FLARE Network Update for CEOS Community

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www.flare-network.com

Better Calibration. Better Data. Better Decisions.

CEOS-IVOS - Reston VA - August 29, 2022

Chris Durell, Brandon Russell, Jeff Holt - Labsphere, Inc.

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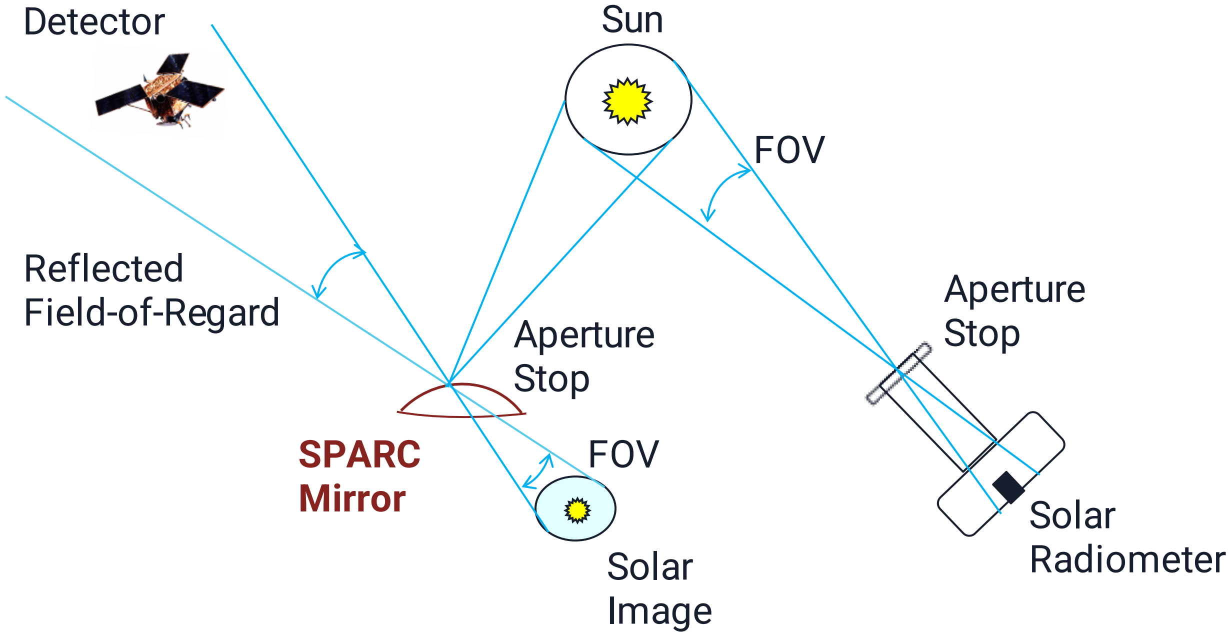
What is FLARE?

SPecular Array Radiometric Calibration (SPARC)

- The Specular Array Calibration (SPARC) physics allows any scale of earth observing sensor GSD to be calibrated to the solar spectral constant just like a solar radiometer
- The sub-pixel mirror acts as a Field-of-View (FOV) aperture stop allowing the sun to be imaged directly as an absolute reference
- The curvature of the spherical mirror and number of mirrors scales the brightness of the sun to an intensity that does not saturate the sensor focal plane



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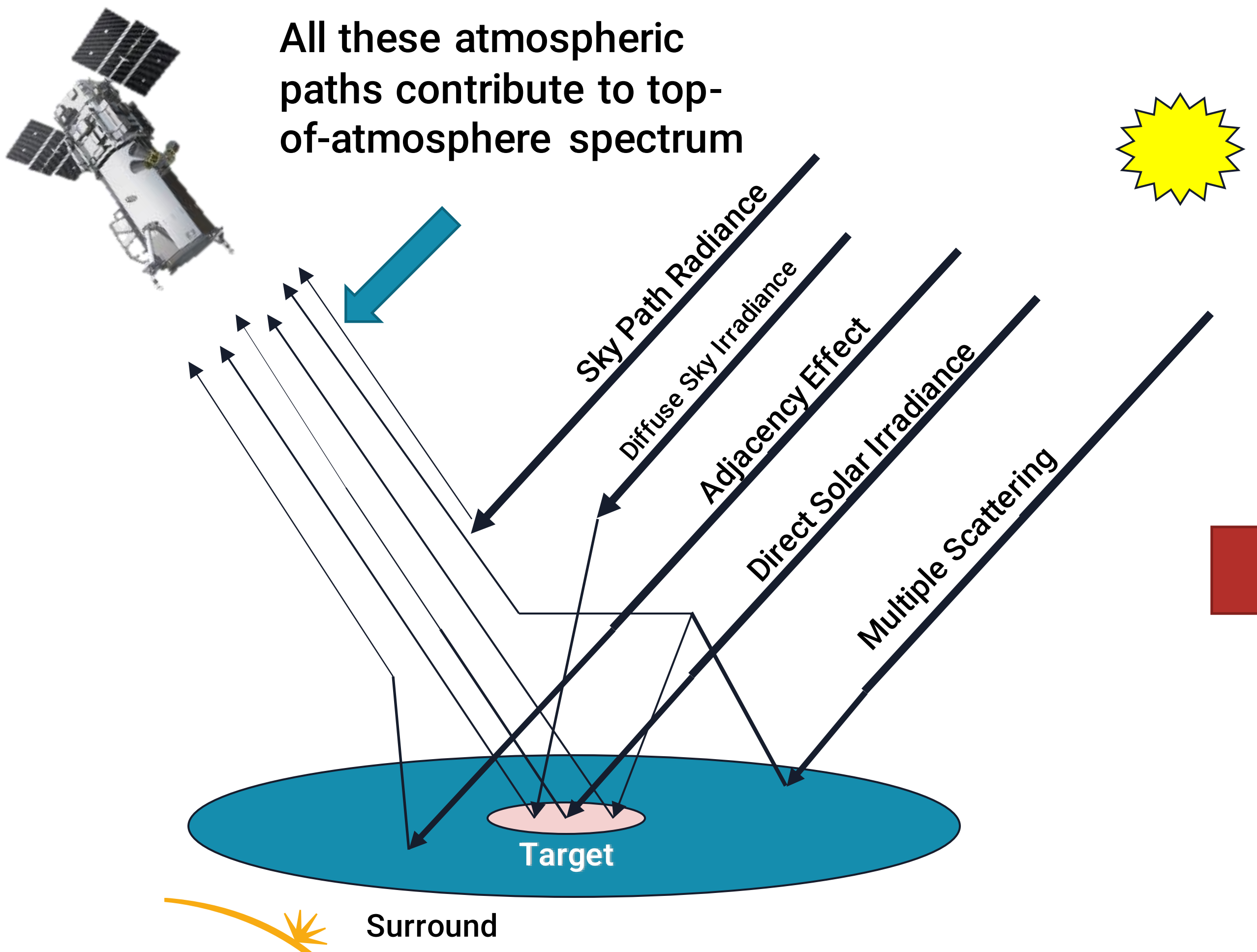
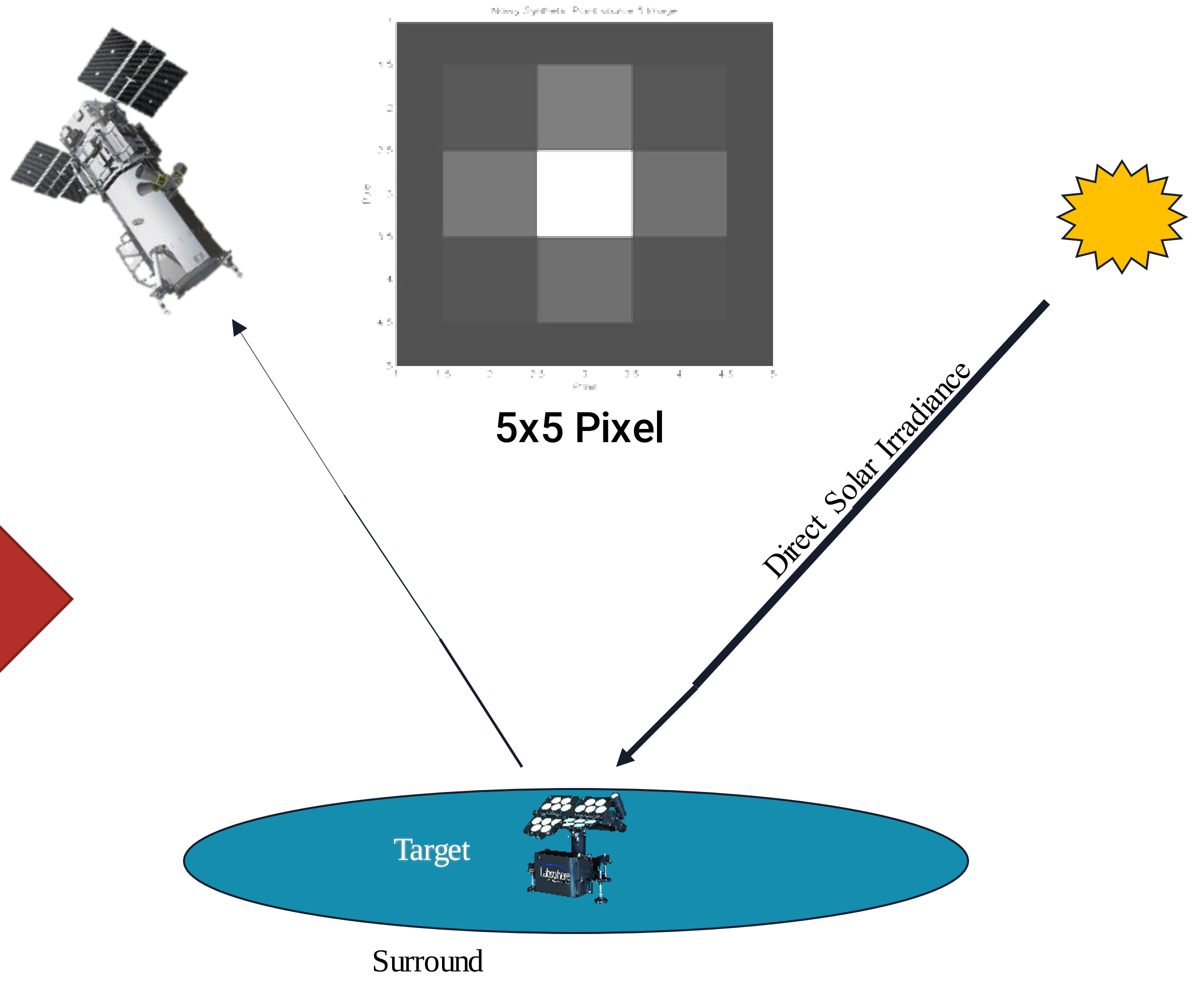
Schiller et al. 2010. The Specular Array Radiometric Calibration (SPARC) method: a new approach for absolute vicarious calibration in the solar reflective spectrum. Remote Sensing System Engineering III. Proc. of the SPIE, Volume 7813

