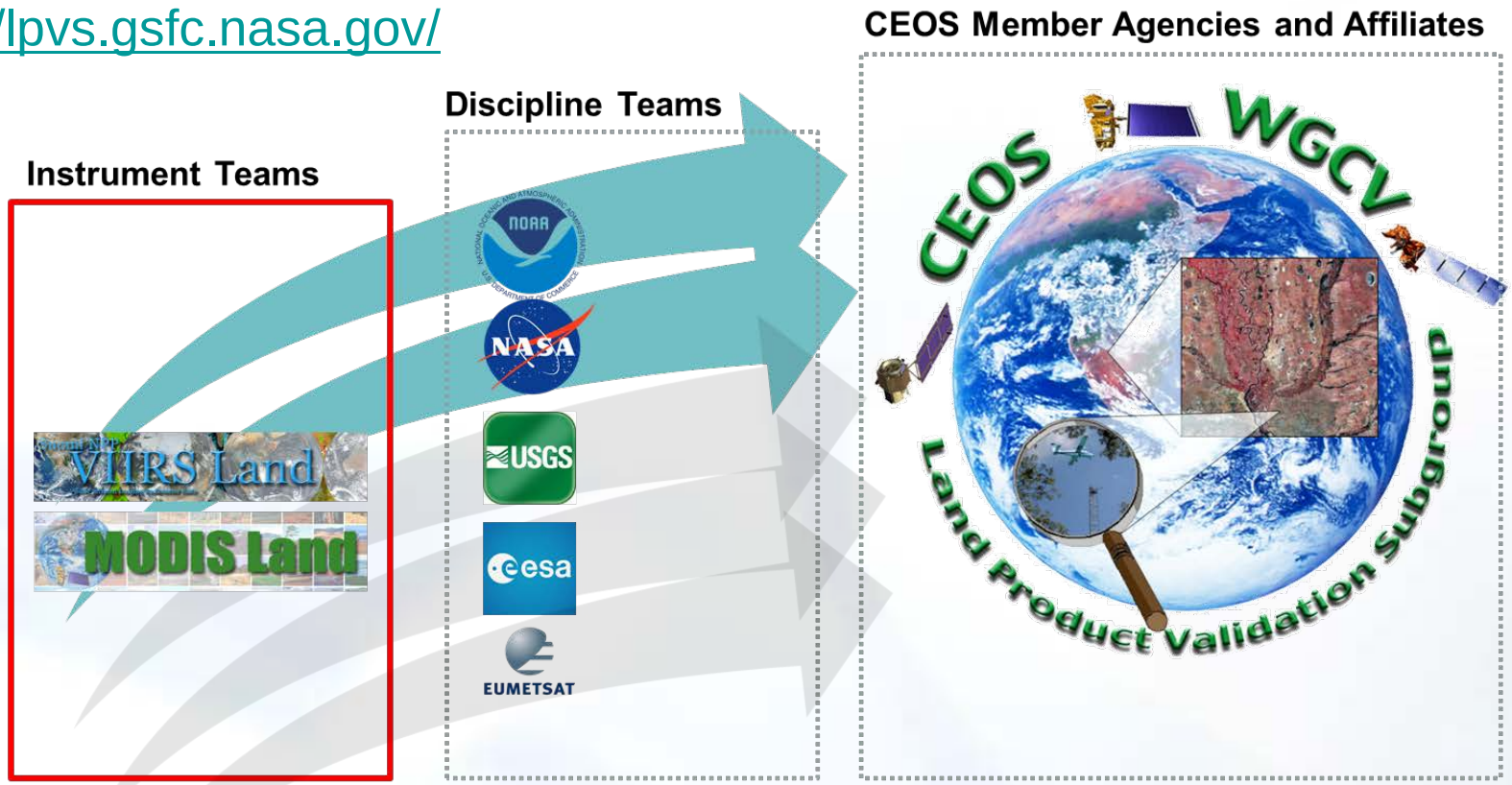
CEOS Land Product Validation Update

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



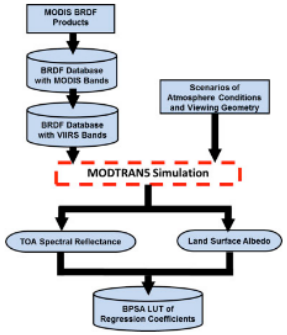
Miguel Román, Fernando Camacho, Jaime Nickeson, Pierre Guillevic, Zhuosen Wang, and Chris Justice
with contributions from the CEOS-LPV agency POCs and focus area leads

Suomi NPP VIIRS Land

Visible Infrared Imaging Radiometer Suite

NOAA Albedo and Bidirectional Reflectance EDR

Yunyue (Bob) Yu, Product Lead
Shunlin Liang, Dongdong Wang, and Yuan Zhou (UMD), Development and Validation

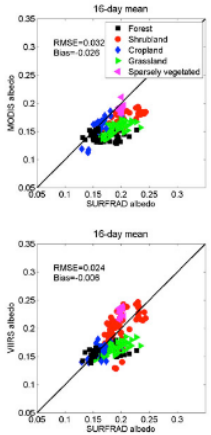


A brief flowchart showing how the BPSA LUT of regression coefficients is generated (Wang et al. 2013).

