WORKING GROUP ON CALIBRATION & VALIDATION

# *CEOS/WGCV/LPV 2015 Report: Validation Datasets and Interagency/International Coordination*

**Miguel Román (NASA/GSFC/JPSS)**
**Jaime Nickeson (NASA/GSFC/SSAI)**
**Gabriela Schaepman-Strub (University of Zurich)**

Committee on Earth Observation Satellites (CEOS)
Working Group on Calibration and Validation (WGCV)
Land Product Validation (LPV)

**2015 JPSS Annual Science Team Meeting: August 24-28, 2015**

# CEOS > WGCV > LPV

**CEOS** - Committee on Earth Observation Satellites

31 CEOS Members

24 Associate Members (eg UNEP, GTOS, IGBP, WMO, GCOS)

CEOS coordinates civil space-based observations of the Earth

This is achieved through its working groups and virtual constellations. The **Working Group on Calibration and Validation (WGCV)** is one of 5 CEOS working groups.

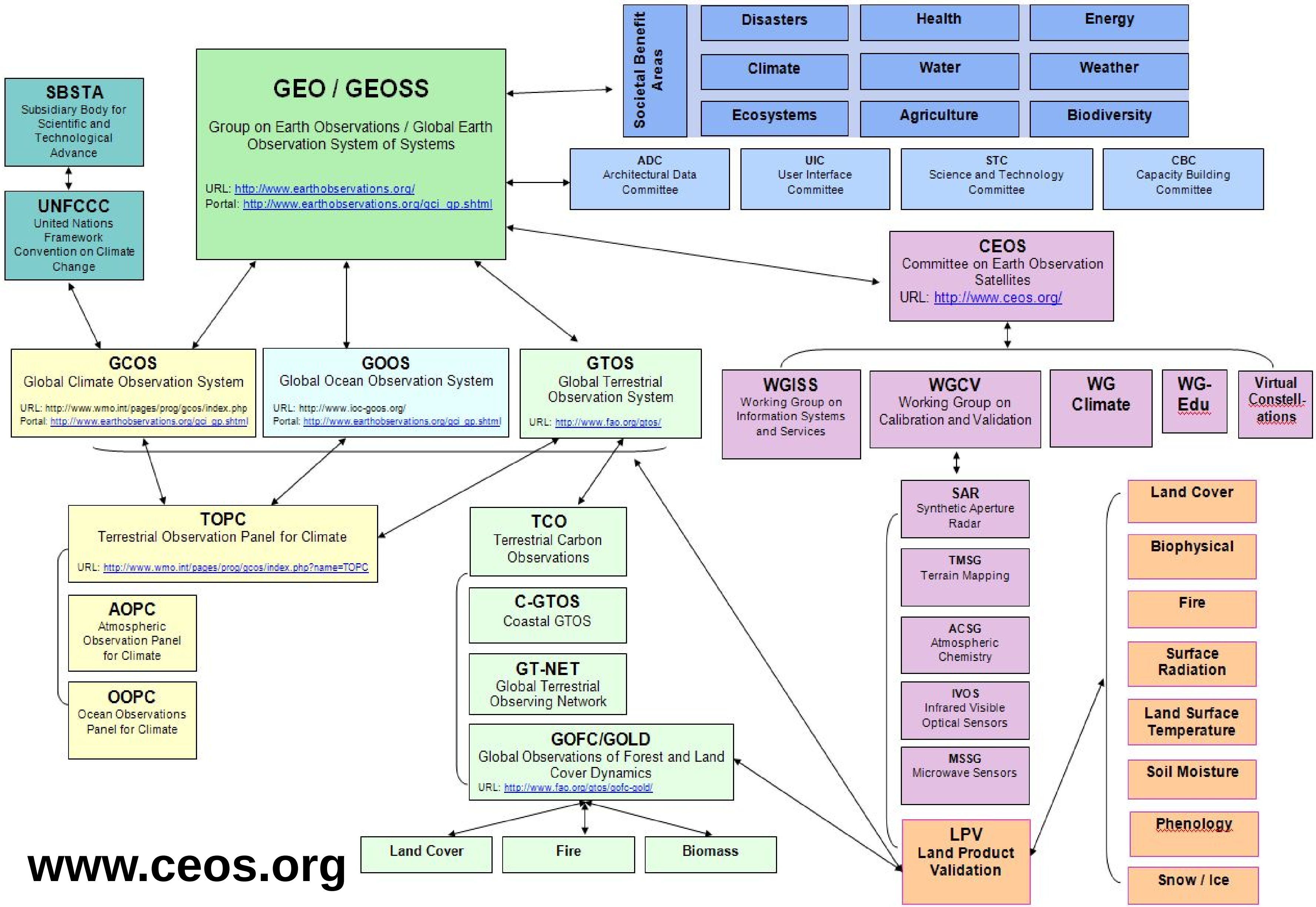
**Land Product Validation (LPV)** is one of 6 WGCV subgroups

Current LPV Officers

| | | |
|---|---|---|
| **Chair** | Gabriela Schaepman-Strub | University of Zurich |
| **Vice-Chair** | Miguel Román | NASA/GFSC/JPSS |
| **LPV Support** | Jaime Nickeson | NASA/GSFC/SSAI |

**9 Focus Areas** with 2 co-leads each

# Linkages between International Programs concerned with Terrestrial Earth Observation




**www.ceos.org**

WORKING GROUP ON CALIBRATION & VALIDATION

# Land Product Validation Subgroup Objectives

1. To **foster and coordinate quantitative validation** of higher level global land products derived from remotely sensed data, in a traceable way, and to relay results to users.

2. To increase the quality and efficiency of global satellite product validation by developing and promoting **international standards and protocols** for
   - **Field sampling**
   - **Scaling techniques**
   - **Accuracy reporting**
   - **Data and information exchange**

3. To provide **feedback to international structures** for
   - Requirements on product accuracy and quality assurance
   - Terrestrial ECV measurement standards
   - Definitions for future missions

# Focus Areas and Co-leaders

* ECV

| Product | North America | EU / China |
|---|---|---|
| **Snow Cover** (T5)*, **Sea Ice** | Thomas Nagler (ENVEO, Austria) | Tao Che (Chinese Academy of Sciences) |
| **Surface Radiation** (Reflectance, BRDF, Albedo [T8]*) | Crystal Schaaf (U. Massachusetts Boston) | Alessio Lattanzio (EUMETSAT) |
| **Land Cover** (T9)* | Pontus Olofsson (Boston University) | Martin Herold (Wageningen University, NL) |
| **FAPAR** (T10)* | Arturo Sanchez-Azofeifa (University of Alberta) | Nadine Gobron (JRC, IT) |
| **Leaf Area Index** (T11)* | Oliver Sonnentag (University of Montreal) | Stephen Plummer (Harwell, UK) |
| **Fire** (T13)* (Active Fire, Burned Area) | Luigi Boschetti (University of Idaho) | Kevin Tansey (University of Leicester, UK) |
| **Land Surface Temperature** (LST and Emissivity) | Pierre Guillevic (University of Maryland) | Jose Sobrino (University of Valencia, SP) |
| **Soil Moisture*** | Tom Jackson (USDA ARS) | Wolfgang Wagner (Vienna Univ of Technology, AT) |
| **Land Surface Phenology** | Matt Jones (University of Montana ) | Jadu Dash (University of  Southampton, UK) |

# JPSS Land Team: Drivers of Innovation

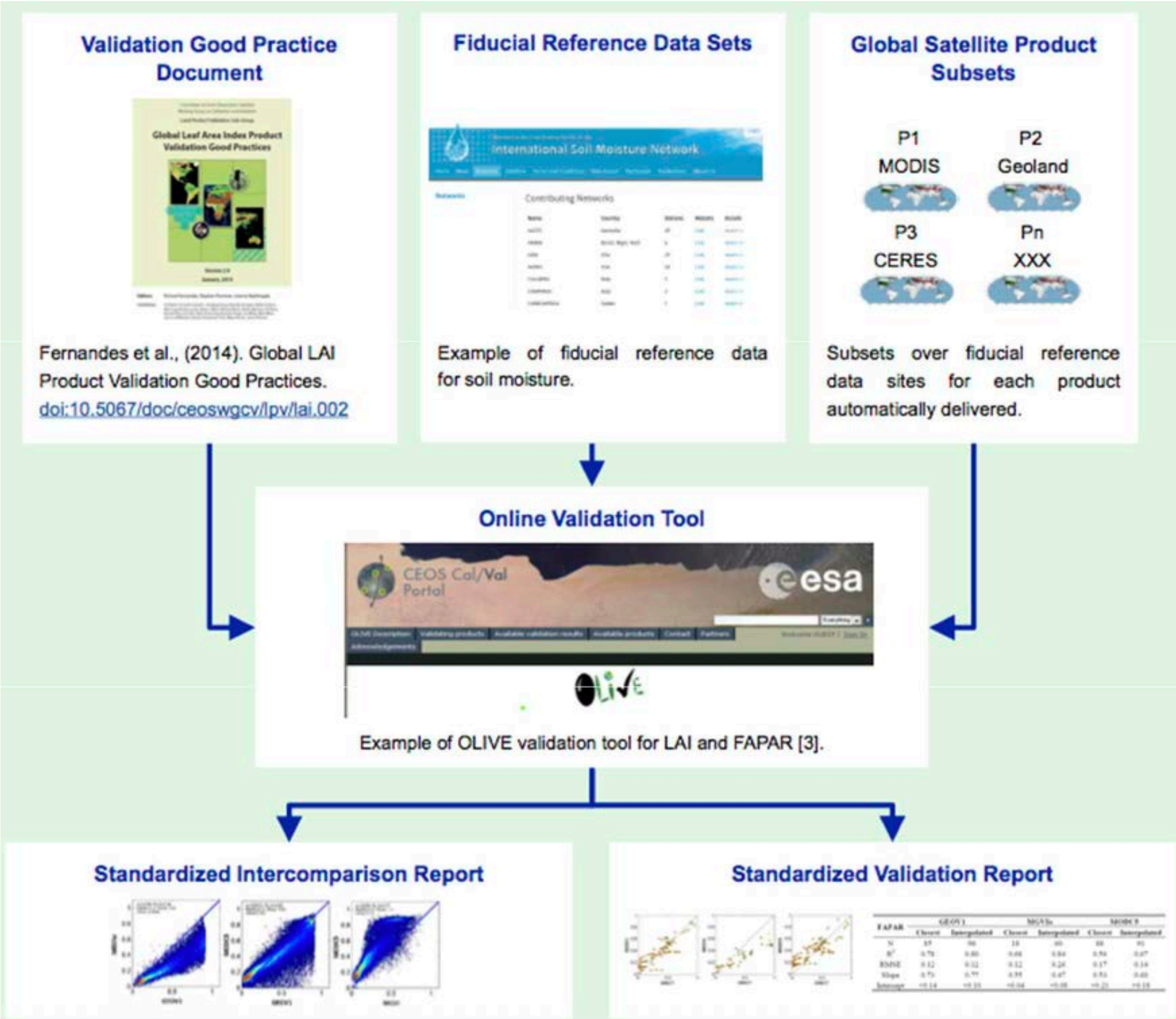
| Innovation Driver | Impact to Product Utilization |
|---|---|
| **Product Development and Cal/Val** | ~0 to 40% |
| **Improved Access & Distribution** | ~40 to 75% |
| **“Game Changing” Applications** | ~75 to ≥100% |