Small Target vs. Large Target Radiometry



Lambertian Large Target Radiometry

Image of target



Small Target Radiometry

Specular Array Calibration (SPARC) Method Significantly Reduces Atmospheric Effects on At-Sensor Calibration Radiance

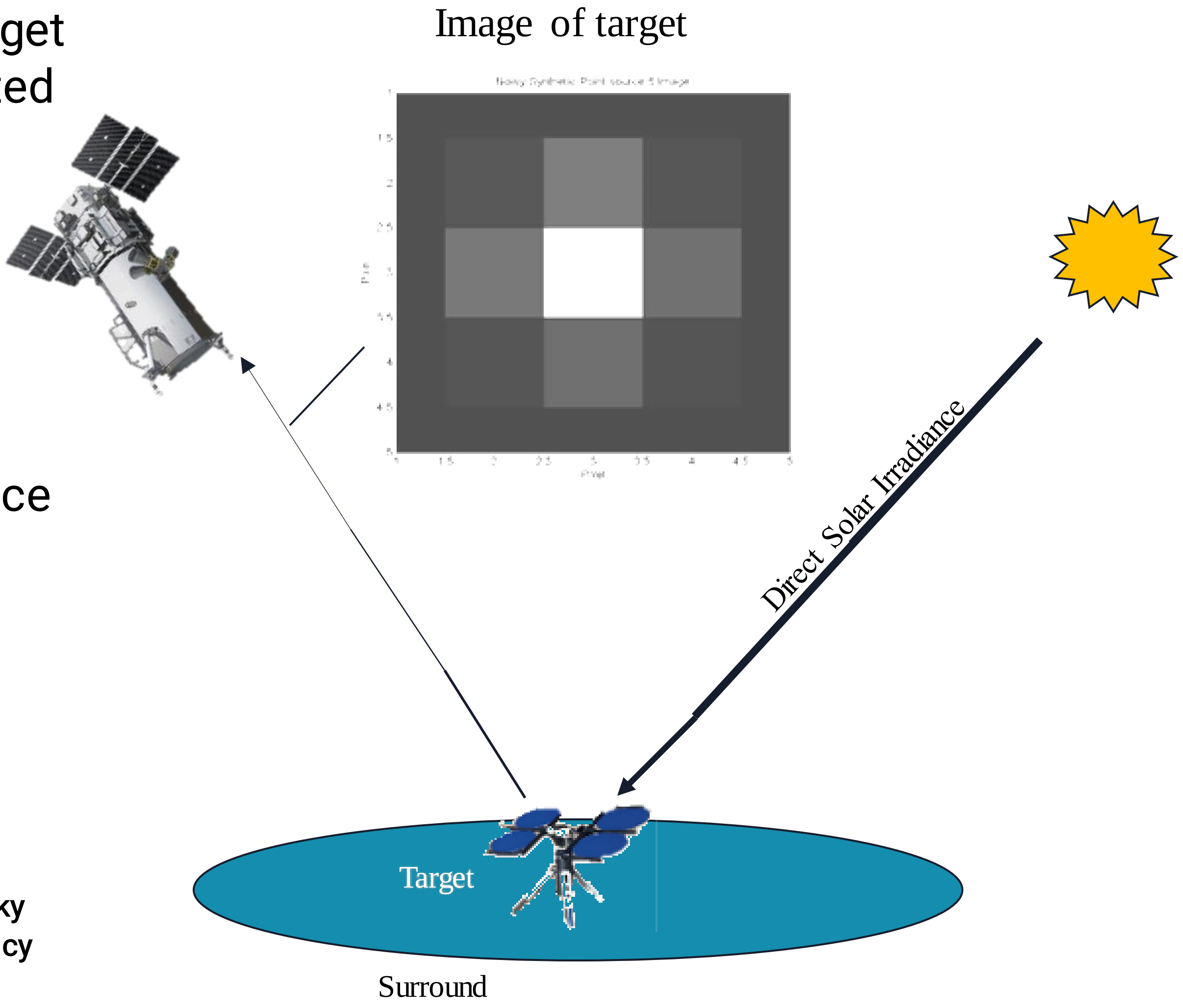
Target signal embedded in a uniform scene. is elevated above the low spatial frequency background and is separable

