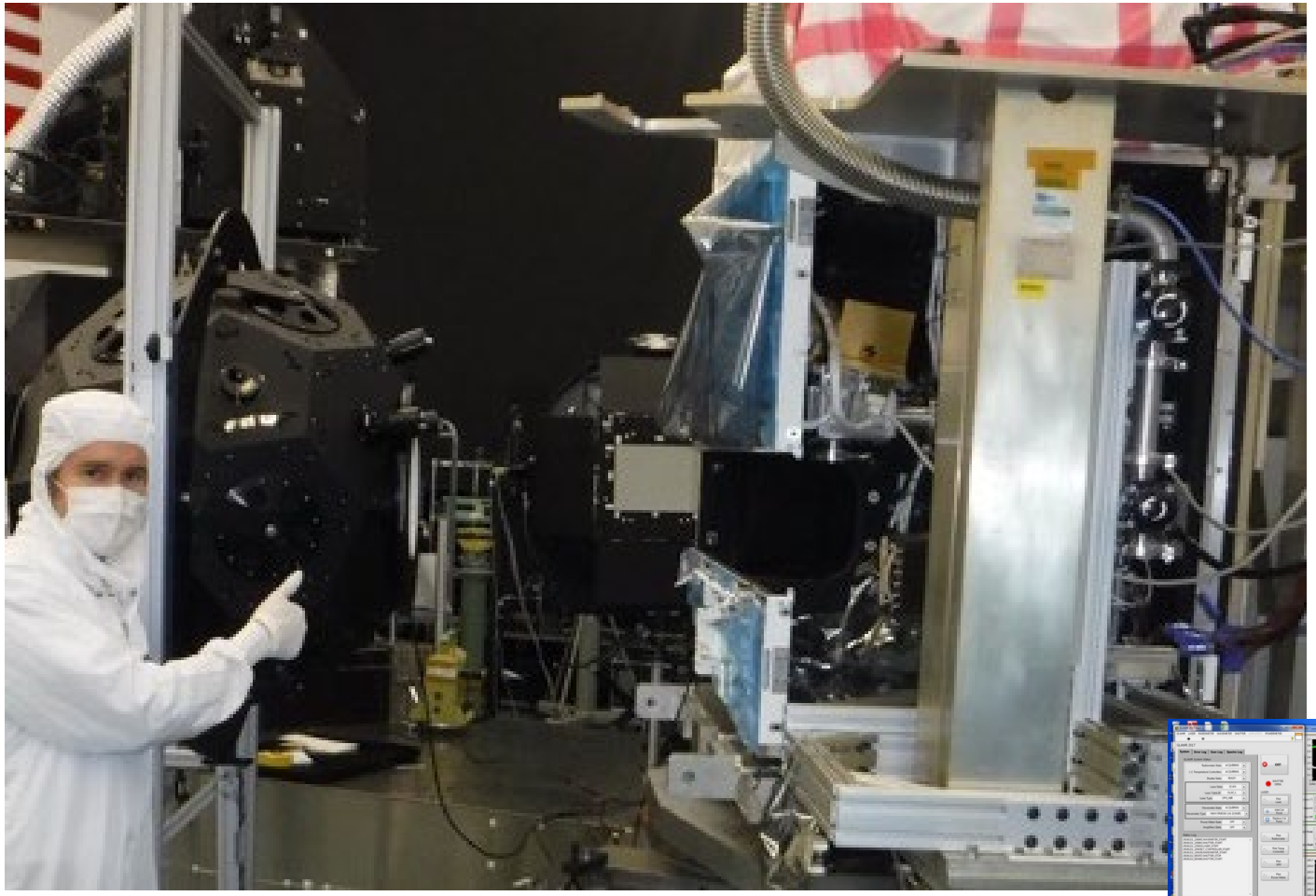


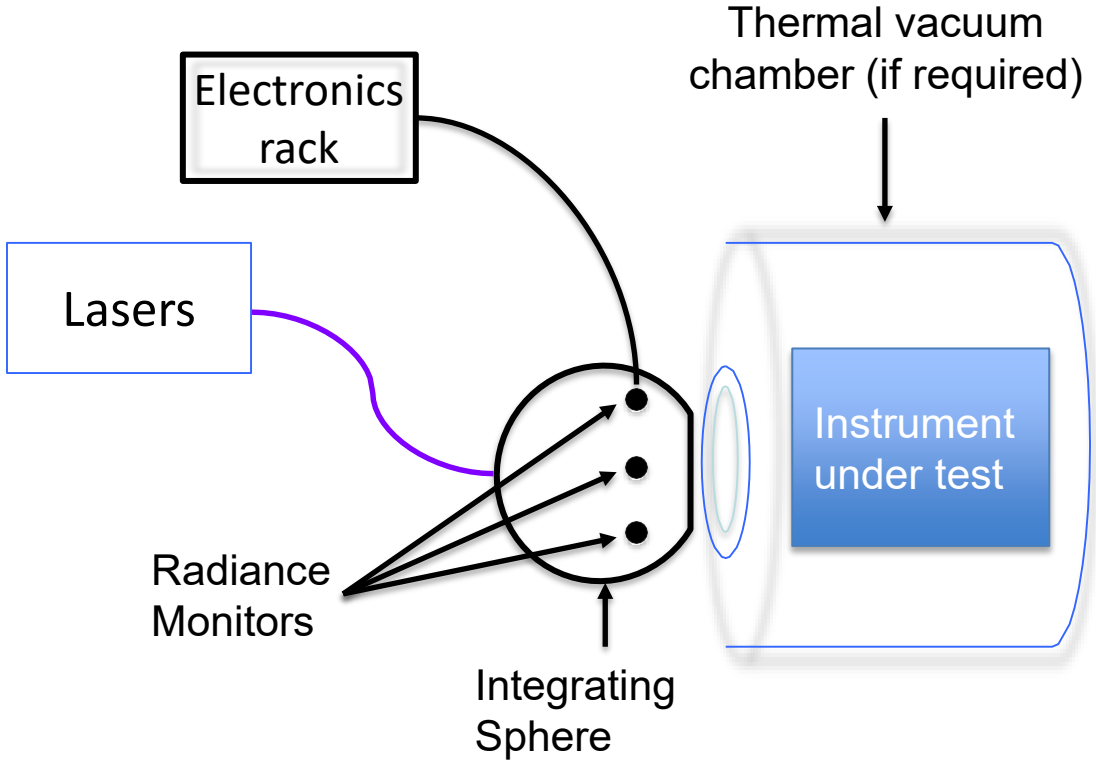

## Monochromator light (traditional method)

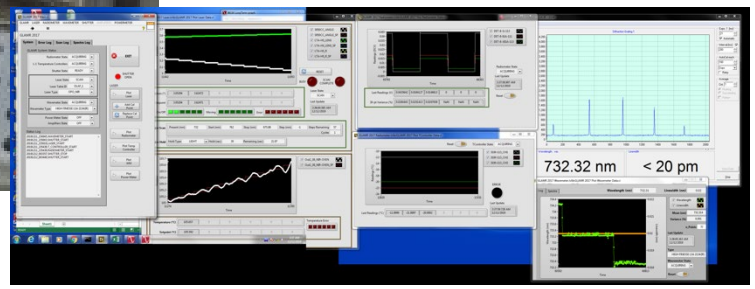
- Slit illumination (underfilled focal plane)
- Polarized
- Spectral smile
- >30% source non-uniformity along-track
- Offline source monitoring
- √ 5 to 6 decades of response (refl solar)
- √ Contiguous spectral sampling
- Nominal spectral interval ~1 nm