Surface albedo, defined as the ratio between shortwave radiation reflected by Earth's surface and shortwave radiation incident at the surface, is a function of both solar illumination and the reflective properties of the Earth's surface. The VIIRS Surface Albedo EDR consists of land surface albedo (LSA), ocean surface albedo and snow or sea ice surface albedo. Among them, LSA is an essential variable linking the land surface and the climate system. It is a unique property for studying how land surface changes affect the energy balance and the overall climate system.

The current VIIRS LSA algorithm is a direct estimation method, which directly links surface broadband albedo with VIIRS top-of-atmosphere (TOA) reflectance through radiative transfer and statistical modeling (left). Since the launching of Suomi NPP, the LSA algorithm has gone through two major improvements. The validated Version 1.0 readiness review was approved in December 2015.

Validation against field measurements at 25 stations shows that VIIRS can estimate surface albedo over non-snow pixels with a root mean square error (RMSE) of 0.024 a small negative bias of 0.006, comparable with the existing MODIS data (right).

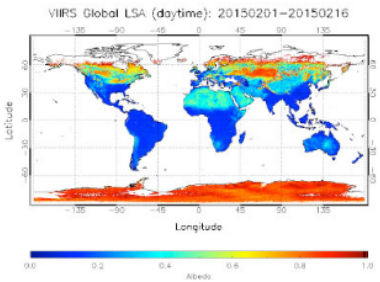


Validation results of 16-day mean snow-free albedo from VIIRS (top) & MODIS (bottom).

With the direct-estimation algorithm, LSA is estimated for all VIIRS land pixels (~ 750 m) with clear-sky conditions.

Two granule products are currently available: a single swath granule dataset with the dimension of 768 x 3200, and a 4-swath aggregated granule dataset with the dimension of 3072 x 3200. The official JPSS Surface Albedo EDR product can be accessed from NOAA's Comprehensive Large Array-data Stewardship System (CLASS).

A composite global map of VIIRS LSA is shown below as an example.



A global map of land surface albedo composite with VIIRS products from Feb 1-16, 2015

Reference

Wang, D. D., S. L. Liang, et al. (2013). Direct estimation of land surface albedo from VIIRS data: Algorithm improvement and preliminary validation. *Journal of Geophysical Research-Atmospheres* 118(22): 12577-12586.

NOAA Surface Type EDR

Xiwu Zhan, Product Lead
Chengquan Huang (UMD), Rui Zhang (UMD), Development and Validation

The VIIRS Surface Type EDR is a swath product built by re-projecting the Gridded Quarterly Surface Type Intermediate Product (ST-IP) and overlaying it with the Active Fire ARP, Snow Cover EDR, and Green Vegetation Fraction for each 750m pixel. The VIIRS Global Surface Type Map represents the continuity of NASA EOS MODIS and NOAA POES AVHRR land cover products.

