FLARE Satellite/Airborne Calibration Network Performance & Validation Progress Report

August 30, 2021

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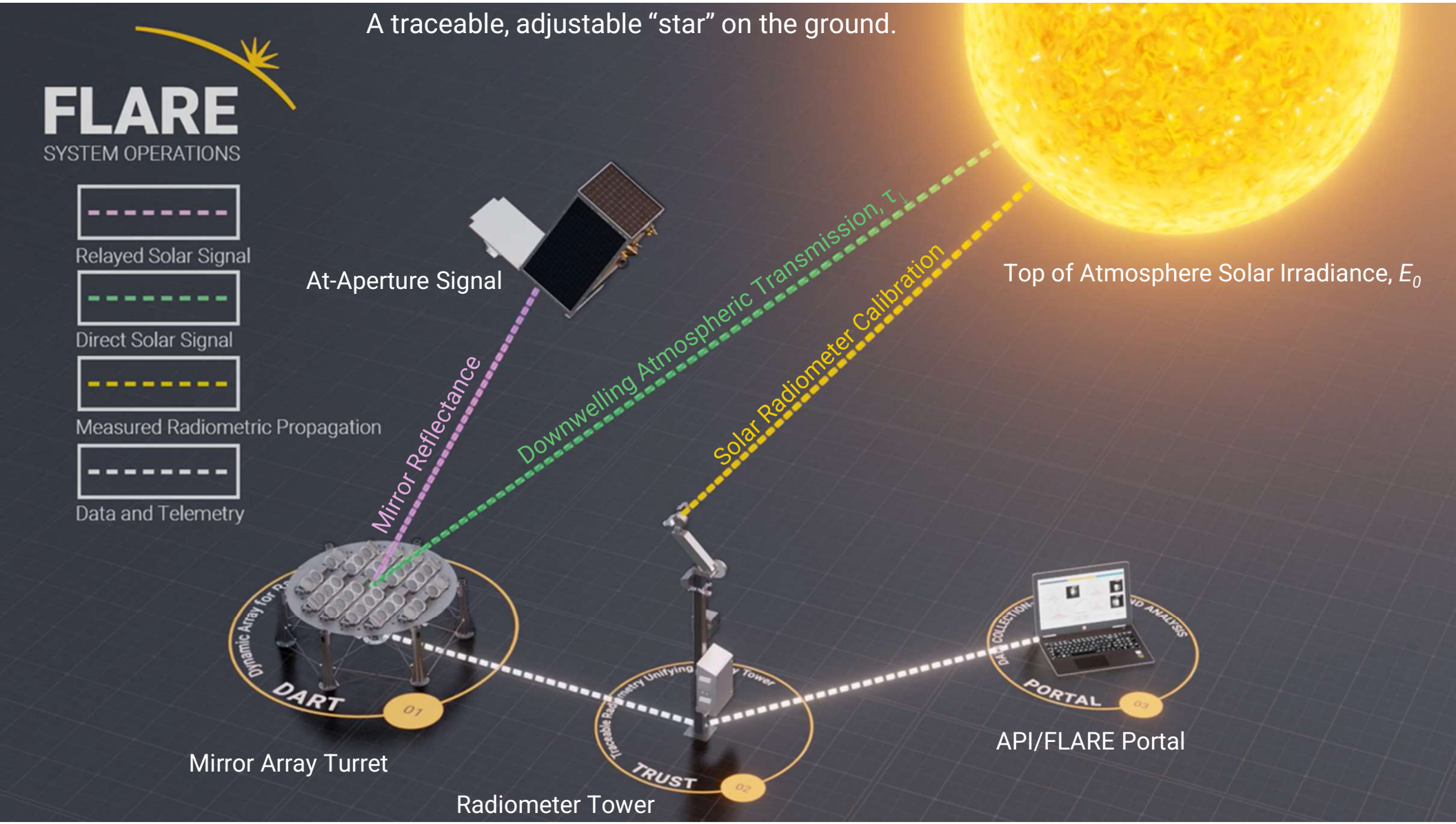
Better Calibration | Better Data | Better Decisions


A traceable, adjustable “star” on the ground.
FLARE
SYSTEM OPERATIONS
Relayed Solar Signal
Direct Solar Signal
Measured Radiometric Propagation
Data and Telemetry
At-Aperture Signal
Mirror Reflectance
Downwelling Atmospheric Transmission, $\tau_{\downarrow}$
Solar Radiometer Calibration
Top of Atmosphere Solar Irradiance, E_0
DART
01
TRUST
02
PORTAL
03
Mirror Array Turret
Radiometer Tower
API/FLARE Portal

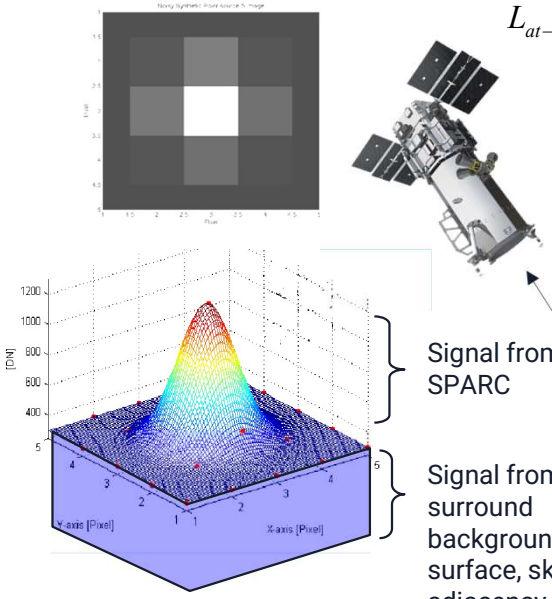
Lambertian vs Specular Targets

Target signal embedded in a uniform scene is elevated above the low spatial frequency background (sky path radiance, adjacency effect, stray light, etc.) and is separable

- Background becomes a bias and is subtracted out based on image data alone
- Sensor response to target radiance is integrated (DN) contained in the PSF
- Atmospheric, adjacency, multiple scattering effects reduce to transmittance only - measured with solar spectrometer coincident with overpass

$$L_{at-sensor}(\lambda,\theta_r) = \rho(\lambda,\theta_r)\tau_{\downarrow}(\lambda)\tau_{\uparrow}(\lambda)E_o(\lambda)\frac{R^2}{4GSD(x)GSD(y)}$$

Watts/(m² sr micron)/mirror



Signal from SPARC

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

The convex mirror acts as an aperture stop isolating the direct solar irradiance as the only contributor to the effective at-sensor calibration radiance

Direct Solar Irradiance

Target

Surround

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FLARE Radiometric Tower: VNIR Spectrometer & SWIR Bands