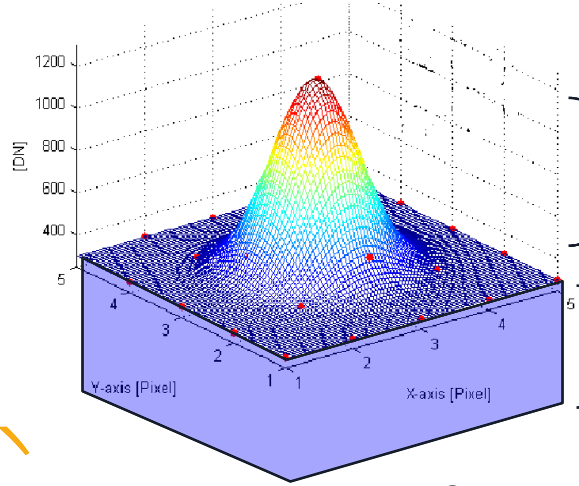
Background and atmosphere becomes a bias and is subtracted out based on image data alone

Sensor response to target radiance is the integrated Digital Number (DN) contained in the PSF

Ground Control Point (GCP)

Atmospheric effects reduced to transmittance only





Signal from SPARC target alone.

Signal from surround background surface, sky path radiance, adjacency effect, stray light, etc.

Oversampling is required to get low uncertainty of PSF

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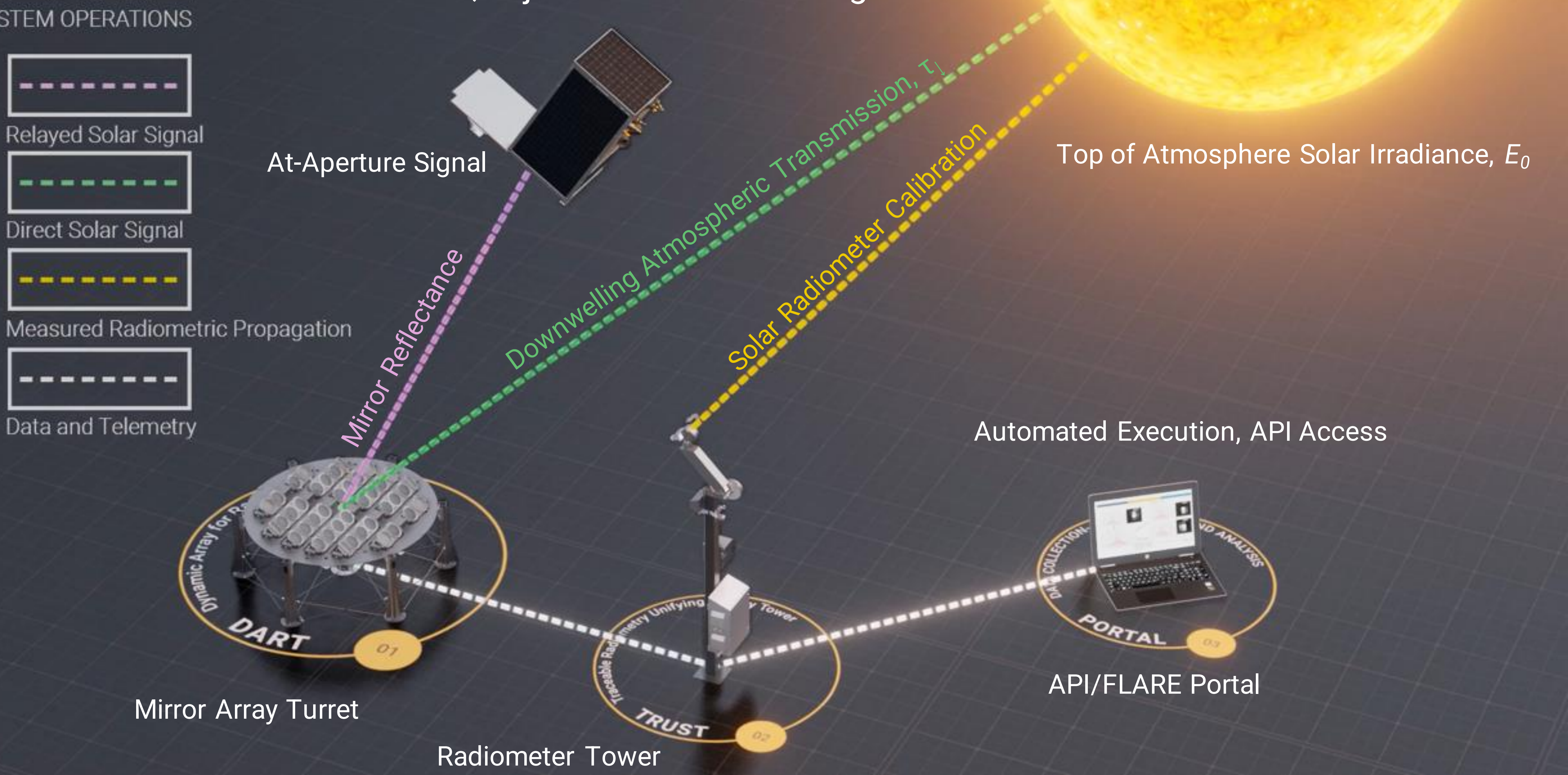
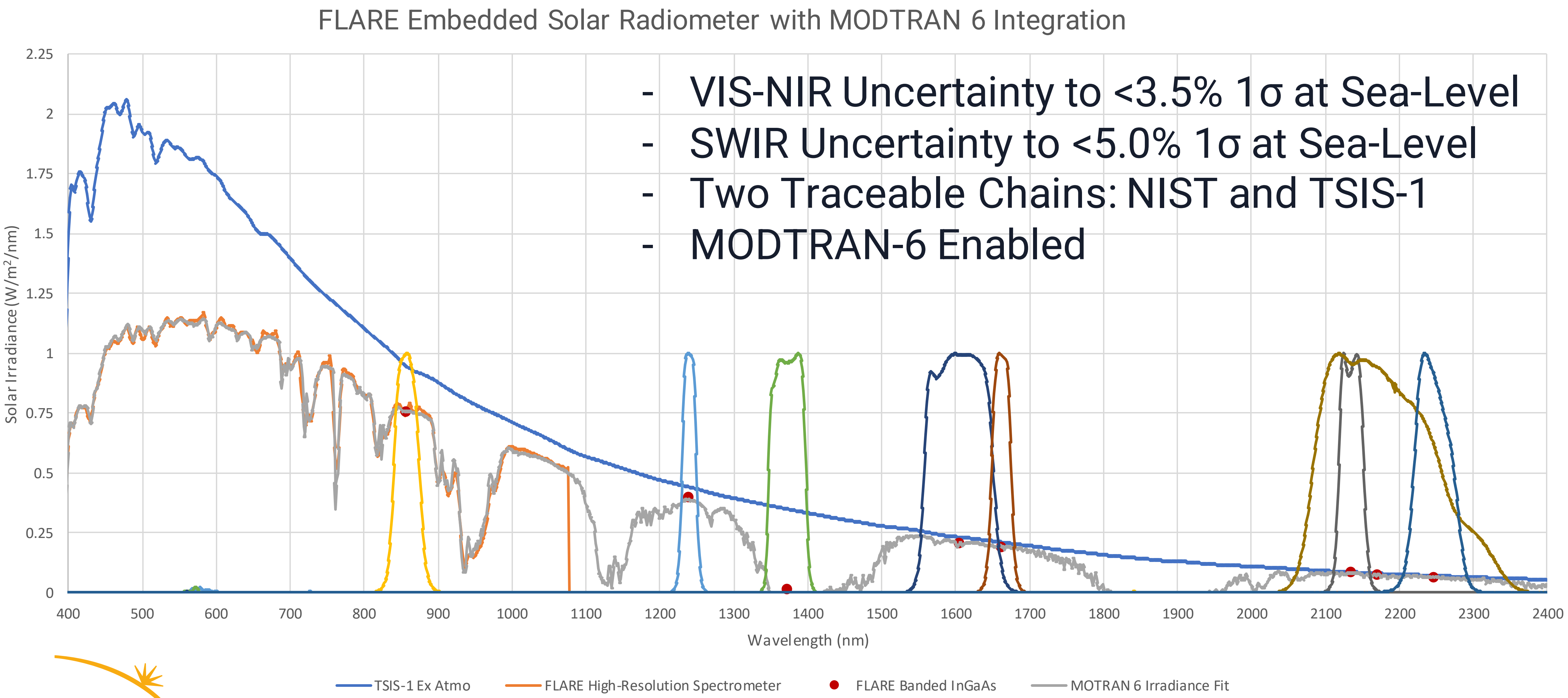
SYSTEM OPERATIONS