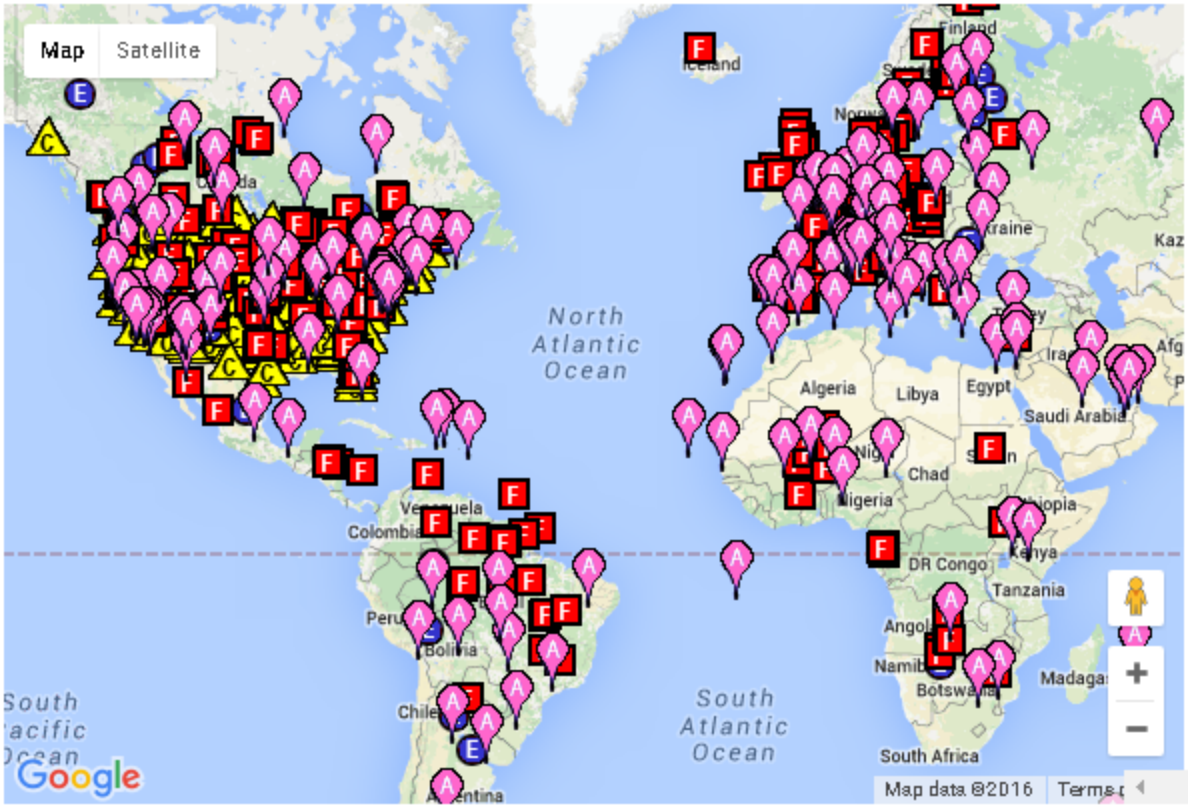
Example of Surface Type EDR product (ST-EDR)

While the VIIRS Surface Type EDR is an input to the VIIRS Land Surface Temperature (LST) EDR and other downstream products in the JPSS IDPS system, the VIIRS Global Surface Type Map is a required input by many land surface models for numerical weather, climate and hydrological models, studies on natural resources and disaster management, and for ecosystem monitoring.

The global surface type map is produced at 1 km spatial resolution based on the previous one or more years of VIIRS surface reflectance, brightness temperature and vegetation index data. Both VIIRS Surface Type EDR and the Global Surface Type Map provide 17 surface type classes following the IGBP classification scheme. Accuracy requirements for the EDR and the global map is a 70 percent metric of correct classification.

The 1st gridded VIIRS global surface type map providing the basis for the Surface Type EDR was generated offline with the MODIS heritage C5.0 decision tree classification algorithm by the University of Maryland's VIIRS Surface Type EDR team and validated by the Boston University validation team. Future annual updates of VIIRS Global Surface Type Map will be developed and validated by the UMD team. The most recent version of the VIIRS Global Surface Type Map is available for download at this ftp link. and information about the product is provided in this Readme document also available by ftp.

MODIS/VIIRS Subsets FTP Access Page



- Peatland
- AB-Western Peatland Poor Fen
- AB-Western Peatland Rich Fen
- Abisko
- Adelaide River
- Agoufou G
- Agoufou S
- Aguamarga
- Aiken
- Ailaoshan
- Akanuma- Kushiro Mire
- Alkkia Scots pine forest
- Alp Weissenstein
- Amoladeras
- Amplero
- Anaktuvuk River Moderate Burn
- Anaktuvuk River