Dock

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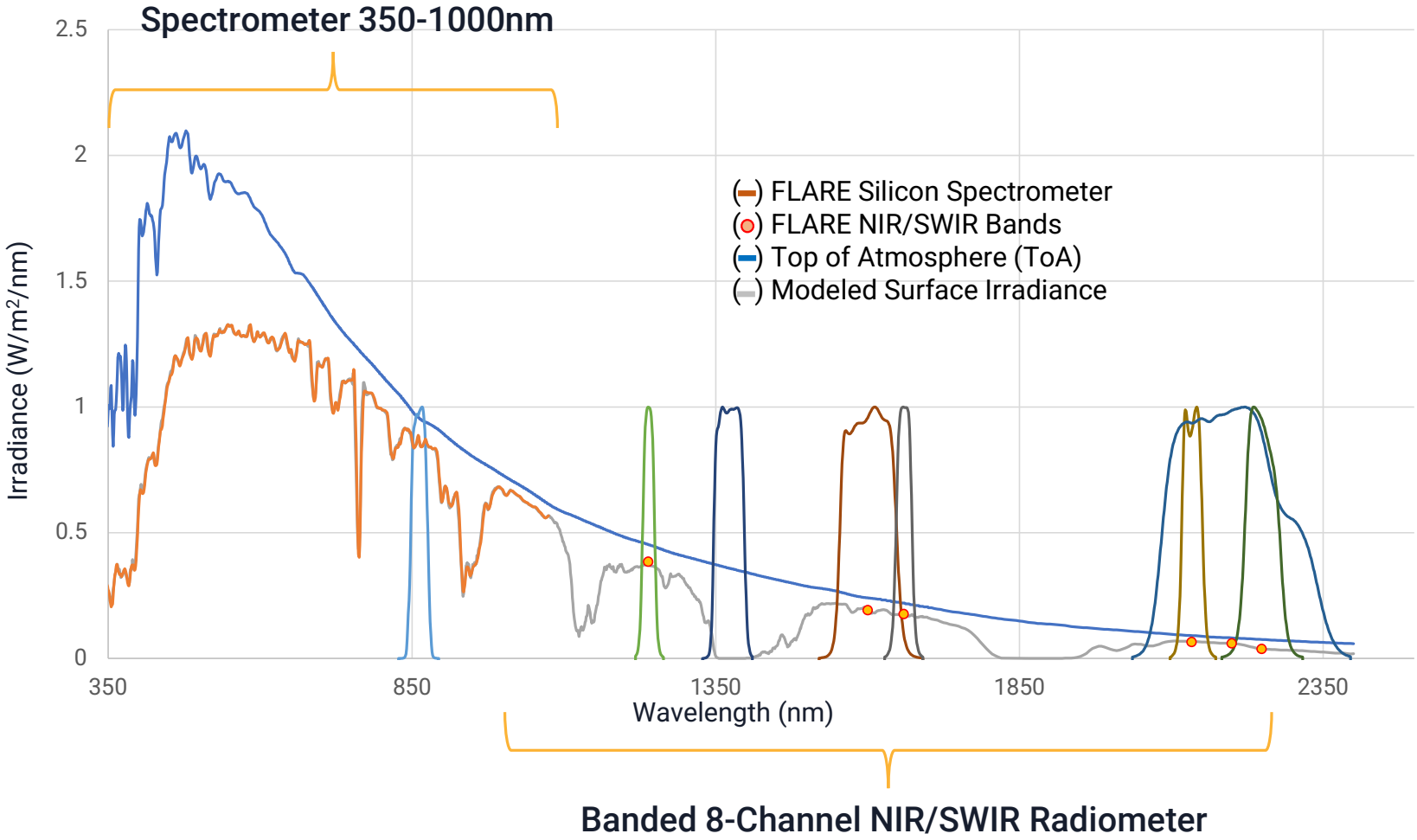
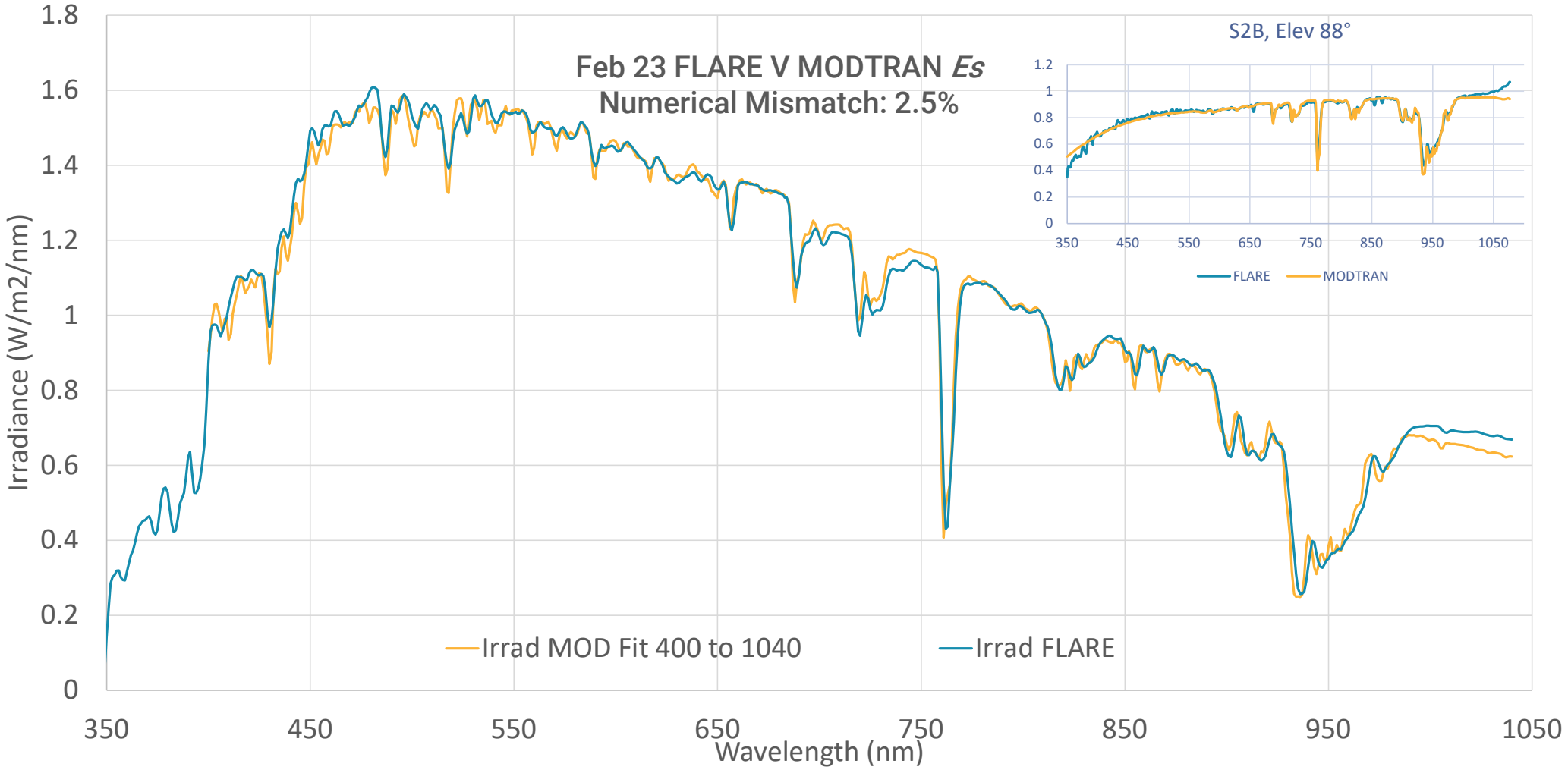
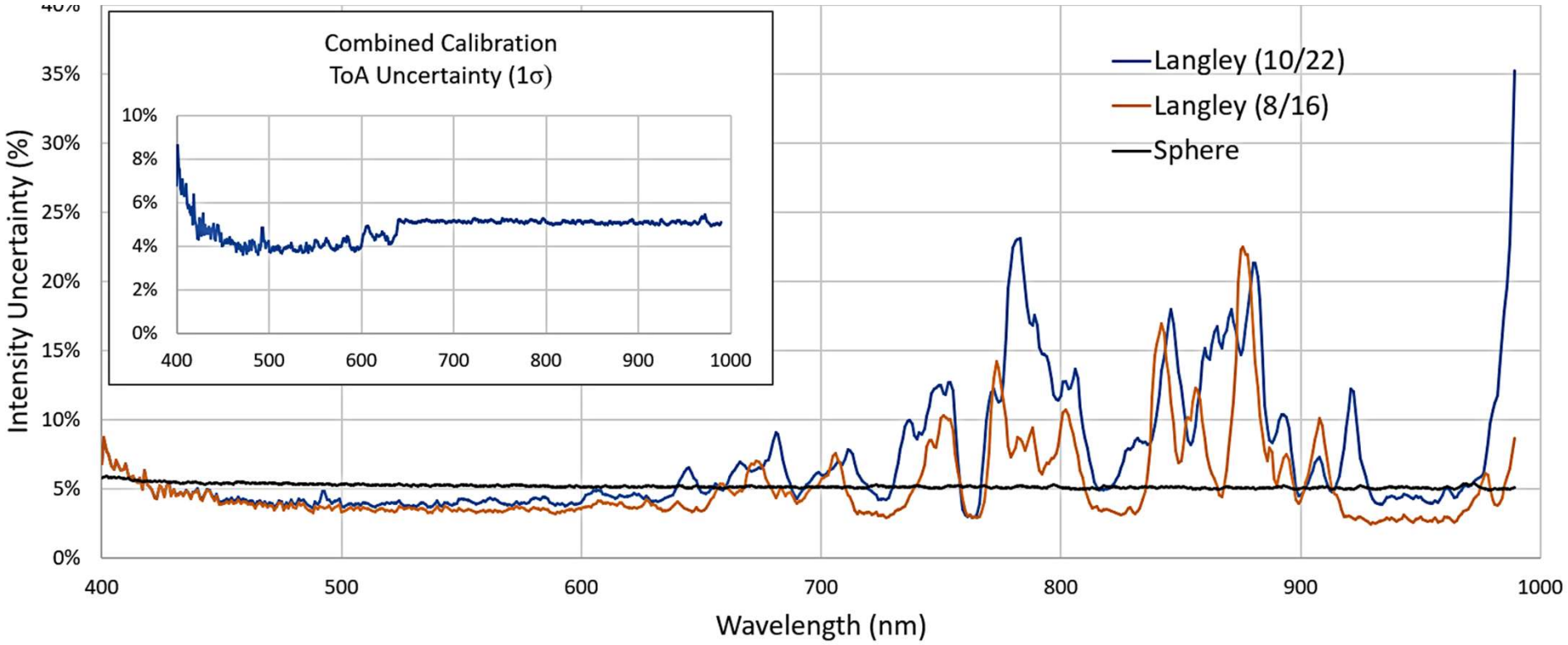