**PGRR Initiatives Integrate**
***across all drivers***

# CEOS LPV Team: Drivers of Innovation

| Innovation Driver | Impact to Land ECV |
|---|---|
| **Validation Protocol Development** | ~0 to 40% |
| **Access to and Distribution of Reference Data & Accuracy Reports** | ~40 to 75% |
| **"Game Changing" Applications** | ~75 to ≥100% |

# JPSS Land Cal/Val Team Contributions to LPV




- ***JPSS Land cal/val team has adopted the CEOS/WGCV LPV framework & validation stages.***
- ***Key JPSS (FY16) contributions:***

1. Tower-based reference data (CRN, BSRN-SURFRAD)
2. Airborne-UAV reference data (MALIBU: Román et al.)
3. Land Product Characterization System (LPCS: K. Gallo)

- ***Participating CEOS member agencies:*** *NOAA-STAR, NOAA-NCDC, USGS-EROS, NASA-GSFC, ESA-ESRIN.*

CEOS/WGCV/LPV subgroup has developed a framework for land product intercomparison and validation based on: **(1) a citable protocol, (2) fiducial reference data, and (3) automated subsetting**. These components are integrated into an **online platform** where quantitative tests are run, and standardized intercomparison and validation results reported.

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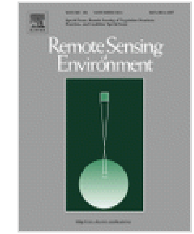
CEOS

Remote Sensing of Environment

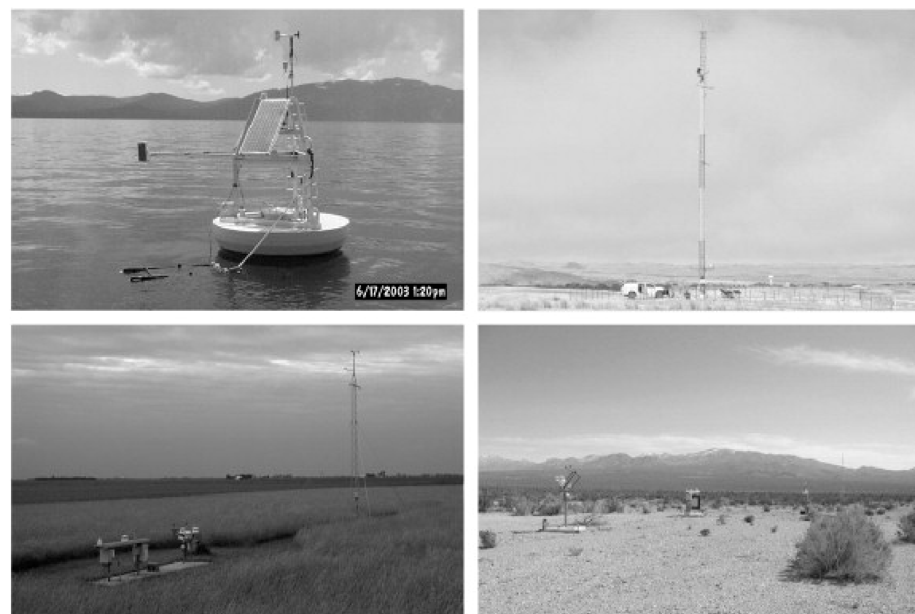
Volume 154, November 2014, Pages 19–37




# Validation of Land Surface Temperature products derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) using ground-based and heritage satellite measurements

Pierre C. Guillevic[a], James C. Biard[b, c], Glynn C. Hulley[a], Jeffrey L. Privette[c], Simon J. Hook[a], Albert Olioso[d], Frank M. Göttsche[e], Robert Radocinski[a], Miguel O. Román[f], Yunyue Yu[g], Ivan Csiszar[g]

**- V1 LST Protocol Published!**
**- Uses VIIIRS as case study**
**- Interagency Collaboration has been key to CEOS-LPV team's sucess. Major players:**
**- NOAA (STAR/NCDC)**
**- NASA (JPL/GSFC)**
**- INRA**



# Protocol for Validation of the Land Surface reflectance using AERONET (J.C. Roger, E. Vermote and B. Holben)

## Validation of Land Surface Reflectance

**The Problem:** **A standard land surface reflectance protocol for using reference AERONET products needs to be agreed on by the MODIS/VIIRS science team.**

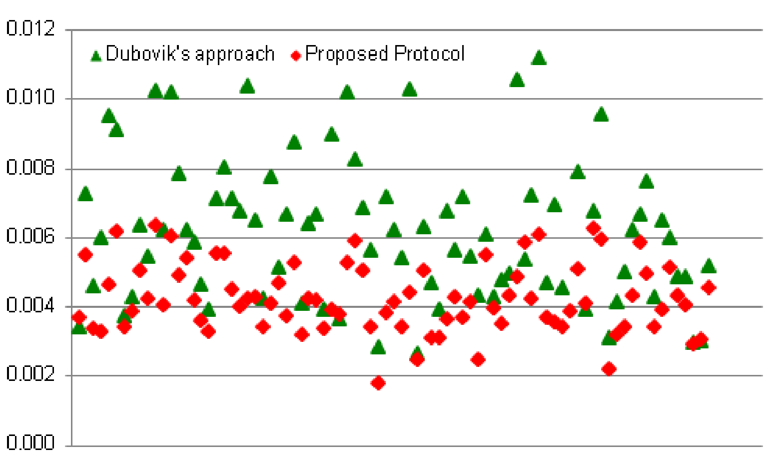
**The Solution:** **A validation protocol for MODIS/VIIRS Land surface reflectance that requires the aerosol model to be readily available.**

## Description of Surface Reflectance Validation Protocol

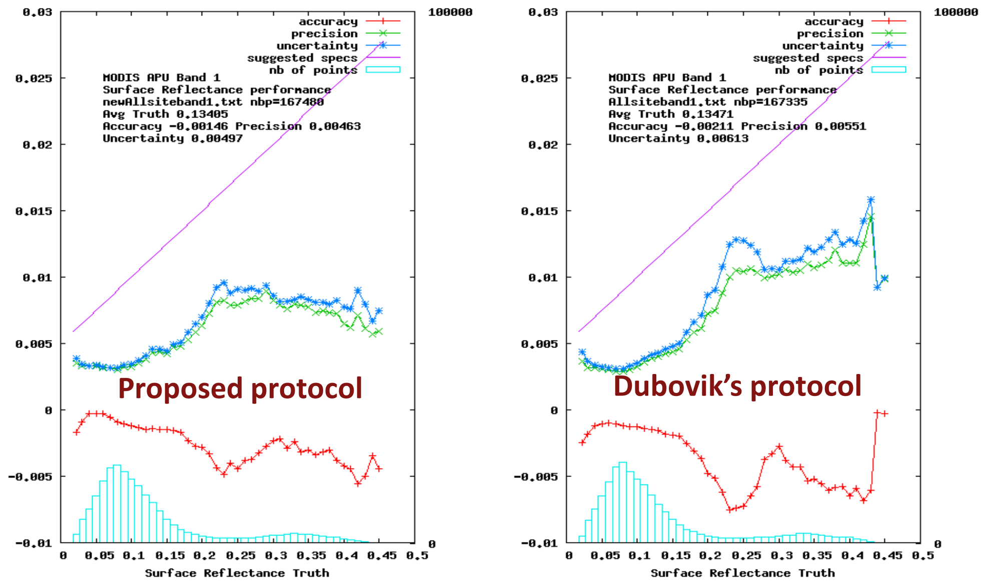
Aerosol models for each AERONET site can be defined using new regressions with optical properties (i.e., $\tau_{440}$ and $\alpha$) as standardized parameters. For the aerosol models, the **aerosol microphysical properties** provisioned by AERONET, including size-distribution (%$C_f$, %$C_c$, $r_f$, $r_c$, $\sigma_r$, $\sigma_c$), complex refractive indices and sphericity, can also be used as standardized protocol measures.