Field Line-of-site Automated Radiance Exposure Network

A traceable, adjustable “star” on the ground



FLARE Solar and Atmospheric Characterization



- VIS-NIR Uncertainty to <3.5% 1σ at Sea-Level
- SWIR Uncertainty to <5.0% 1σ at Sea-Level
- Two Traceable Chains: NIST and TSIS-1
- MODTRAN-6 Enabled

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Evolution to a Mobile Platform

Smaller…Lighter…Mobile…

60m GSD FLARE Beacon System
(3.5m Diam. x 1.5m (H))

15m GSD FLARE Lantern Mobile Systems (1m x 1m x 1m)

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Turn-Key Modular Mobile FLARE Lantern Automatic Node Deployment

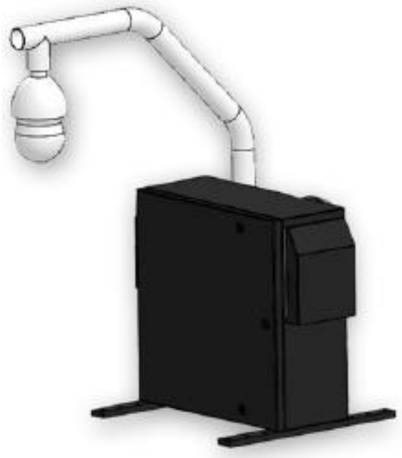
Enables Single Point or Multi-Point Arrays

Lantern Point 1
& Embedded FLARE Radiometer

"Plug and Play"

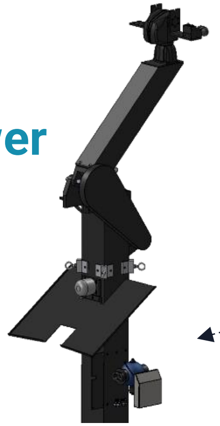
Central Controller

- Power distribution
- Network communication
- Scheduling (FLARE Portal)
- Profile/Sequence Control
- Perimeter Camera
- GPS clock, etc.
- 100-240VAC, 50-60Hz



Lantern Point 2, 3, 4…etc.
(no Radiometers)

Separate Radiometer Tower
(optional)



Solar Power or Generator
(Options)

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Modular Mirror Sets & Plates

Basic Configuration

10 m GSD, various levels

“More” Configuration

Group A: Up to 10 m GSD

Group B: 1 - 5 m

Group C: <1 m

“Bigger” Configuration

(Basic Configuration with more mirrors)

10 - 20 m GSD, various levels

30 m GSD “low level”

More signal

More GSDs

LANTERN Hub Controller

Connects LANTERN points and radiometric instrumentation

A single controller enables a constellation of LANTERN points

System perimeter camera

FLARE - Transformational Cal/Val Capabilities

- Automated, GSD-scalable, collection On-Demand:
  - Satellite, Airborne & UAS
- Different Surface Reflectance Types & FOV validations
  - Deserts, PICS, Agriculture, Coastal/Water, Urban, etc.
  - Assess PSF over different parts of swath
- Puts calibration in different atmospheres
  - Low Atmosphere / High Altitude = Low Uncertainty
  - Sea Level, Urban
- BRDF assessment
- Easy Mobility enables propagation of a global network
- Hyperspectral: Spatial and Spectral (per band)
- Ground Control Points (GCP) for Geolocation
- Polarized or synthetic-spectrum traceable targets

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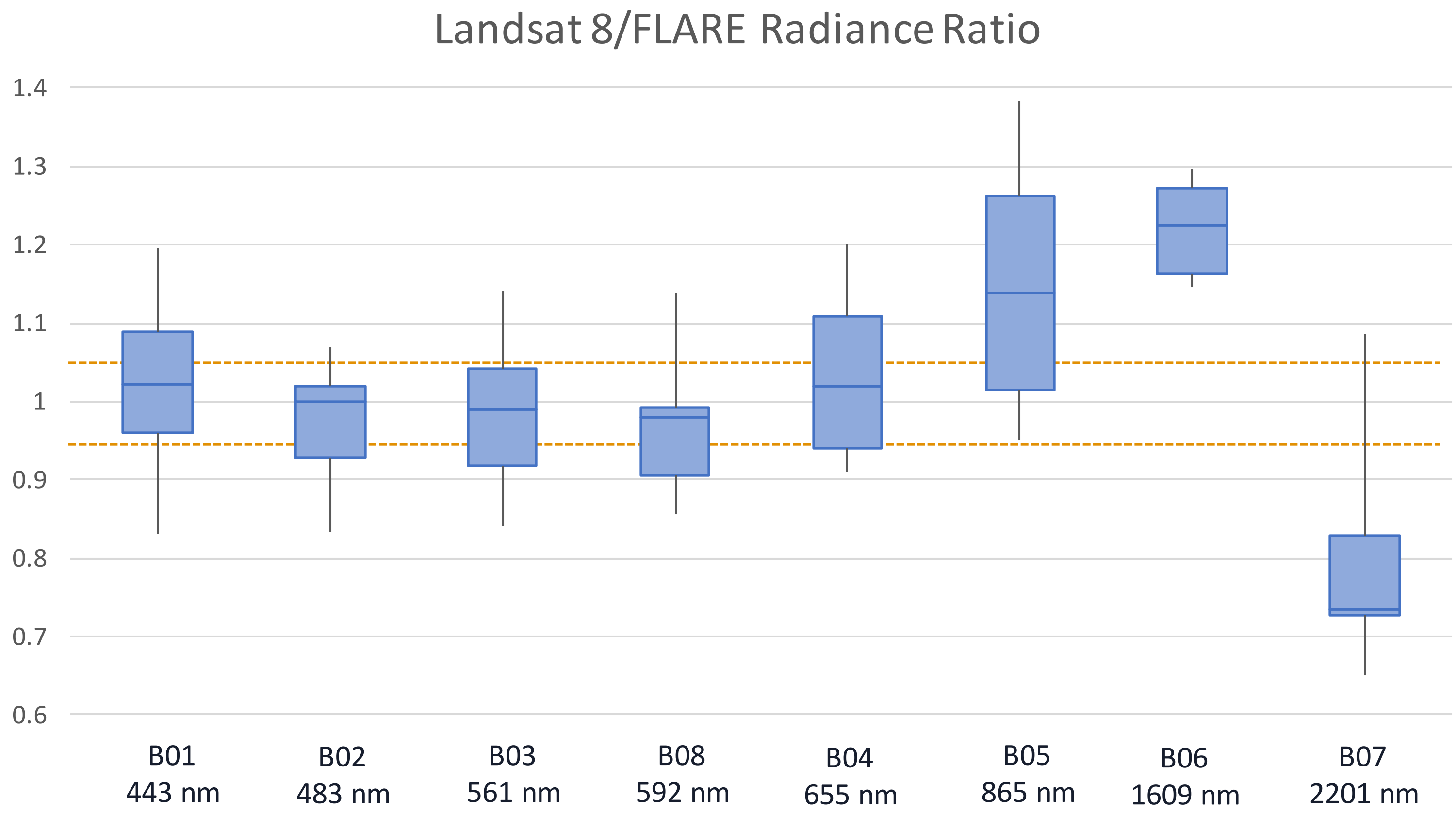
Landsat 8/9 and Sentinel 2A/2B Processing Archive: 2020-2022