Integration of MODTRAN to FLARE Radiometric Processing



Dual Traceability - Langley & Sphere Methods

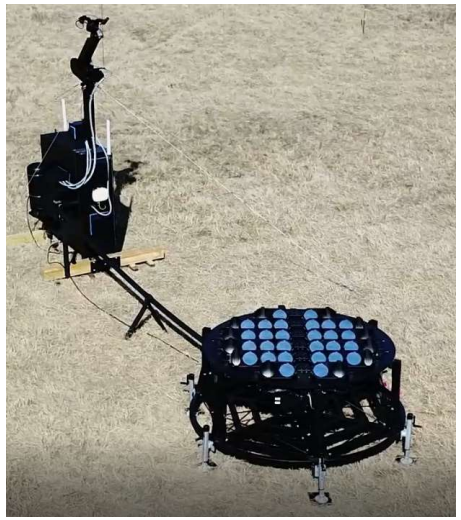


Prelim. SWIR Uncertainty Analysis < 5%

FLARE Nodes

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

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



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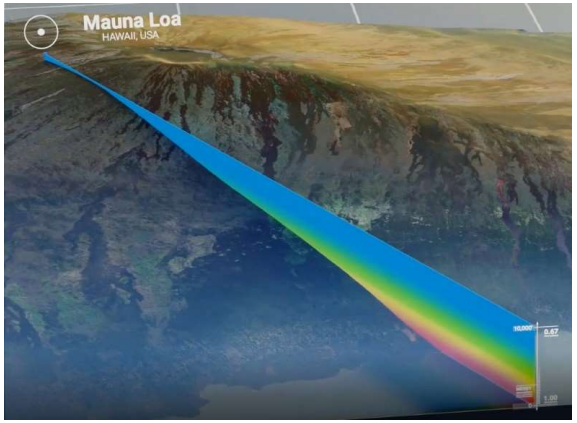
FLARE Development

- Mobile Node future development
  - 2022
  - Prototype at Beta site

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

- Planned Nodes
  - **Mauna Loa (3300m)**
    - **Spring '22**
  - Railroad Valley Playa, Tenerife – TBD
  - Atacama, Australia, Gobabeb - TBD



FLARE Mission Quality Metrics

IMAGE QUALITY PARAMETER	DESCRIPTION
Absolute Radiometric Performance	Imagery reported in-band radiance relative to uncertainty requirements.
Absolute Geolocation	Location error of imagery reported coordinates for FLARE signal center position relative to known values.
Multi-Spectral Registration	Inter-channel spatial band co-registration error based on evaluation of FLARE signal center position in reported bands.
Modulation Transfer Function	Nyquist MTF, other sensor resolution metrics (Point Response Function, Line Response Function, Rayleigh/Sparrow Criterion, Ground Spot Size, etc.).
National Imagery Interoperability Rating Scale	NIIRS value for provided imagery with FLARE target in-scene, derived through General Image Quality Equation v 5. Predicted NIIRS rating for sensor under alternative atmospheric conditions and solar/sensor geometries.

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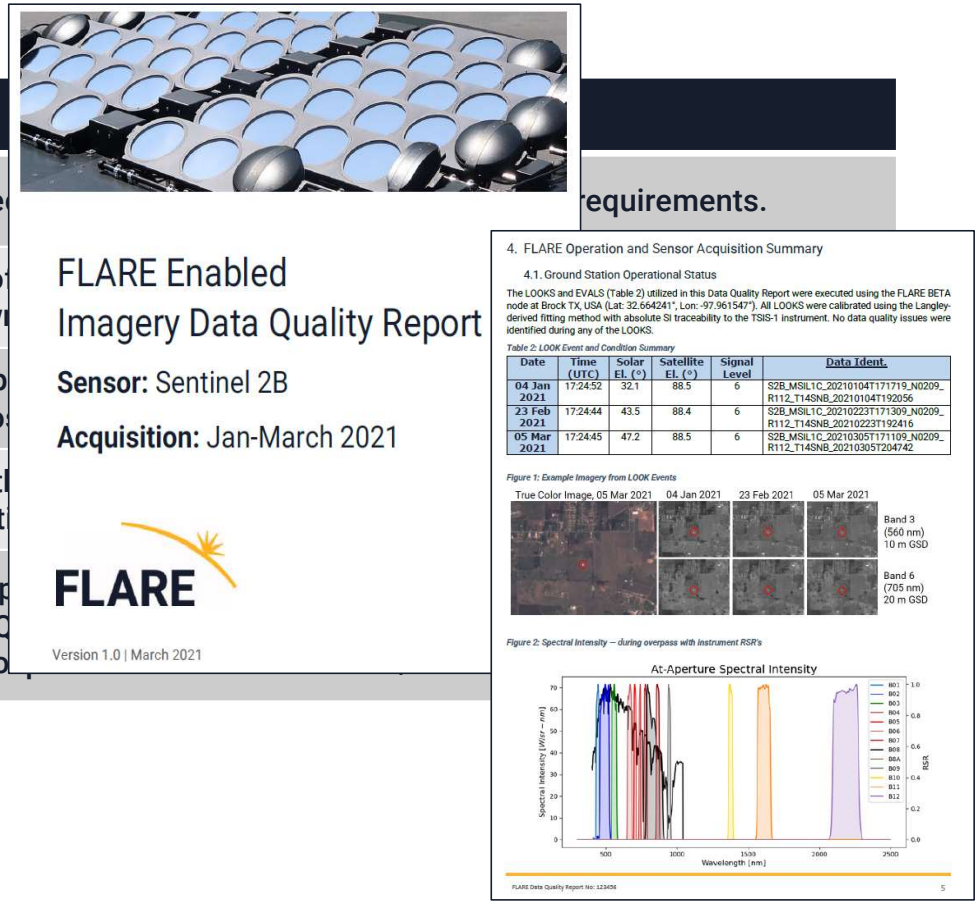
FLARE Mission Quality Metrics

IMAGE QUALITY PARAMETER	
Absolute Radiometric Performance	Imagery reporte… …requirements.
Absolute Geolocation	Location error o… relative to known…
Multi-Spectral Registration	Inter-channel sp… signal center po…
Modulation Transfer Function	Nyquist MTF, oth… Response Funct…
National Imagery Interoperability Rating Scale	NIIRS value for p… General Image Q… alternative atmo…



FLARE Enabled
Imagery Data Quality Report

Sensor: Sentinel 2B

Acquisition: Jan-March 2021

FLARE

Version 1.0 | March 2021

4. FLARE Operation and Sensor Acquisition Summary

4.1. Ground Station Operational Status

The LOOKS and EVALS (Table 2) utilized in this Data Quality Report were executed using the FLARE BETA node at Brock TX, USA (Lat: 32.664241°, Lon: -97.961547°). All LOOKS were calibrated using the Langley-derived fitting method with absolute SI traceability to the TSIS-1 instrument. No data quality issues were identified during any of the LOOKS.

