FLARE Spatial and Radiometric Capability for CAL-VAL Sites

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Labsphere, Inc.

VH-RODA 2021 online workshop

Better Calibration | Better Data | Better Decisions

Topics

- Review of SPARC and FLARE Principles
- System Design, Installation and Expansion Plans
- Benefits for CAL-VAL Sites
- Example FLARE Results (time permitting)

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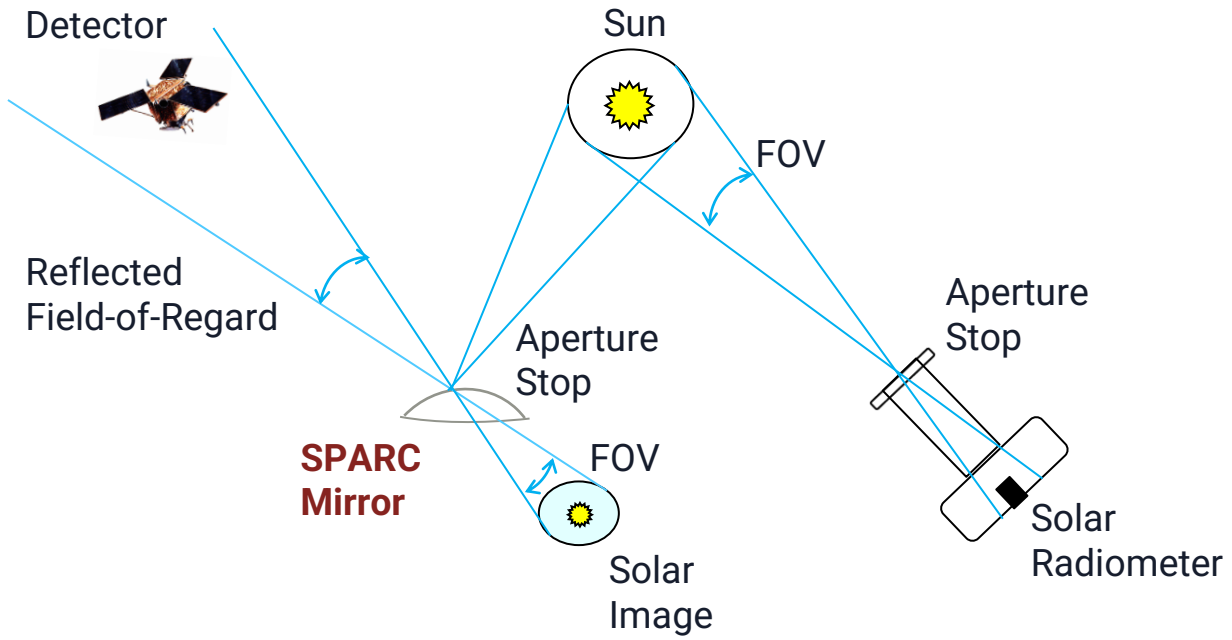
What are SPARC and FLARE?

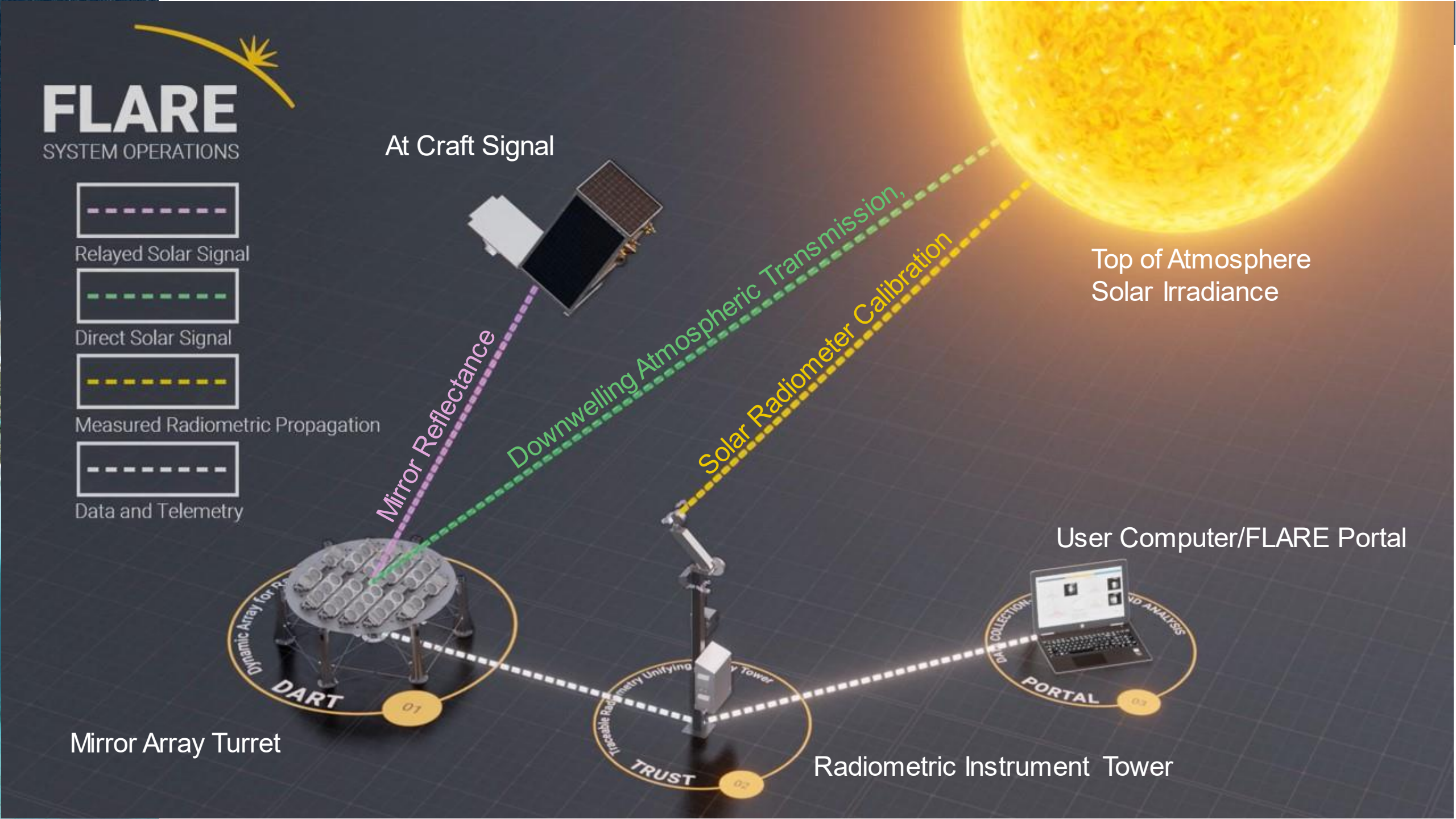
SPecular Array Radiometric Calibration (SPARC)

The SPARC method allows any earth observing sensor to be calibrated to the solar spectral constant just like a solar radiometer. FLARE uses SPARC Mirrors.

The mirror acts as a Field-of-View (FOV) aperture stop just as with an aperture stop on a typical solar radiometer allowing the sun to be viewed directly as an absolute reference.



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


FLARE
SYSTEM OPERATIONS
Relayed Solar Signal
Direct Solar Signal
Measured Radiometric Propagation
Data and Telemetry
At Craft Signal
Mirror Reflectance
Downwelling Atmospheric Transmission,
Solar Radiometer Calibration
Top of Atmosphere
Solar Irradiance
User Computer/FLARE Portal
DART
01
TRUST
02
PORTAL
03
Mirror Array Turret
Radiometric Instrument Tower


FLARE
SYSTEM OPERATIONS
Relayed Solar Signal
Direct Solar Signal
Measured Radiometric Propagation
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At Craft Signal
Top of Atmosphere
Solar Irradiance
FLARE is a traceable, adjustable “star” on the ground.
User Computer/FLARE Portal
Mirror Array Turret
Radiometric Instrument Tower
DART
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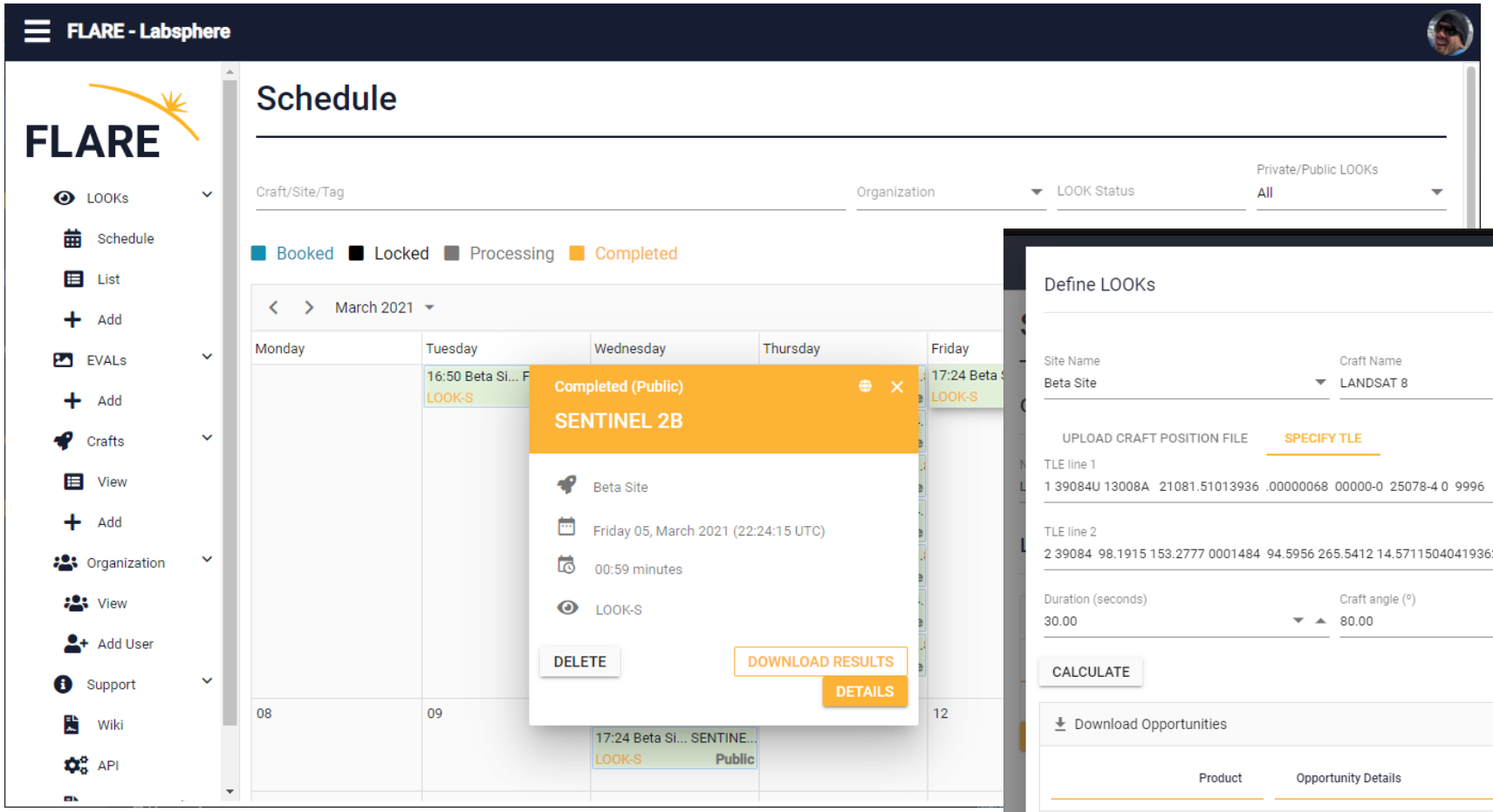
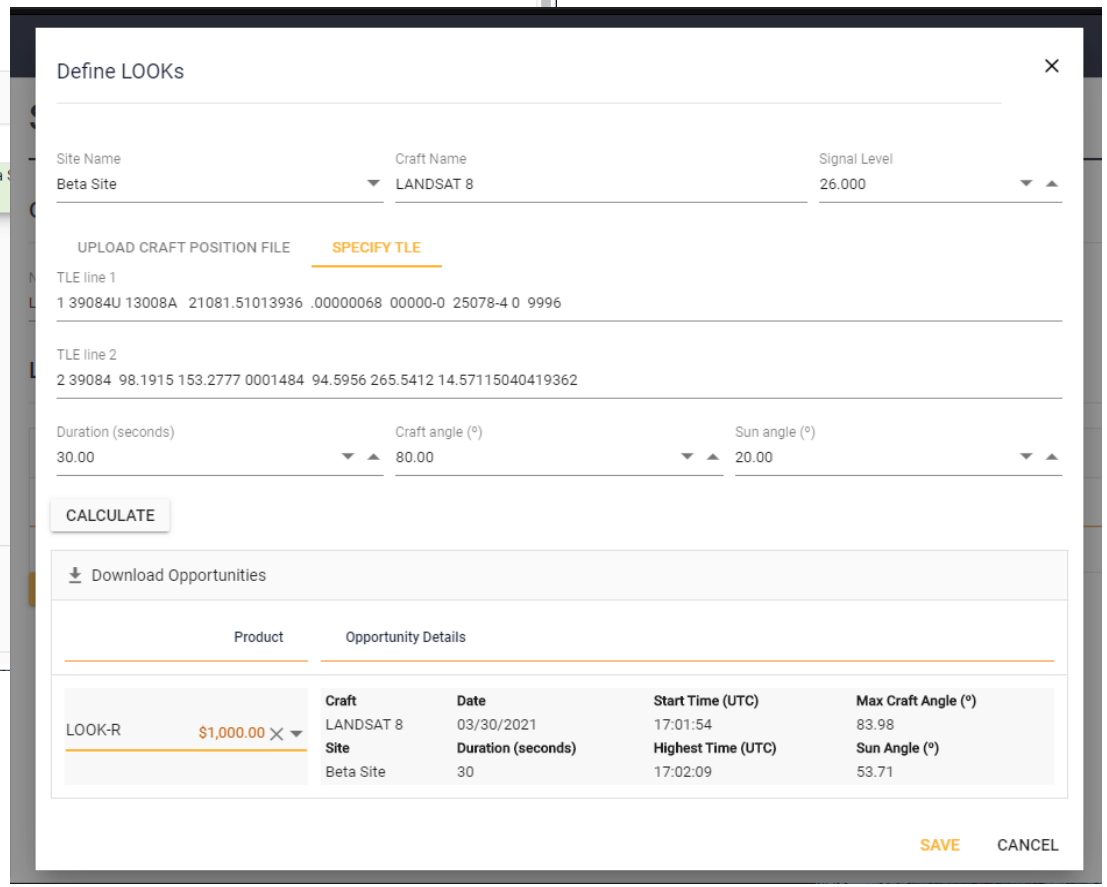
PORTAL