Courtesy of Chris Moeller / University of Wisconsin CIMSS

# Experimental set up



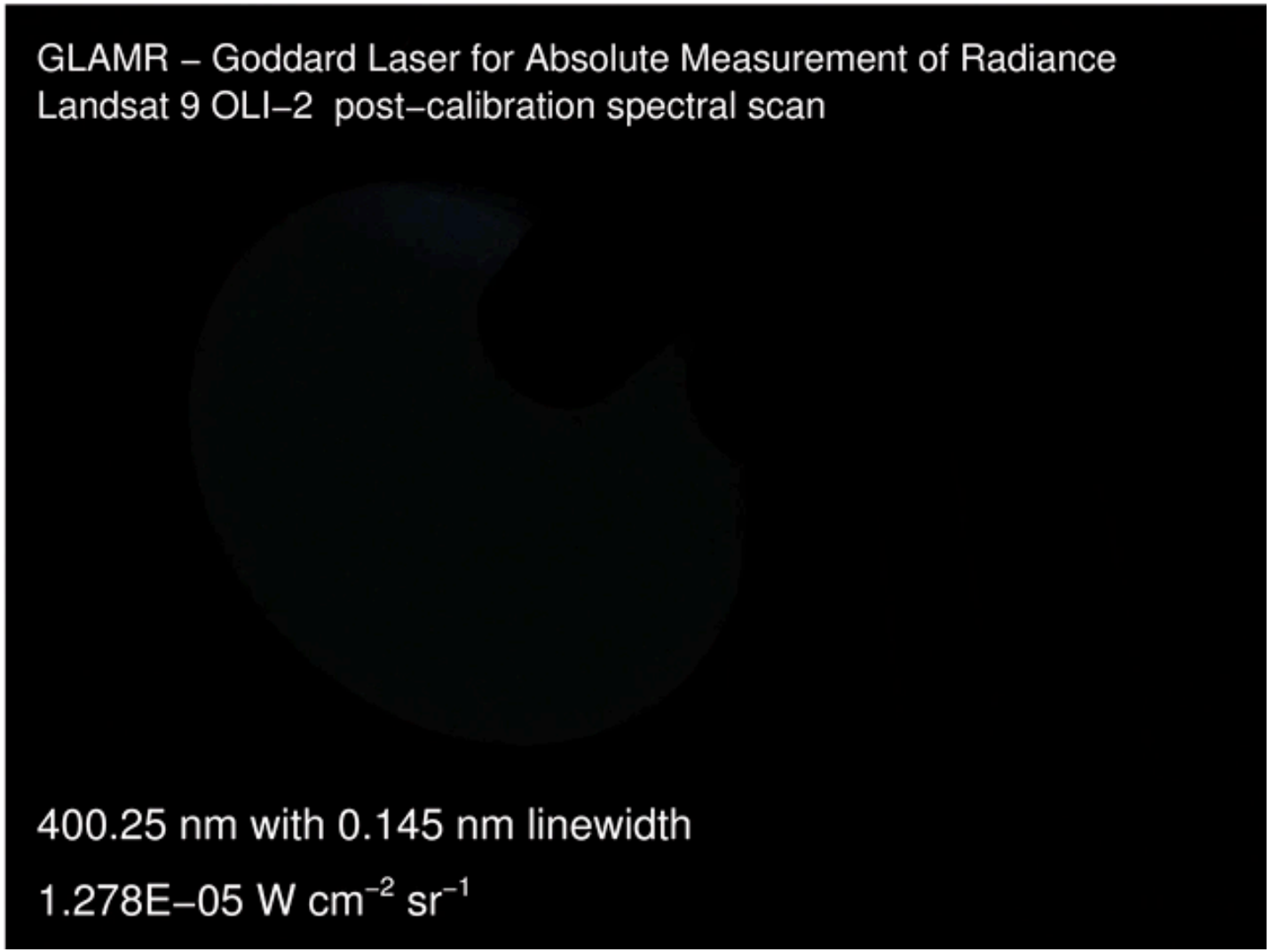


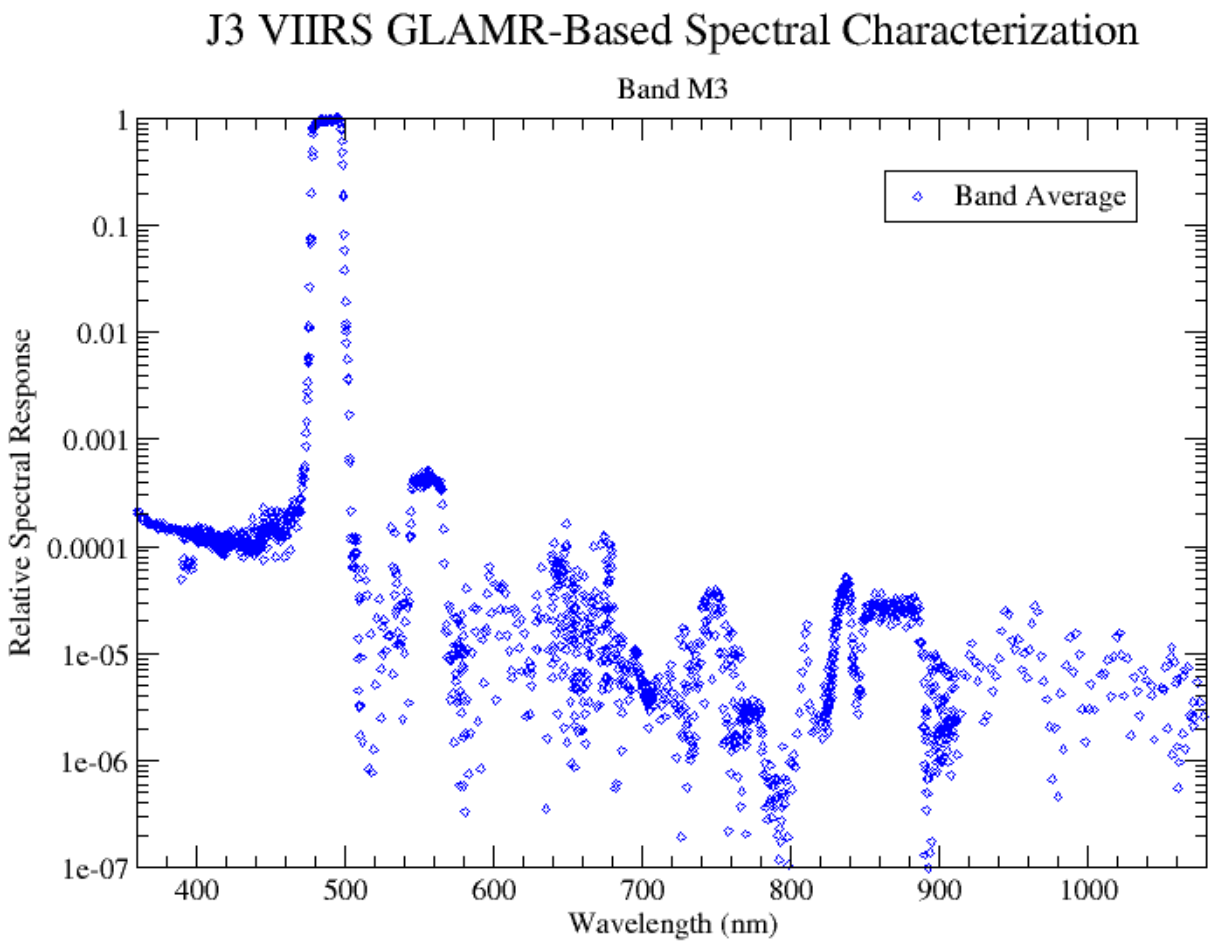

Extensive software backend for laser control, data acquisition, and instrument interface

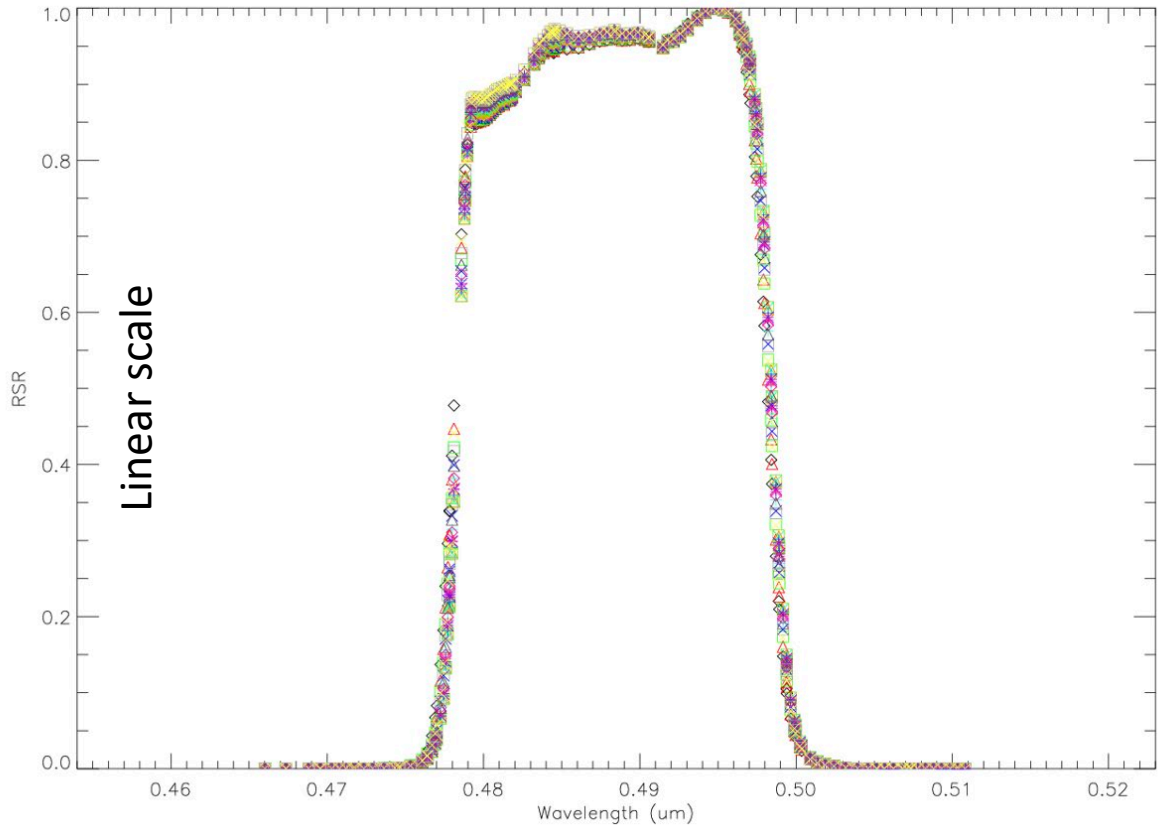
# GLAMR spectral scan example

GLAMR sphere in front of Ball TVAC chamber