**Comparisons with AERONET indicate that parameter standardization produces Accuracy-Precision-Uncertainty (APU) metrics up to 20% lower than the current baseline (Dubovik et al., 2002).**

*Uncertainties on the retrieved surface reflectance for 40 AERONET sites*
*MODIS band 1 (red) – synthetic input surface reflectance = 0.05*

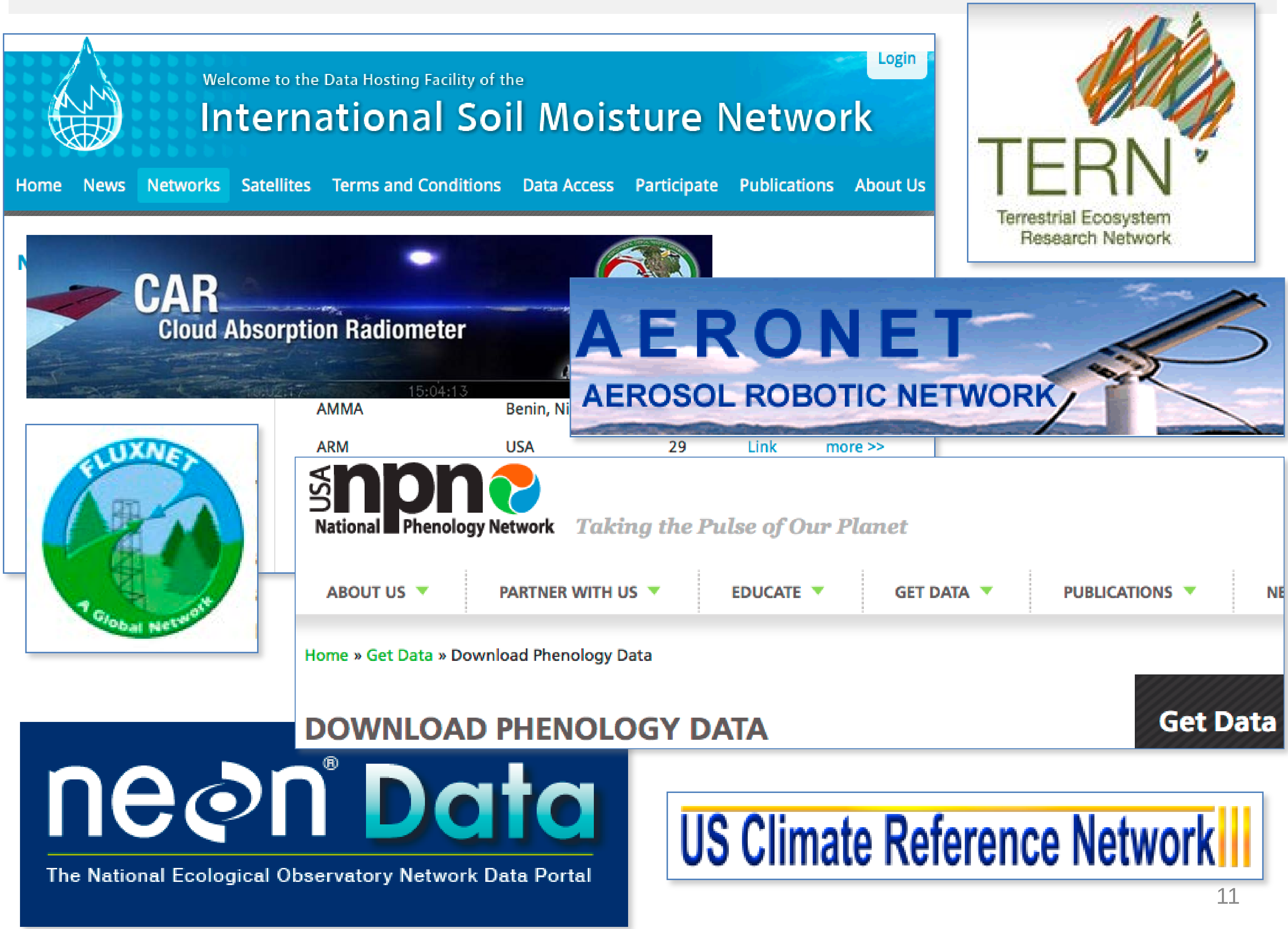



*Example of APU for MODIS band 1 (red) for the whole 2003 year data set*




**Team Response:** **Further classification of errors requires the adoption of consistent and agreeable protocols across MODIS/VIIRS land surface reflectance products. This is also crucial to enable objective assessment and characterization of downstream product impacts (e.g., NDVI/EVI, LAI/FPAR, BRDF/Albedo/NBAR).**

# Fiducial Reference Data Sets



# Relaying Validation Results to our Users

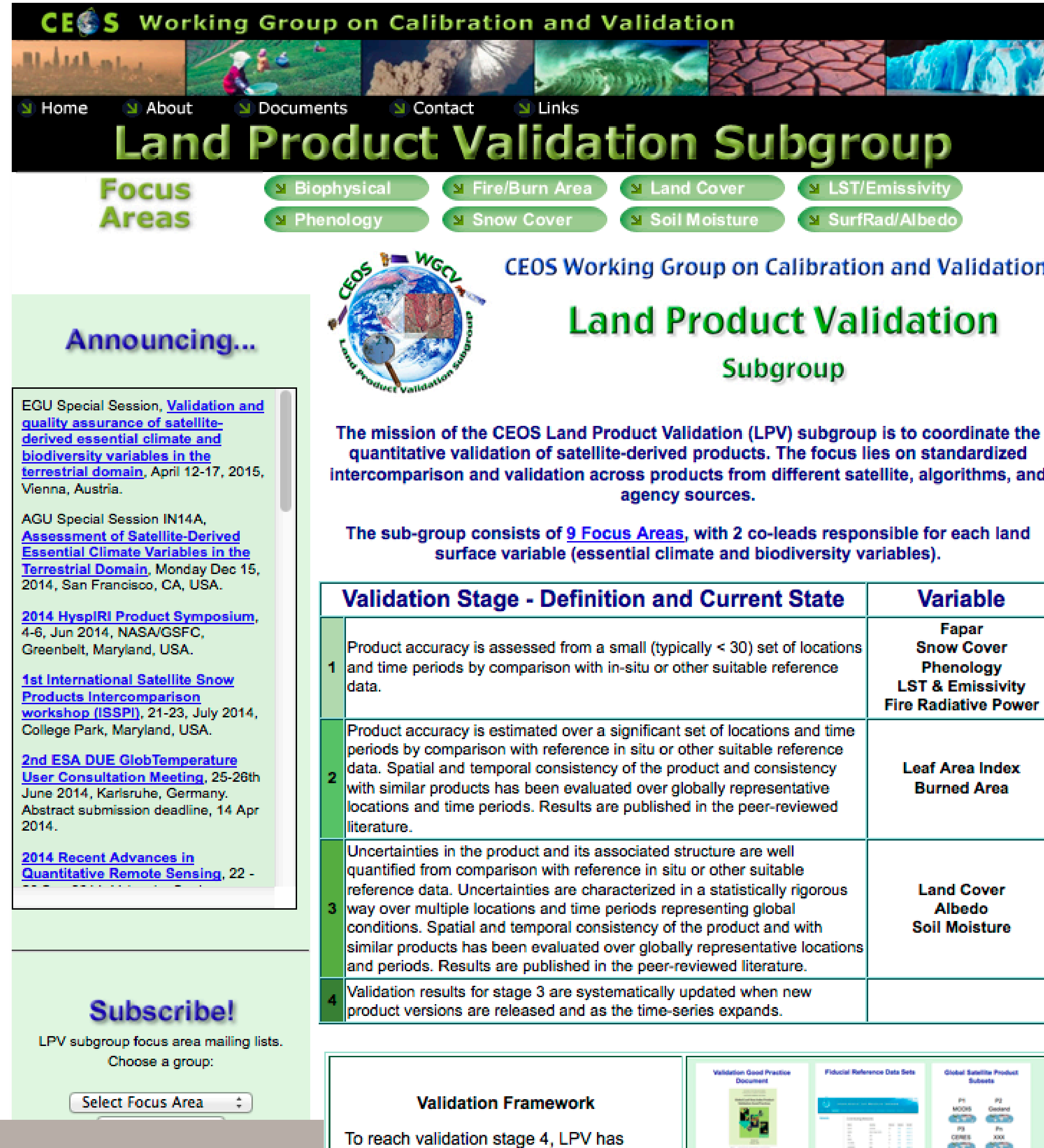
## LPV Web Site
## 15 years and running..

Established in 2000

Subscribed member list has grown ***to nearly 700 members*** over the years.

Each focus area (ECV) has pull down menu of links to

- Home page
- References
- Collaboration
- Products



CEOS Working Group on Calibration and Validation

Home | About | Documents | Contact | Links

Land Product Validation Subgroup

Focus Areas: Biophysical | Fire/Burn Area | Land Cover | LST/Emissivity | Phenology | Snow Cover | Soil Moisture | SurfRad/Albedo

Announcing...

EGU Special Session, Validation and quality assurance of satellite-derived essential climate and biodiversity variables in the terrestrial domain, April 12-17, 2015, Vienna, Austria.

AGU Special Session IN14A, Assessment of Satellite-Derived Essential Climate Variables in the Terrestrial Domain, Monday Dec 15, 2014, San Francisco, CA, USA.

2014 HyspIRI Product Symposium, 4-6, Jun 2014, NASA/GSFC, Greenbelt, Maryland, USA.

1st International Satellite Snow Products Intercomparison workshop (ISSPI), 21-23, July 2014, College Park, Maryland, USA.

2nd ESA DUE GlobTemperature User Consultation Meeting, 25-26th June 2014, Karlsruhe, Germany. Abstract submission deadline, 14 Apr 2014.

2014 Recent Advances in Quantitative Remote Sensing, 22 -

Subscribe!

LPV subgroup focus area mailing lists. Choose a group:

Select Focus Area

CEOS Working Group on Calibration and Validation

Land Product Validation Subgroup

The mission of the CEOS Land Product Validation (LPV) subgroup is to coordinate the quantitative validation of satellite-derived products. The focus lies on standardized intercomparison and validation across products from different satellite, algorithms, and agency sources.