Landsat 8 OLI Radiometric Archive - Arlington



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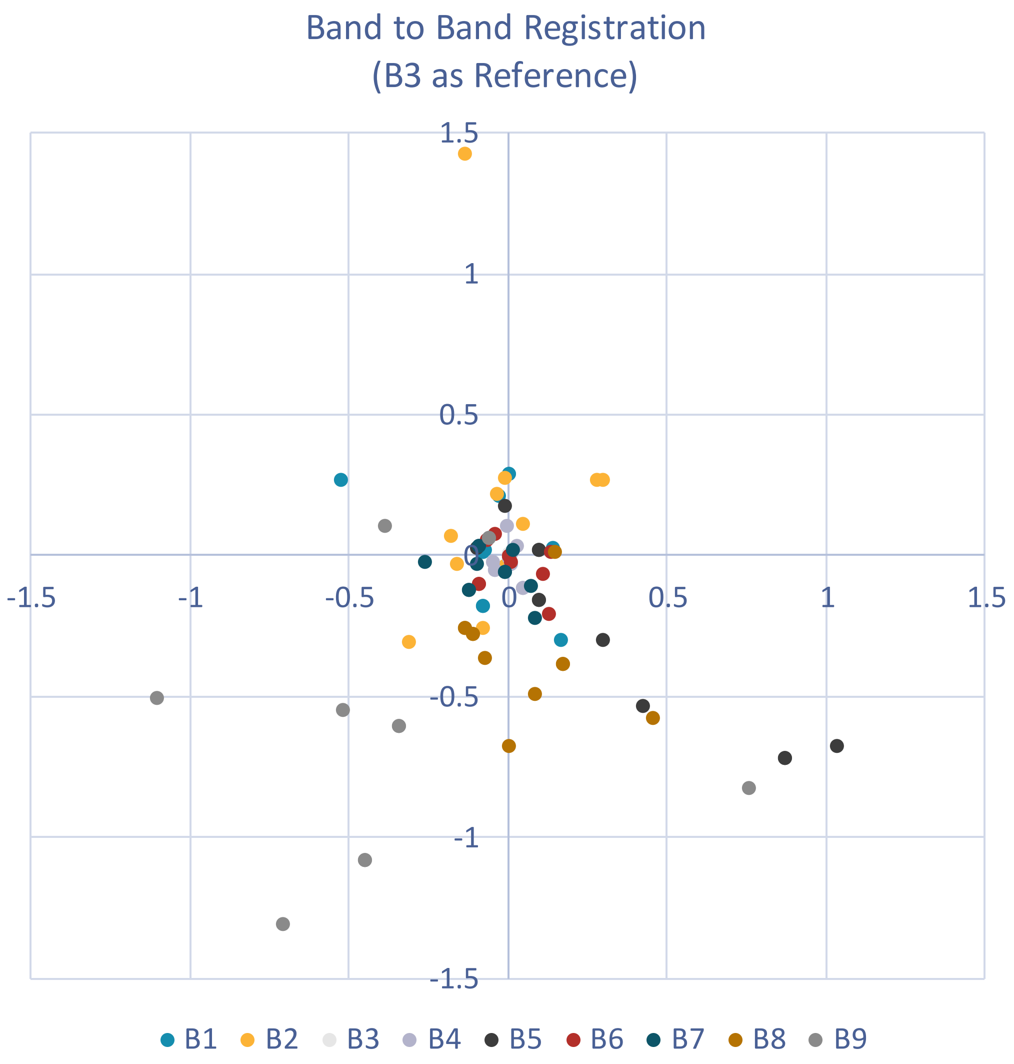
Landsat 8 OLI Radiometric Archive

- Median ratio < 3% difference in VIS bands (B1-4, B8)
- Significant biases in NIR/SWIR (B5-7)
  - B9 (cirrus) not included in analysis
- Sources of bias/variation under investigation
  - Processing level: georectification, resampling
  - Refinements to extraction radius – larger radius captures more energy, potentially adds noise
  - Radiometric modeling/screening
  - Vegetative background – high reflectance in NIR leading to over subtraction
  - Effects of background heterogeneity (next talk)
- Archive analysis in process
  - Beta site comparison – proximity to structures? Background heterogeneity?

Band to Band Registration (Pixel Space)

- Fitting routine - 2D Moffat function
  - ML based – under refinement (proprietary)
- Finds center of signal (sub pixel)
  - Band to Band
  - Absolute GCP
  - PSF estimate
- Single band/acquisition input
  - Under-sampled but can be applied to individual point source
- Comparison to oversampled PSF model in process*