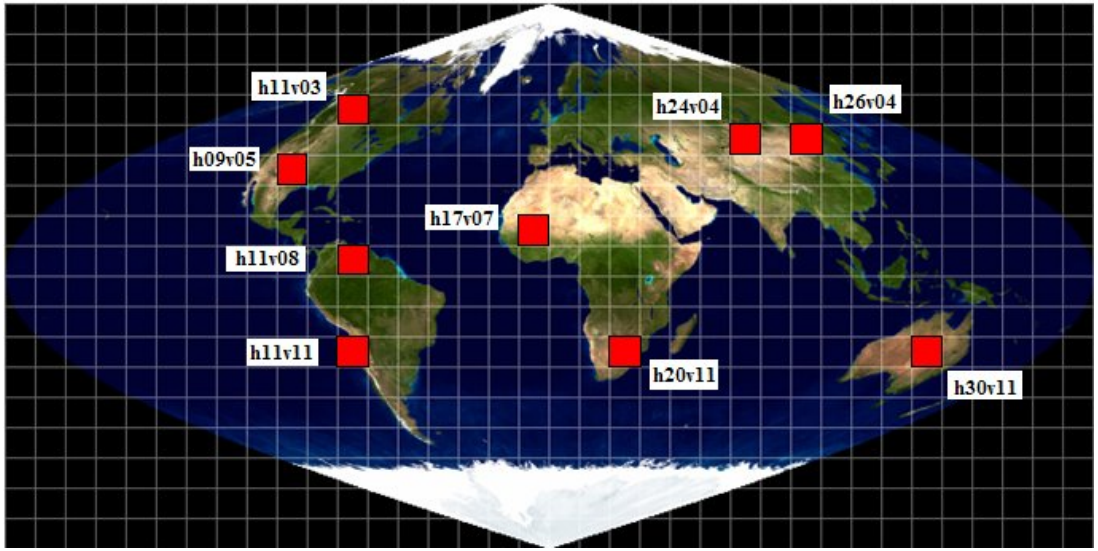
Product Short Name	Product Description
NPS_CMIP_L2	VIIRS/NPP Cloud Mask 5-Min L2 Swath IP 750m - Subset
NPS_IMFT_L1	VIIRS/NPP Imagery Resolution 5-Min Swath SDR 375m - Subset
NPS_QMMVIIP_L2	VIIRS/NPP Gridded Annual Min/Max Vegetation Index Quarterly 5 Min Swath IP 750m Granulation - Subset
NPS_QSIP_L2	VIIRS/NPP Gridded Surface Types Quarterly 5-Min L2 Swath IP 750m Granulation - Subset
NPS_QSLWMIP_L2	VIIRS/NPP Gridded Surface Types Land Water Mask Quaterly 5-Min L2 Swath IP 750m Granulation - Subset

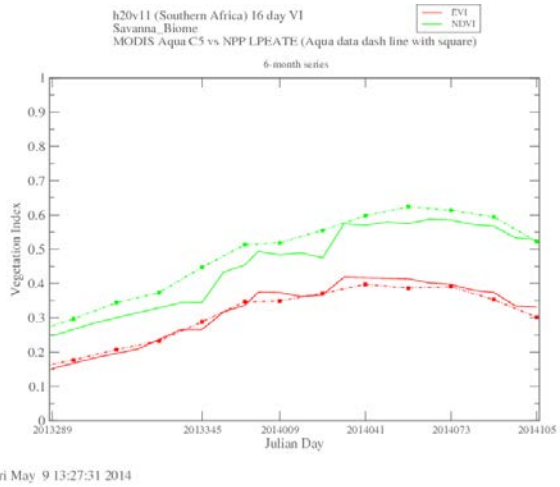
Used by multiple teams (VIIRS ST, VCST, LPDAAC, ORNL, NOAA/STAR)

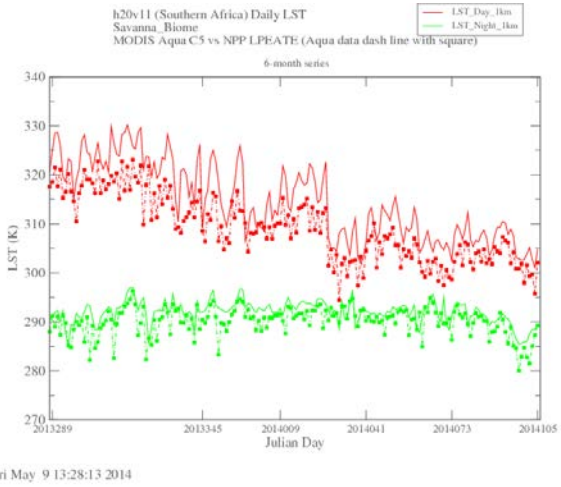
Land Product Quality Assessment Golden Tile Time Series

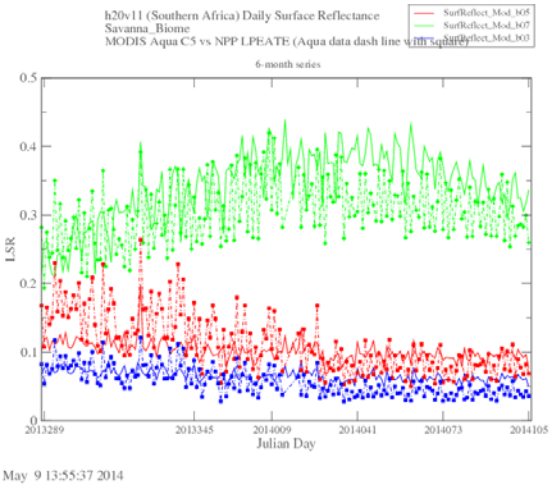
Approach:

Summary statistics for (10° X 10°) SIN golden tiles.









Early VIIRS (solid lines) vs. Aqua MODIS C6 (dashed-dot lines) **Vegetation Index** (left), **LST** (center), and **Surface Reflectance** (right). 6-month trending shown for observations from savanna class (tile h20v11).