FLARE Portal: Network Access via Cloud User Interface





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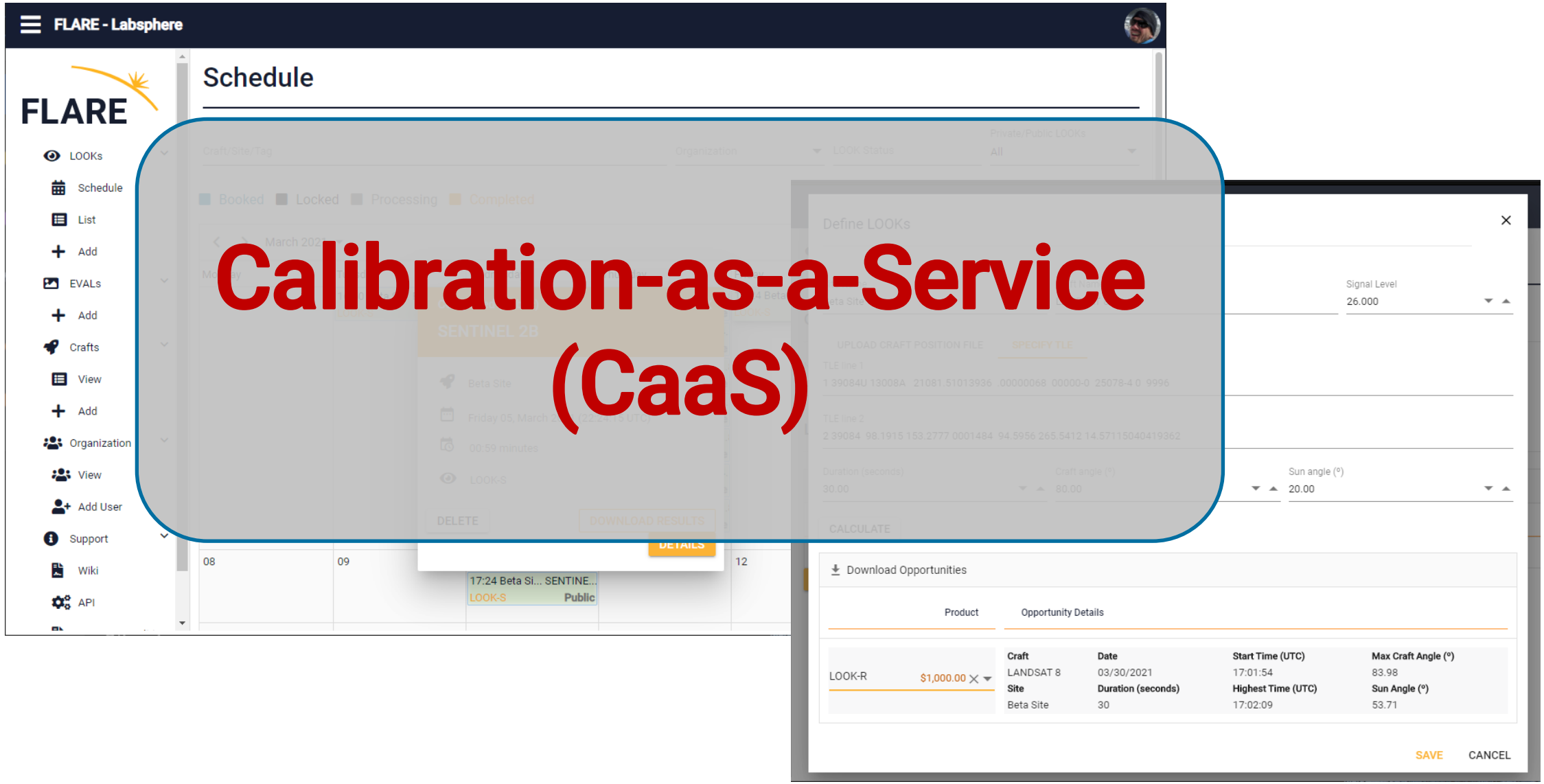
FLARE Portal: Network Access via Cloud User Interface



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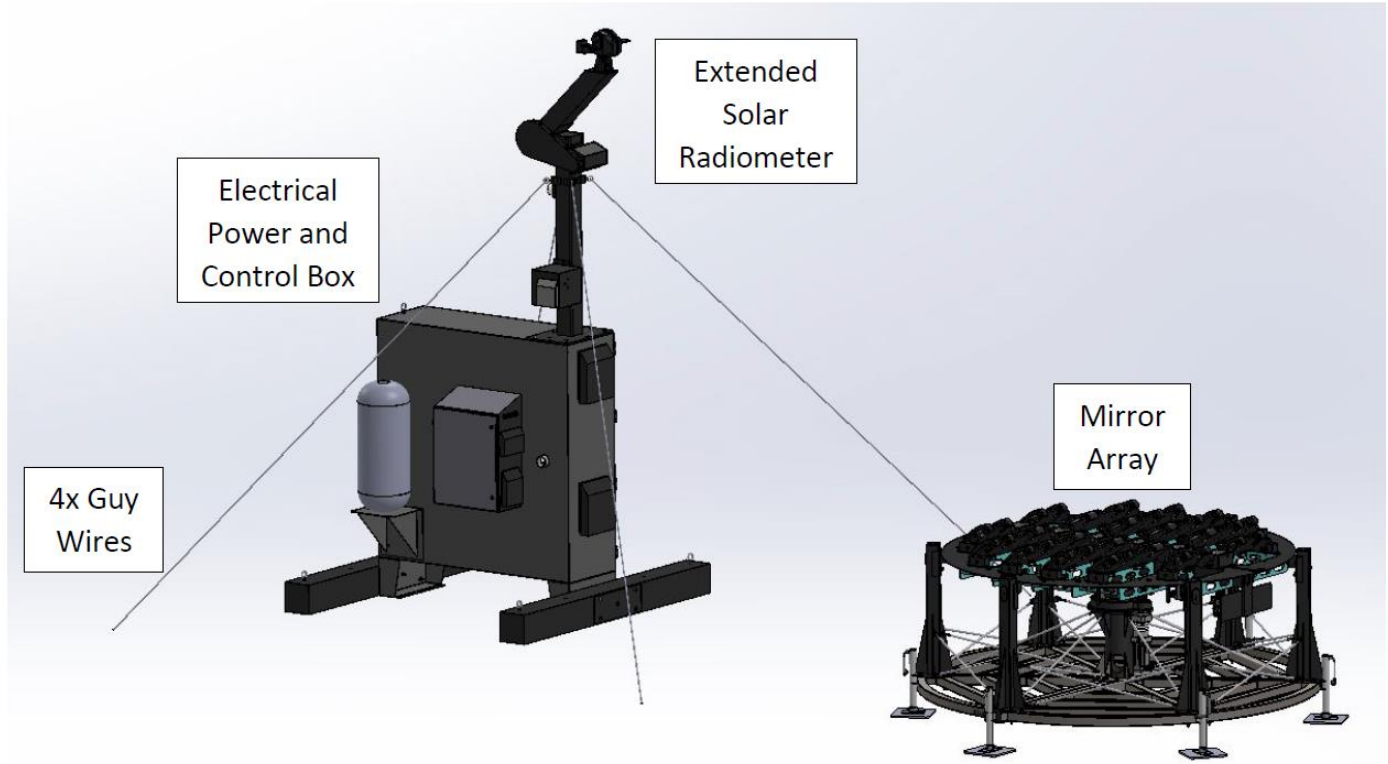
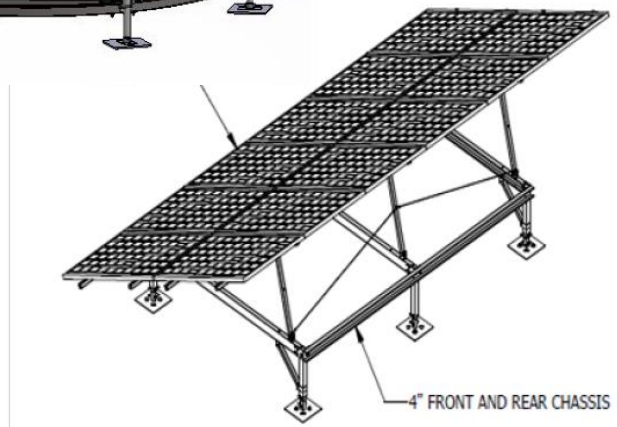
System Design, Installation and Expansion Plans

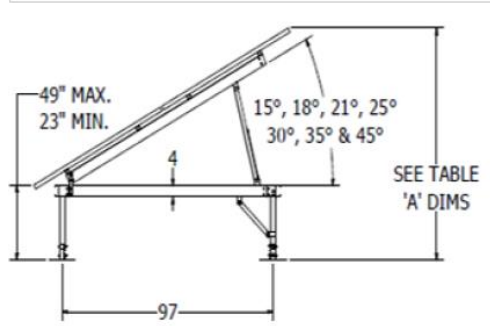
Example: FLARE System to be Deployed at Mauna Loa

Full System Model (without Solar)