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*Conran et al. 2021, IGARSS

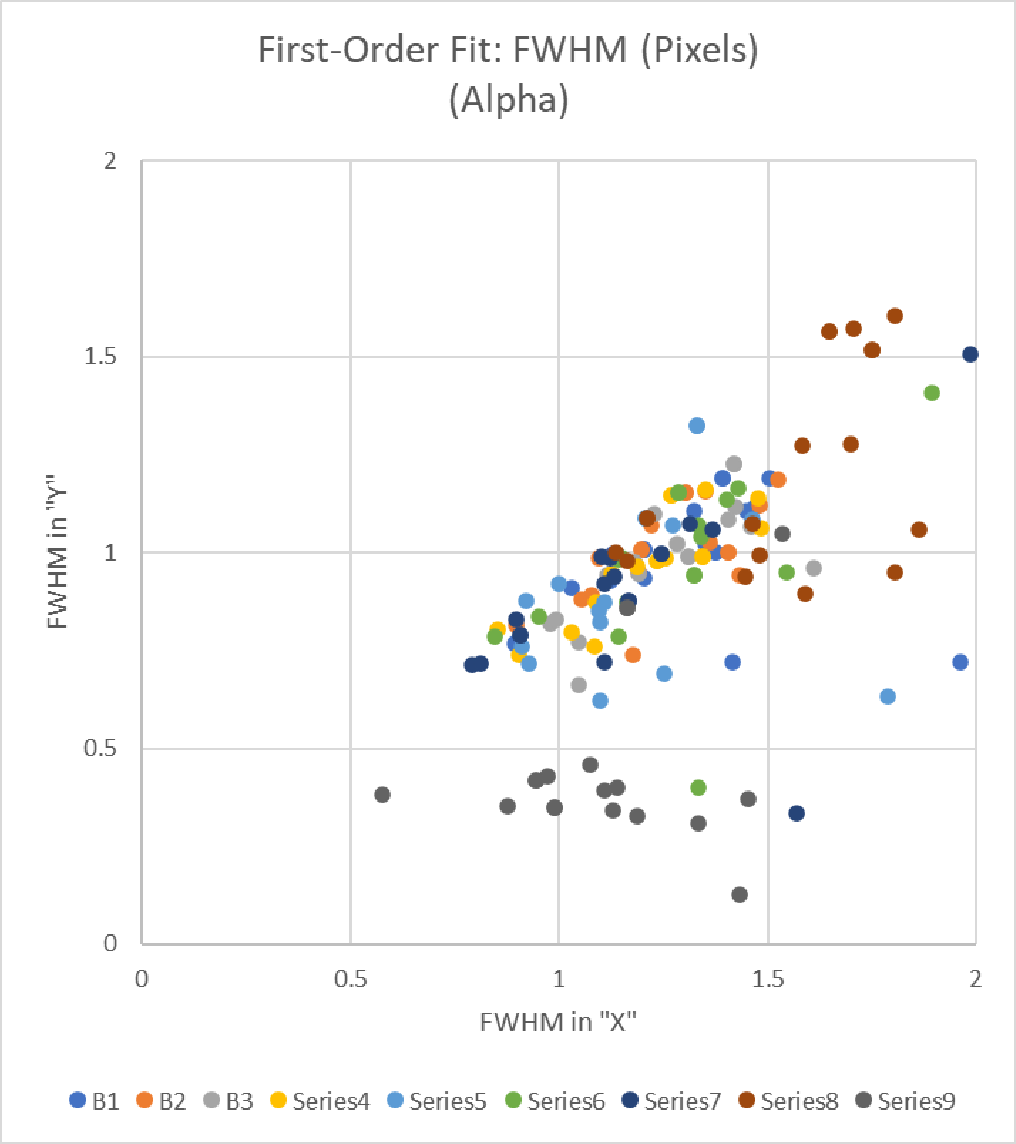
Point Spread Function (Pixel Space)

- Fitting routine - 2D Moffat function
  - ML based – under refinement (proprietary)

- Finds center of signal (sub pixel)
  - Band to Band
  - Absolute GCP
  - PSF estimate

- Single band/acquisition input
  - Under-sampled but can be applied to individual point source

- Comparison to oversampled PSF model in process*



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*Conran et al. 2021, IGARSS

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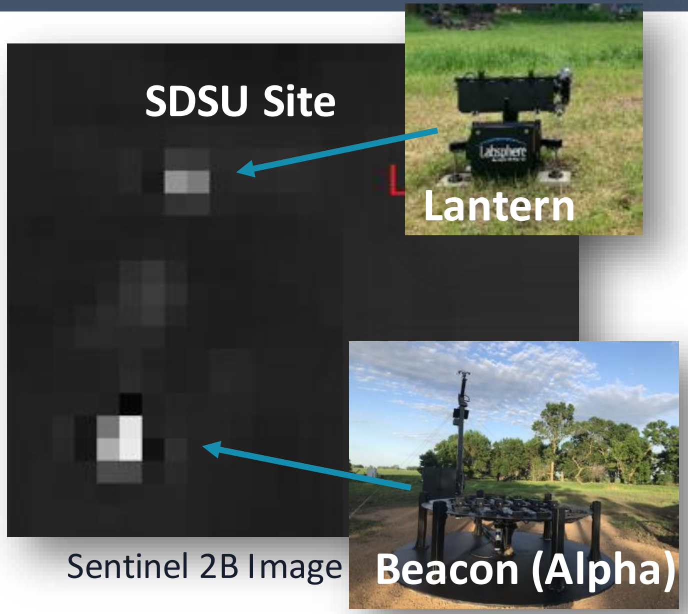
FLARE Campaigns and Activity

Recent FLARE Highlights – Leveraging Partnerships

- SRIX4VEG (ESA): NPL, NRC, RIT & Hyspex Mirrors/PF Targets
- FLARE Lantern Successful Deployment @ SDSU – Star-tracker Alignment!
- NEON Campaign dual-point FLARE: World-class instrument validation
- Peer-Reviewed papers: BigMAC (SDSU and USGS) and G-SCALE (RIT and NRC)



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G-SCALE: Ground to Space Calibration Experiment

Tait Preserve, Rochester, NY July 23 2021

Simultaneous Vicarious Calibration of UAV (Hyper), Airborne (Hyper) and Satellite (MS) in VNIR-SWIR

- International Public/Private Partnership
  - Labsphere
  - Maxar
  - Rochester Institute of Technology
  - National Resource Council Canada

- Combination of traditional and mirror methods
  - Large reflective panels and tarps
  - Solar radiometers
  - Ground based SVC reflectance measurements
  - Reference and test targets

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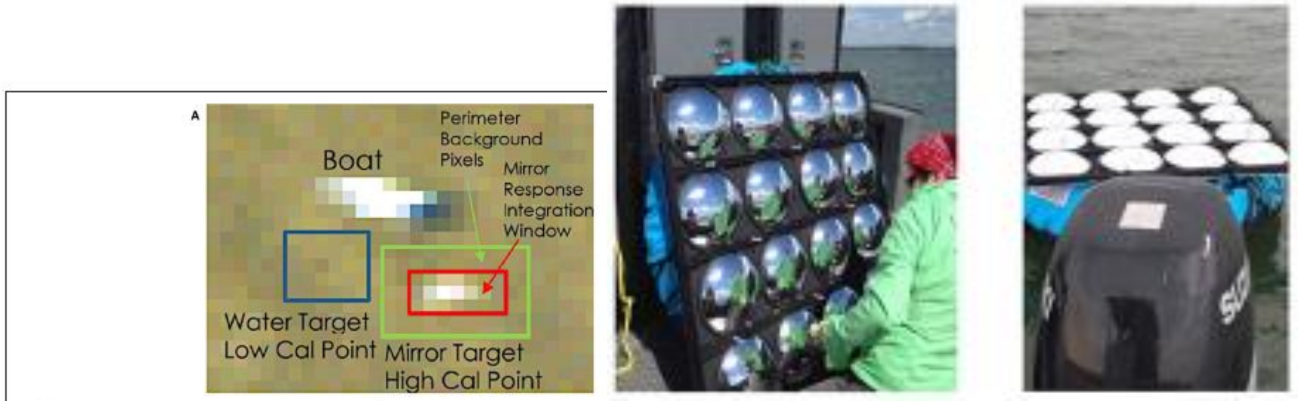
Water & Dark Target Radiometry

ELM at dark target sites for carbon sources and sinks

Ortiz et al. 2017. Intercomparison of approaches to the Empirical Line Method for vicarious hyperspectral reflectance calibration. *Frontiers in Marine Science* 4, 296