Table 2: LOOK Event and Condition Summary

Date	Time (UTC)	Solar El. (°)	Satellite El. (°)	Signal Level	Data Ident.
04 Jan 2021	17:24:52	32.1	88.5	6	S2B_MSIL1C_20210104T171719_N0209_R112_T14SNB_20210104T192056
23 Feb 2021	17:24:44	43.5	88.4	6	S2B_MSIL1C_20210223T171309_N0209_R112_T14SNB_20210223T192416
05 Mar 2021	17:24:45	47.2	88.5	6	S2B_MSIL1C_20210305T171109_N0209_R112_T14SNB_20210305T204742

Figure 1: Example Imagery from LOOK Events

True Color Image, 05 Mar 2021 | 04 Jan 2021 | 23 Feb 2021 | 05 Mar 2021

Band 3 (560 nm) 10 m GSD

Band 6 (705 nm) 20 m GSD

Figure 2: Spectral Intensity – during overpass with Instrument RSR's

At-Aperture Spectral Intensity

Spectral Intensity [W/(m² – nm)]

Wavelength [nm]

RSR

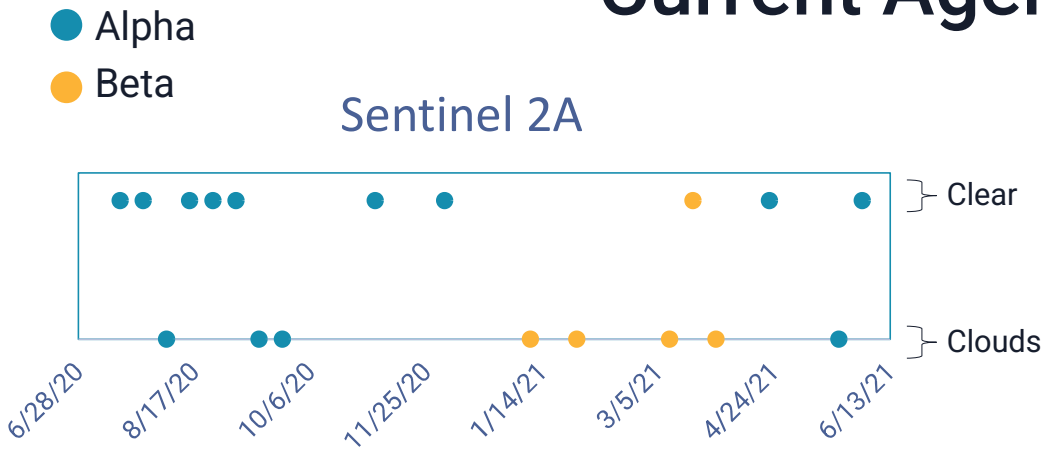
FLARE Data Quality Report No: 123456

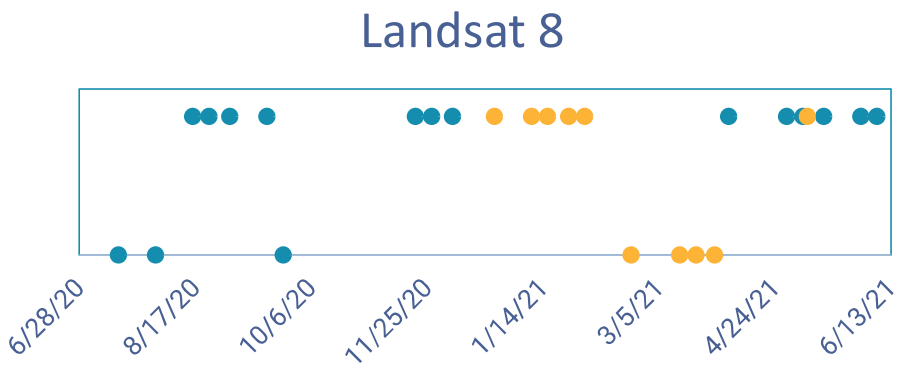
5

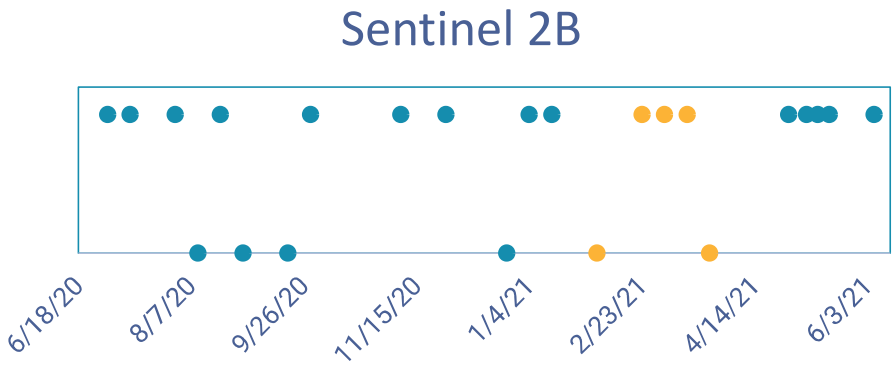
FLARE

Successful Engagements with Small Sat and Agency Assets

Current Agency Archive







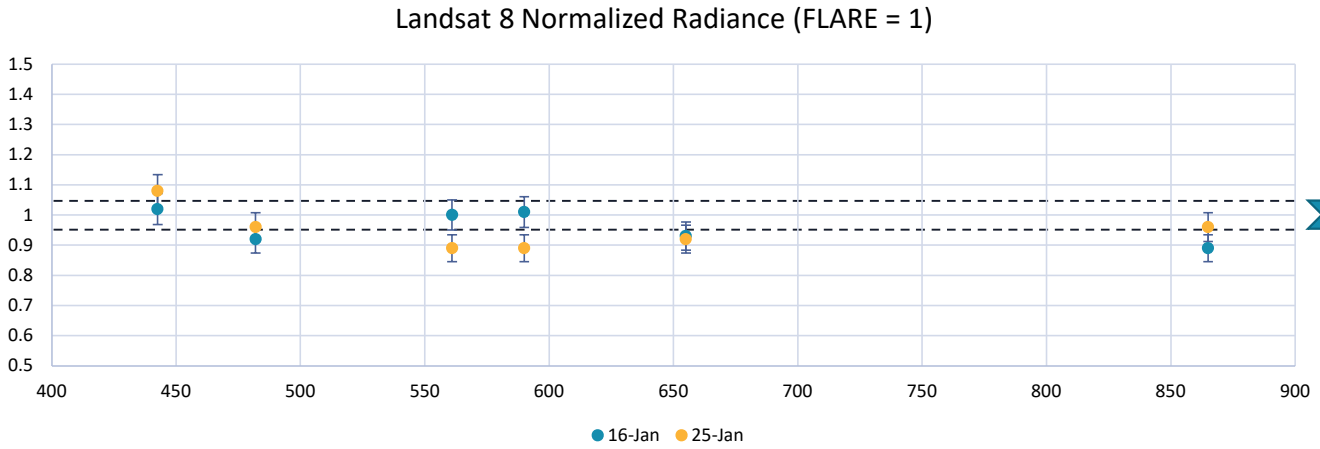
~60% yield including partly cloudy days.

Successful LOOKS with PRISMA, ISRO LISS-3 also added.