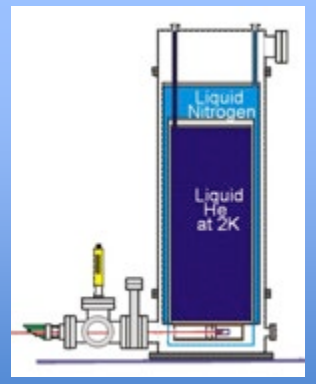
# Spectral response product



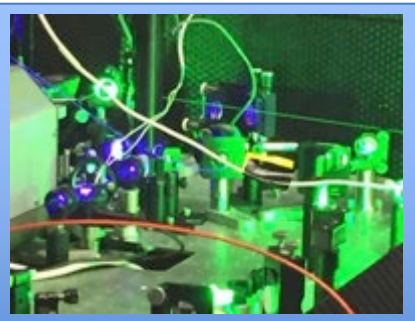



# Traceability Path and Improvement

## NIST Facility




POWR
Primary Optical Watt Radiometer

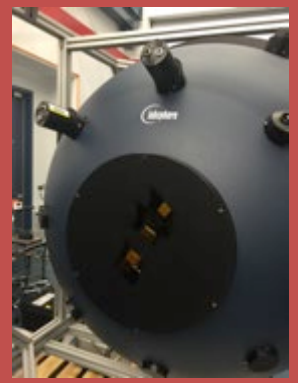


Stabilized laser source is used to transfer radiometric scale from POWR to portable transfer radiometer via another standard radiometer