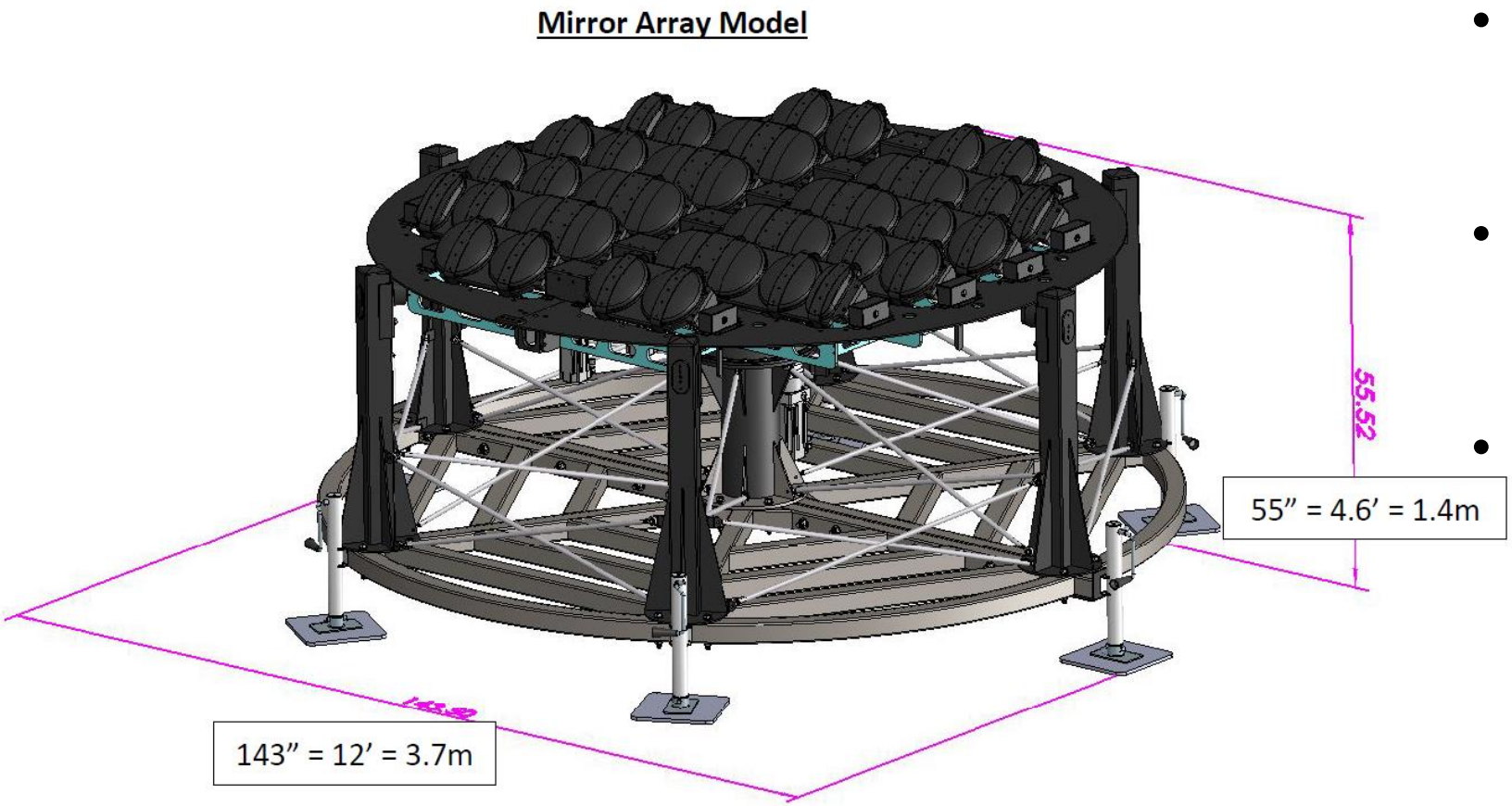


Solar Array



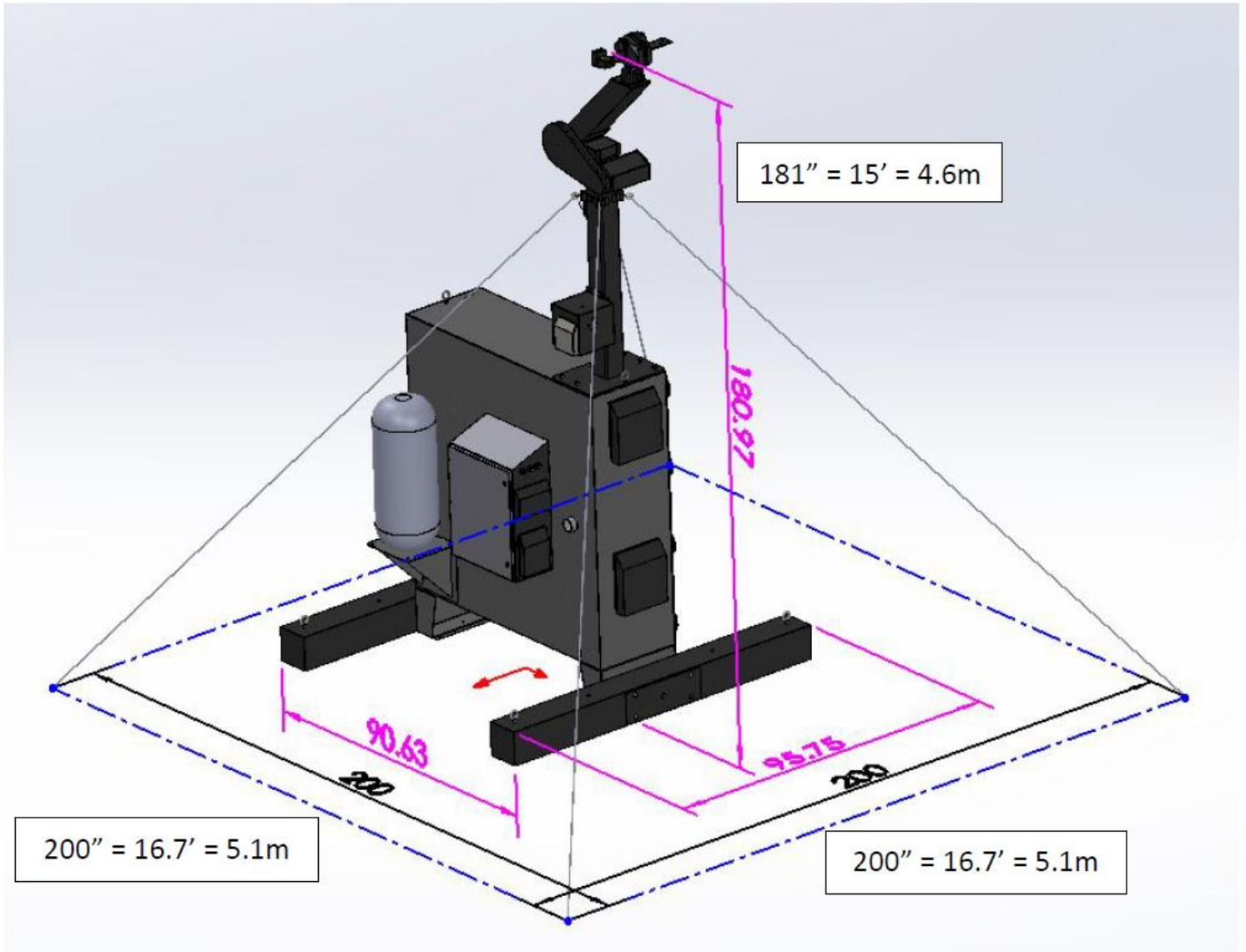


Mirror Turret Design – Low Impact, Self Leveling



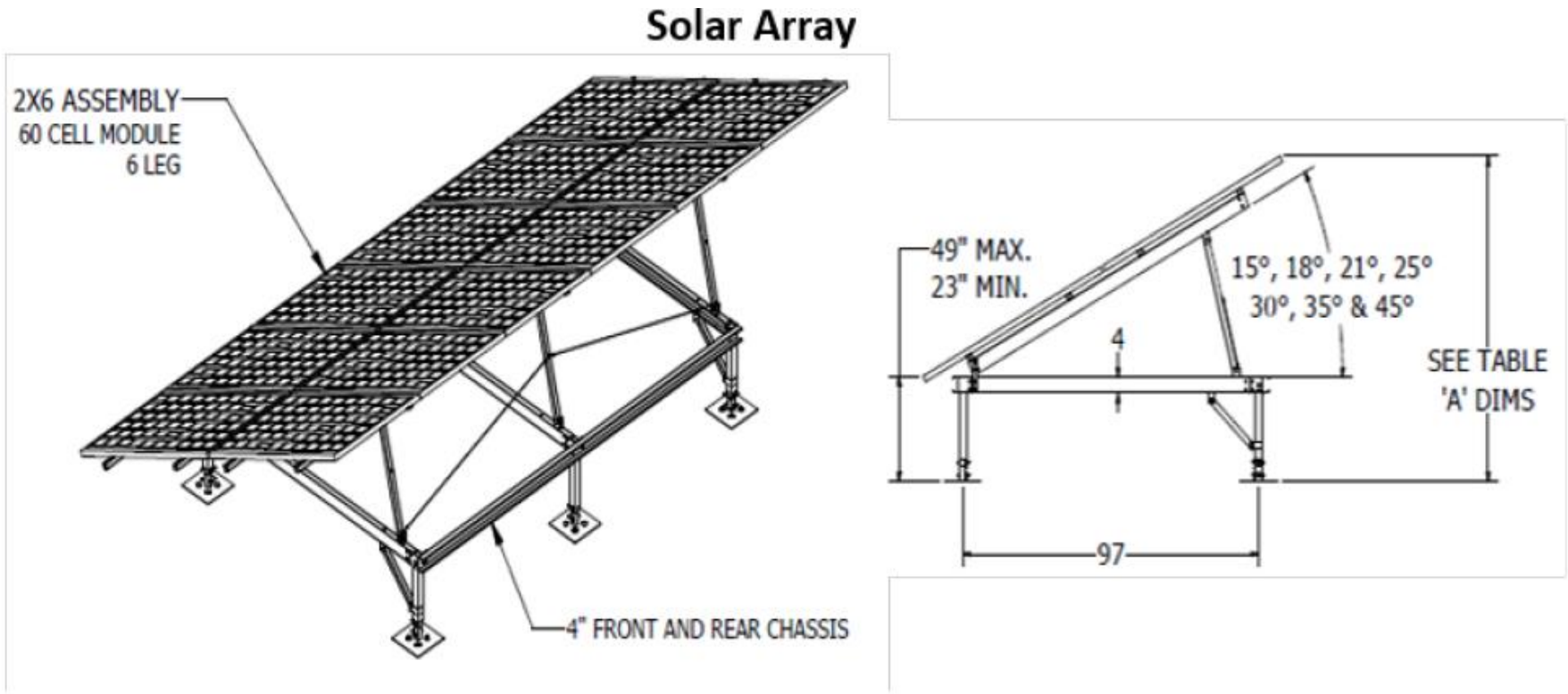
- Drop-in System (semi-mobile)
- 40 covered mirror positions
- Azimuth & Elevation pointing

Radiometer Tower & Control Box = Guy Wires & Leveling



- Articulated Radiometer Head
- Spectrometer 350-1000nm
- SWIR Radiometer with (8) Filter bands (0.9-2.5um)
- On-board Calibration sphere 0.3-2.5um

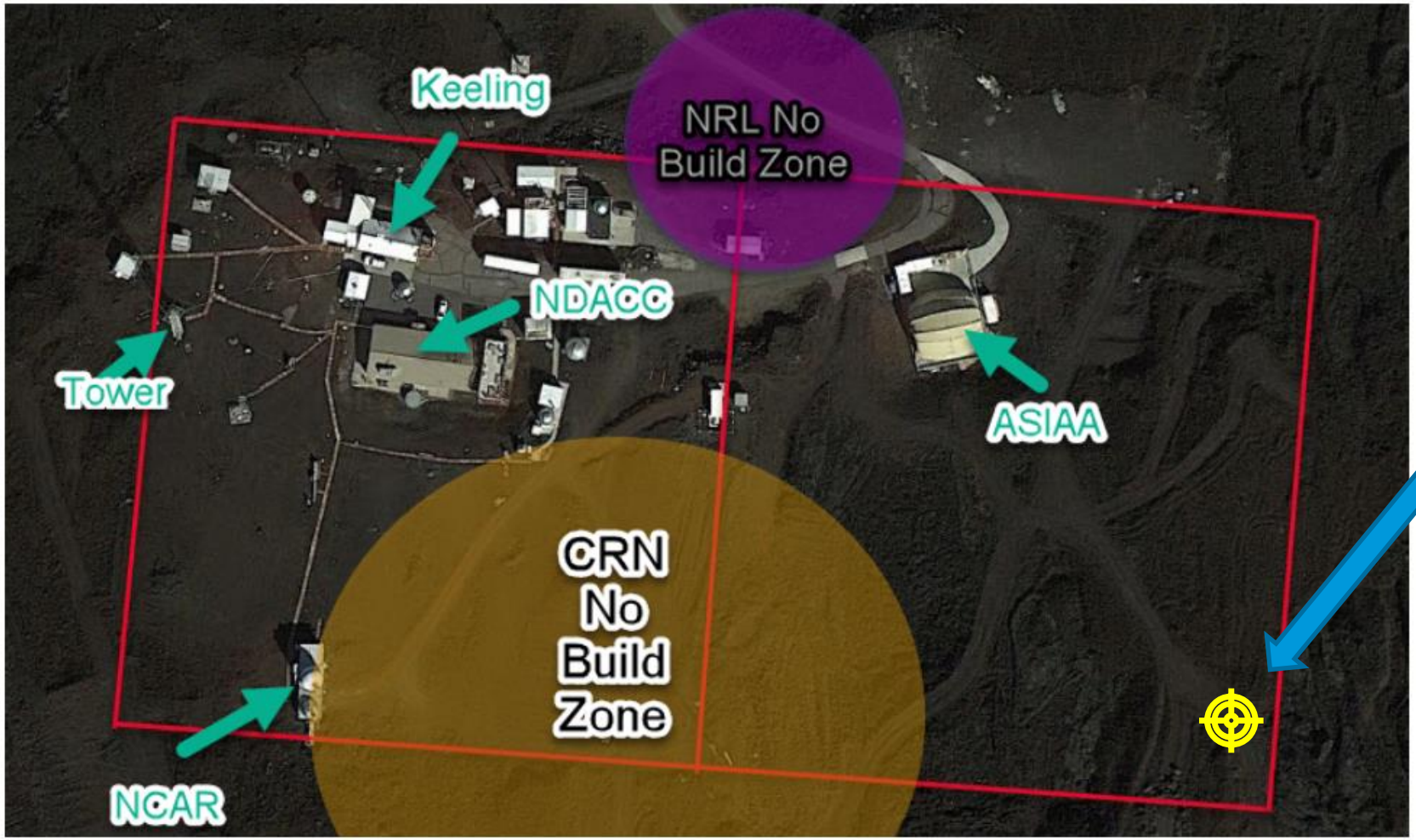
Solar Array & Communications



All Network activation is through cellular/satellite network connection

FLARE system requires no power infrastructure

Mauna Loa Observatory Site – 8 acres total



The red lines show MLO's property boundary (note that NOAA has two 4-acre parcels).

The yellow area is designated as a "No Build Zone" for the NOAA Climate Reference Network (CRN) project.

The purple area defines the "No Build Zone" for the Naval Research Laboratory (NRL) projects.

MLO FLARE location:

Away from structures in 6% reflectance lava field.

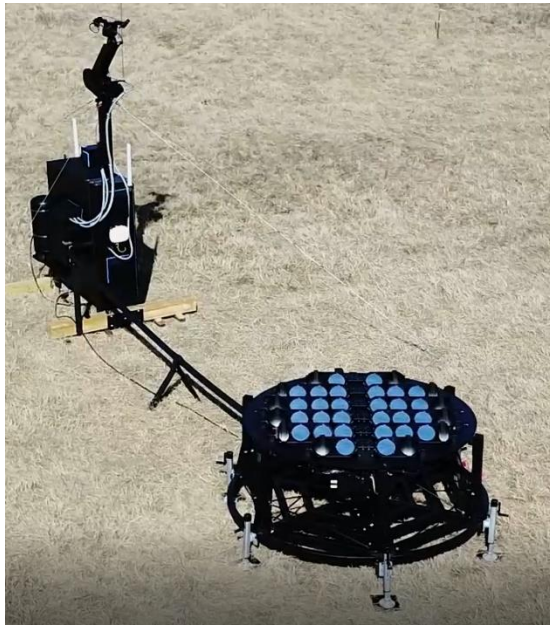
FLARE Installation Logistics

- 7-Pixel Diameter minimum area with *generally* uniform dark background for best results
  - 30m = ~200m Diam. Area
- Current Design & Future Concepts
  - 0.3m to 50m in current designs
  - Can be scaled to smaller (<0.3m) and larger pixel sizes (>50m).
- Each FLARE Node is part of the FLARE Network: Accessible to all customers
  - Priority access to partner organization funding node build
  - Node operation and maintenance by Labsphere
  - Seeking joint funding efforts
- Data can be made free / reduced charge / preferential access for science team projects.
- Can be a Public (Govt) / Private partnership
- European FLARE site build = European Entity (contracting purposes)
  - HALMA, parent company of Labsphere, is a worldwide company with European Offices

FLARE Nodes

- **Alpha Node**
  - Arlington, SD
  - SDSU Evaluati partnership

- **Beta Node**
  - Ft. Worth, TX

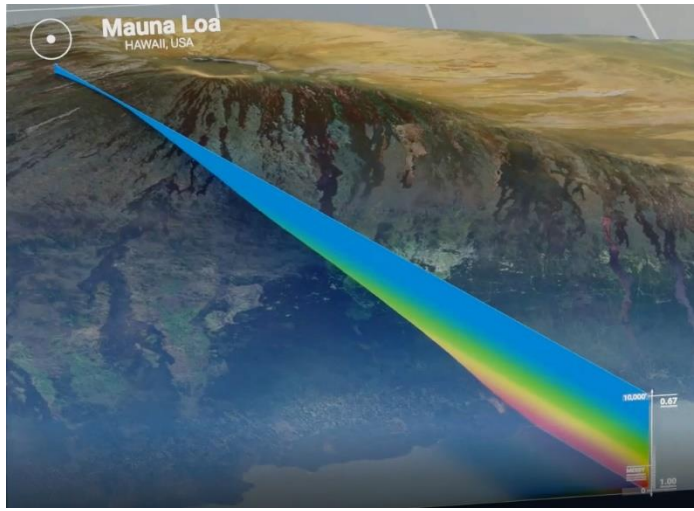


FLARE Development

- **Mobile Node Update on Roadmap**
  - Prototype at Beta site

- **Custom Campaigns**
  - Manual campaigns for targeted geometry
  - Commissioning Projects - individual assets or constellations
  - Lamasquere?

- **Future Nodes**
  - **Mauna Loa (3300m)**
  - Railroad Valley Playa, NV
  - Tenerife, Canary Isl. (ESA)
  - Atacama, Chile (ESO)
  - Pinnacles, Australia
  - Gobabeb, Namibia



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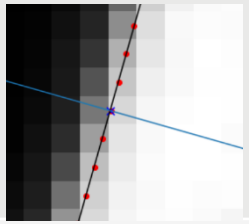
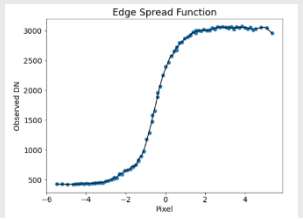
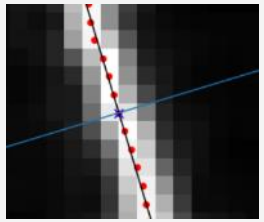
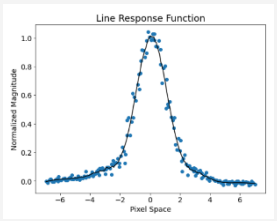
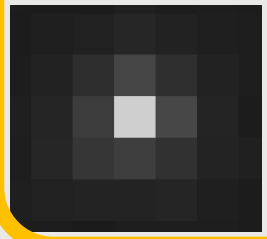
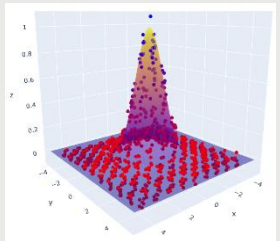
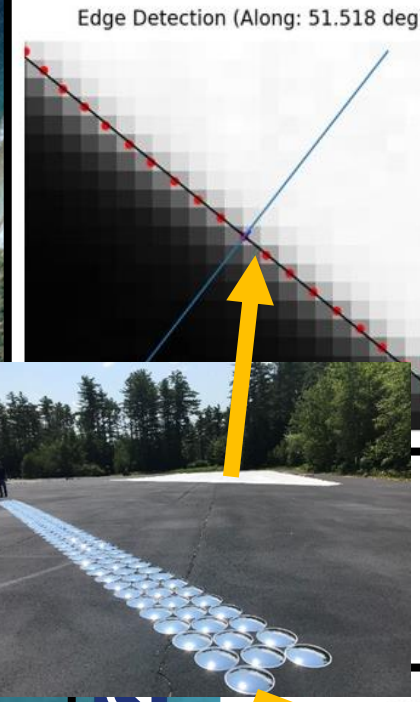
Benefits of FLARE to CAL-VAL Sites

On-Orbit Spatial Quality Assessment Overview

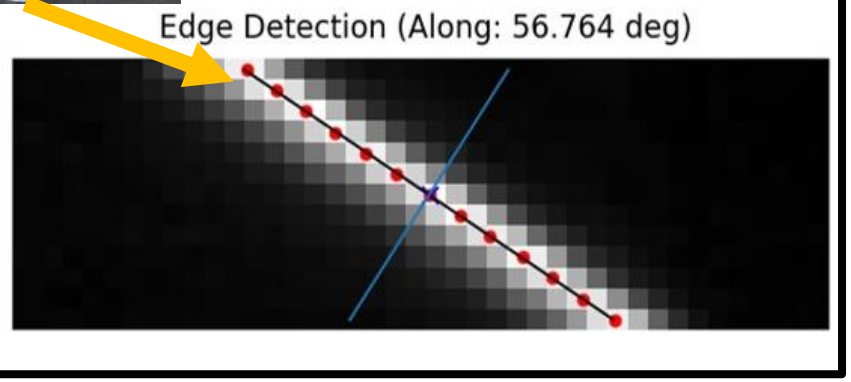
Method	Procedure	Advantage	Disadvantage
Edge Method  	• Indirectly estimates the LSF • Both methods provide similar results	• **ISO is a standard procedure** • Robust • Easy to implement	• Derivative • Edge modeling • **Introduction of noise** • BRDF effects • Large footprint • Directional layout
Line Method  	• Directly estimates the LSF	• **No numerical derivative** • Lower noise • Single image analysis	• **Line width** • Directional layout • Small GSD Satellites
Point Method  	• Directly estimates the 2D PSF	• Non-directional • Consistent • **True Impulse Response** • Small footprint	• **Not oversampled** • Multiple mirrors or overpasses