CEOS-LPV's Core Mission

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

Instrument Teams

VIIRS Land

MODIS Land

Discipline Teams

Agency POCs:

NOAA — I. Csiszar, M. Vargas

NASA — H. Margolis, M. Román

USGS — G. Stensaas, J. Dwyer

esa — S. Plummer, F. Gascon

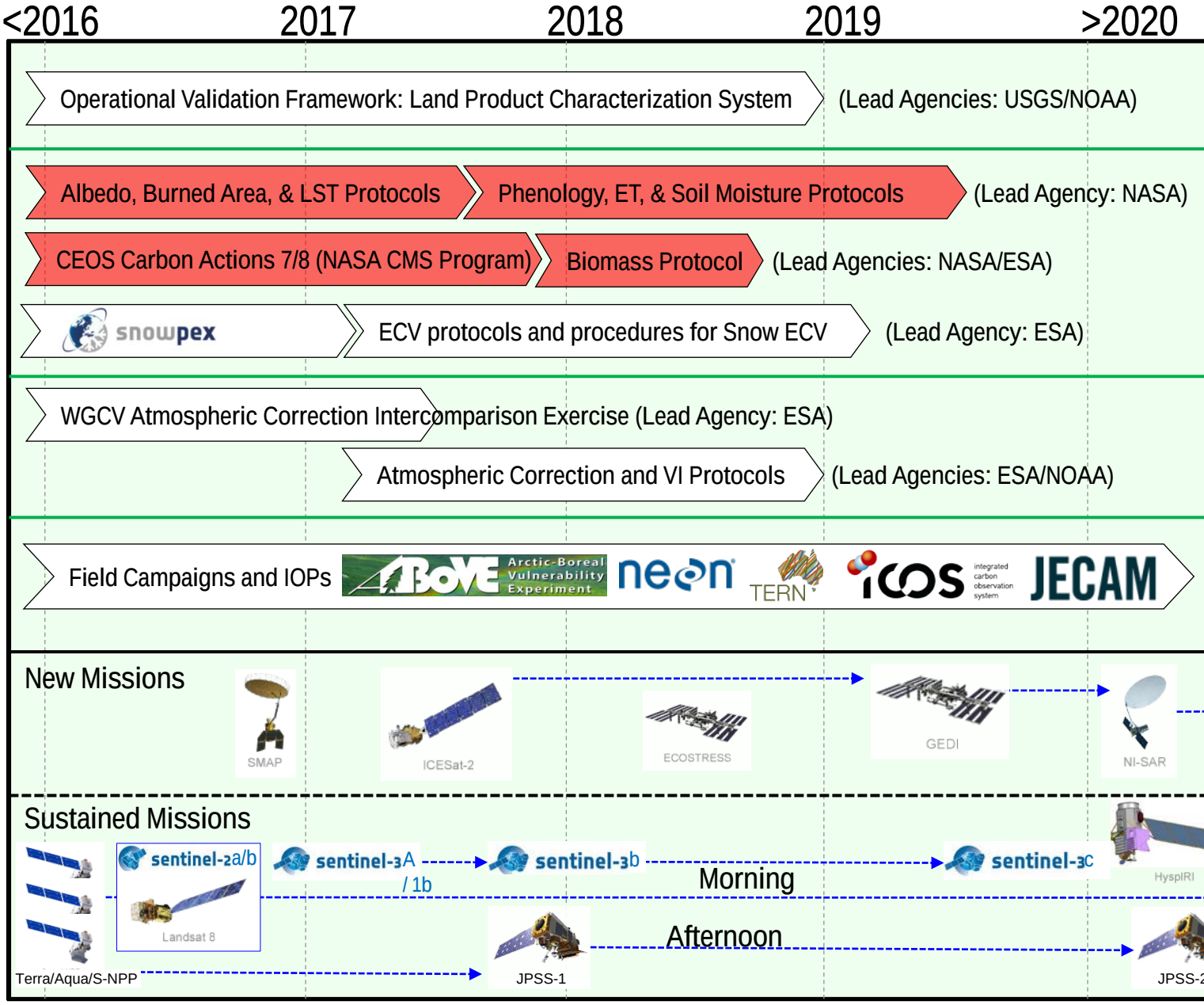
EUMETSAT — A. Lattanzio

CEOS Member Agencies and Affiliates

http://ceos.org/about-ceos/agencies/

To integrate across LPV Focus Areas, CEOS Space Agencies, and the Land Discipline & Instrument Teams.