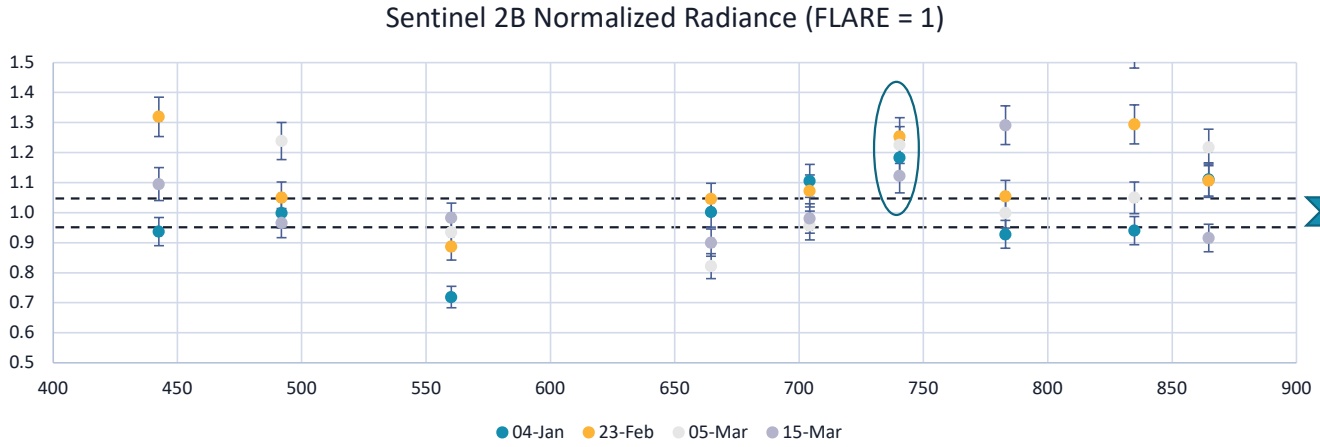
INVITATION:
Looking for partners to examine this data set and work on performance metrics of FLARE System with Landsat 8 and Sentinel 2A/2B

FLARE

Temporal Trending on Sentinel 2B and Landsat 8

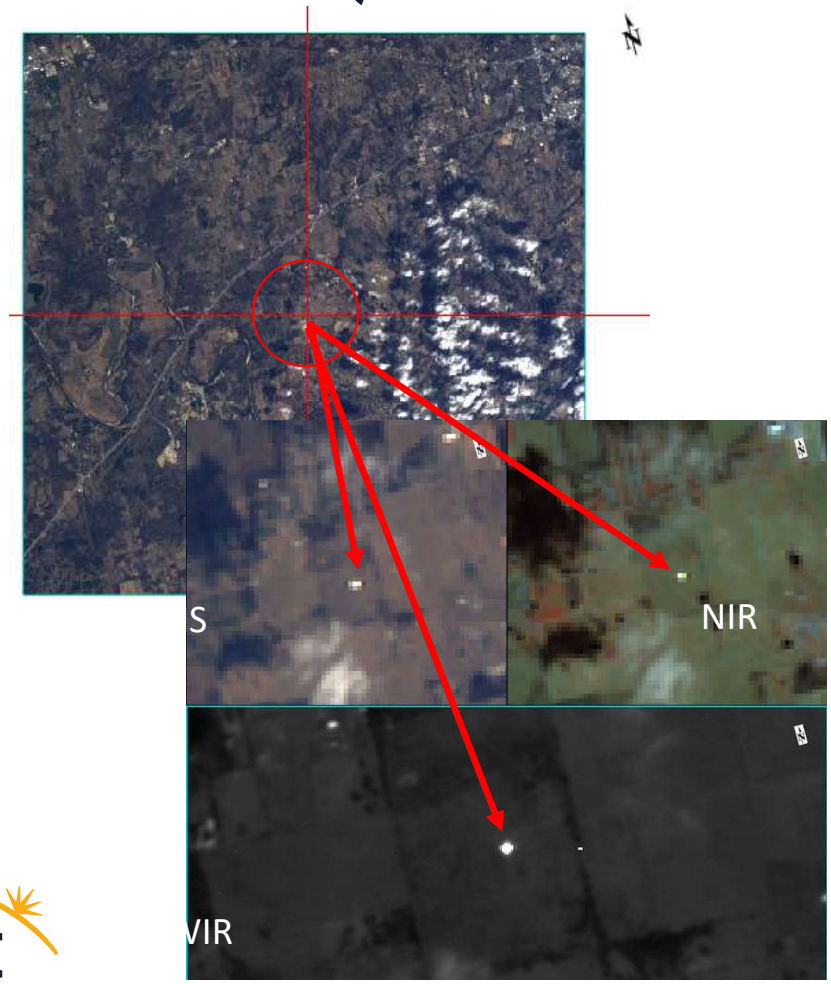


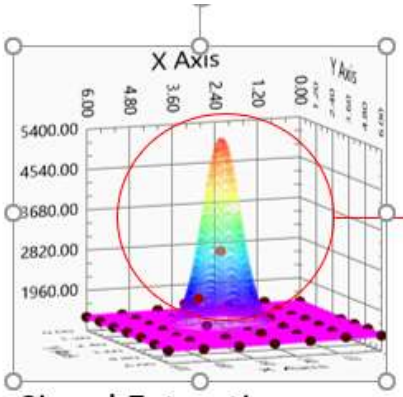
		LS8/FLARE	
Band	CW	16-Jan	25-Jan
1	443	1.02	1.08
2	482	0.92	0.96
3	561	1.00	0.89
4	655	0.93	0.92
5	865	0.89	0.96
6	1609	1.01	0.93
7	2201	1.02	1.28
8	590	1.01	0.89



		S2B/FLARE			
Band	CW	04-Jan	23-Feb	05-Mar	15-Mar
1	443	0.94	1.32	1.64	1.09
2	492	1.00	1.05	1.24	0.97
3	560	0.72	0.89	0.93	0.98
4	665	1.00	1.05	0.82	0.90
5	704	1.11	1.07	0.96	0.98
6	740	1.18	1.25	1.23	1.12
7	783	0.93	1.05	1.00	1.29
8	835	0.94	1.29	1.05	1.56
8A	865	1.11	1.11	1.22	0.92