On-Orbit Spatial Quality Assessment: Edge, Line and Point Target Overview

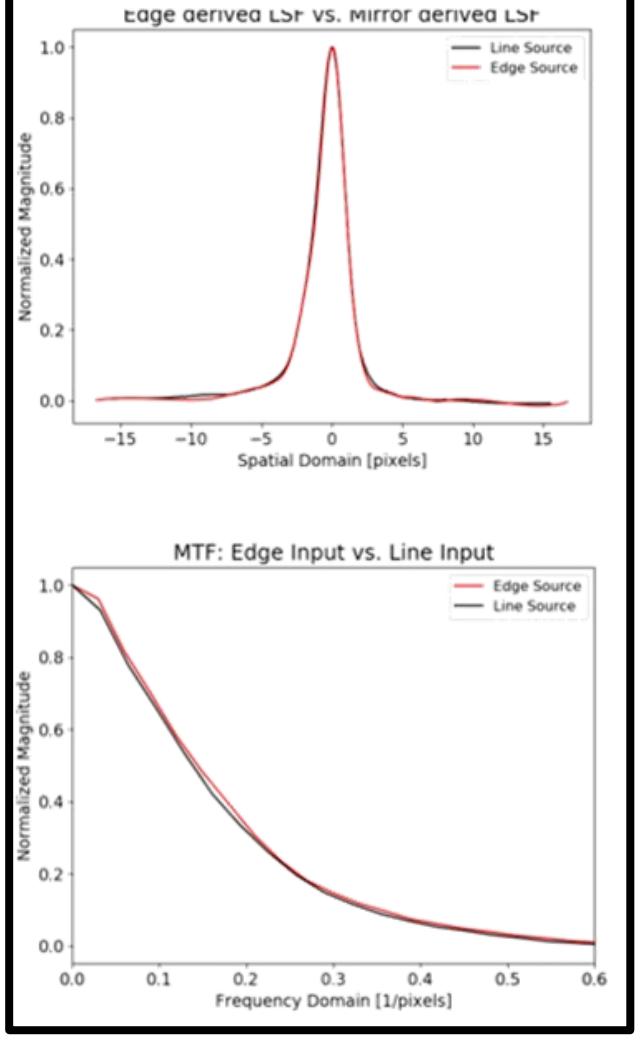


Edge Target

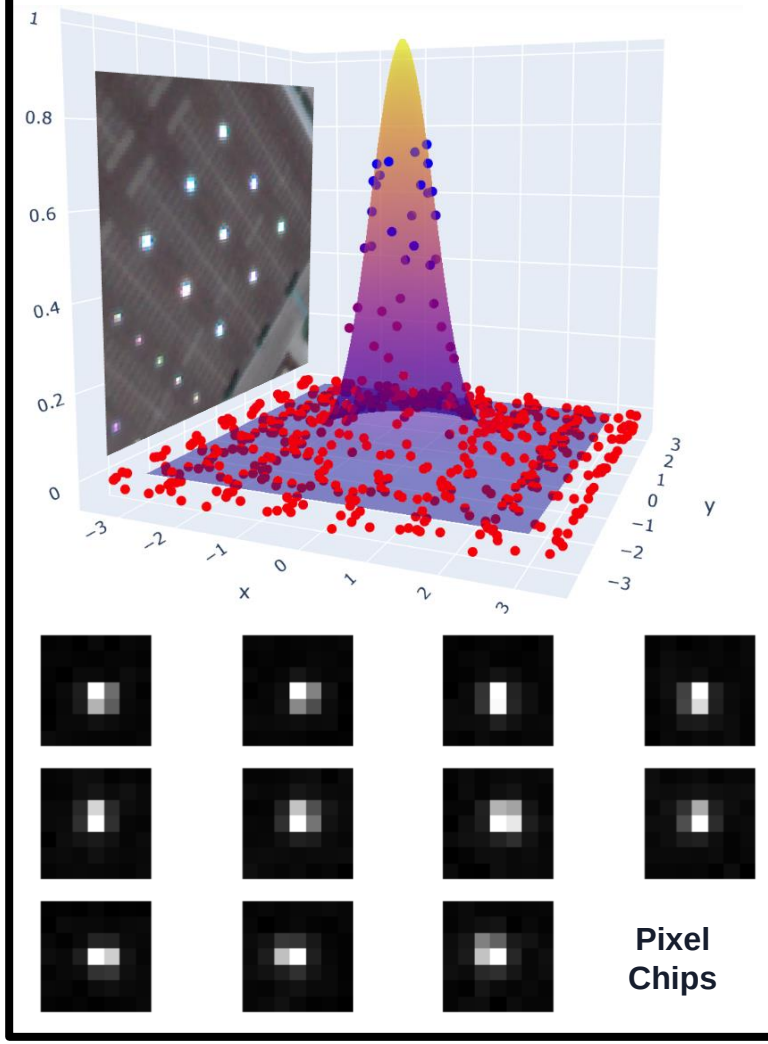
Mirror Line



Mirror Line vs Edge Target

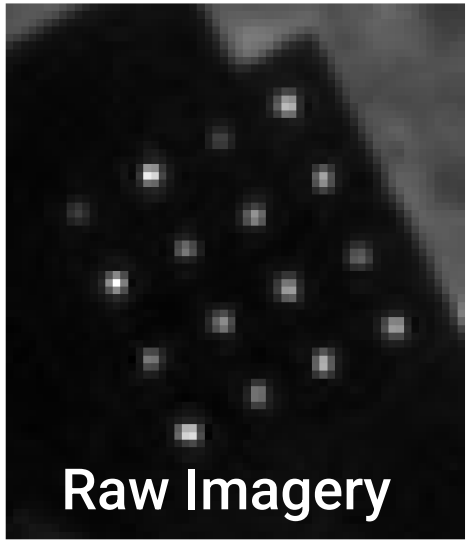


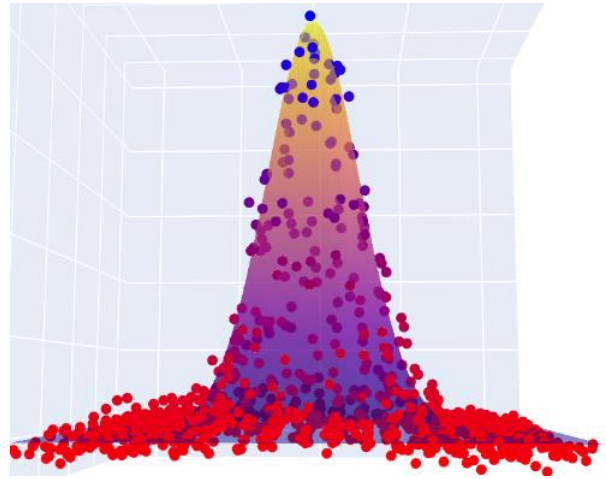
FLARE Point Response Function

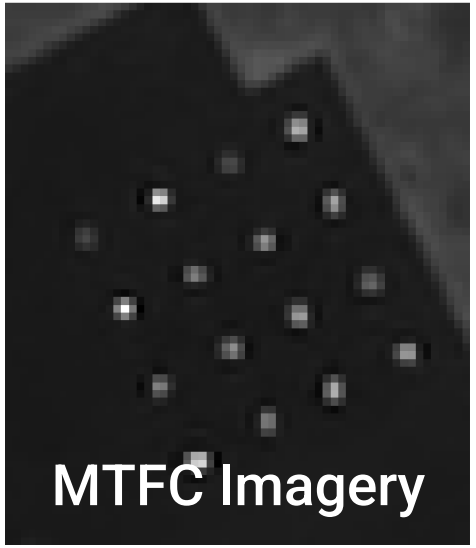


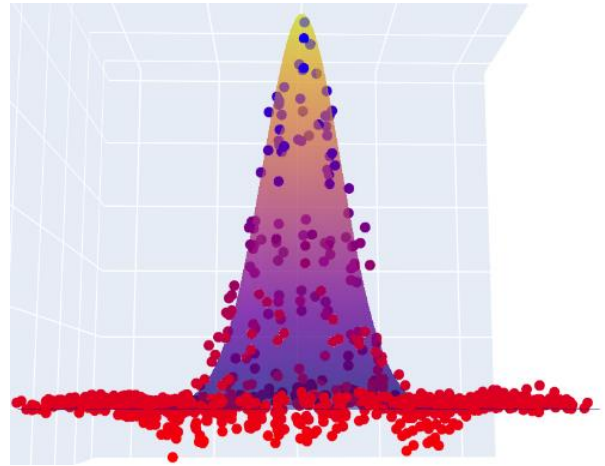
Point Sources = Processing Insights

- Point Response Function
- Ground Control Points (<2cm)
- Assess algorithms for MTFC
- Developing kernels for deconvolution at L0, L1, L2, etc.
- Insights and forensics on images



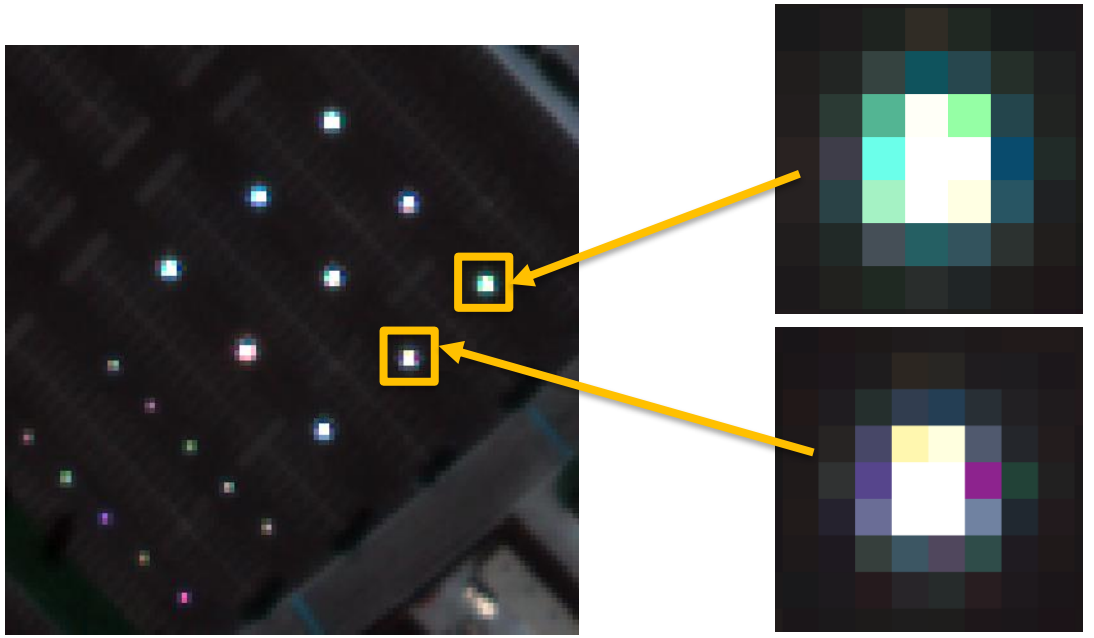




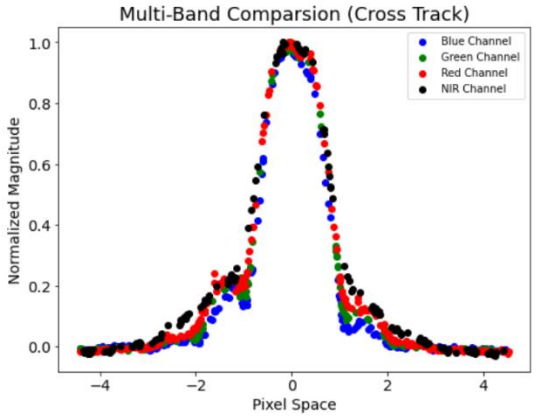


Automatically detect/characterize reconstruction or enhancement processing with FLARE

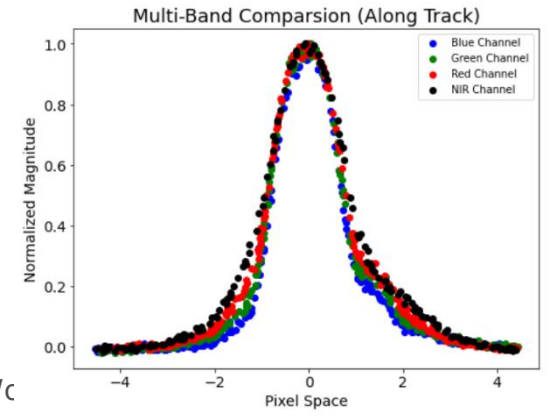
- Small target radiometry method
- Point Source = Omni-Directional Insight in one Image
  - Cross-Track
  - Along-Track
- Band dependence readily visible and quantifiable in Image Quality (IQ) evaluations
- Variance in spatial resolution per band are *automated and quantified.*