The sub-group consists of 9 Focus Areas, with 2 co-leads responsible for each land surface variable (essential climate and biodiversity variables).

| | Validation Stage - Definition and Current State | Variable |
|---|---|---|
| 1 | Product accuracy is assessed from a small (typically < 30) set of locations and time periods by comparison with in-situ or other suitable reference data. | Fapar<br>Snow Cover<br>Phenology<br>LST & Emissivity<br>Fire Radiative Power |
| 2 | Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature. | Leaf Area Index<br>Burned Area |
| 3 | Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically rigorous way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature. | Land Cover<br>Albedo<br>Soil Moisture |
| 4 | Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands. | |

Validation Framework

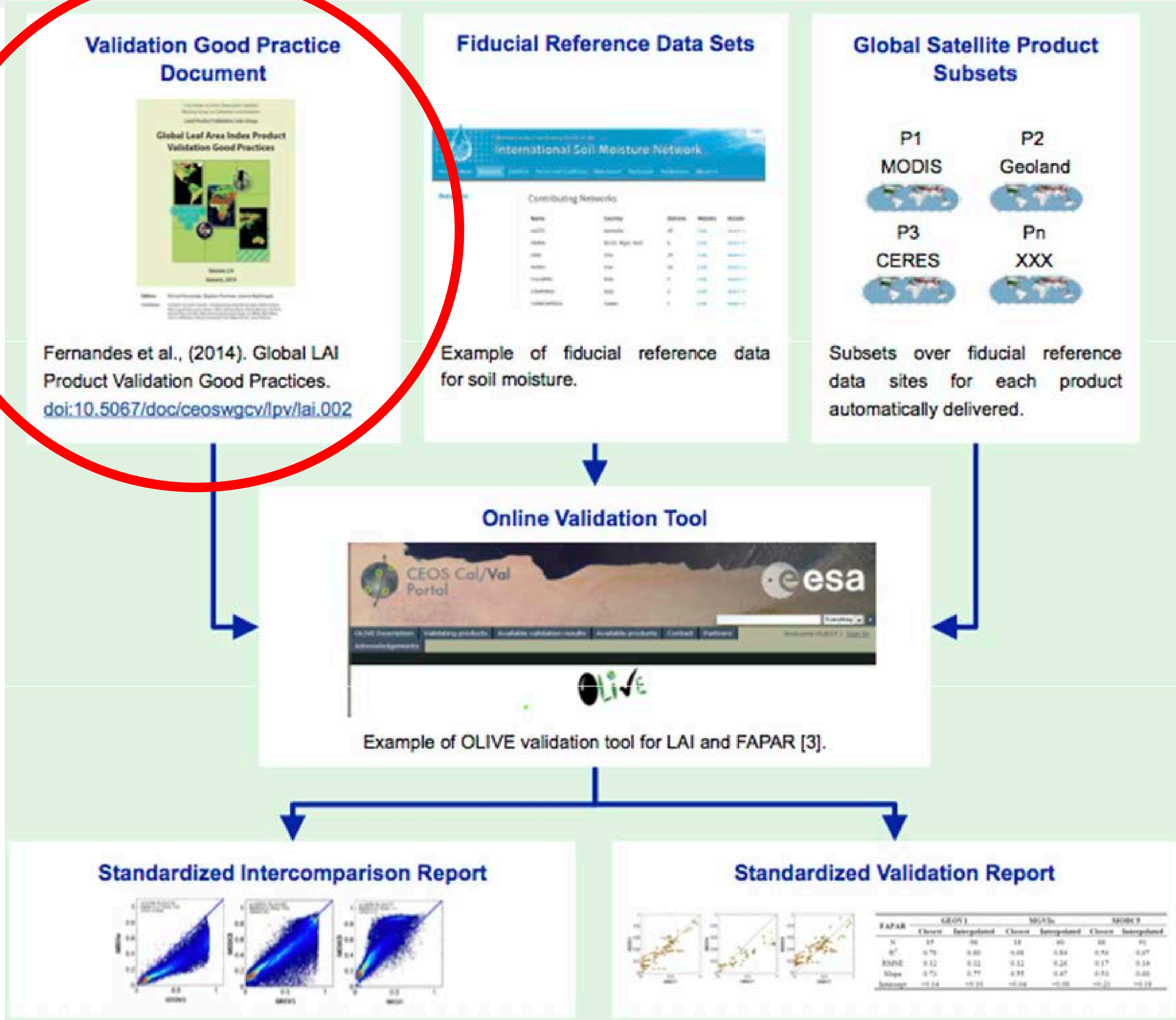
To reach validation stage 4, LPV has developed a framework for product

**http://lpvs.gsfc.nasa.gov**

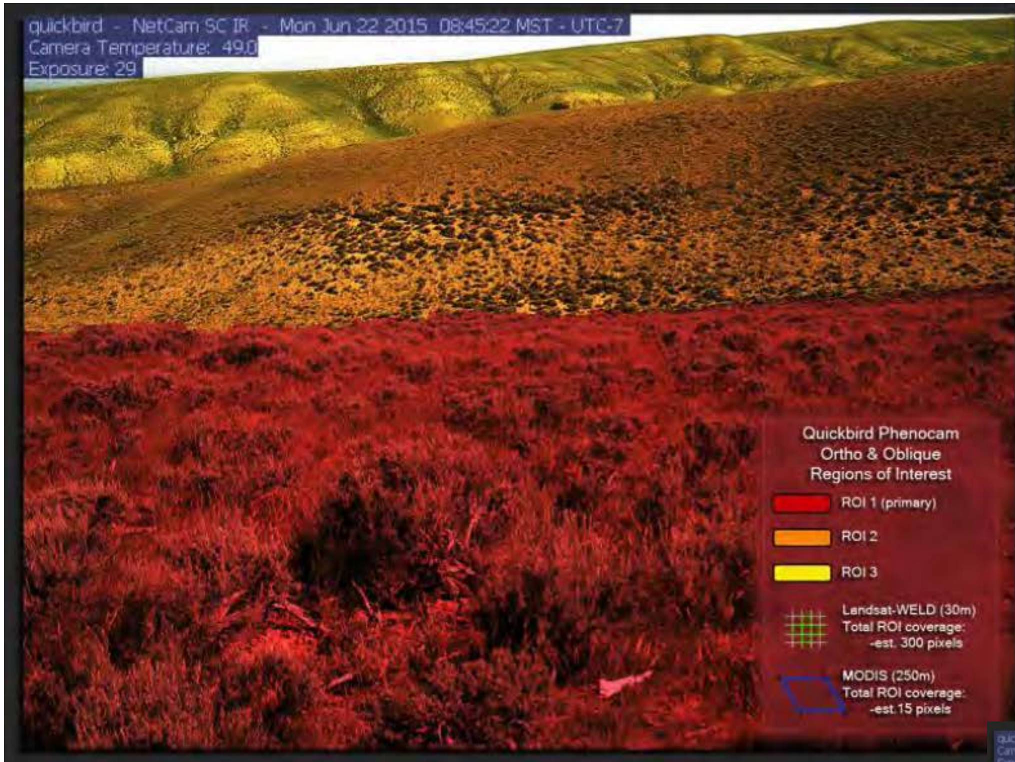
# CEOS LPV Team: Drivers of Innovation Performance

| Innovation Driver | Impact to Land ECV |
|---|---|
| **Validation Protocol Development** | 0 to 40% |
| **Access to and Distribution of Reference Data & Accuracy Reports** | 40 to 75% |
| **"Game Changing" Applications** | 75 to ≥100% |
| **How About This Driver?** | |