PRISMA (FLARE Beta Site) - >220 Bands





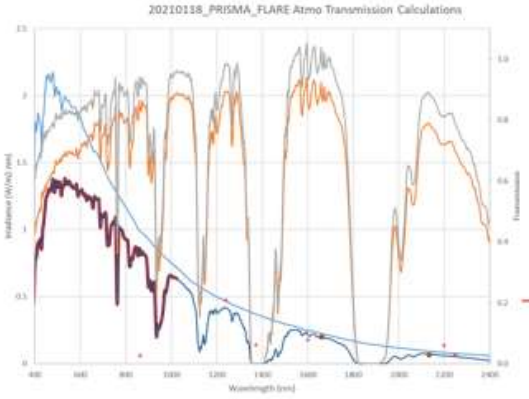
Signal Extraction

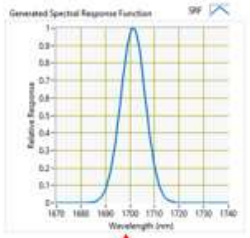
DN Scaling

Radiance per Band

Radiance per Band

SPARC Propagation





Band RSR

Spectral Values

FLARE

Images Courtesy of Leonardo DRS

Brock Texas, July 4-15, 2021

- Worldview 2, 3 (Maxar)
- Kompsat 3, 3A (KARI

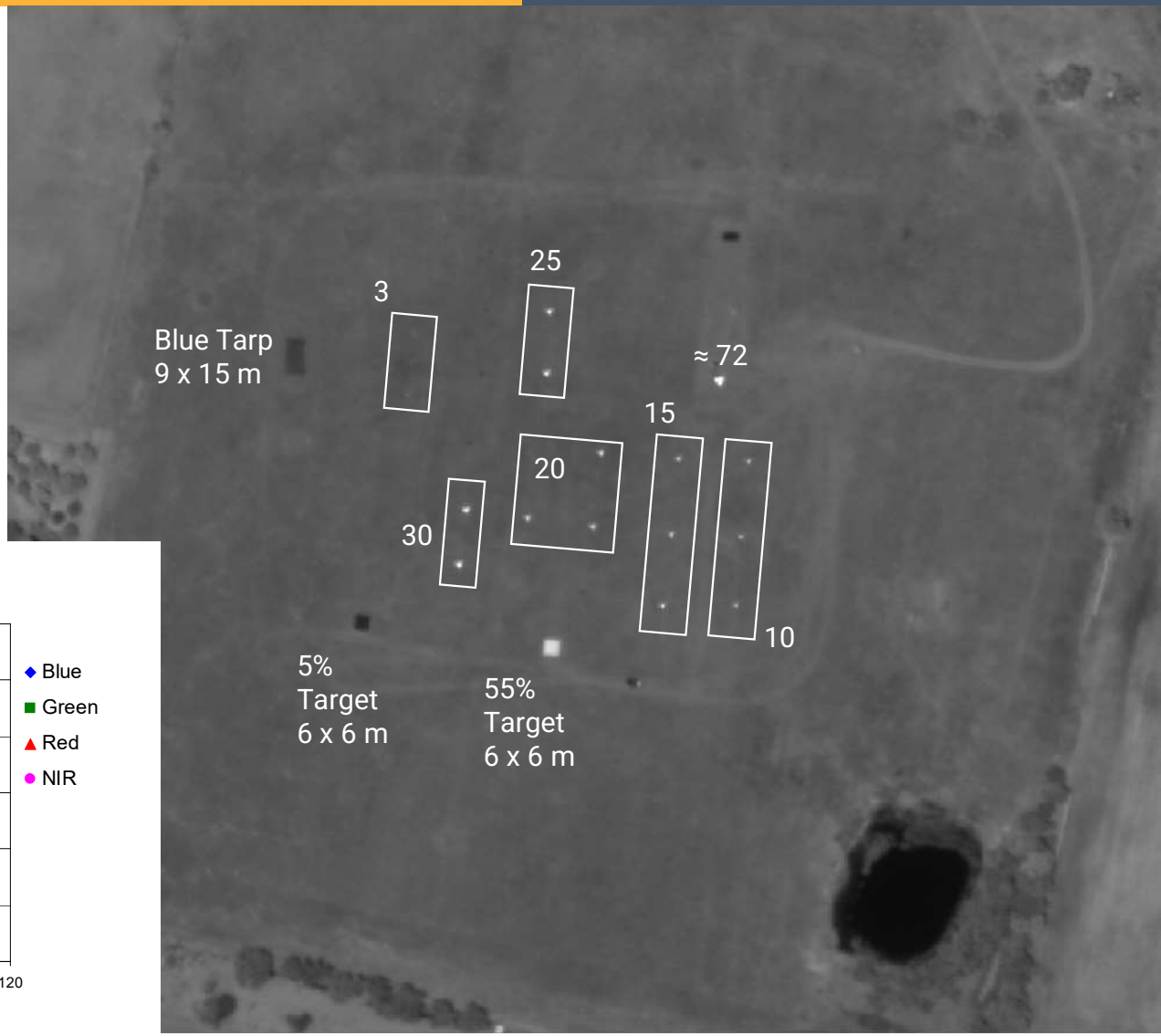
- Multiple Assets
  - BETA Automated System
  - FLARE Radiometer
  - ASD FieldSpec 4
  - Manual Mirror Arrays
  - Lambertian Targets (Permaflect)
  - Blue Tarp

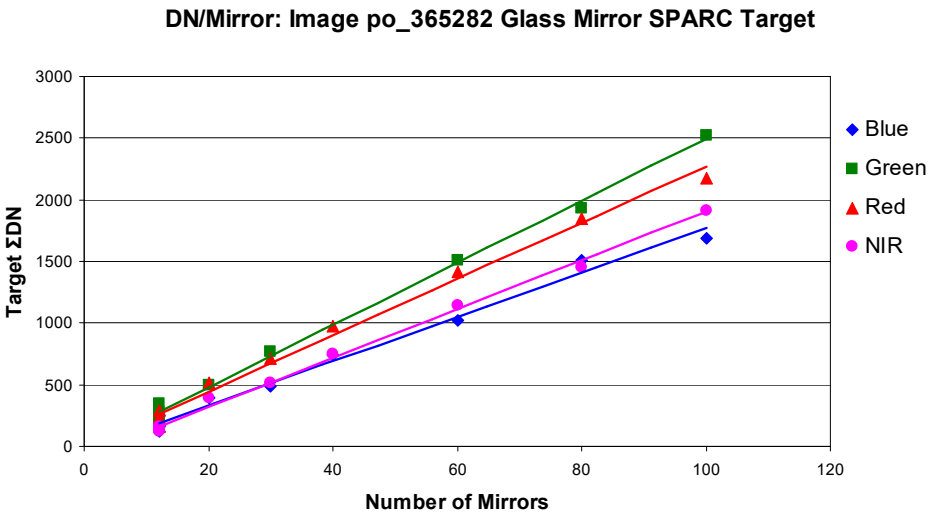
KompSat 3 PAN Band, July 8 2021, 14:45 Local

Image Courtesy of KARI

Brock Texas, July 4-15, 2021

- Mirror Based Empirical Line Method
  - Linearity of Pan, MS, NIR Bands
  - Absolute gain
  - Low radiance verification
  - Offset





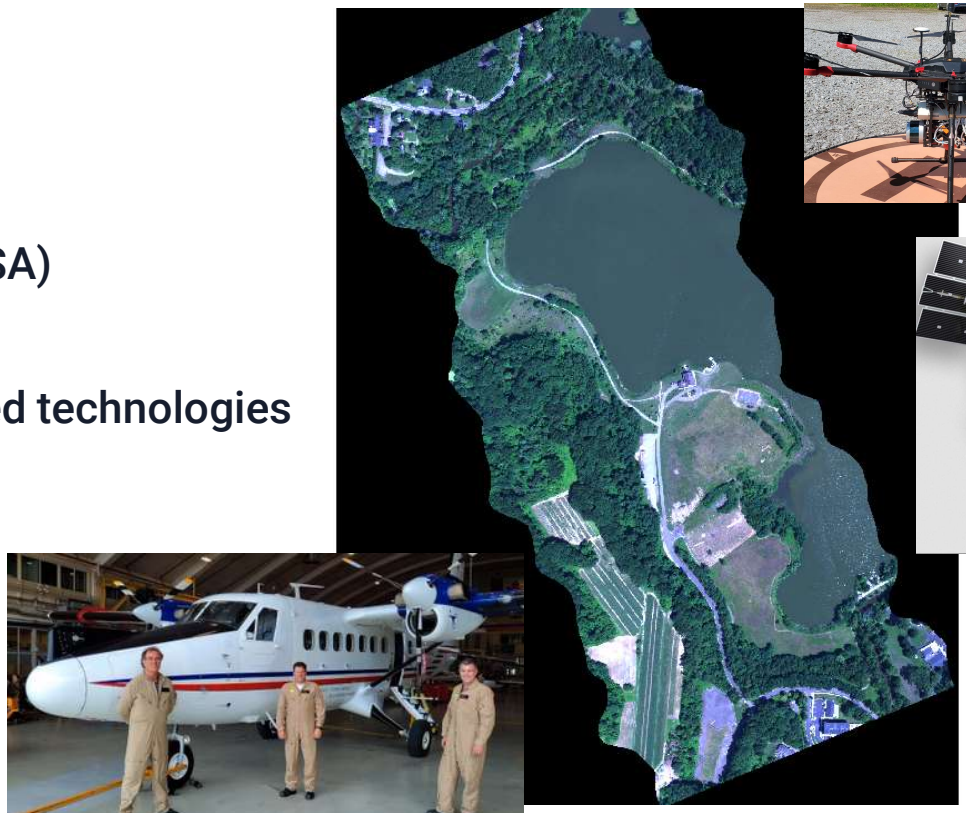
G-SCALE: Ground to Space Calibration Experiment

Tait Reserve, 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 (ESA)

- Combination of traditional and mirror-based technologies
  - Large reflective panels and tarps
  - Solar radiometers
  - Ground based ASD measurements
  - Reference and test targets