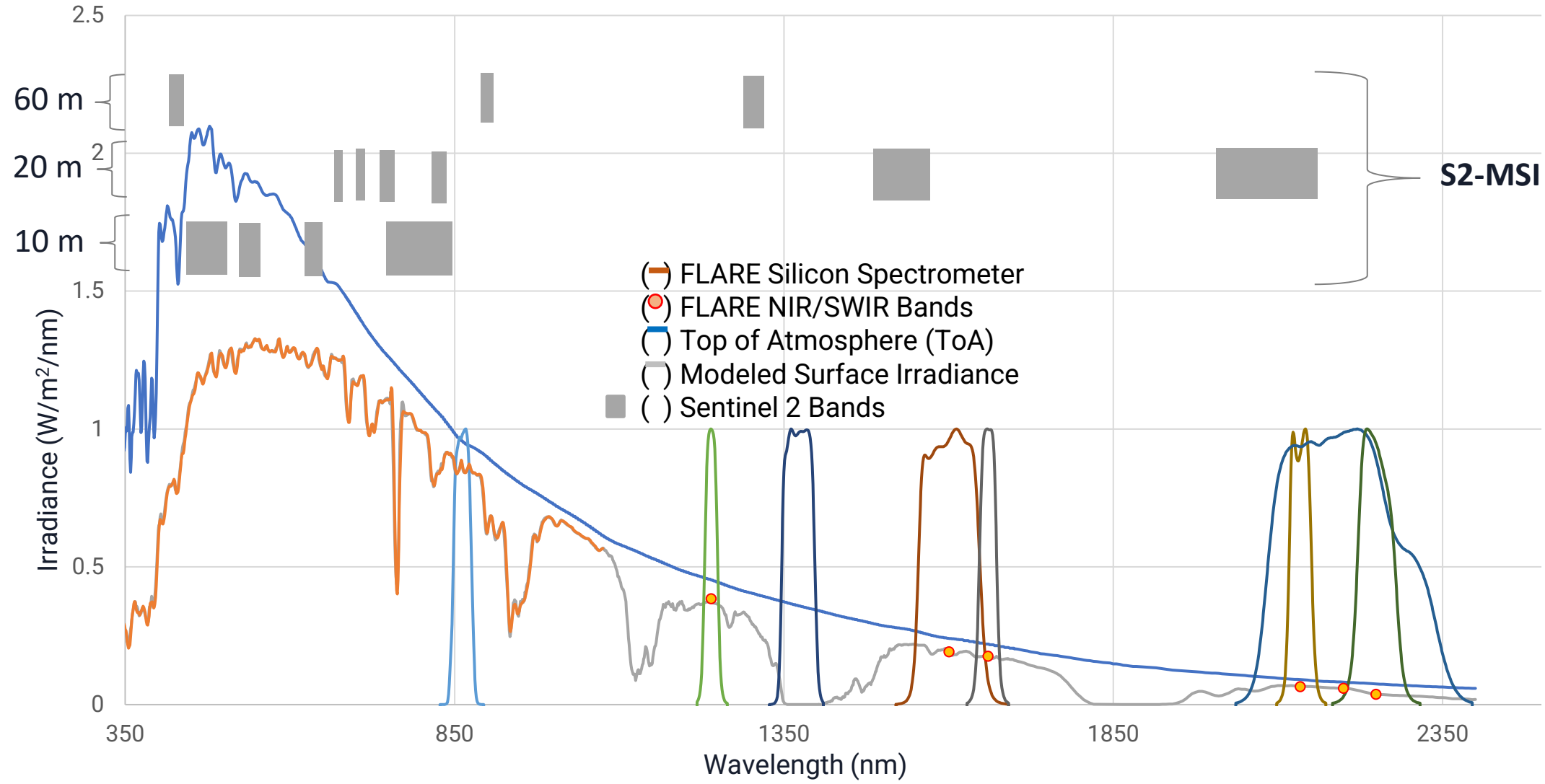
Cross-Track



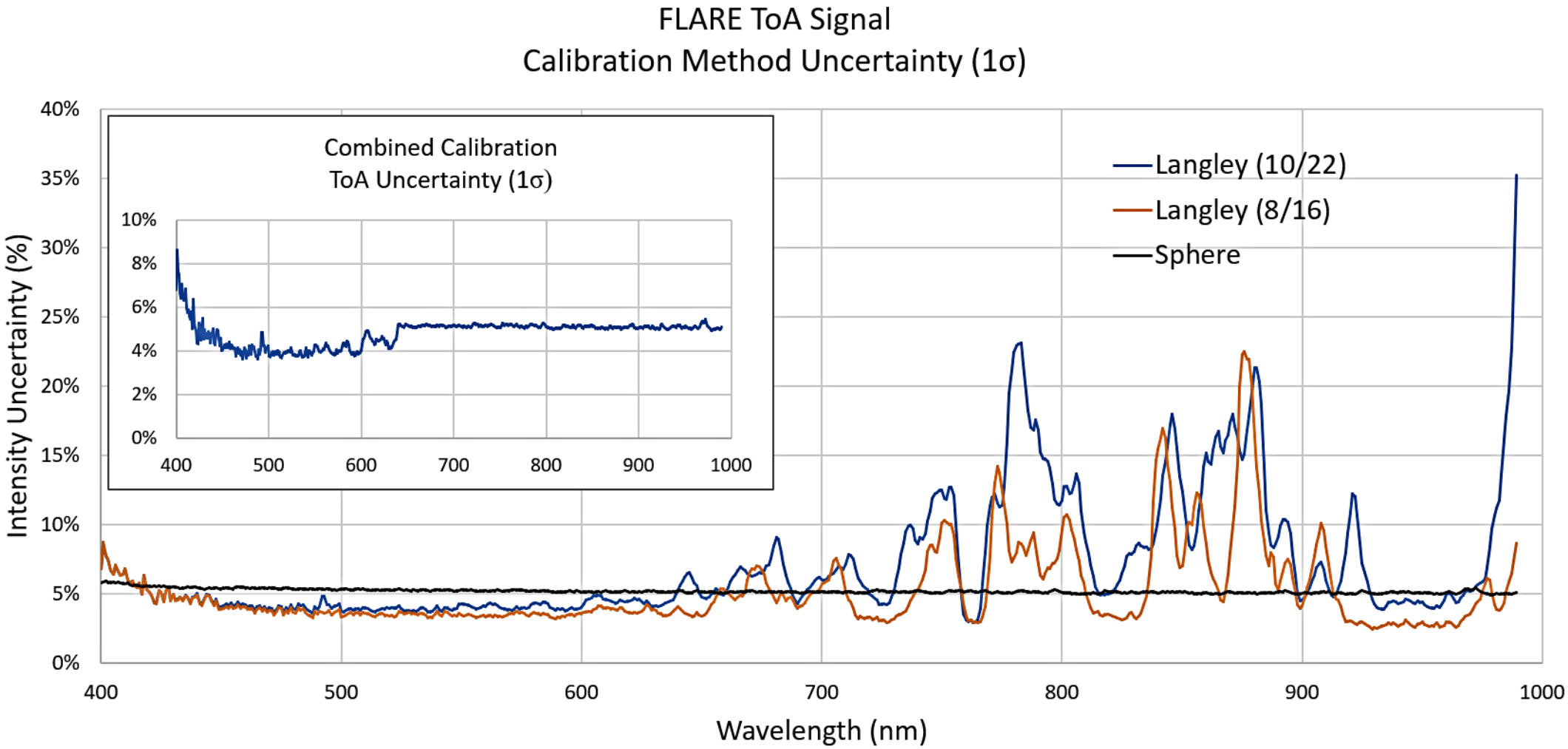
Along-Track



FLARE Radiometric System vs. Sentinel 2 bands



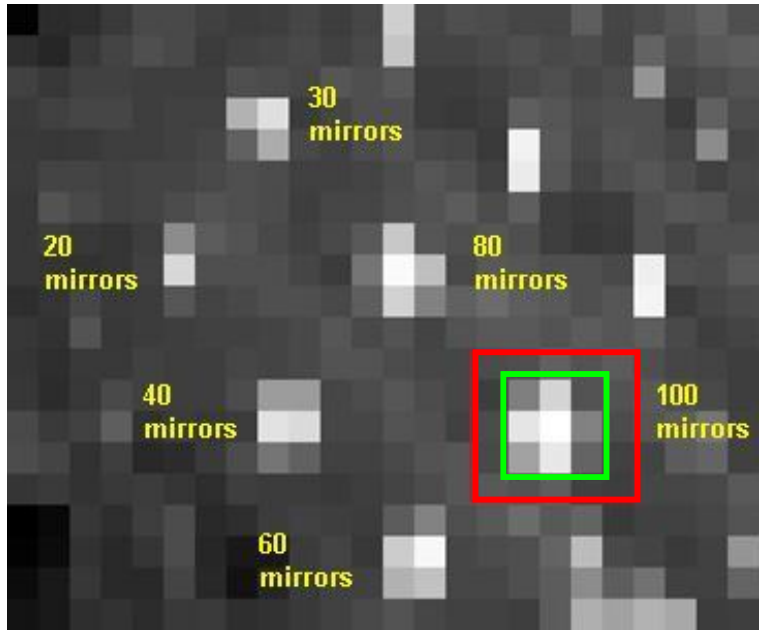
FLARE Top of Atmosphere (ToA) Signal Dual Traceability - Langley & Sphere Methods



Full SWIR Uncertainty Analysis Coming Soon

Mirror Empirical Line Method (MELM)

Different mirror in targets = multiple levels in a scene



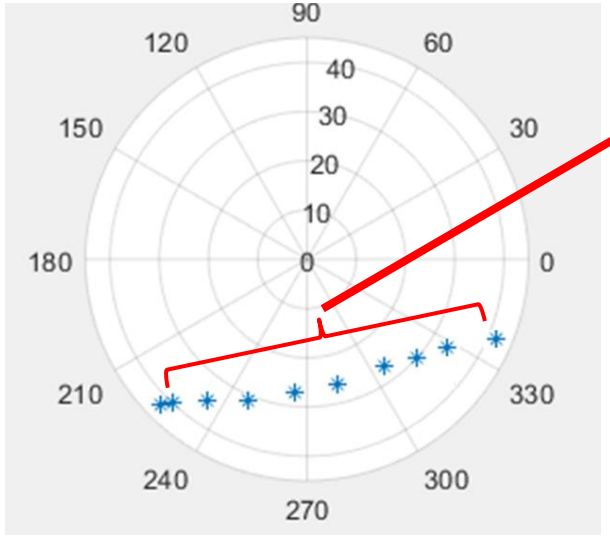
Spectral Band	Slope: DN/Mirror	R^2
Blue	17.9	0.9898
Green	25.2	0.9972
Red	22.8	0.9917
NIR	19.8	0.9965

Results for Sept. 10, 2009 IKONOS collect.

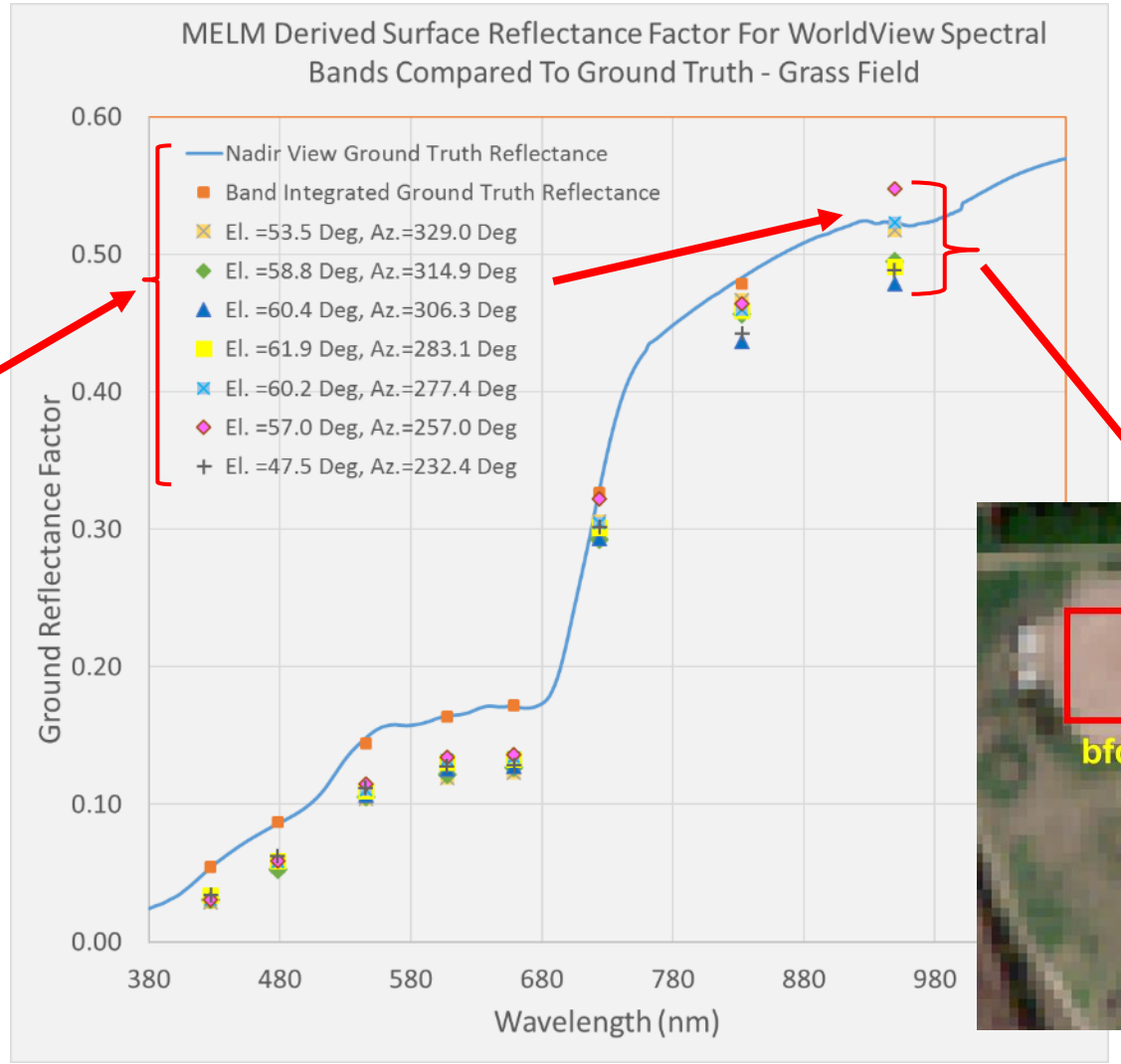
- MELM via Multi-LOOK events or Multi-Points in scene both provide
  - **Low Reflectance signal verification**
  - **Gain**
  - **SNR**

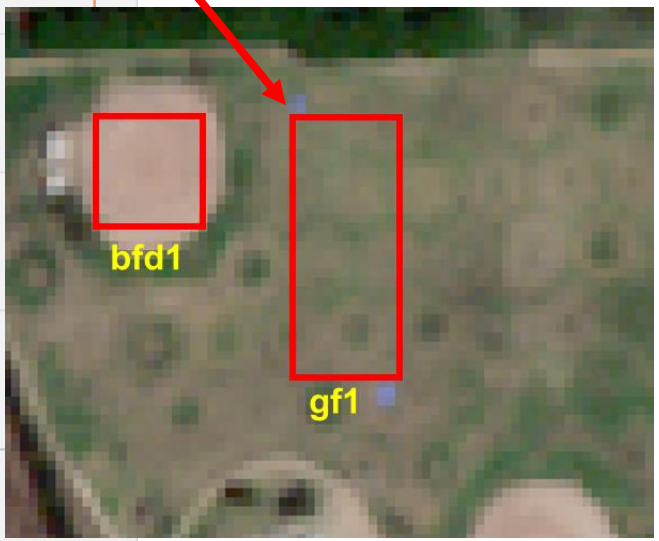
BRDF Validation via Pointing Angular Overpass

A FLARE target is a constant radiometric reference that tracks the satellite
= BRDF of *anything in the scene* can be determined



Pointing Satellite Overpass & multiple angle image collections





FLARE Primary Benefits to a CAL-VAL Site

New and independent method vs. classic vicarious calibration

- Radiometry & Spatial in ONE EVENT
- Fully automated synthetic target
- Small or Large target radiometry
- Impulse system response
- Band registration
- Geospatial Control Points
- Applies to all levels (L0, L1, L2, etc.)
- One-Sigma <3.5% VNIR Uncertainty

Scales and applies to Airborne, UAV & Satellite calibration (mirror changes)

- Common radiometric calibration & harmonization for all data sources
- **FLARE** can be scaled from 0.01m to ≥1km GSD Pixels (OLCI, MODIS, etc)

FLARE Advanced Benefits to a CAL-VAL Sites

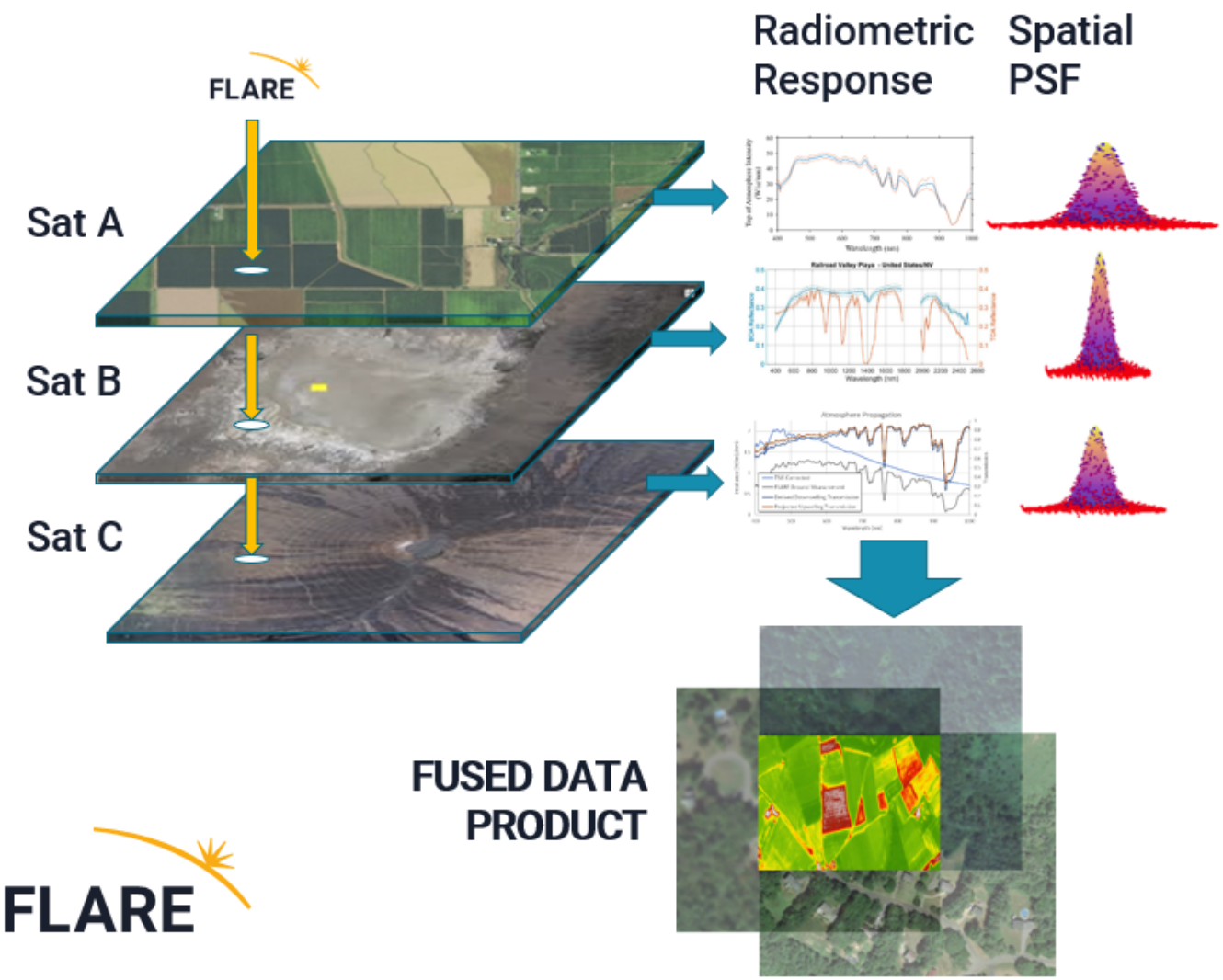
Added CAL-VAL Capabilities

- BRDF Ground Truth
- Empirical Line Method
  - SNR, Gain, Dark Target verification
- Point Method yields
  - PRF, GSD, MTF & NIIRS
- Partially Cloudy = OK to Use FLARE
- Polarization / Synthetic Spectral
- Mobile Stations are possible
- Dedicated campaigns (Lamasquere?)