CEOS-LPV 5-Year Roadmap



Vision

All missions support validation & validation is on-going

Uncertainty information determined through standard practices & protocols

Algorithms are iteratively improved based on validation results

Lead Coordinating Agency: NASA

The LPV Validation Framework

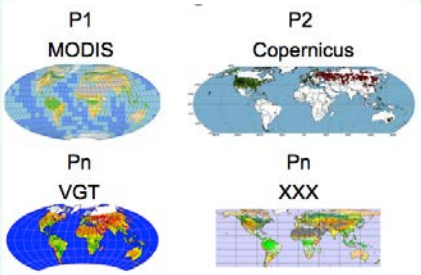
Validation Good Practice Document

Fernandes et al., (2014). Global LAI Product Validation Good Practices. doi:10.5067/doc/ceoswgcv/lpv/lai.002

Fiducial Reference Data Sets

Example of fiducial reference data for soil moisture.

Global Satellite Product Subsets



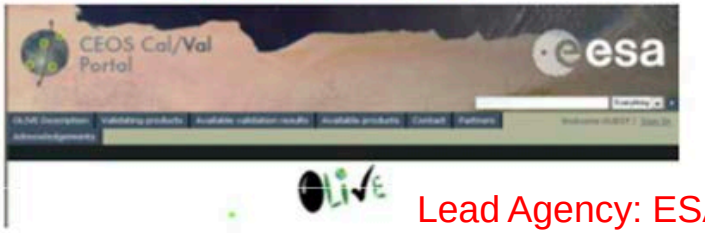
Subsets over fiducial reference data sites for each product automatically delivered.

Lead Agencies: Various

Lead Agency: NASA

Lead Agencies: USGS/NOAA

Online Validation Tool

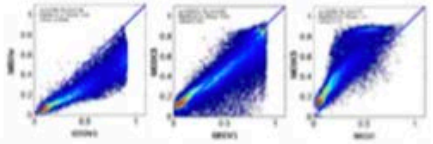


Lead Agency: ESA

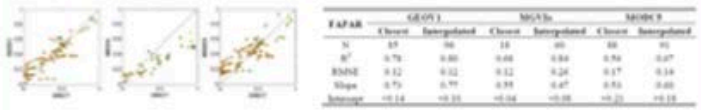
Example of OLIVE validation tool for LAI and FAPAR [3].

Lead Agency: ESA

Standardized Intercomparison Report



Standardized Validation Report

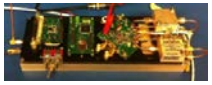


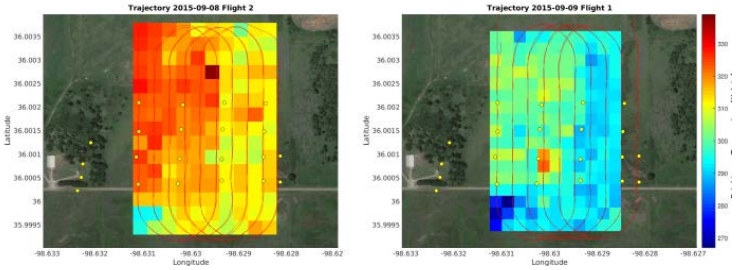
NASA small-UAS Partnerships:

GSFC, ARC and *BlackSwift Technologies LLC*

Two Instrument Systems

Soil Moisture (w/ L-Band Radiometer - SBIR)



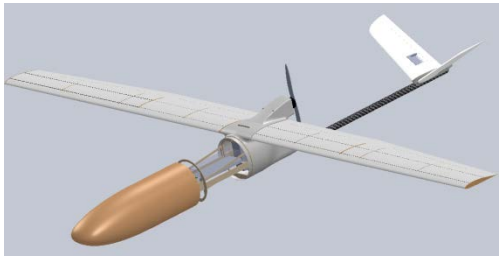


Multiangle, Multispectral imaging sensors (Román, et al - IRAD)
Surface Reflectance/Albedo, VI, LAI&FPAR, and Burned Area.

Two Types of s-UAS

Tempest (Established Platform)

SuperSwift (New, GeoScience Tailored Platform)



Electric s-UAS (both):
Max Wt. ~15 lbs
P/L Wt. ~5 lbs
Endurance~1 Hr

SBIR·STTR
America's Seed Fund™
POWERED BY NASA

http://sbir.nasa.gov/content/black-swift-technologies-llc

NASA Flight Readiness Review Approval COA-Gov't

National Aeronautics and
Space Administration

Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337-5099

Reply to Attn. of: Code 830 / AFSRB Chairman April 20, 2016

TO: 840/PM, Tempest UAS

FROM: 830/Chairman, Airworthiness and Flight Safety Review Board (AFSRB)

SUBJECT: Flight Release for the Tempest UAS

REF:
(a) FRR Meeting Minutes. March 25, 2016.
(b) UAS FOM, March 2016
(c) Tempest UAS Pilot Operating Handbook (Flight Manual)
(d) NPR 7900.3, "Aircraft Operations Management Manual", July 15, 2011

1. In accordance with the recommendations of the AFSRB in Reference (a), the Tempest UAS is certified for flight under the sUAS Provisions of the UAS FOM, Reference (b). All flights shall be flown in accordance with the Tempest UAS pilot operating handbook, Reference (c), UAS FOM and NPR7900.3, Reference (d). In the event of conflicting guidance, the more restrictive policy shall be used.