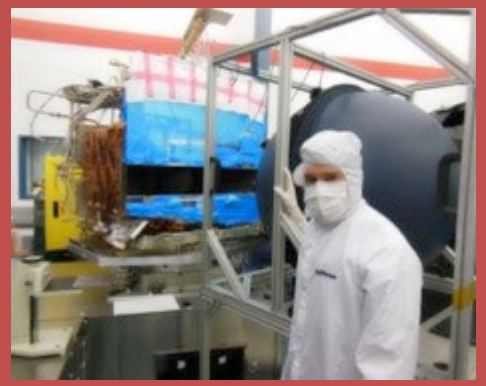
LTD-11 #107 transfer radiometer

## Sensor facility

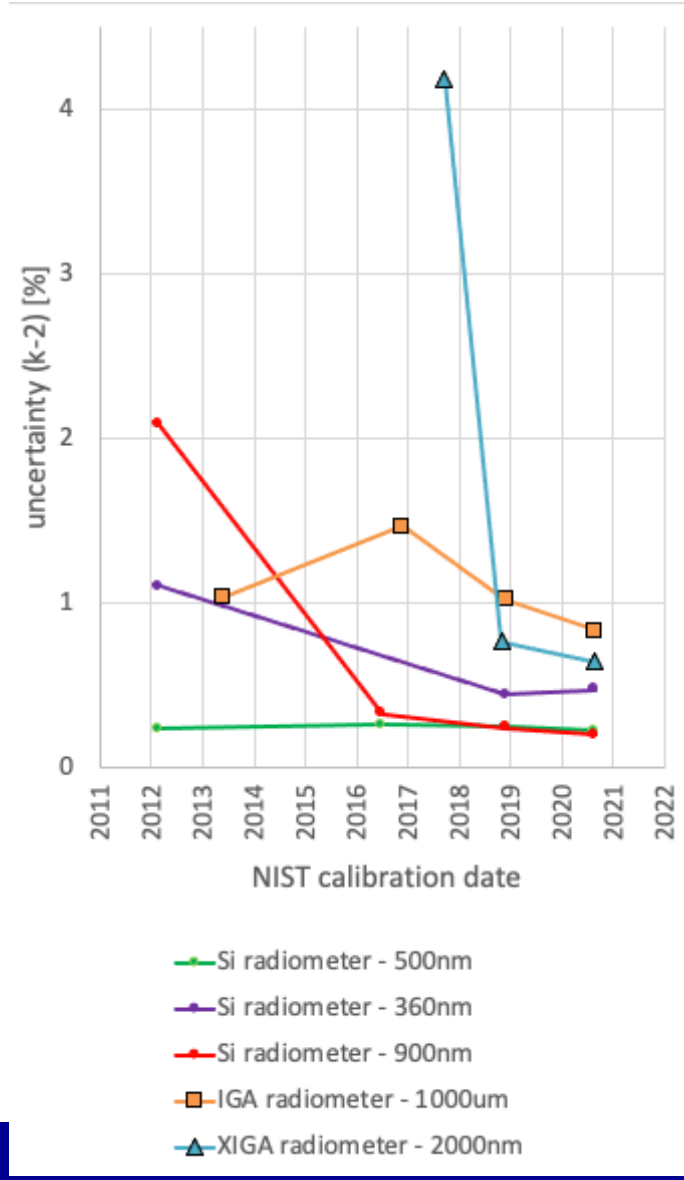
LTD-11 #107 transfer radiometer



Sphere Monitor

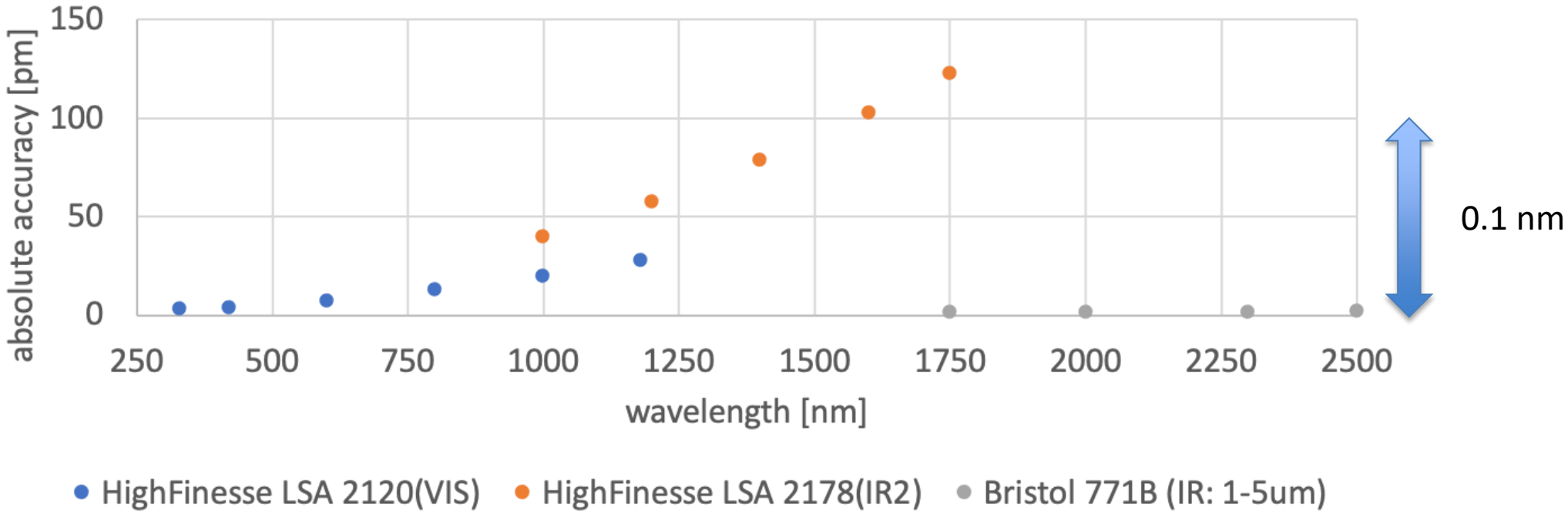


Satellite/airborne sensor



# Wavelength Uncertainty

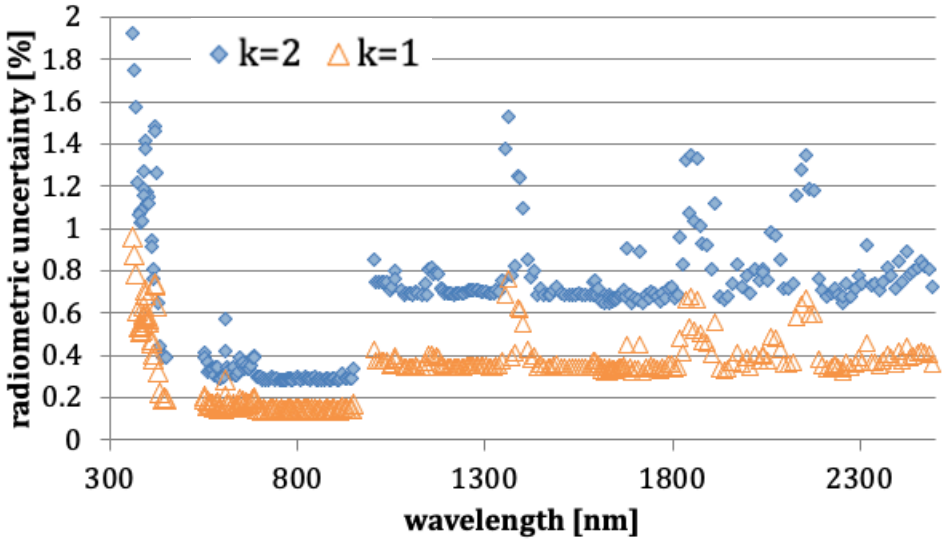
- Wavelength is continuously measured throughout tests at 5-10 Hz
- Wavelength accuracy depends on spectral region and device used for measurement
- Devices include wavemeters and Laser Spectrum Analyzers



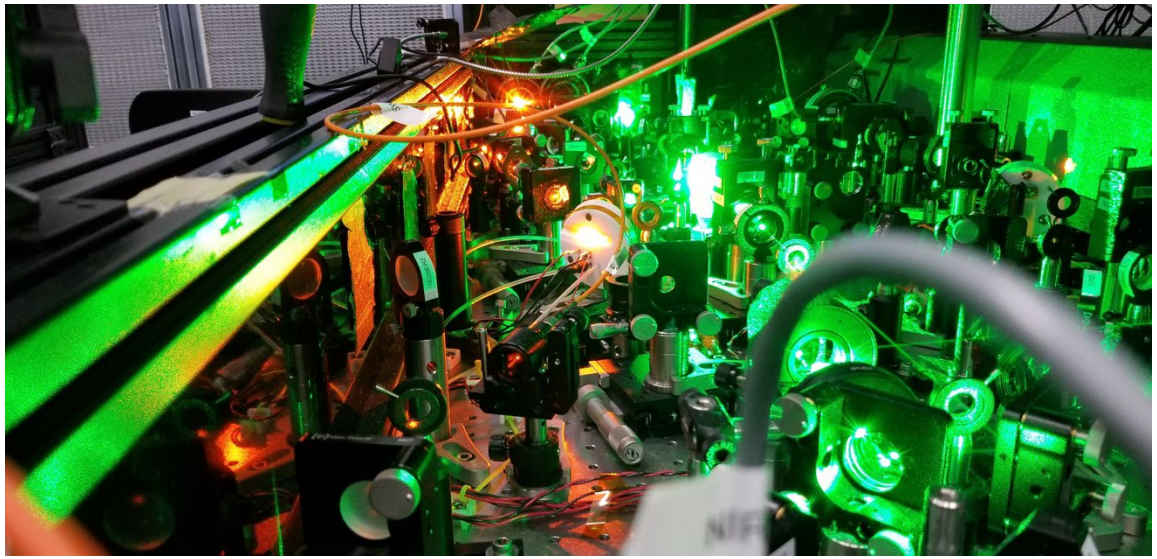
# GLAMR Error Budget

**GLAMR Absolute Radiometric Output Accuracy (0.29% k=2)** *for 860 nm*

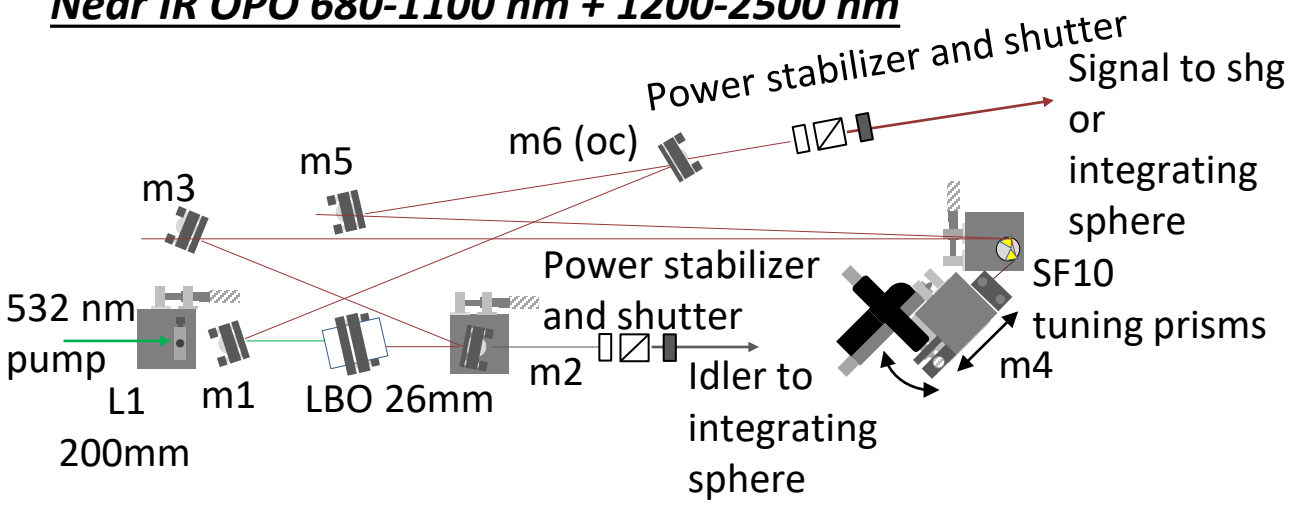
| Transfer radiometer traceability (0.20% k=2) | Sphere calibration repeatability (0.01% k=2) | Sphere calibration reproducibility (0.17% k=2) | Sphere uniformity (0.2% k=2) | Measurement noise (0.02% k=2) | Linearity (0.041% k=2) | Fluorescence (0.00% k=2) | Angular Variability (TBD) |
|---|---|---|---|---|---|---|---|
| Based on NIST-provided characterization of transfer radiometers (Aug 2021) | Two-sigma variability between three sphere calibrations performed on the GLAMR sphere. | Variability between sphere calibrations with the setup disturbed each time. | Sphere uniformity of the OCI 20" sphere. | Two-sigma variability of signal during a typical measurement. | Beam-conjoiner results for Transfer Radiometer delivered in Jan 2020.<br><br>*WIP: Transfer TR linearity to SM. Determine if we need separate uncertainties for $L_{low}$ and $L_{high}$.* | Fluorescence of sphere characterized Spring/summer 2021<br><br>*Fluorescence has no effect at 860nm* | Imagers and transfer radiometers measure the sphere normal to the exit port.<br><br>*Winter 2022* |