Atmospheric measurements on FLARE Sites in the Network

- Quantifies atmosphere to get to surface reflectance
- **MODTRAN** enabled
- Compliments/Enhances AERONET
  - Hyperspectral / SWIR
  - Hyperspectral atmospheric correction (Inversion)
  - Chemo-Optical data sharing with local aerosol/radiometric

Calibration for ALL Assets = Enabling ARD



- **Go right to surface reflectance**
  - Atmospheric characterization and removal
  - Sensor response to known signals
  - BRDF
- **Provide a stable, traceable reference for any GSD/FOV**
  - Understand Geometry – PSF, MTF
  - Understand Radiometry – 0.35-2.5um
  - Precise Geo-location (GCP)
- **Harmonize different EO constellations & architectures**

- **Time Series / Change Detection**
- **Monitoring / Diagnostic Efforts**
- **Optimize ML/AI results**

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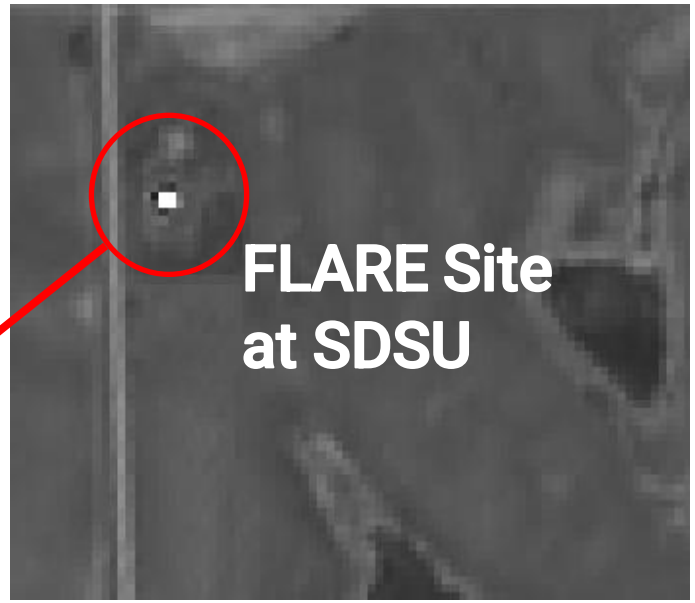
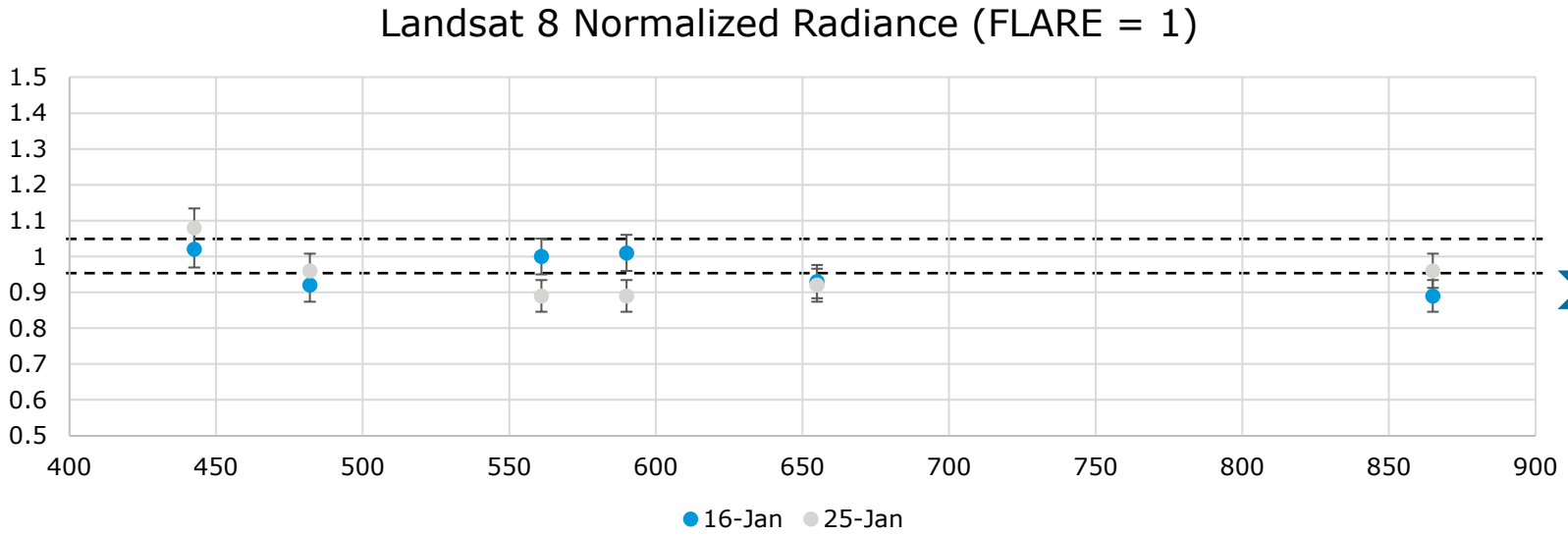
Examples of FLARE Results

Sentinel 2A: ToA Radiometric Comparison Lambertian Target vs. FLARE (SDSU)

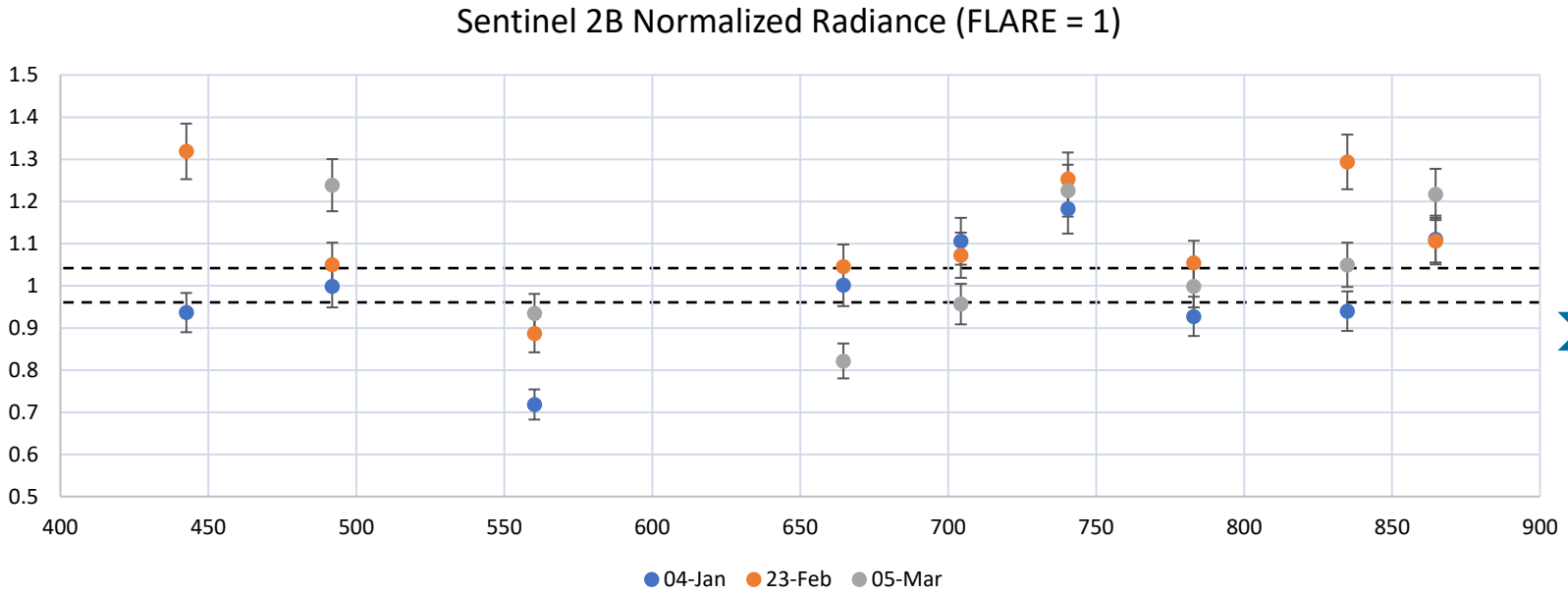
CW	Band	Diffuse Lambertian ToA Radiance Uncertainty (1σ)	FLARE SPARC ToA Intensity Uncertainty (1σ)
443	Band 1 - Coastal Aerosol	2.7%	2.2%
490	Band 2 - Blue	3.1%	2.7%
560	Band 3 - Green	4.0%	2.6%
665	Band 4 - Red	5.4%	4.3%
705	Band 5 - Red Edge	4.8%	4.8%
740	Band 6 - Red Edge	3.9%	4.9%
783	Band 7 - Red Edge	3.9%	6.3%
842	Band 8 - NIR	3.8%	6.1%
865	Band 8A - Red Edge	3.6%	7.0%
945	Band 9 - Water Vapor	8.8%	2.2%



Temporal Trending on Landsat 8 and Sentinel 2B



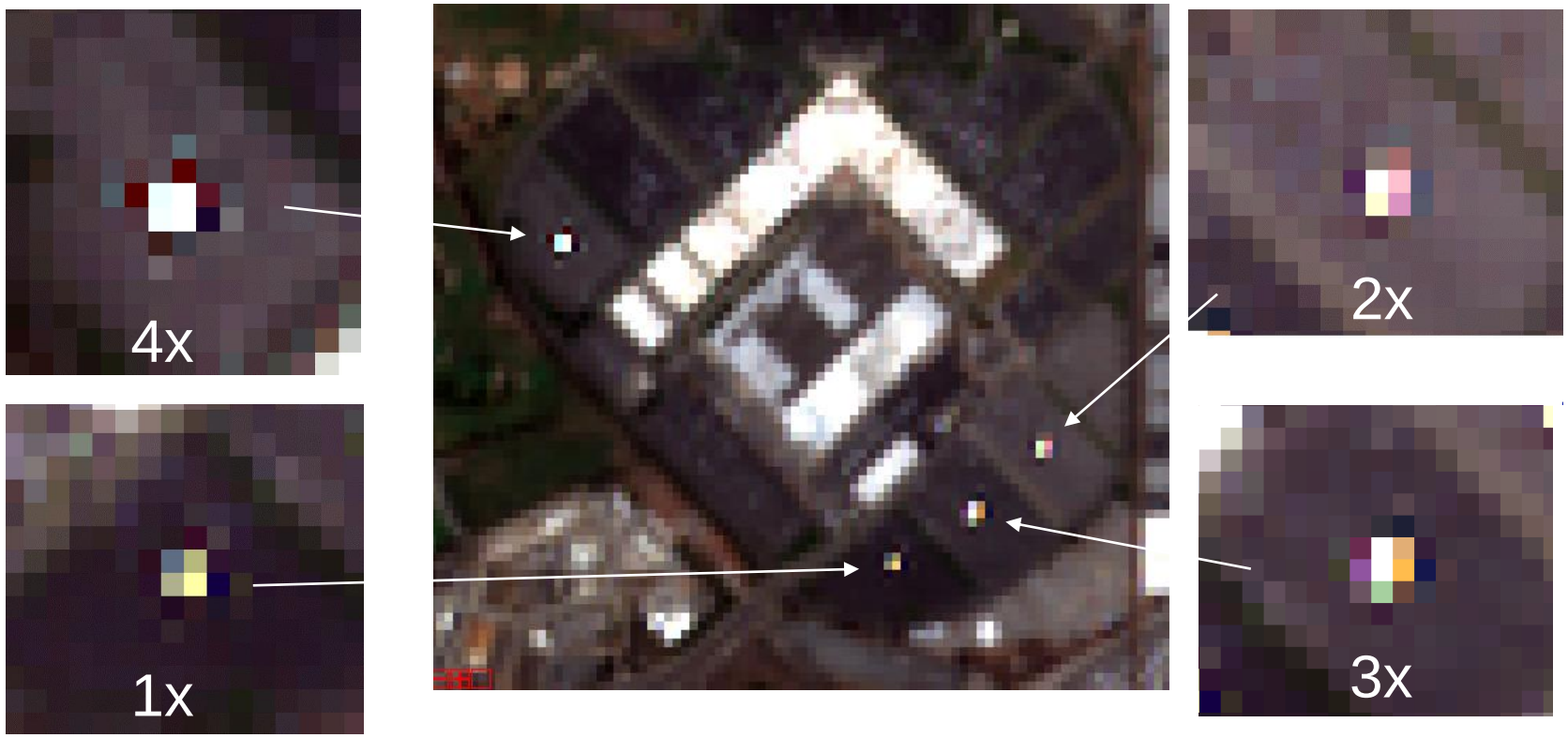
			LS8/FLARE	
Band	CW	GSD	16-Jan	25-Jan
1	443	30	1.02	1.08
2	482	30	0.92	0.96
3	561	30	1.00	0.89
4	655	30	0.93	0.92
5	865	30	0.89	0.96
6	1609	30	1.01	0.93
7	2201	30	1.02	1.28
8	590	15	1.01	0.89



			S2B/FLARE		
Band	CW	GSD	04-Jan	23-Feb	05-Mar
1	443	60	0.94	1.32	1.64
2	492	10	1.00	1.05	1.24
3	560	10	0.72	0.89	0.93
4	665	10	1.00	1.05	0.82
5	704	20	1.11	1.07	0.96
6	740	20	1.18	1.25	1.23
7	783	20	0.93	1.05	1.00
8	835	10	0.94	1.29	1.05
8A	865	20	1.11	1.11	1.22
9	945	60	1.80	9.91	6.20

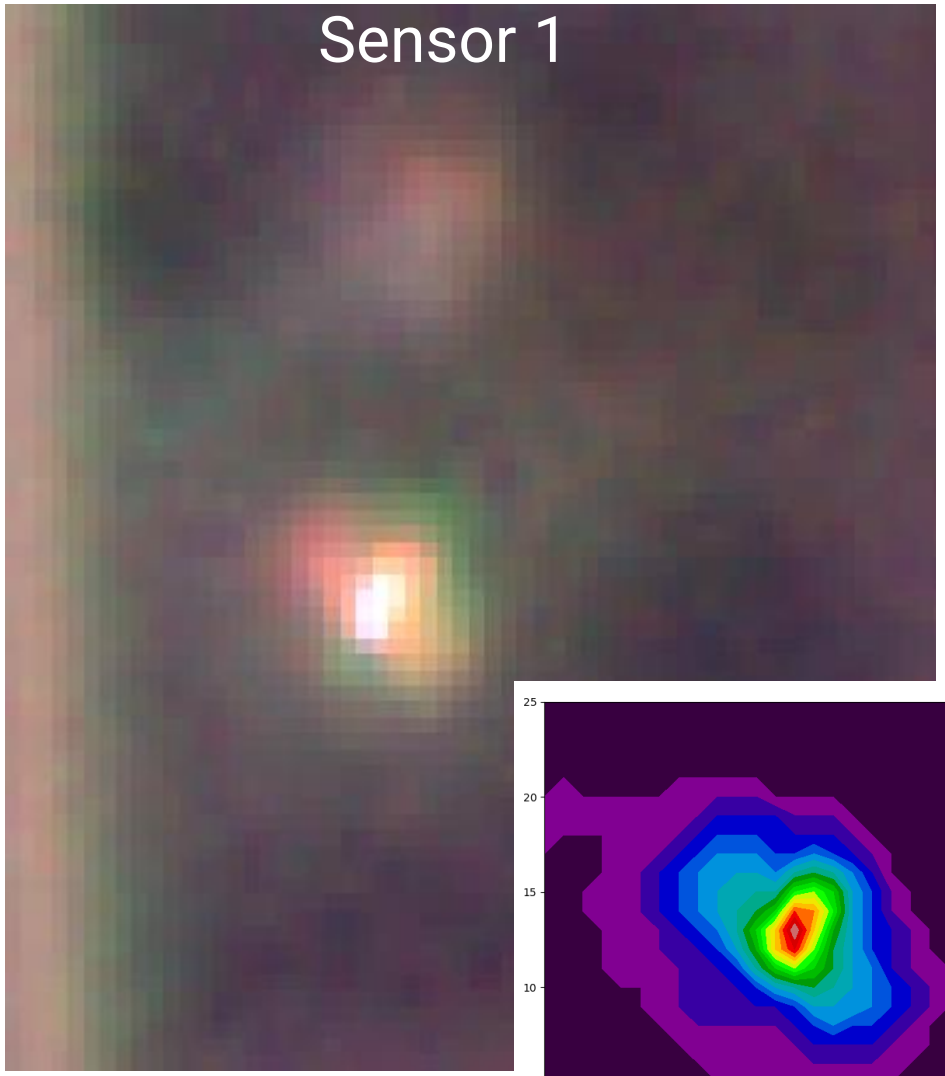
Sentinel 2A 10 m GSD Image of SPARC Targets Level 1C