FAA Section 333 and Transport Canada Full Blanket Exemptions

U.S Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

December 11, 2015

Exemption No. 13967
Regulatory Docket No. FAA–2015–1684

Mr. Jack Elston
Black Swift Technologies
2100 Central Avenue
Boulder, CO 80301

Dear Mr. Elston:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

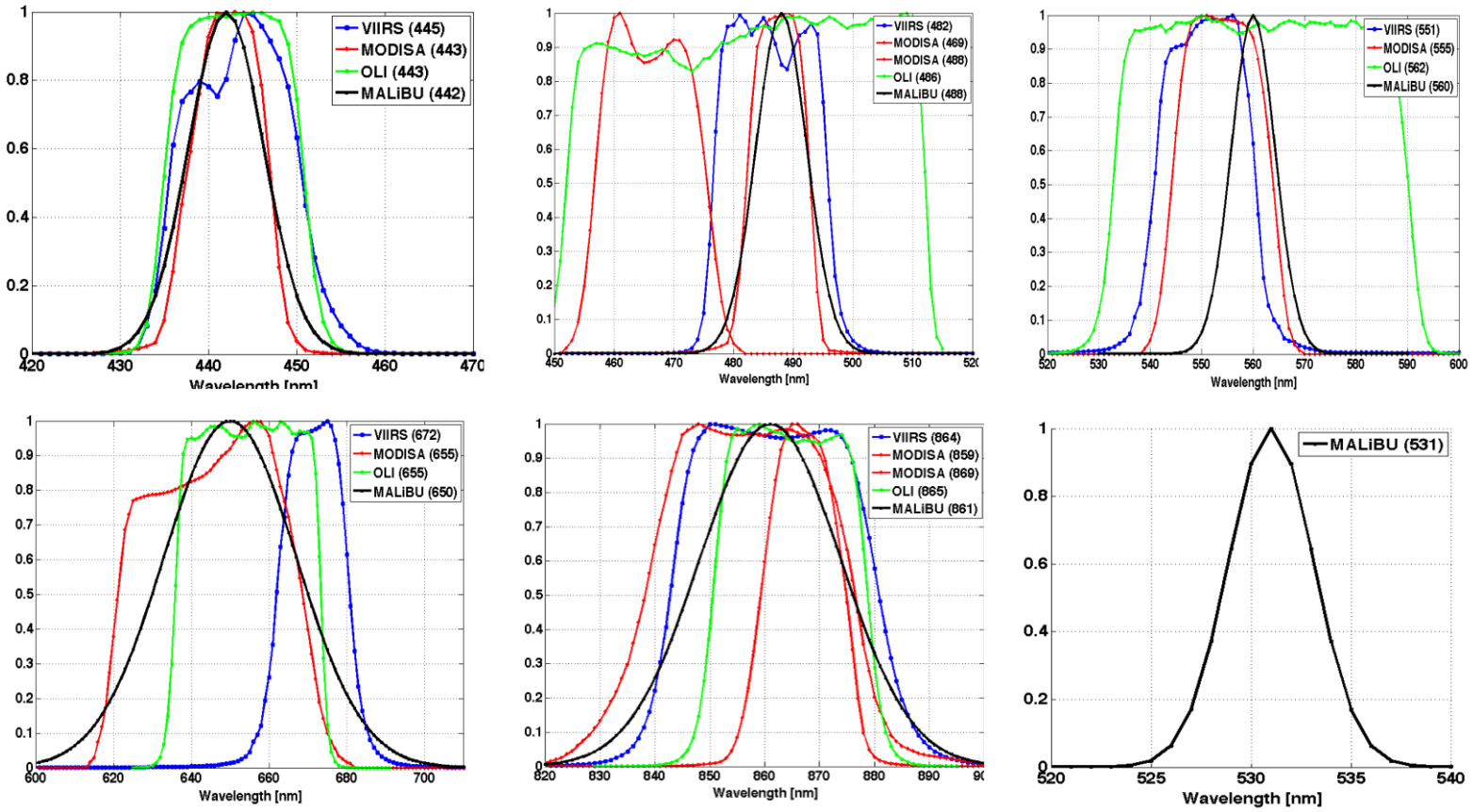
BlackSwift TECHNOLOGIES
2100 CENTRAL AVE STE 102
BOULDER, CO 80301
(720)638-9656

This document is concerned with operations of UAS in Canada for commercial use weighing less than 25 kg (55 lbs). More specifically, this document is concerned with operations of UAS that do NOT require a Special Flight Operations Certificate (SFOC). To operate a UAS that is exempt from an SFOC, this falls into 2 categories, sub 2 kg and 2 kg to 25 kg. The requirements and operational limitations for each class are listed below in the following two sections. The infographic outlining these rules is attached in the Appendix. However, the detailed requirements listed in the following two sections are taken from the more detailed Advisory Circular (AC) No. 600-004 [1]. Note that Transport Canada can issue a fine of up to $25,000 to a company not following these rules.