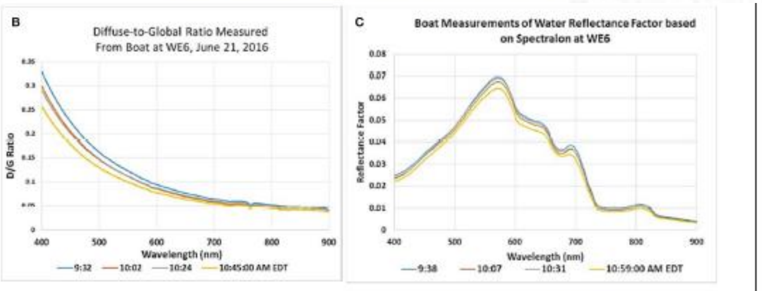
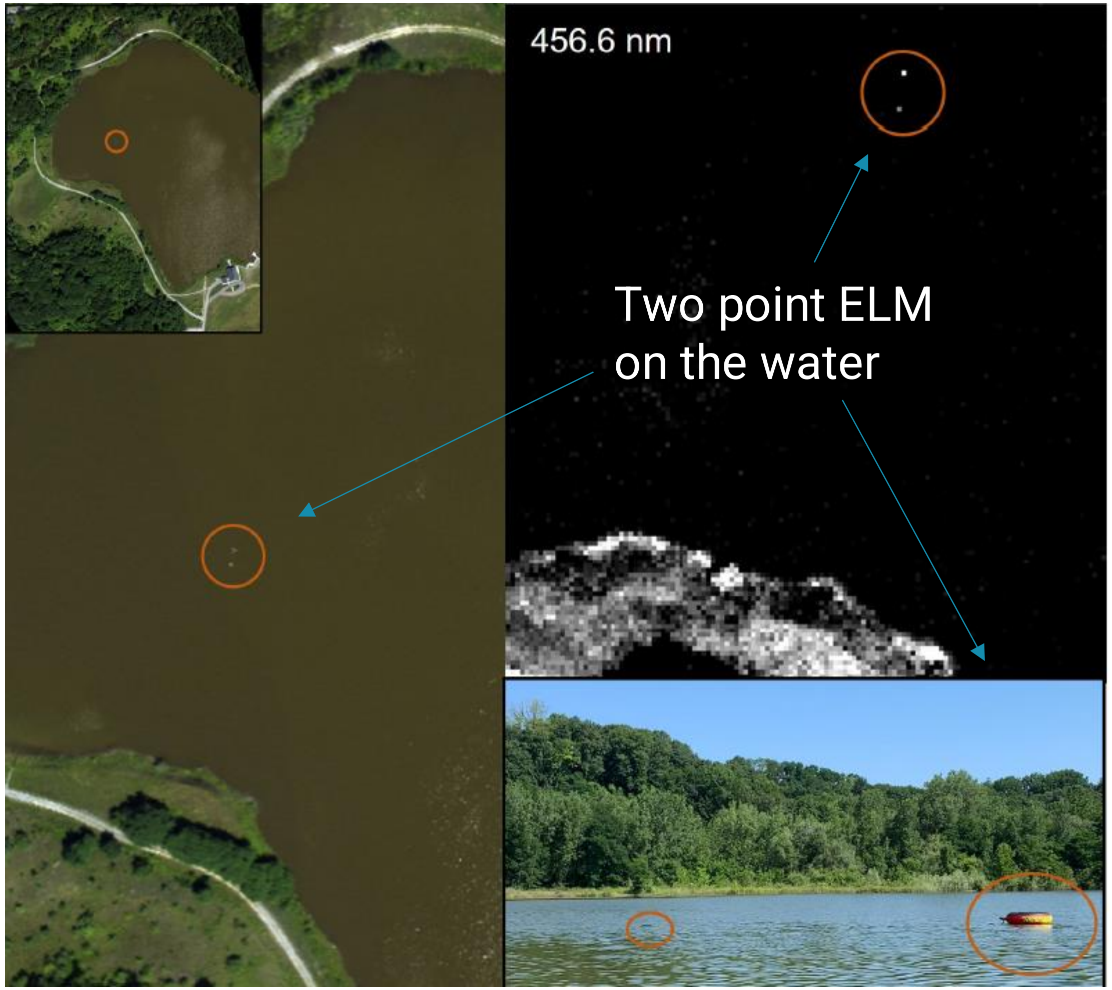


FIGURE 2 | (A) NASA Glenn, second generation Hyperspectral imager (HSI2) image pixels from swath 15_MBSP, acquired on June 21, 2016, of the mirror reflectance target (red box: high calibration point), water (blue box: low calibration point) and boat at station Western Erie 6 WE6. Though the mirror target is smaller than an instantaneous field of view (IFOV) pixel, the energy reflected at the mirror is spread out over multiple pixels due to the aircraft motion, sensor system point spread function and pixel resampling during processing. Pixels included in target integration are indicated by green and red boxes. **(B)** Example diffuse to global ratio spectra, and **(C)** water surface reflectance spectra measurements taken from the boat located at WE6 on June 21, 2016.

Russell et al. 2022. An overview of the Ground to Space CALibration Experiment (G-SCALE): Concept, execution, and initial results. *Submitted.*



NRC·CNRC

RIT

MAXAR

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BigMAC – Surface Reflectance Validation

ALPHA System @
Arlington, SD "The Farm"

Manual Mirror Arrays for
Planet and RIT UAV @
Brookings, SD

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Lantern & Beacon – NEON & L9 SNO – 7/29/22