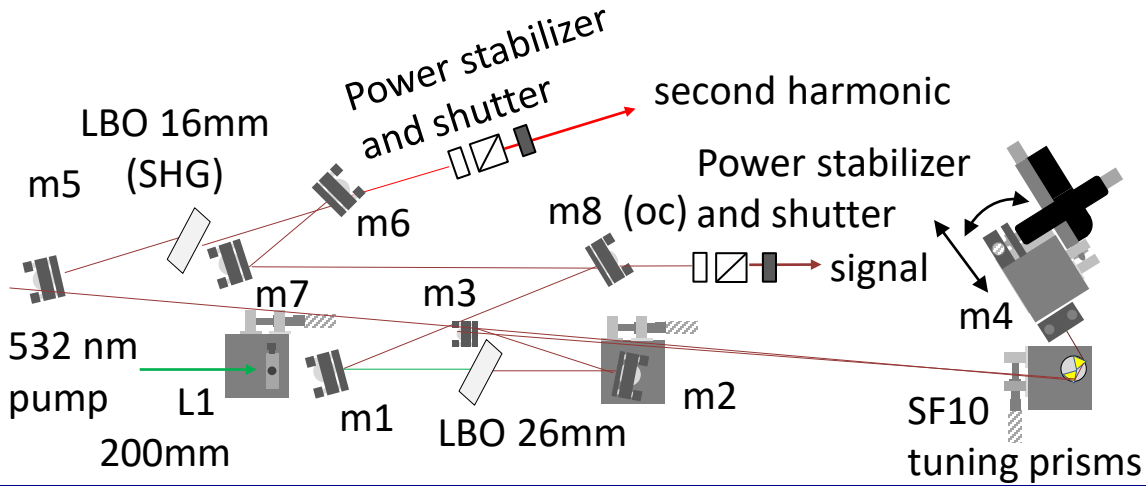
# Custom OPOs



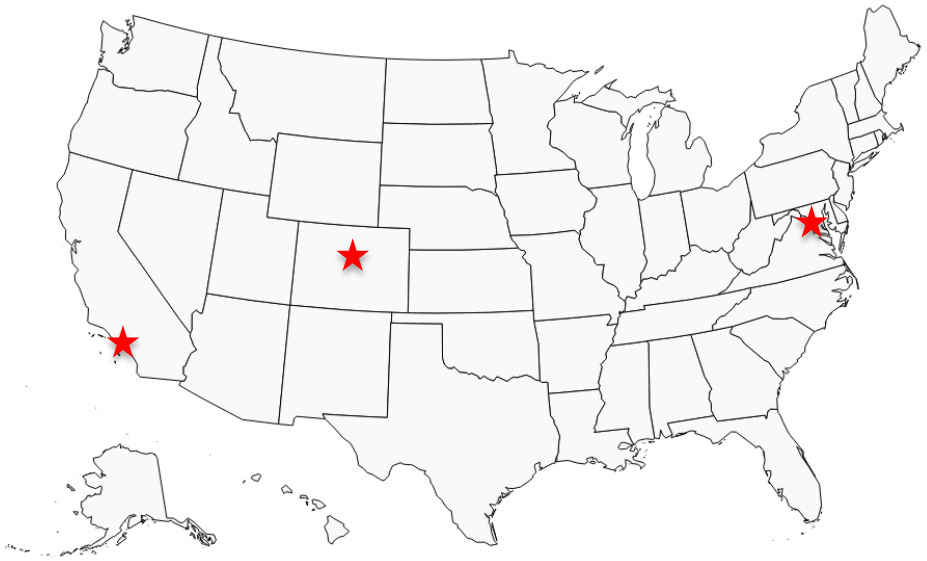
***Near IR OPO 680-1100 nm + 1200-2500 nm***