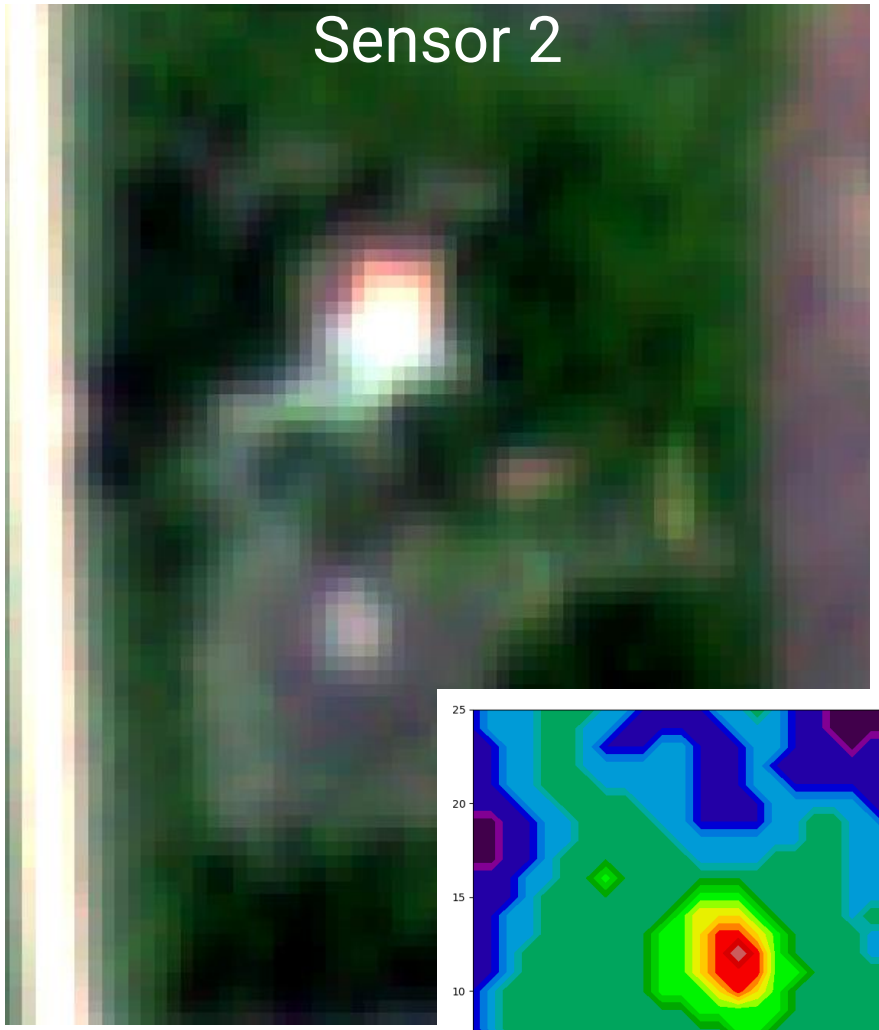
- Targets are subpixel, > 1.5 m in size.
- Intensity step is incremental, 1 to 4 without saturation.
- Targets visibly affecting pixels up to 6 x 6 pixel area (includes resampling for orthorectification).
- Coloring in the wings of the profile indicates that the effects of the resampling are **band dependent**.

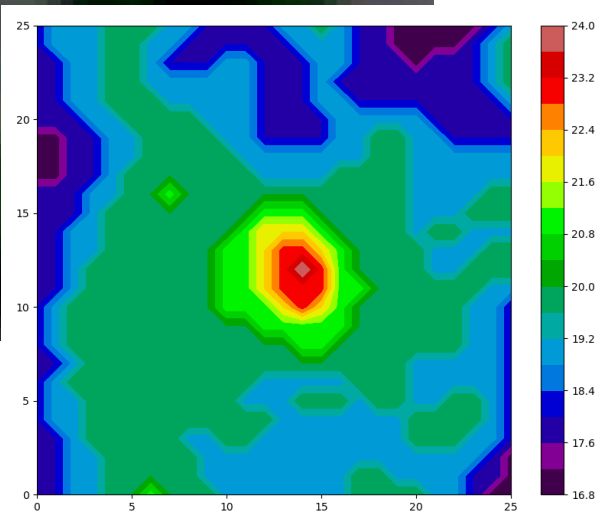


- Resampling methods need to be improved so as to use the PRF/MTF information to direct the energy back into the pixel that contains the target.

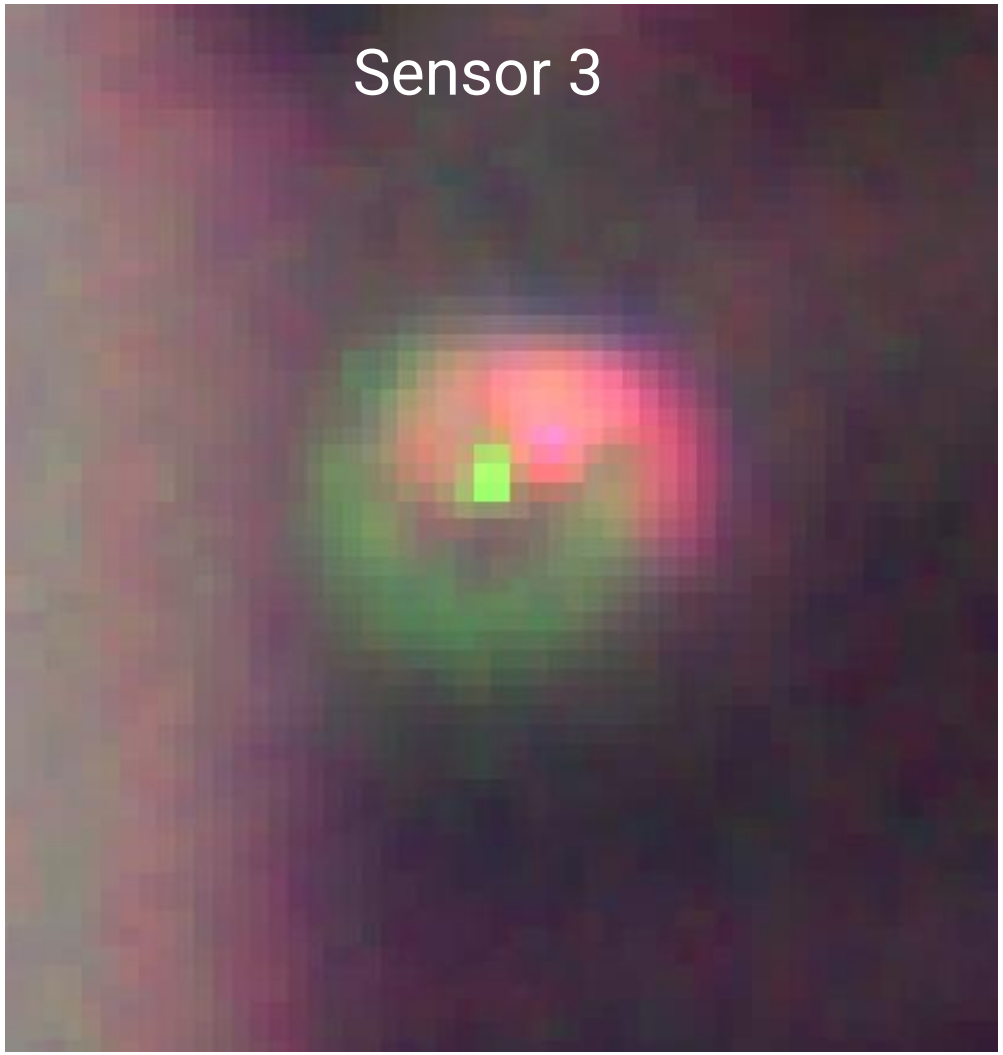
Small Satellite Constellation – Example 1 (3m GSD)

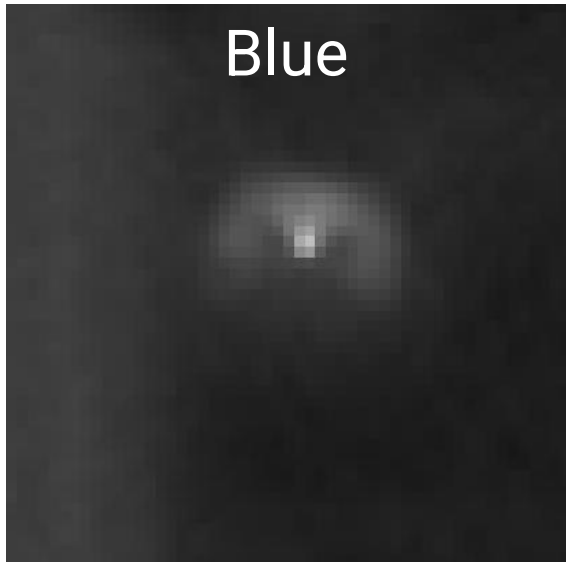


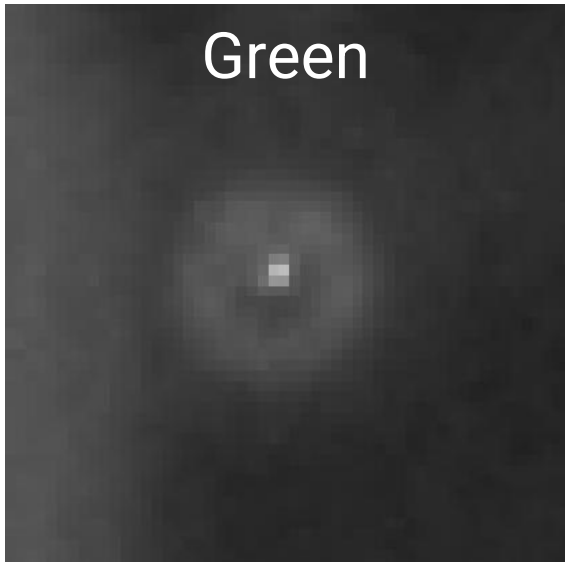


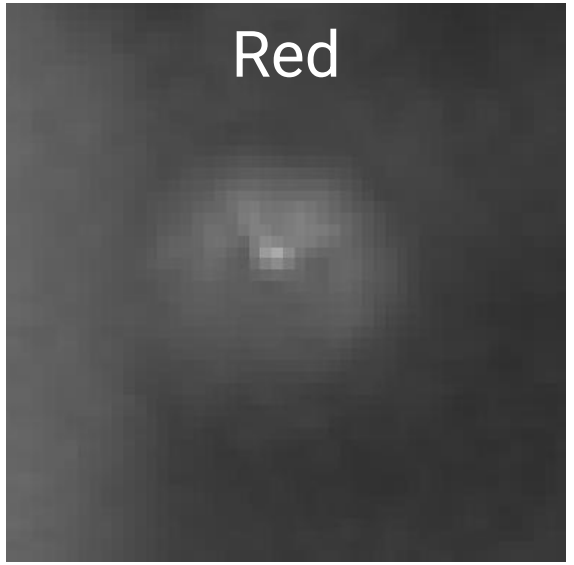


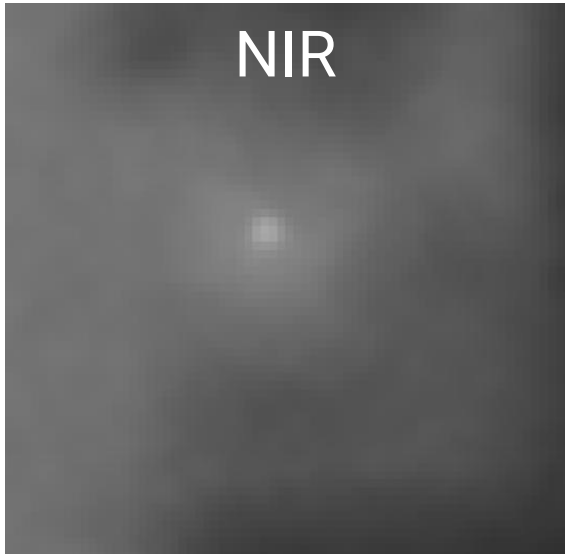
Small Satellite Constellation – Example 2 (3m GSD)



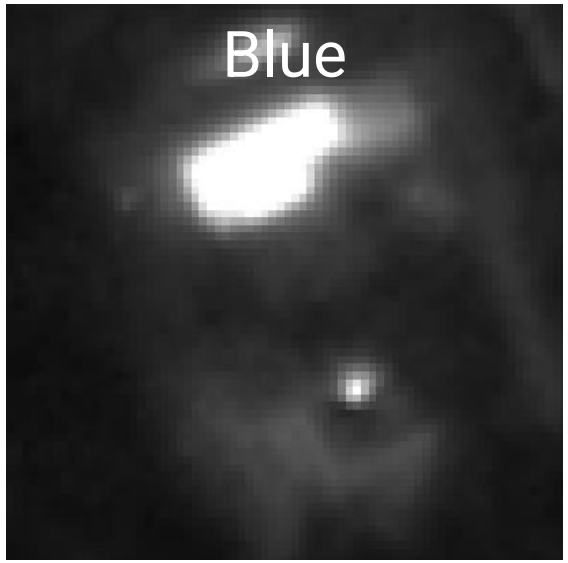


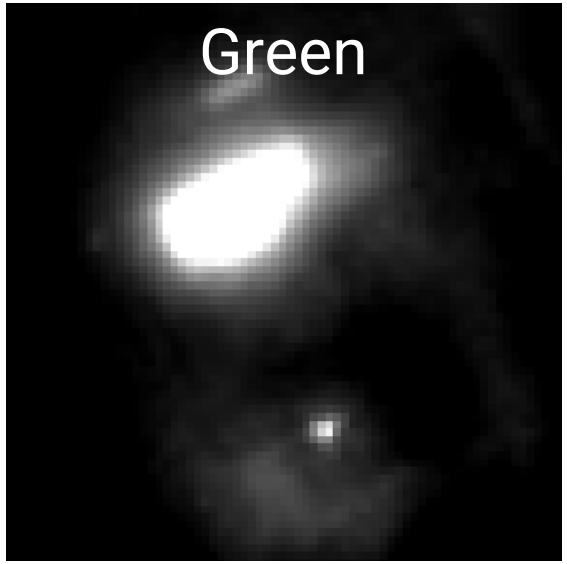


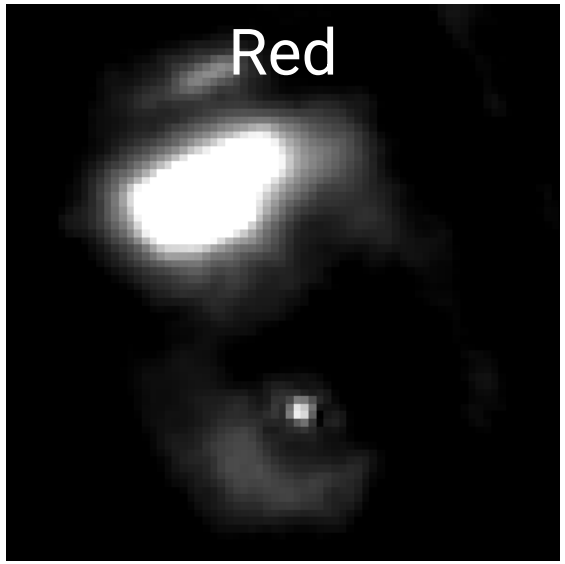


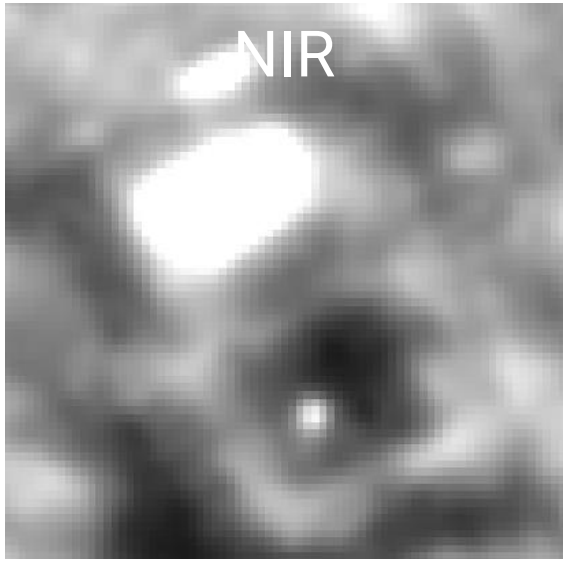


Small Satellite Constellation - Example 3 (3m GSD)