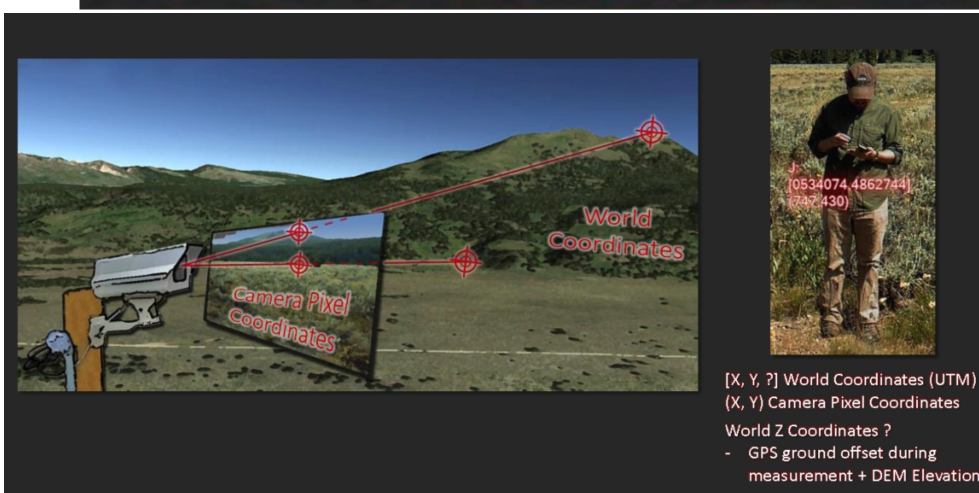
# A Land Validation Framework

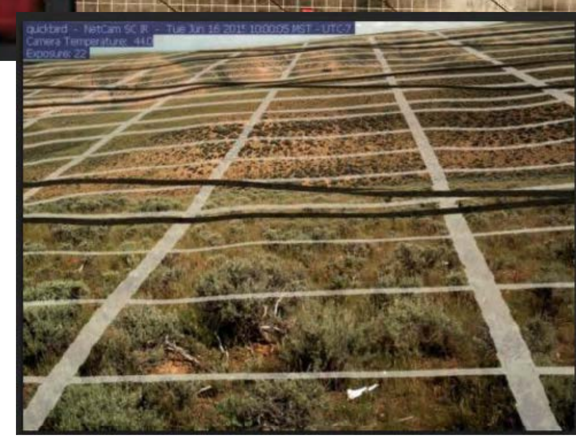


# Scaling Phenology (USGS)







USGS/NCCSC PhenoCam Project
Credit: Joseph Krienert / Jeff Morisette

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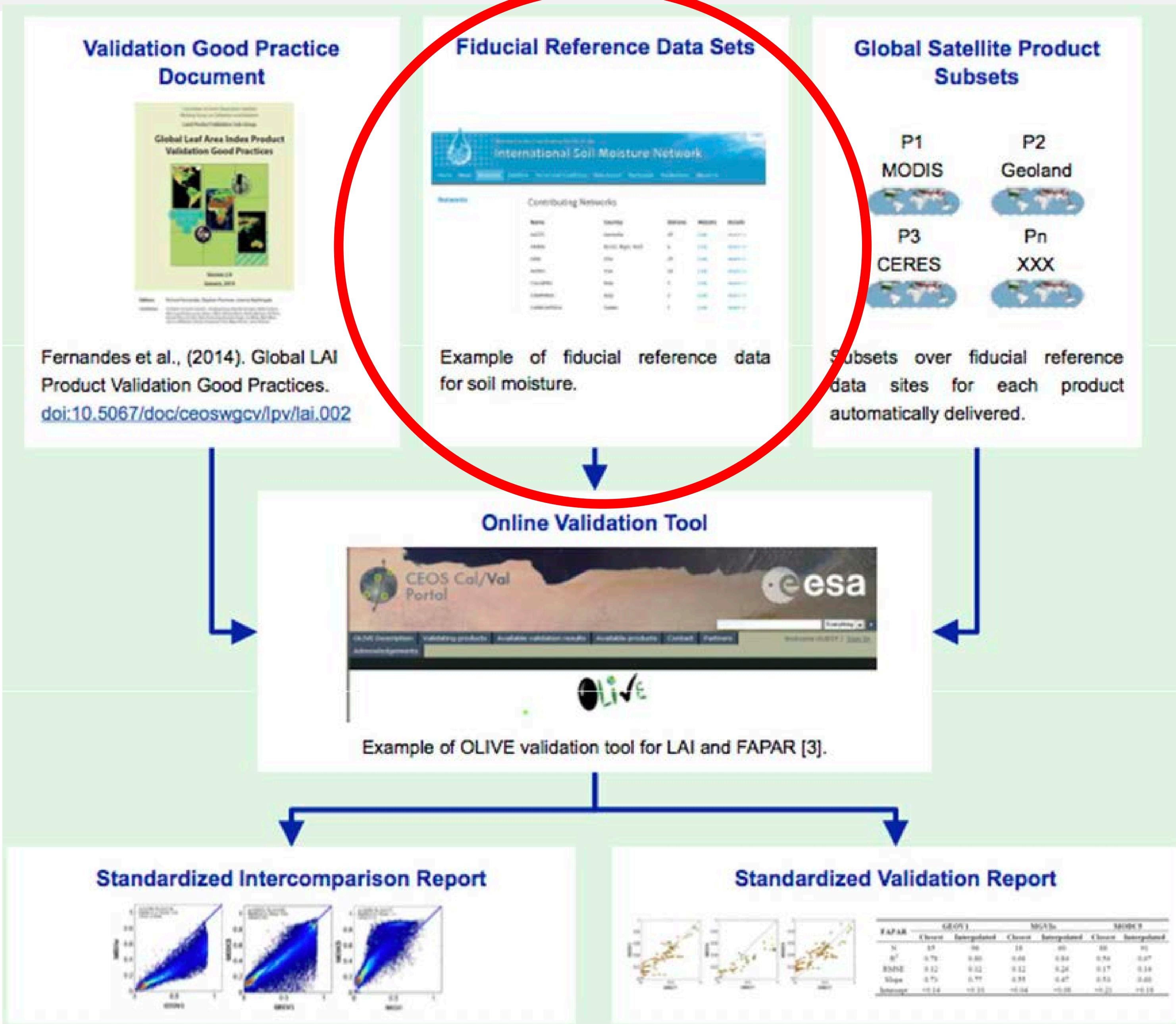
# A Land Validation Framework



# Fiducial Reference Data Collection: Challenges



– *CEOS/WGCV/LPV Goal*: To characterize land product uncertainties in a statistically rigorous way (i.e., over multiple locations and time periods representing global conditions).

– *Our Challenge*: To work within the constrains of NOAA/NASA missions, programs, and airborne assets (e.g., deployments costs on P3-B: ~$4000/flight hour).

– *Our Strategy to-date*: "Piggy-backing" has brought us some gains; but it requires a lot of:

1. Patience (work with lead PIs and identify common goals),
2. Good Luck (e.g., nominal operations + clear skies),
3. Hard Work (countless hours of mostly unfunded effort; esp. for post-processing and science data analysis).

# Multi AngLe Imaging Bidirectional Reflectance Distribution Function Unmanned Aerial System (MALIBU)

PI: Román/GSFC 619; Instrument PI: Pahlevan/Sigma Space 619

Goddard Space Flight Center

## Description and Objectives:

- Design a low-cost imaging approach to validate critical land climate data records
- Radiometric/Spectral calibration of dual Tetracam cameras at GSFC calibration facility
- Platform integration and Field Deployment
- Subpixel (10 meter) land biogeophysical product retrieval (PRI, NDVI, BRDF/Albedo, Reflectance) and validation efforts (MODIS/MISR, VIIRS, Landsat/OLI, and GOES-R).

## Key challenge(s)/Innovation:

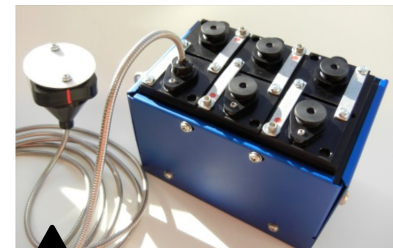
- Accurate earth gridding & geo-location of the collected images.

## MALIBU Platform and Payload

Tempest Blackswift UAS

- Programmable flight path
- Endurance (~60-90 min)
- Altitude: 100-500 m
- Cruise speed: 50 km/h
- Weight: 3 kg

- Two six-channel cameras
- Irradiance sensor
- FOV ~ 50deg
- Weight 0.7kg (each)



Mini-MCA6 Equipped with Incident Light Sensor

## Approach:

- Specify/Study camera specifications
- Work closely with the camera vendor during the fabrication
- In-house camera calibration
- Work closely with platform vendor during integration phase
- Test flights and geo-location tests
- Design flight plans and data collection procedure
- Data processing and product generation

## Application / Mission:

- Develop international protocols for assessment of terrestrial essential climate variables.

**Key Members:** Geoff Bland (610W), Joel McCorkel (618), Zhuosen Wang (ORAU), Ed Masuoka (619), Robert Wolfe (619), Jack Elston (Black Swift), John Augustine (NOAA), and Ivan Csiszar (NOAA).

## Milestones and Schedule:

| | |
|---|---|
| Start of the project | 10/2014 |
| Camera procurement | 11/2014 |
| Camera characterization | 12/2014 |
| System Integration | 03/2015 |
| Test flights | 04/2015 |
| Data collection | 06/2015 |
| Post-deployment calibration | 07/2015 |
| Data processing | 09/2015 |

TA-08; New Tools of Discovery; $TRL_{in} = 4$

# Task Objective

- **Objective: To deploy an Unmanned Aircraft System (UAS) that can enable high spatial and angular resolution mapping of terrestrial essential climate variables.**
- **MALIBU sensor suite performance metrics:**
  - **Two Tetracam optical units**
  - **Combined FOV ~ 100° (50° x camera)**
  - **GIFOV < 10 meters**
  - **Geolocation accuracy < 0.7 pixel***
  - **Signal to Noise > 300**
  - **Radiometric uncertainty < 5% attained through frequent GSFC in-house calibration**

***Challenges: All-of-the-Above Strategy: Onboard IMU (Uncertainty = $0.1^{deg}$) + Onboard GPS (Uncertainty < 1 m) + Ground Control Points (image-based geolocation).**

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# Six types of drone concepts ‘crazier’ than MALIBU…