Supporting spatial and radiometric evaluation for Hyperspectral Assets

AVIRIS-NG

NSF | neon Operated by Battelle

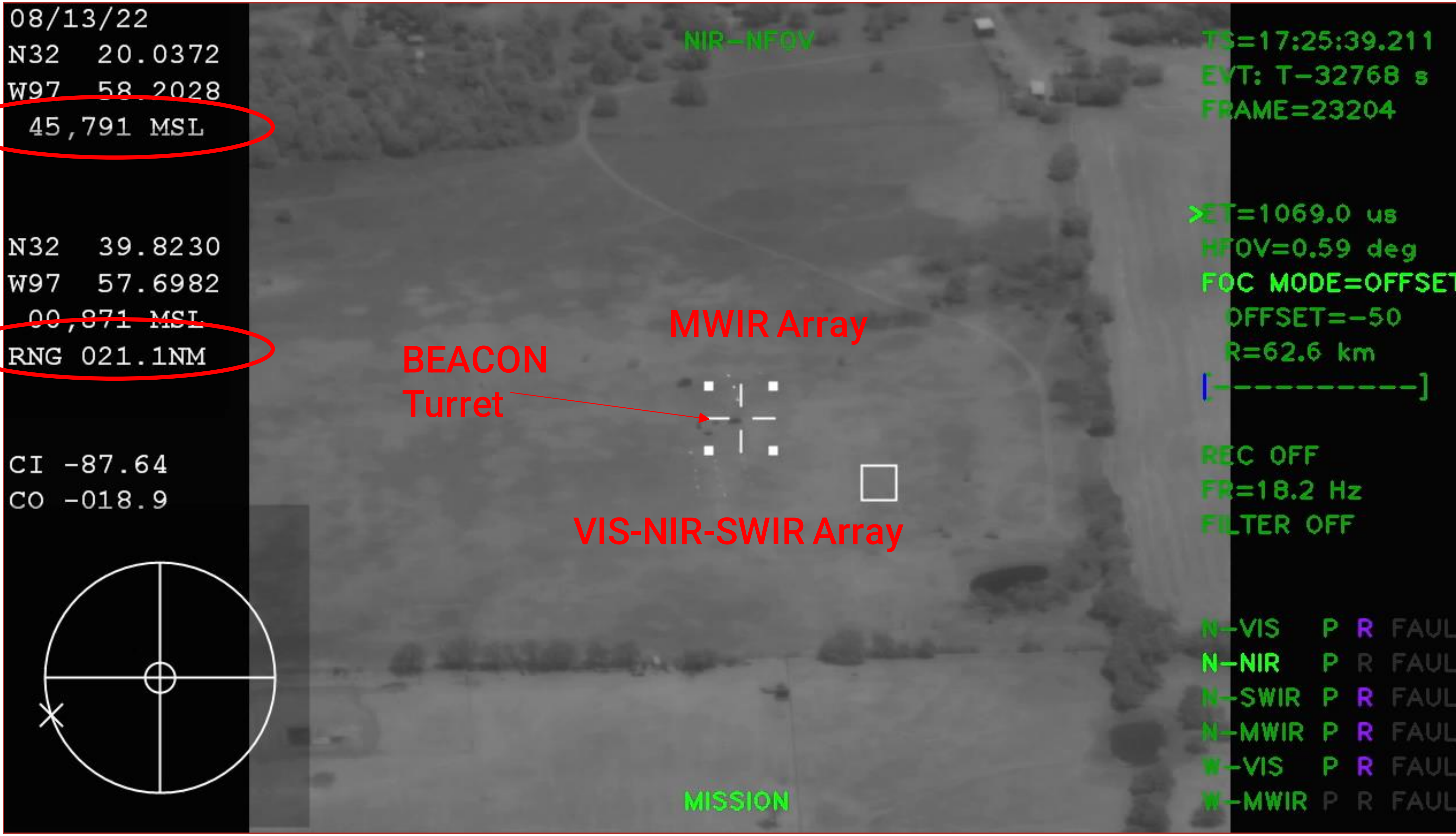
South Dakota State University

USGS science for a changing world

8/13 - SCI-FLI 0.4-5.0 – FLARE for Artemis Camera

SAMI
SCIFLI AIRBORNE MULTISPECTRAL IMAGER

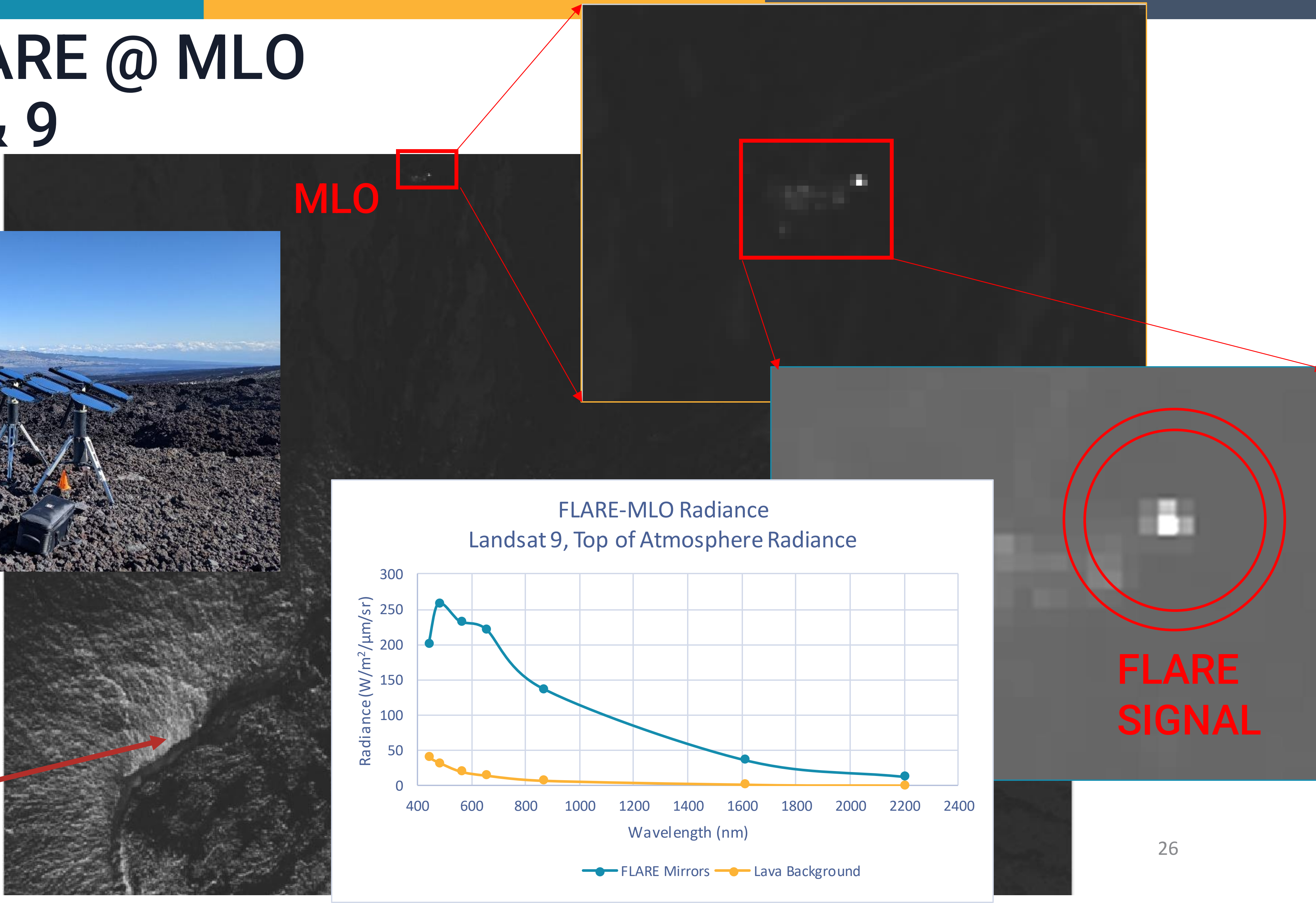
Full Motion Video Airborne Slant Range Radiometry & Spatial Test



SCIENTIFICALLY CALIBRATED IN-FLIGHT IMAGERY
SCIFLI
VERUM VIDERE
NASA LANGLEY

FLARE

Testing FLARE @ MLO Landsat 8 & 9



SDAV UH HILO

Mauna Loa Caldera with Snow

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FLARE Benefits to NASA/NOAA's Mission

NOAA ESRL
Aeronet Platform
at MLO

FLARE Mirrors
Deployed on MLO

- **Interoperable <2% Calibration Method**
  - **Fast implementation – immediate benefit**
- **Atmospheric measurements on FLARE Sites in the Network**
- **Improve NASA/NOAA AERONET Calibration activities at MLO**
- Supporting NIST & NASA LUSI Lunar radiance validation at MLO
- Replication?: Tenerife, Atacama, MOBY

UNIVERSITY of HAWAI'I HILO

SDAV UH HILO

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Discussion at CEOS

Conversations at CEOS

- Compliance to CEOS-ARD – Can we get certified?
- What does CEOS need to endorse FLARE as a method?
  - How do we get there?
- Are there vehicles for funding?
  - How can we get active with more programs?
  - Anyone interested in an experiment
- Are we missing anything?

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Thank you!

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