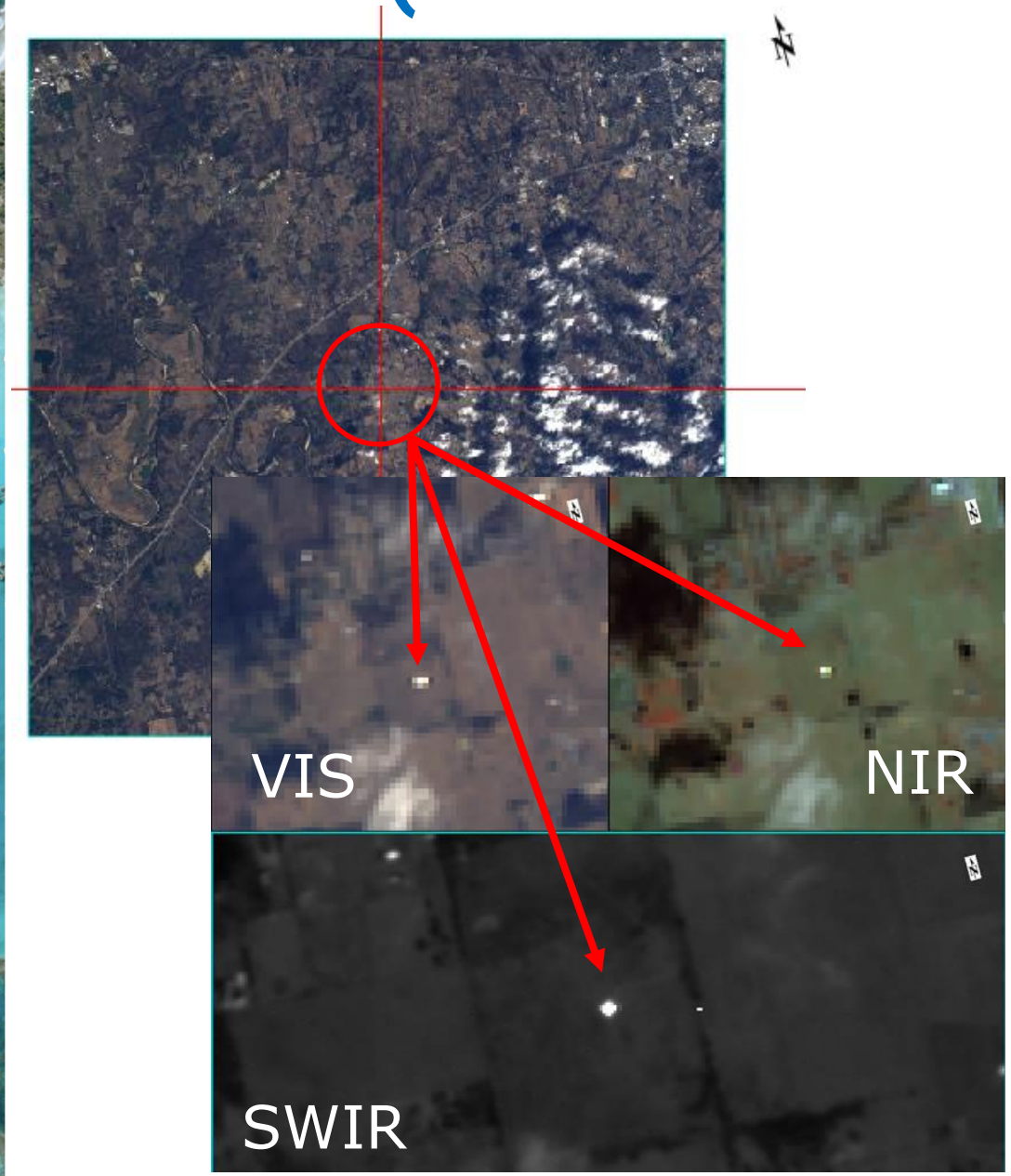


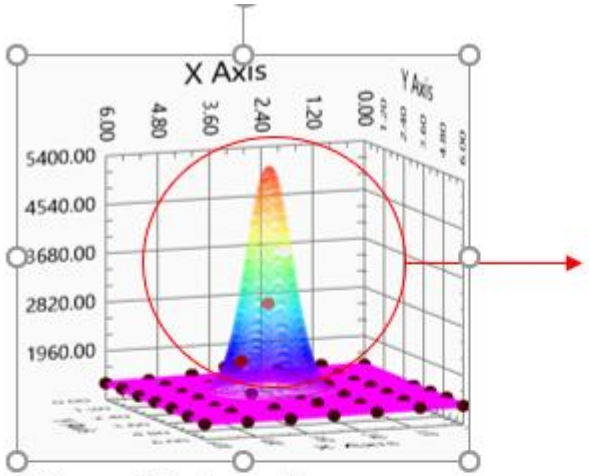






PRISMA (FLARE Beta Site) - >220 Bands





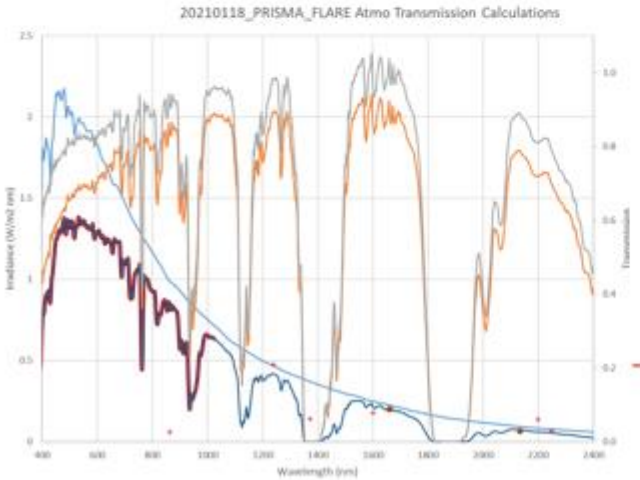
Signal Extraction

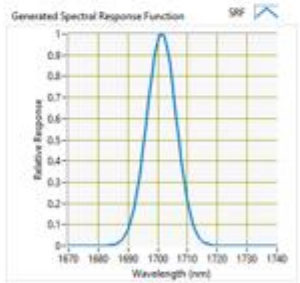
DN Scaling

Radiance per Band

Radiance per Band

SPARC Propagation



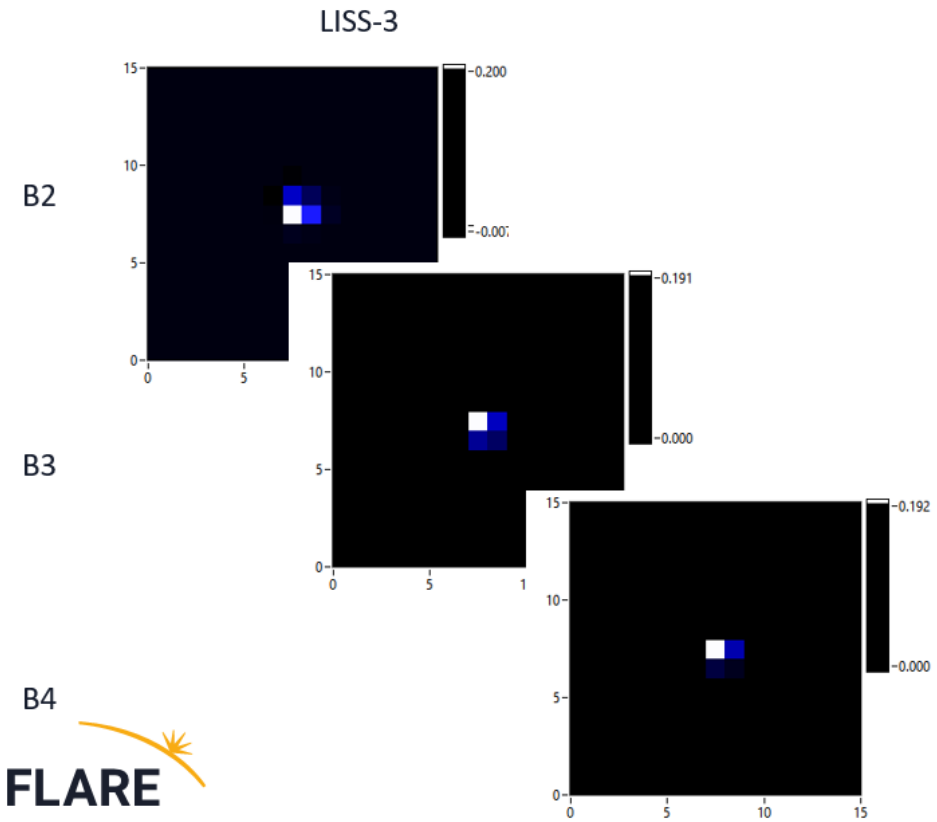


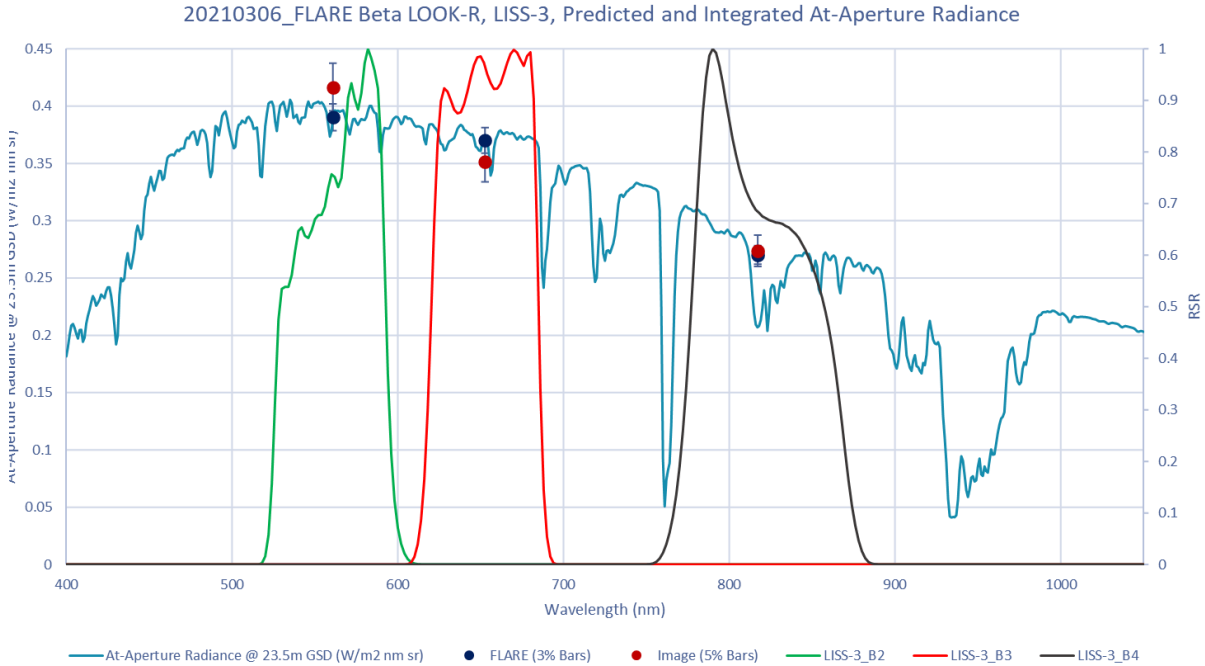
Band RSR

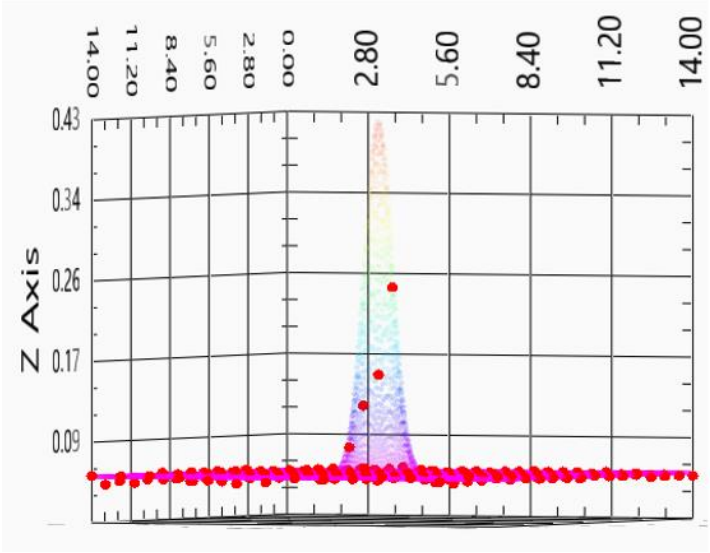
Spectral Values

Images Courtesy of Leonardo DRS

ISRO – ResourceSat3A (LISS3)

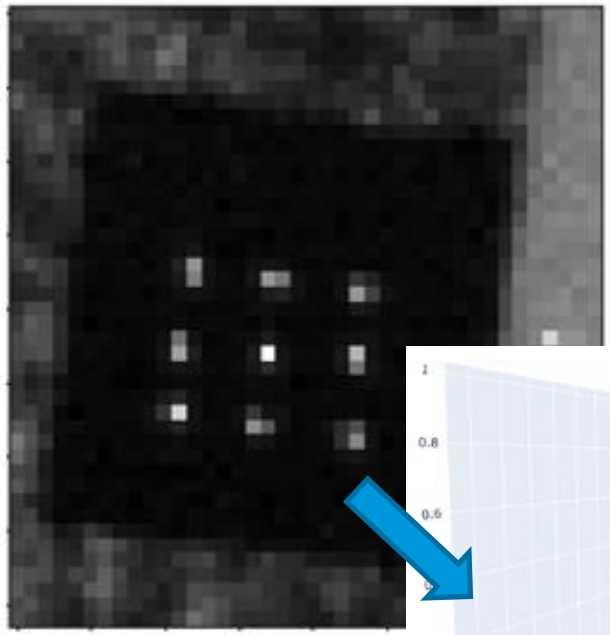


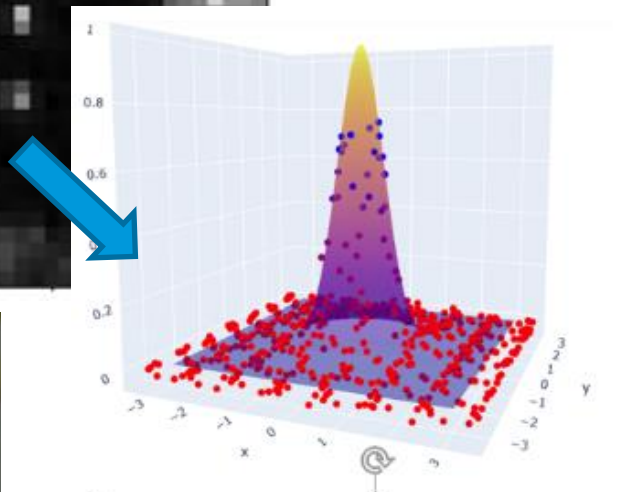




Hyperspectral UAV Example

GSD ~ 4cm





- FWHMx: 1.244 pix
- FWHMy: 1.242 pix
- RMSE: 1.48%

Images Courtesy of RIT DIRS Laboratory

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Better Calibration. Better Data. Better Decisions.

Thank you!

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