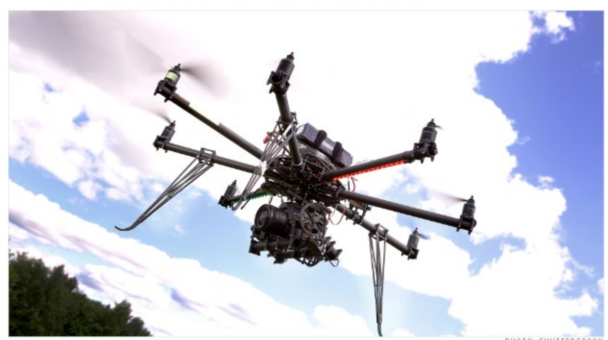
## Package Delivery


## IED Detection

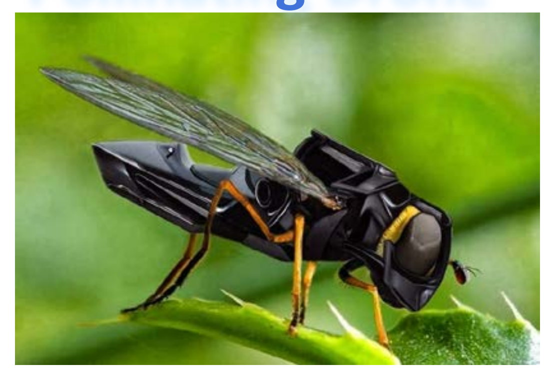
## Hurricane Drone

## Food Delivery


## Wildfire Drone

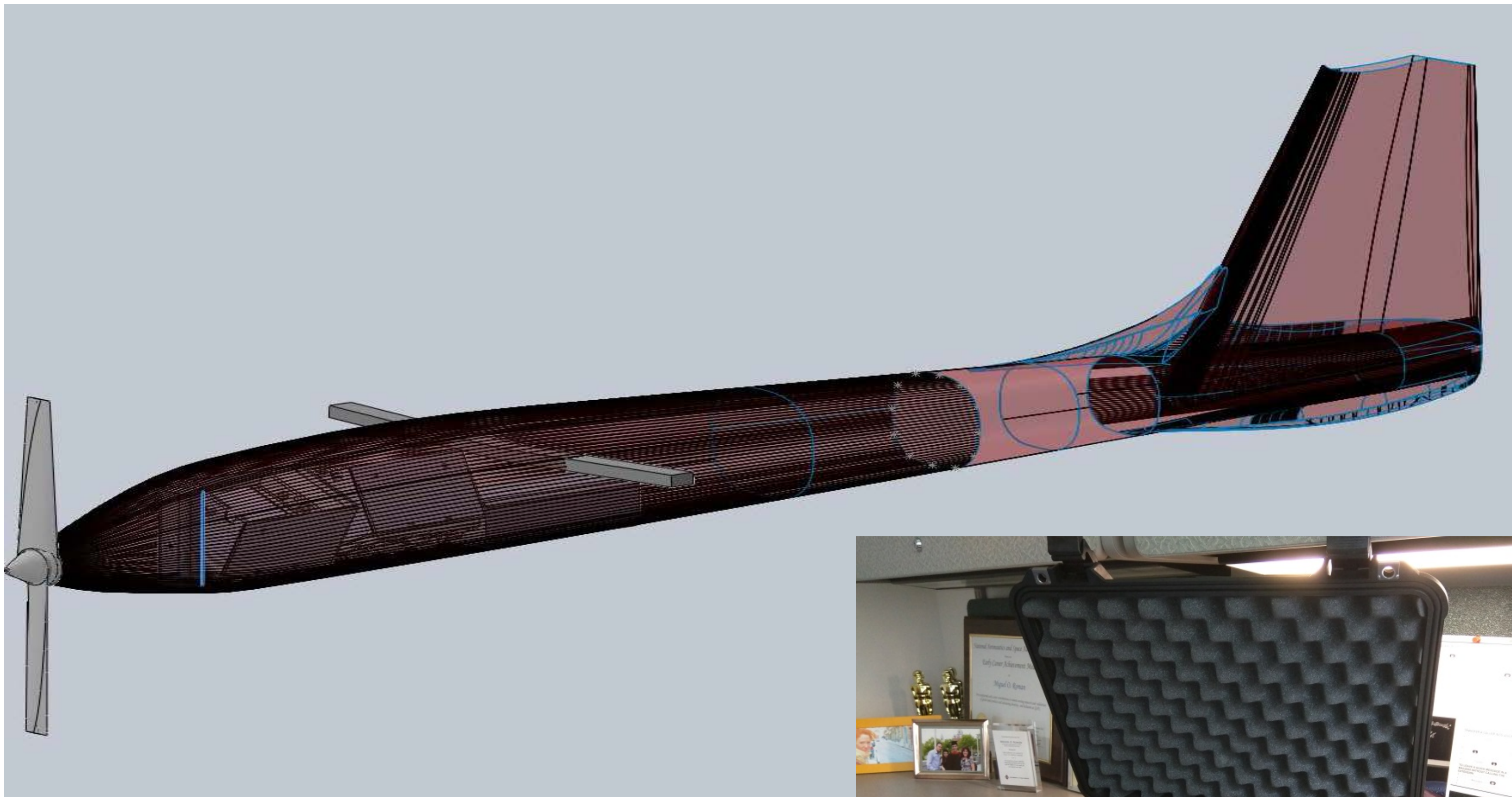



## Pollinating Drone

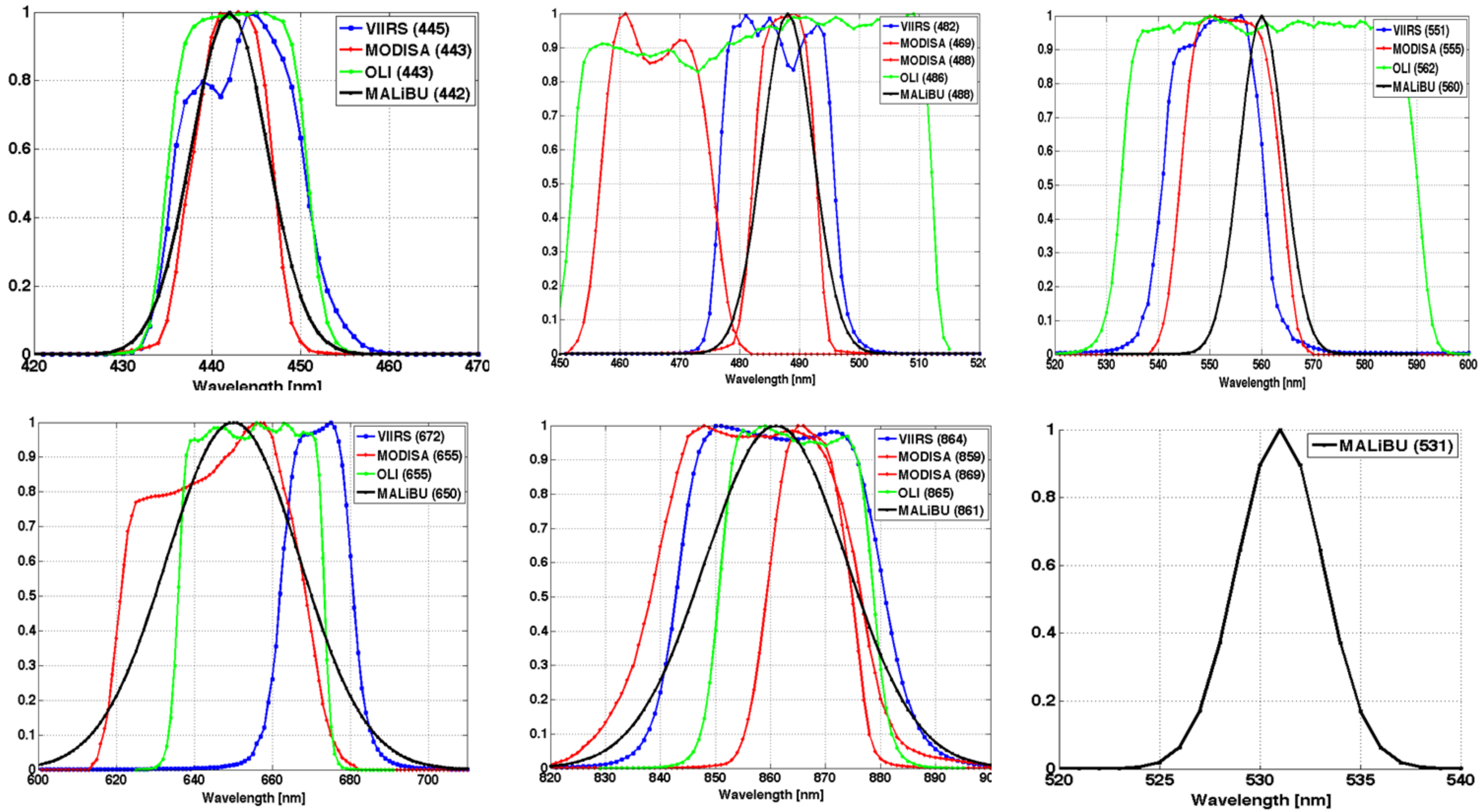


# MALIBU Imaging Geometry

- **Camera mounts**



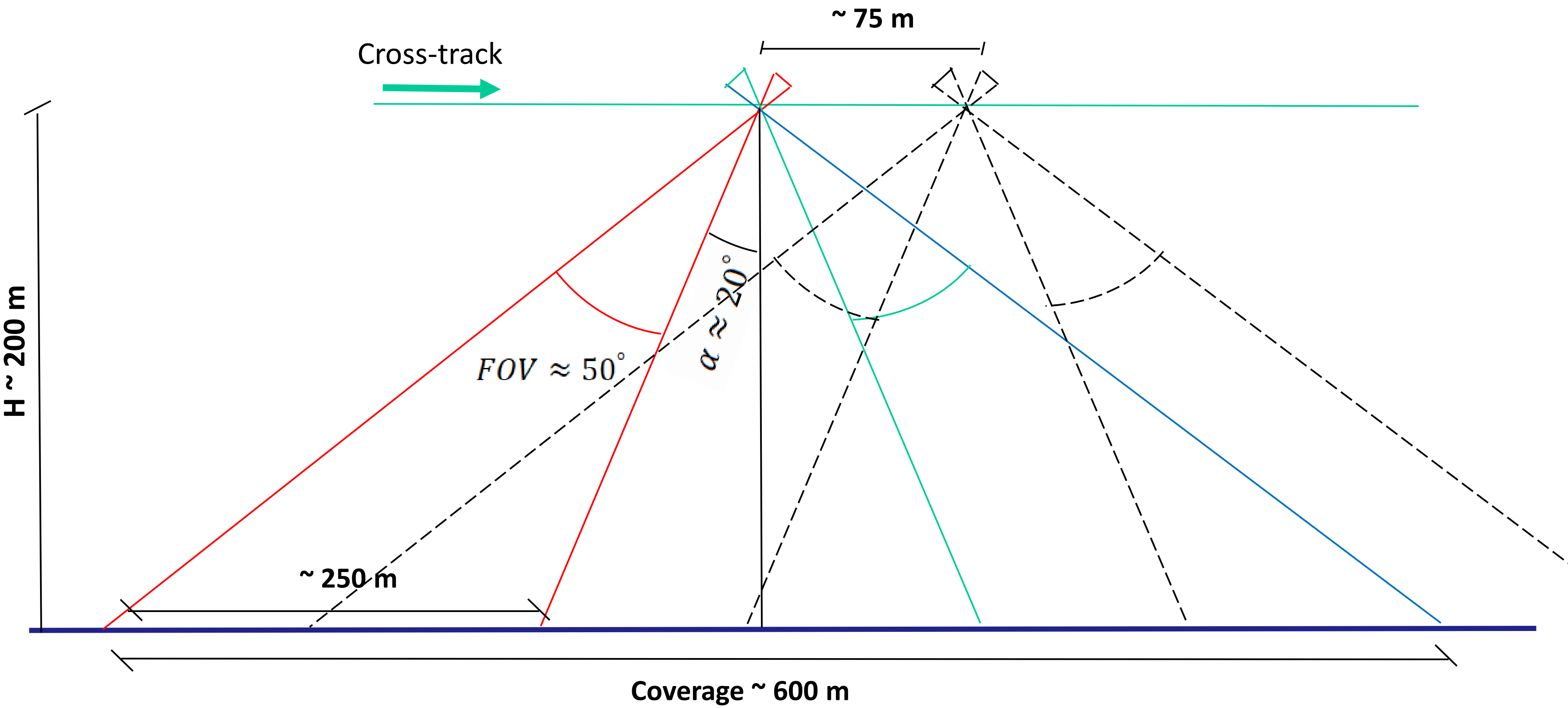