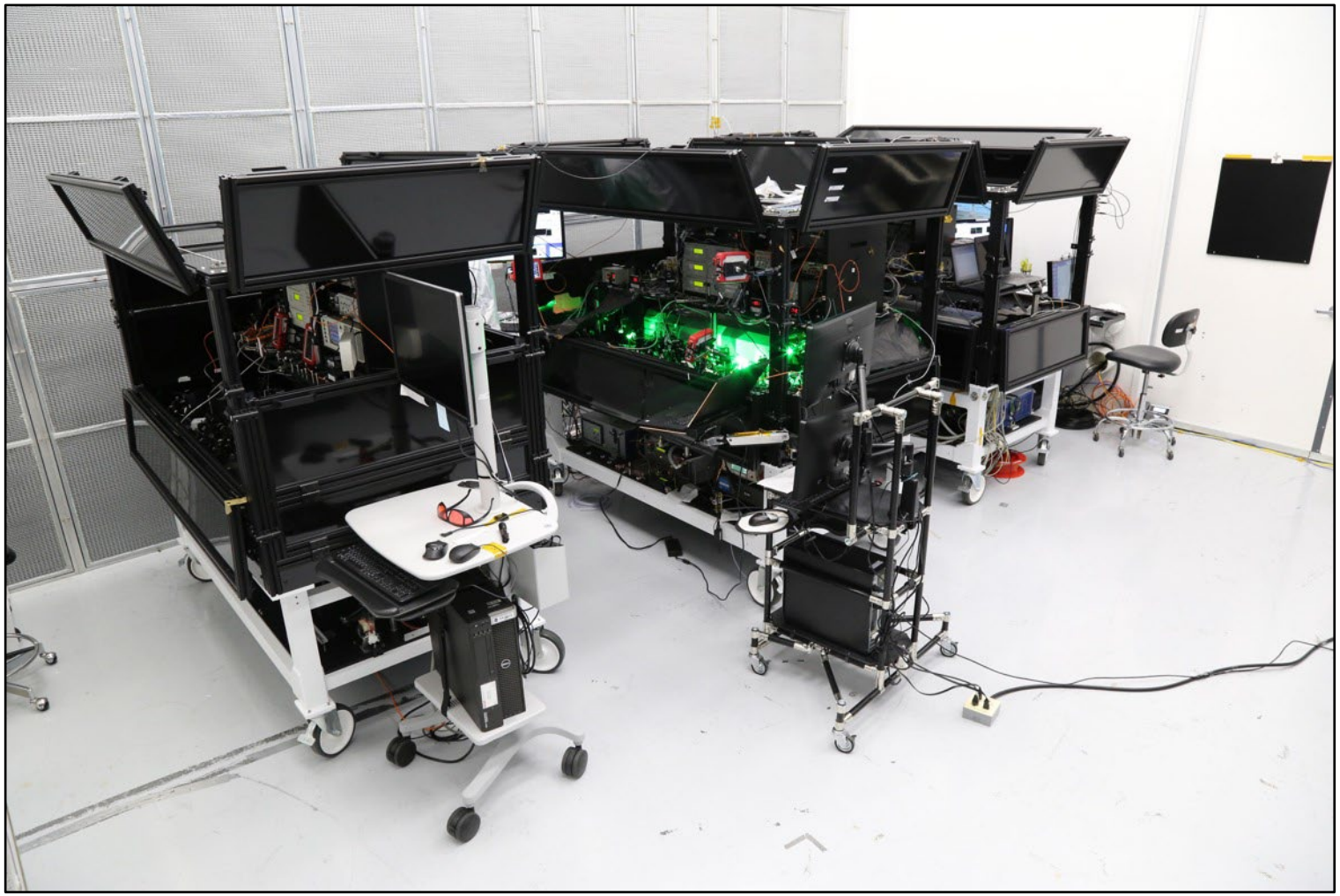



***Shortwave IR-OPO 1080-1400 nm + 540-700 nm***

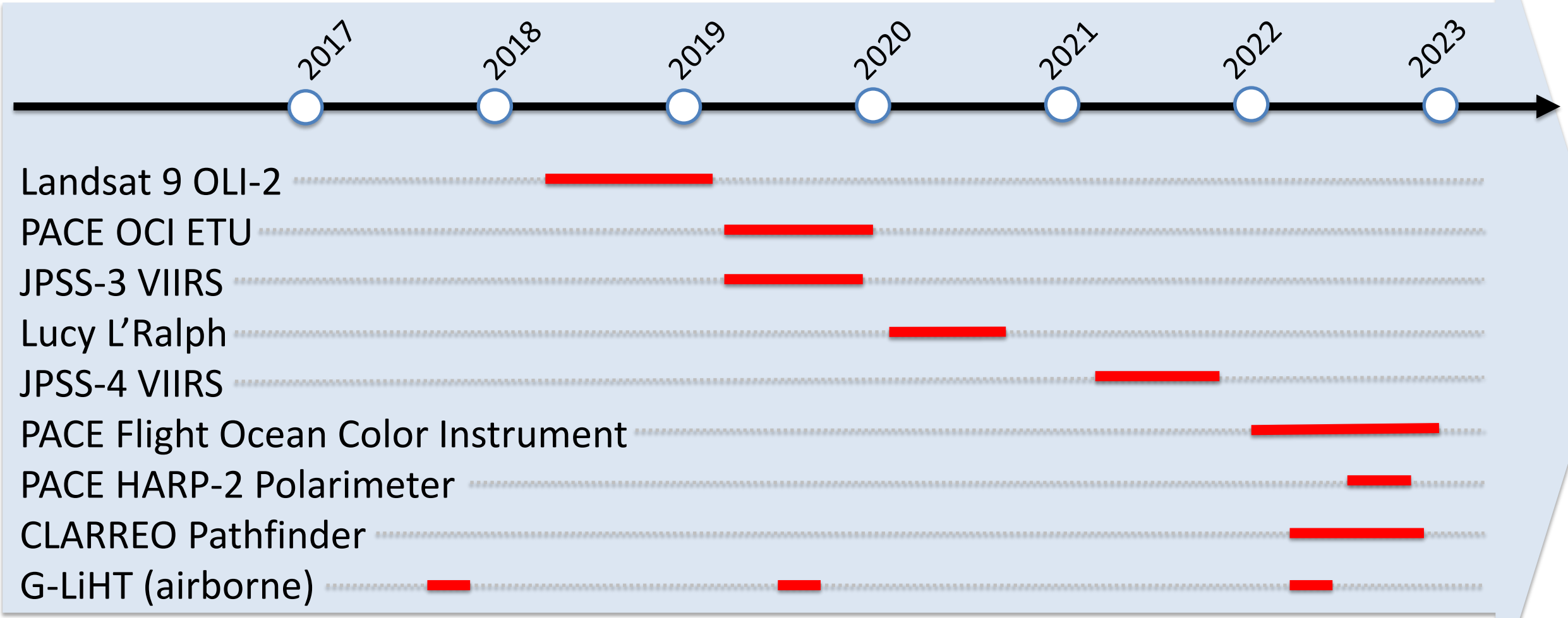


# Deployable to sensor vendor facilities





# Recent Partner Projects

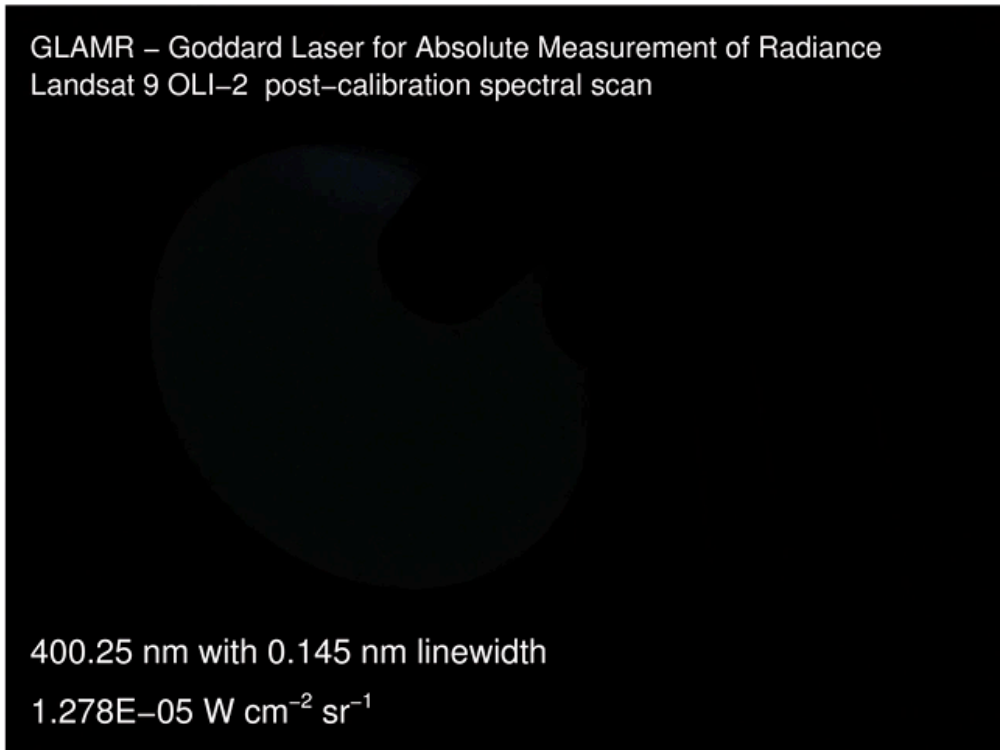



Research Scanning Polarimeter (RSP) characterized in 2015

# Conclusion

The GLAMR-like method of instrument characterization matches advancements in instrument performance.

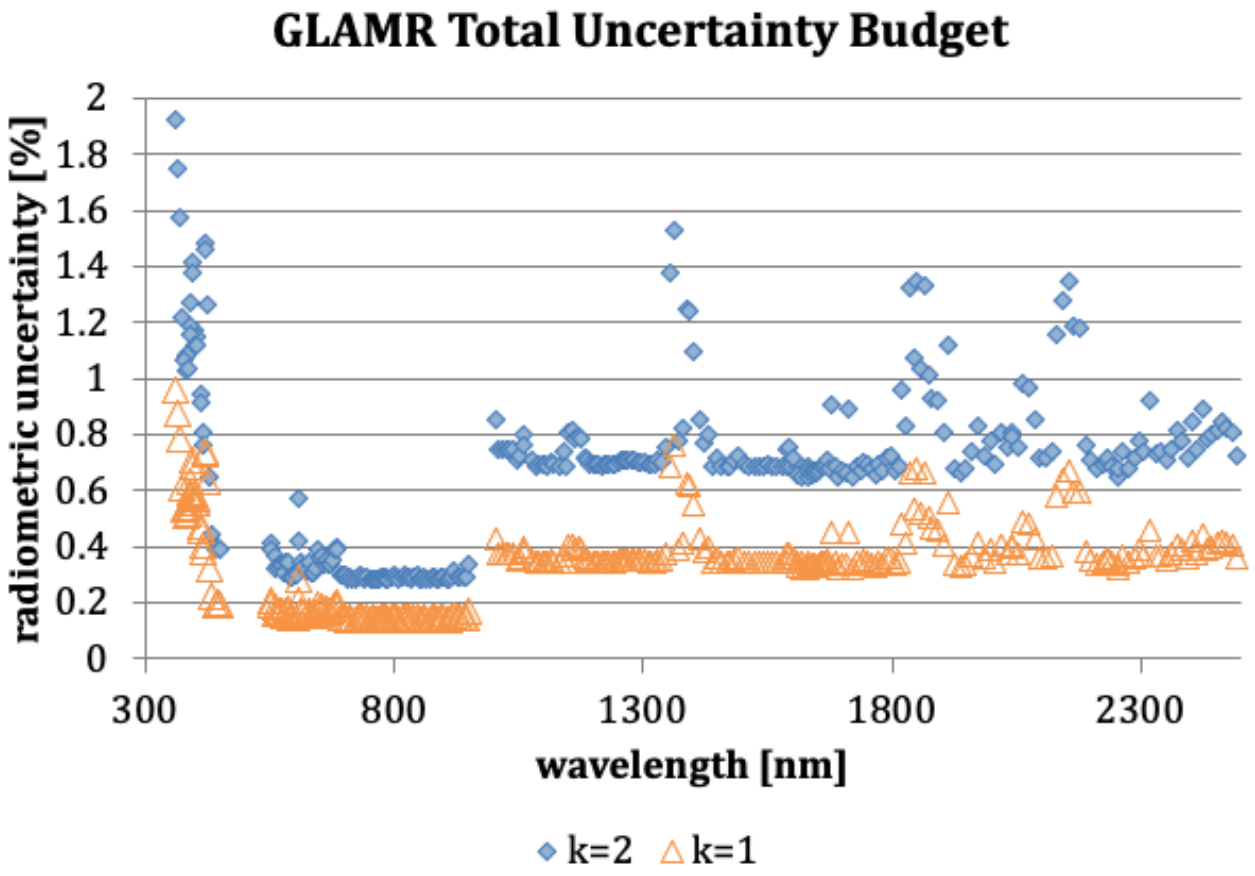
- Advancing instrument performance
  - Higher SNR
  - Better spatial resolution
  - Increasing number of instruments
  - Advancing science and algorithms
- …needs to be matched with advancing monochromatic, flood illumination-based characterization
  - Full-field and full-aperture illumination provides characterization in flight-like conditions
  - GLAMR provides a ‘pure’ signal relative to traditional test methodology
  - Extensive source knowledge relative to traditional techniques
  - Provides radiometric uncertainty levels only achieved with monochromatic-based characterization methodology



# *BACKUP*

# Total uncertainty (full spectral)

Total uncertainty (k=1 and k=2)



# Summary of GLAMR-like characterization advantages

- Full-field and full-aperture illumination provides characterization in flight-like conditions
  - Fully characterizes electronic and optical crosstalk
  - More accurate than component testing based on data from non-flight conditions
- GLAMR provides a ‘pure’ signal relative to traditional test methodology
  - unpolarized,
  - non-dispersive,
  - no spectral "smile",
  - and highly uniform
- Extensive source knowledge relative to traditional techniques
  - GLAMR output is continuously monitored
- Provides radiometric uncertainty levels only achieved with monochromatic-based characterization methodology