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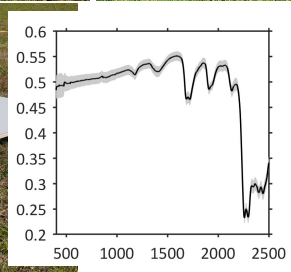
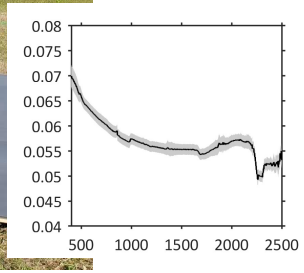
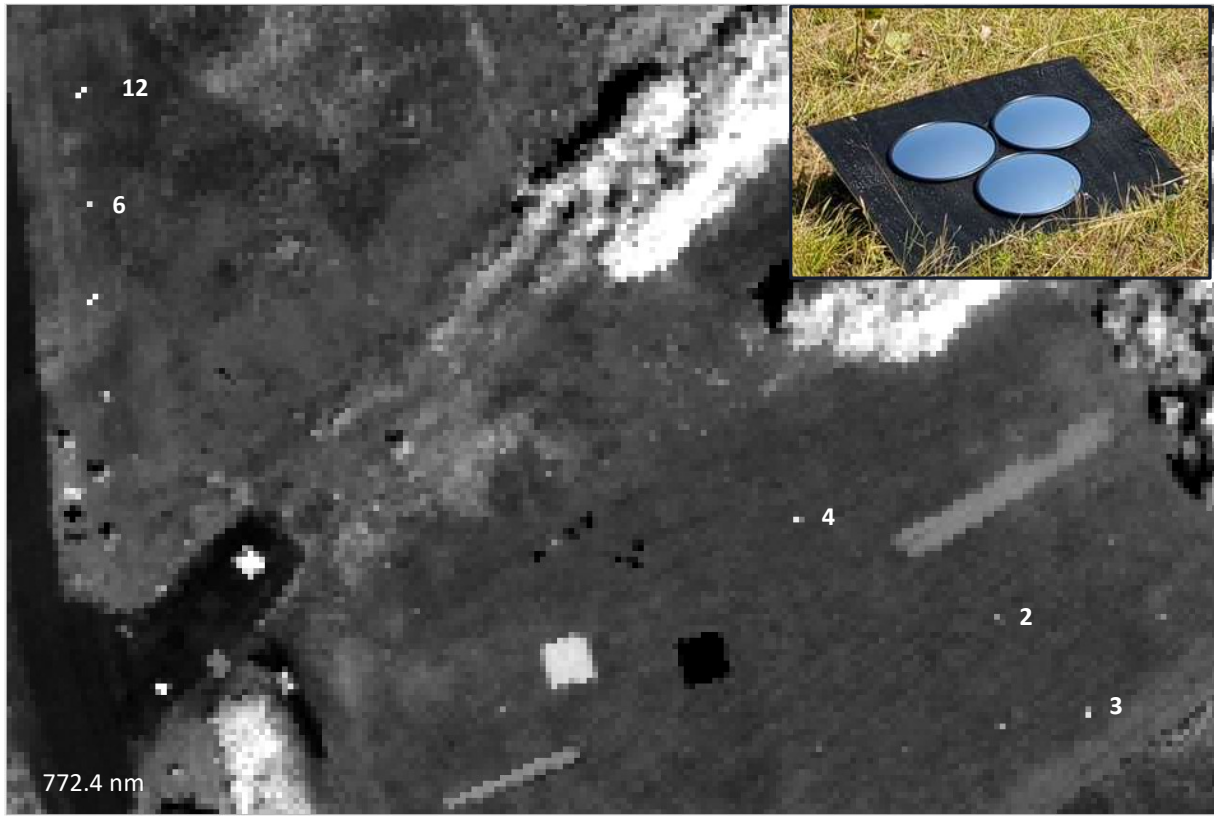
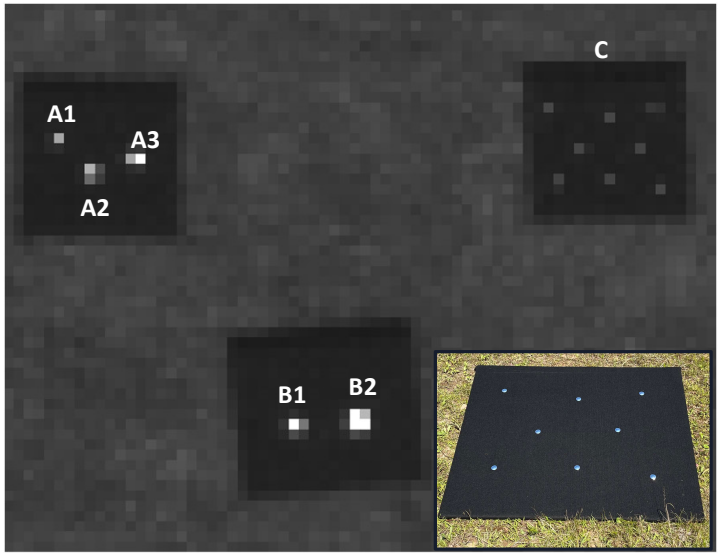
Psuedo-Lambertian Reflectance Targets


0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
500
1000
1500
2000
2500


0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
500
1000
1500
2000
2500



MELM arrays for linear absolute gain/offset of CASI/SASI airborne HSI



Radiometric/spatial arrays for calibration and MTF of UAV sensors

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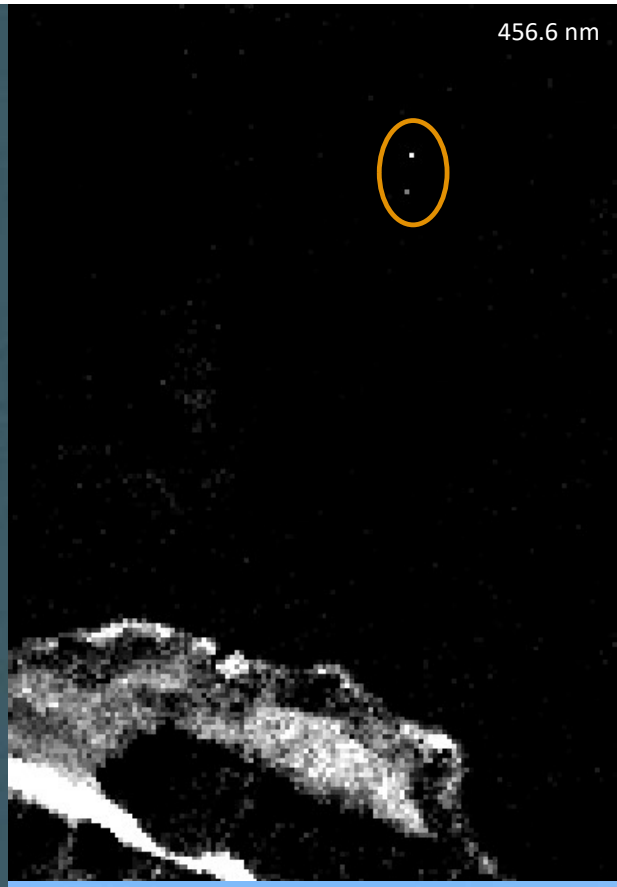
Floating SPARC – Low Radiance Calibration Targets

Water-leaving radiance is typically low SNR – and can be in non-linear response range of detector. Floating mirrors provide 2 traceable, absolute calibration points, in-situ and tuned for dark target radiometry.



Recent Campaign Activities

- Aug 8 - 13: Joint work with MAXAR, SDSU for Worldview 2,3, GeoEye

- CURRENT ACTIVITY: Big Multi Agency Collection (BigMAC):
  - Aug 27 – Sept 5
  - Multi-Team Validation of Landsat surface reflectance products
    - USGS EROS CalVal CoE
    - FLARE/Labsphere
    - RIT
    - SDSU
    - NASA
    - Univ. of AZ