# MALIBU Spectral Response




**442, 488, 531, 560, 650, 861nm**
**+ Tetracam's Incident Light Sensor**

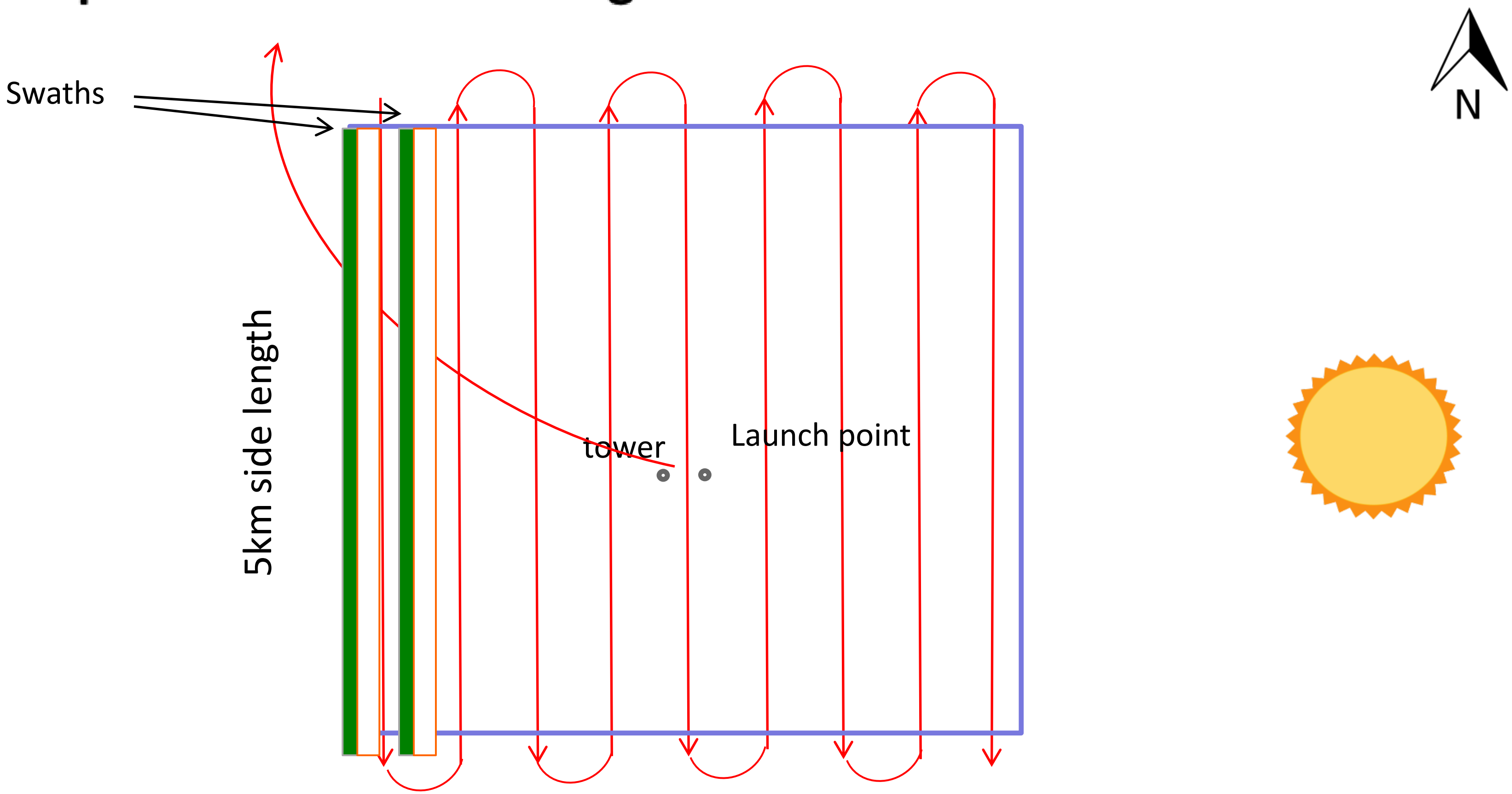
# Viewing Geometry: Cross-track

- **Dual Tetracam cameras (with non-overlapping swaths) mounted on the platform across-track**



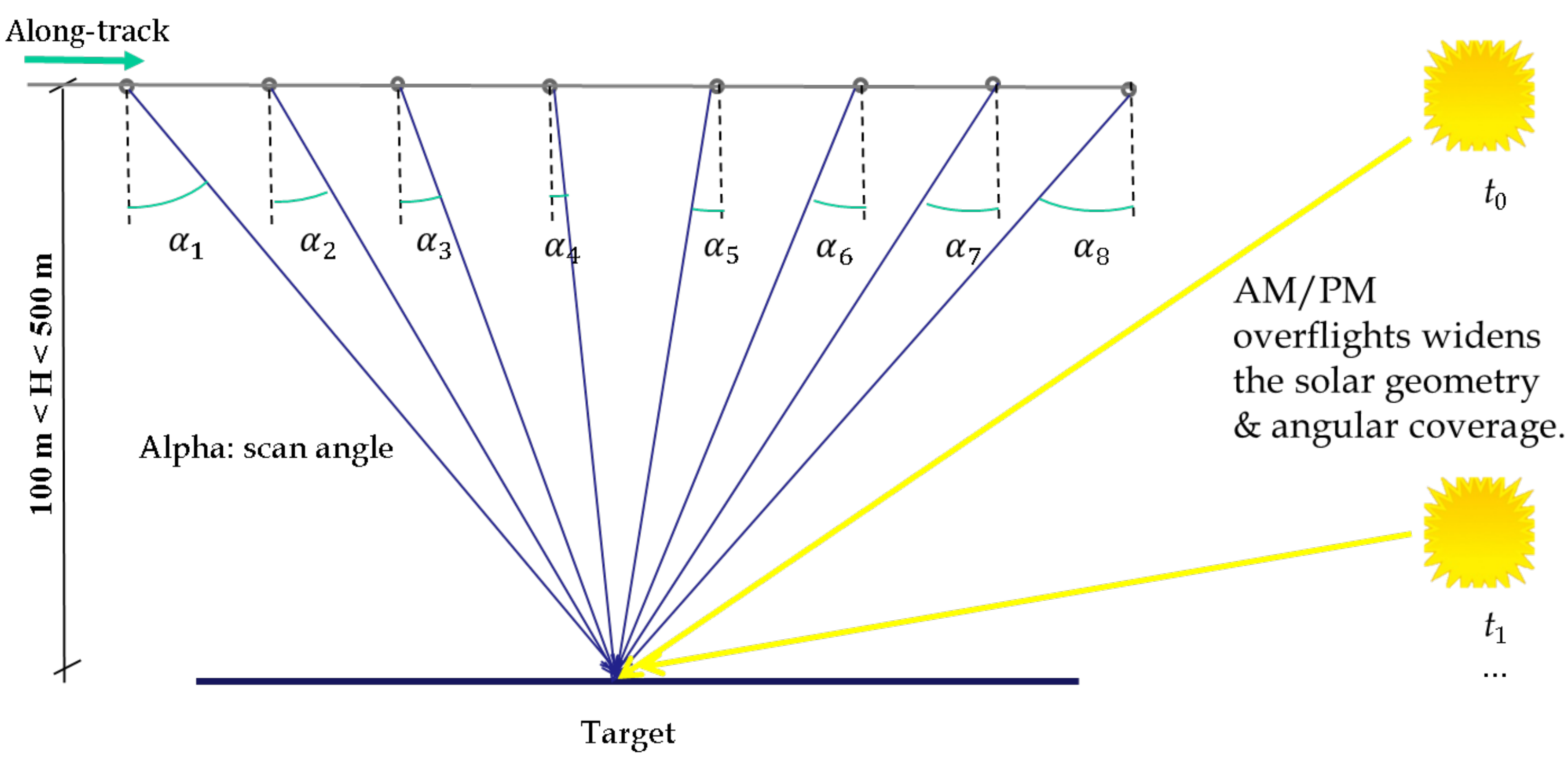
# MALIBU Flight Path

- 5×5 $km^2$ is covered during two-day deployment
- Requires visible line-of-sight less than 5 km

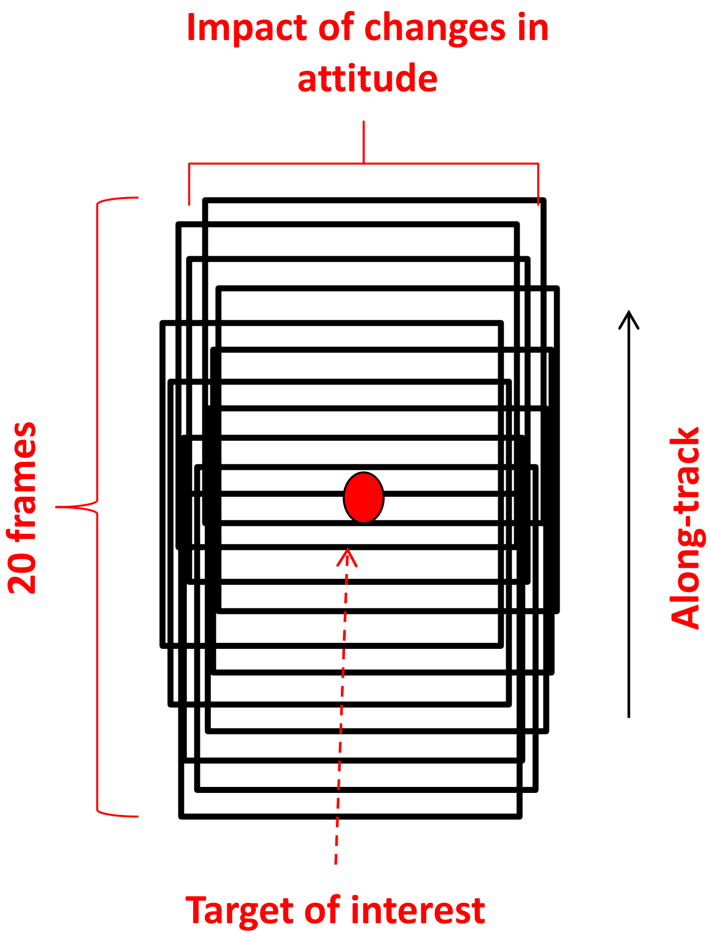


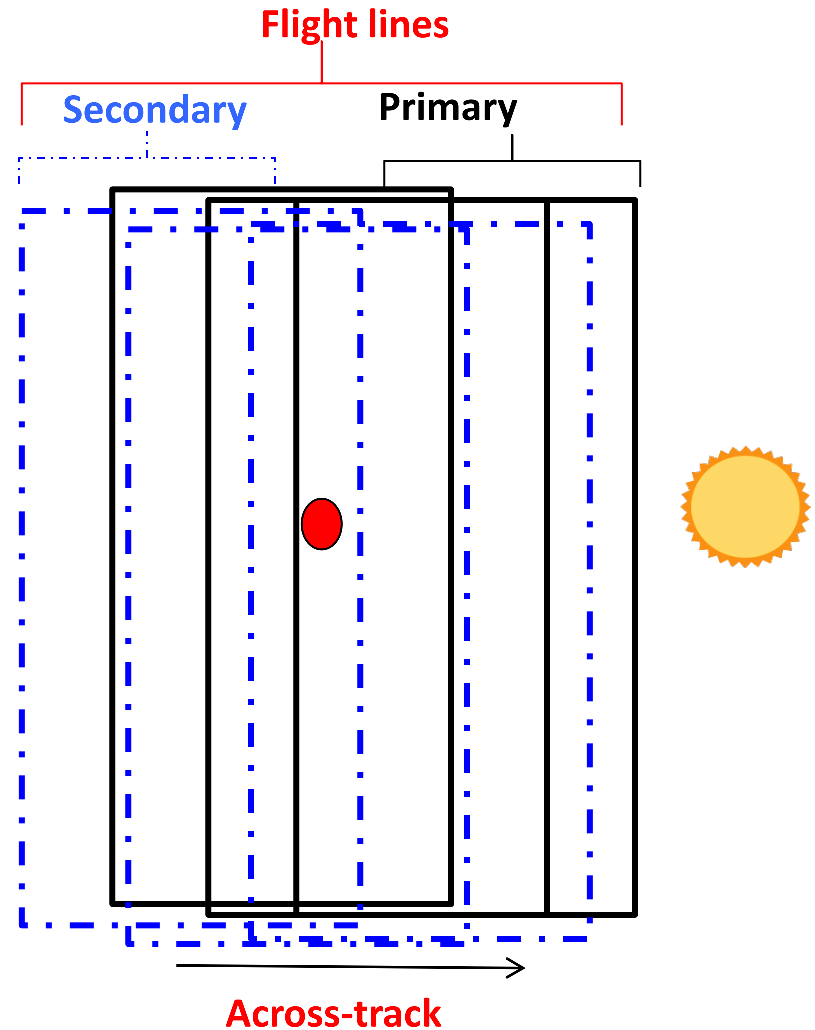
# MALIBU Flight Path(cont.)

**Overlapping scenes along-track provide multi-angular retrievals.**



# Overlapping Regions



# First MALIBU Test Site: NOAA-Surfrad Table Mountain, CO

- Located ~8 miles north of Boulder, CO.
- Part of NOAA ESRL, US SURFRAD, and the international BSRN reference network .
- John Augustine (NOAA/ESRL, Site PI) is MALIBU team collaborator.

- In-situ measurements include: MFRSR, LI-COR PAR, Yankee UVB-1 Ultraviolet Pyranometer, ventilated Eppley pyrgeometer and ventilated Spectrosun pyranometers.
- Blackswift Tempest has been deployed extensively at this site (69 flights completed since 2010).

| | |
|---|---|
| Latitude: | 40.12498 |
| Longitude: | -105.23680 |
| Elevation: | 1689 m |
| Installed: | July 1995 |

# How About J2 Cal/Val??

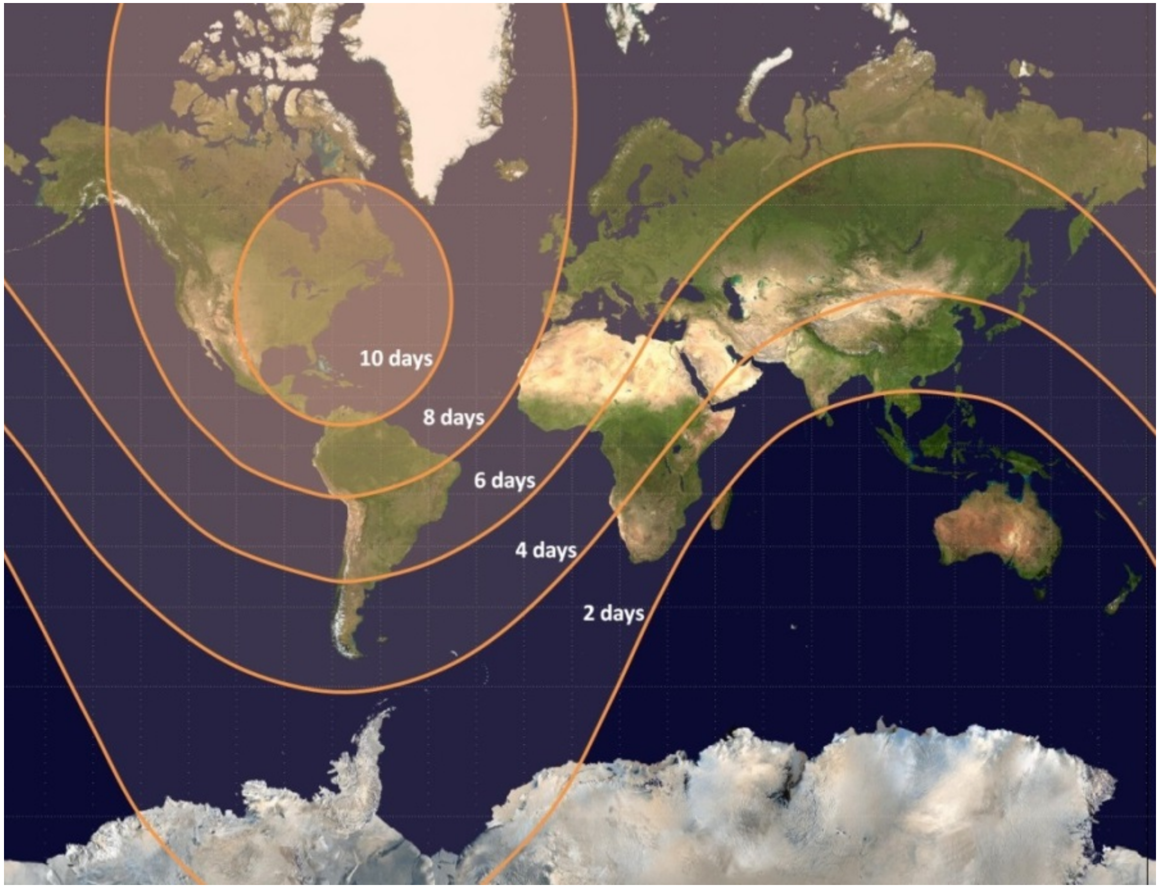
(2020 and beyond…)

# VA001 Aircraft


**Vanilla Aircraft, LLC**

# ConOps

- **18,500 nm** range, **10 day** endurance, with 30 pound payload
- 2 aircraft could keep a payload on-station indefinitely

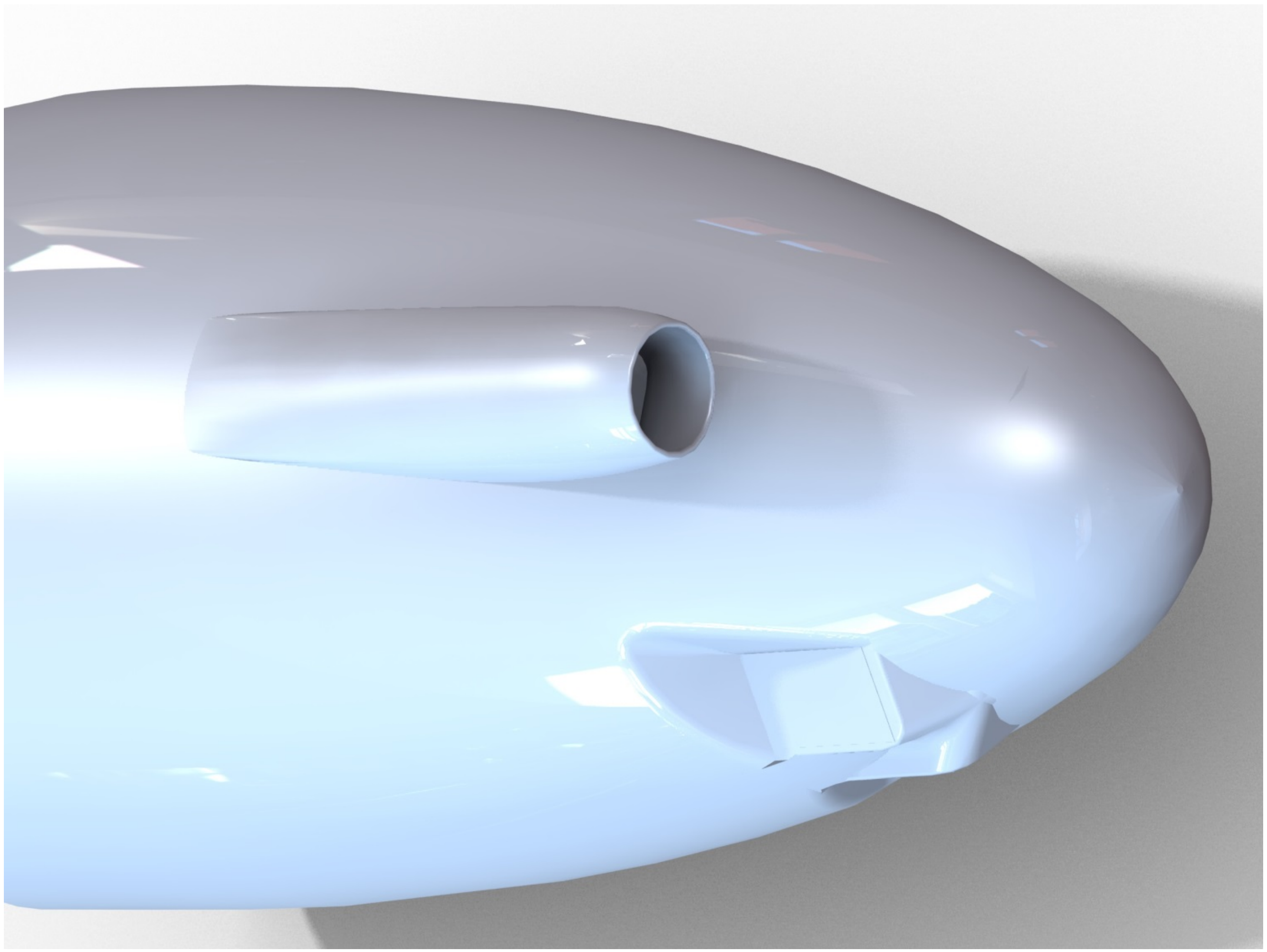



Contours of on-station endurance with launch and recovery from the eastern United States

**Vanilla Aircraft, LLC**

# TetraCam Micro MCA-6

- Multi-spectral imaging, two systems each 45° from nadir



**Vanilla Aircraft, LLC**


If you want to go fast, go alone.
If you want to go far,
go together.
African Proverb