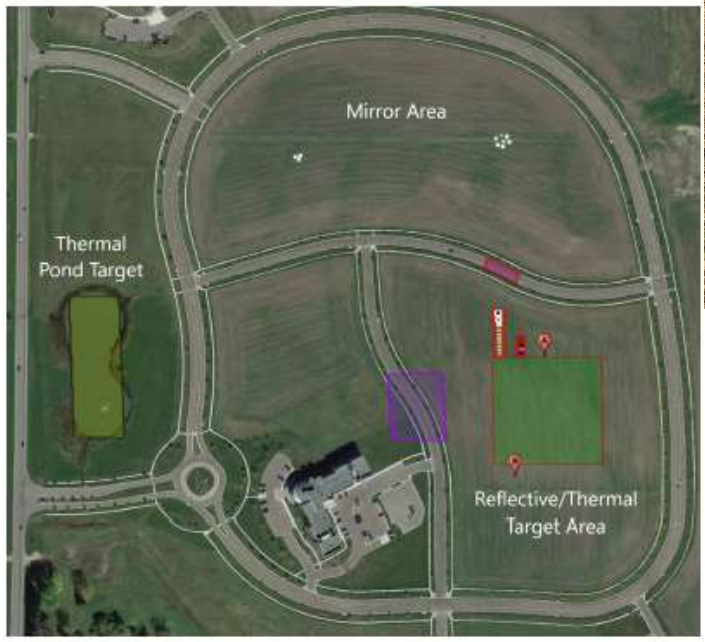


Figure 1-2. Field Campaign Site

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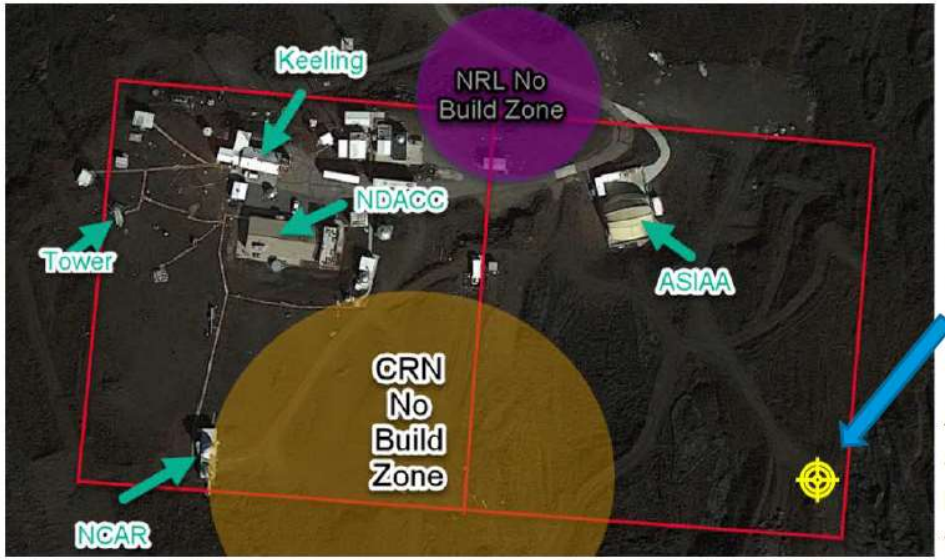
Next Stop: Mauna Loa

- NASA ESTO Contract for SLI-T
- Approved to place FLARE station at NOAA Mauna Loa Observatory
- Working through final permitting & logistics: Operational in 7-10 months
- Benefits to FLARE and EO Community
  - Elevation (~3,300 m)
  - Stable atmosphere, above marine inversion layer, aerosols
  - Low uncertainty radiometry, <2%
  - AERONET, MLO-LUSI, others: cooperation and data sharing

Mauna Loa Observatory Site – 8 acres total



MLO FLARE location:

Away from structures in 6% reflectance lava field.

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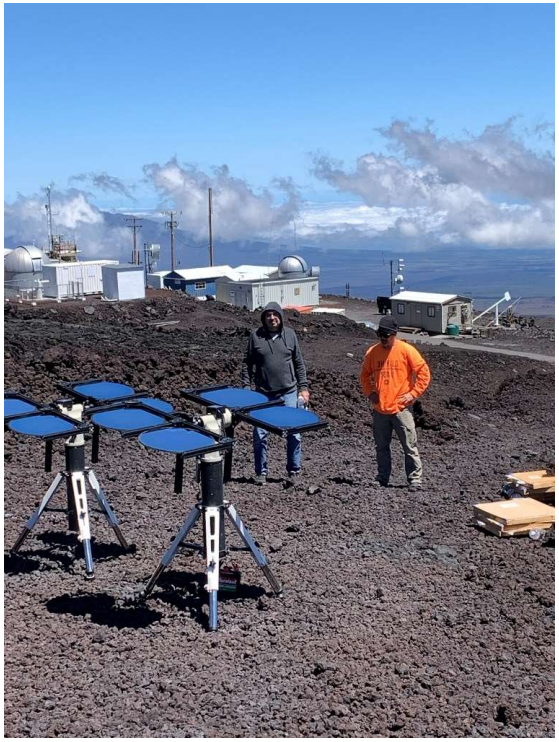
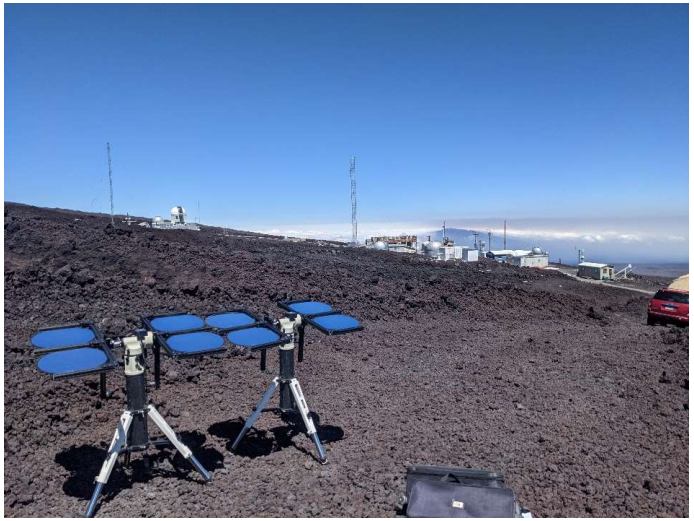
Testing on MLO & Hawaii is underway…

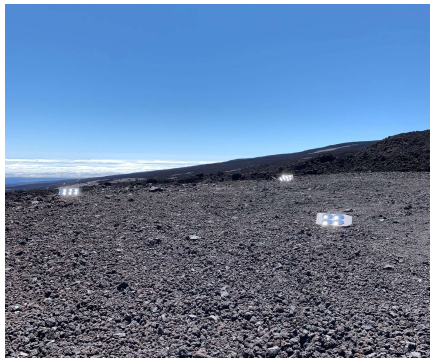
June 29, 2021 - MLO



July 9, 2021 – Sea Level

August 1, 2021 – MLO





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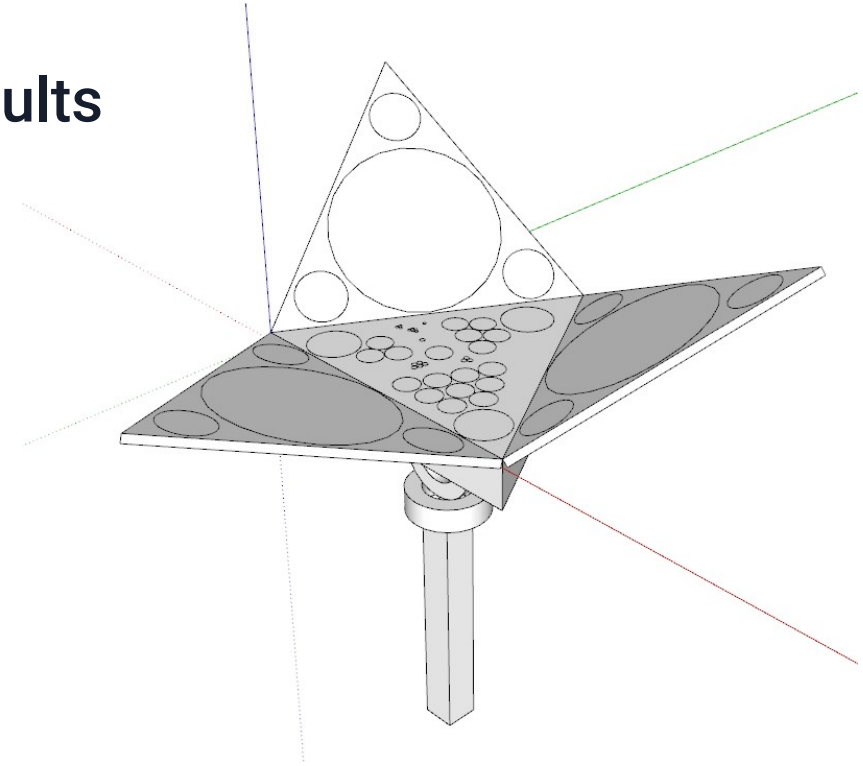
Future Work

- Continue processing of Campaign results for Commercial Customers and Govt. Agency contracts.
- Peer-reviewed publication of results
- Examine L8-S2 Data Archive with partners
- Mobile station development
- Open to ANY campaign or test plan suggestions…come talk to us



Mobile “PETAL” Turret

FLARE

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www.flare-network.com

Better Calibration. Better Data. Better Decisions.

Thank you!

Questions and Comments may be directed to:

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