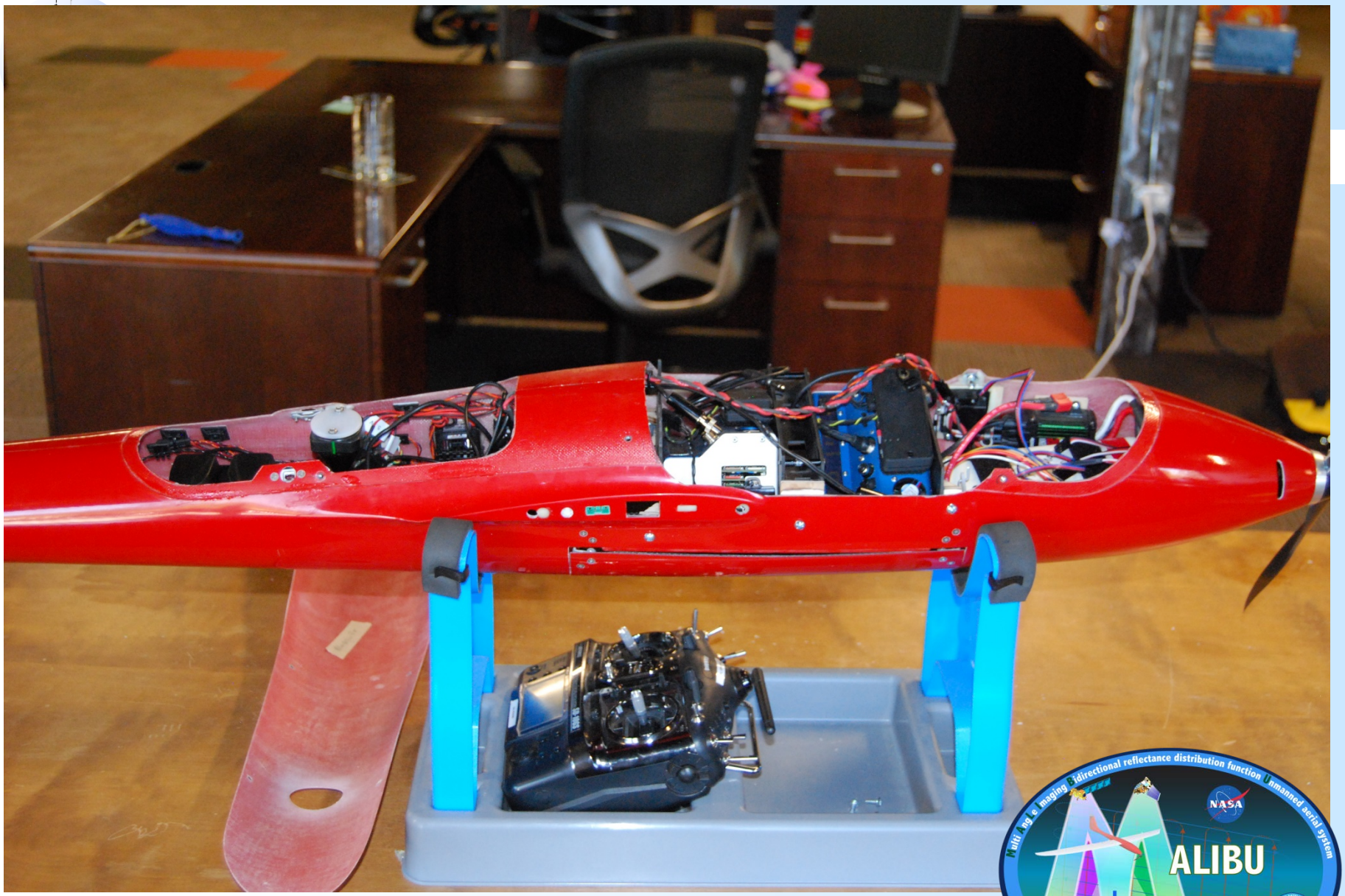
The operator must have the following 4 things in their possession, ready to show to any Transport Canada representative:

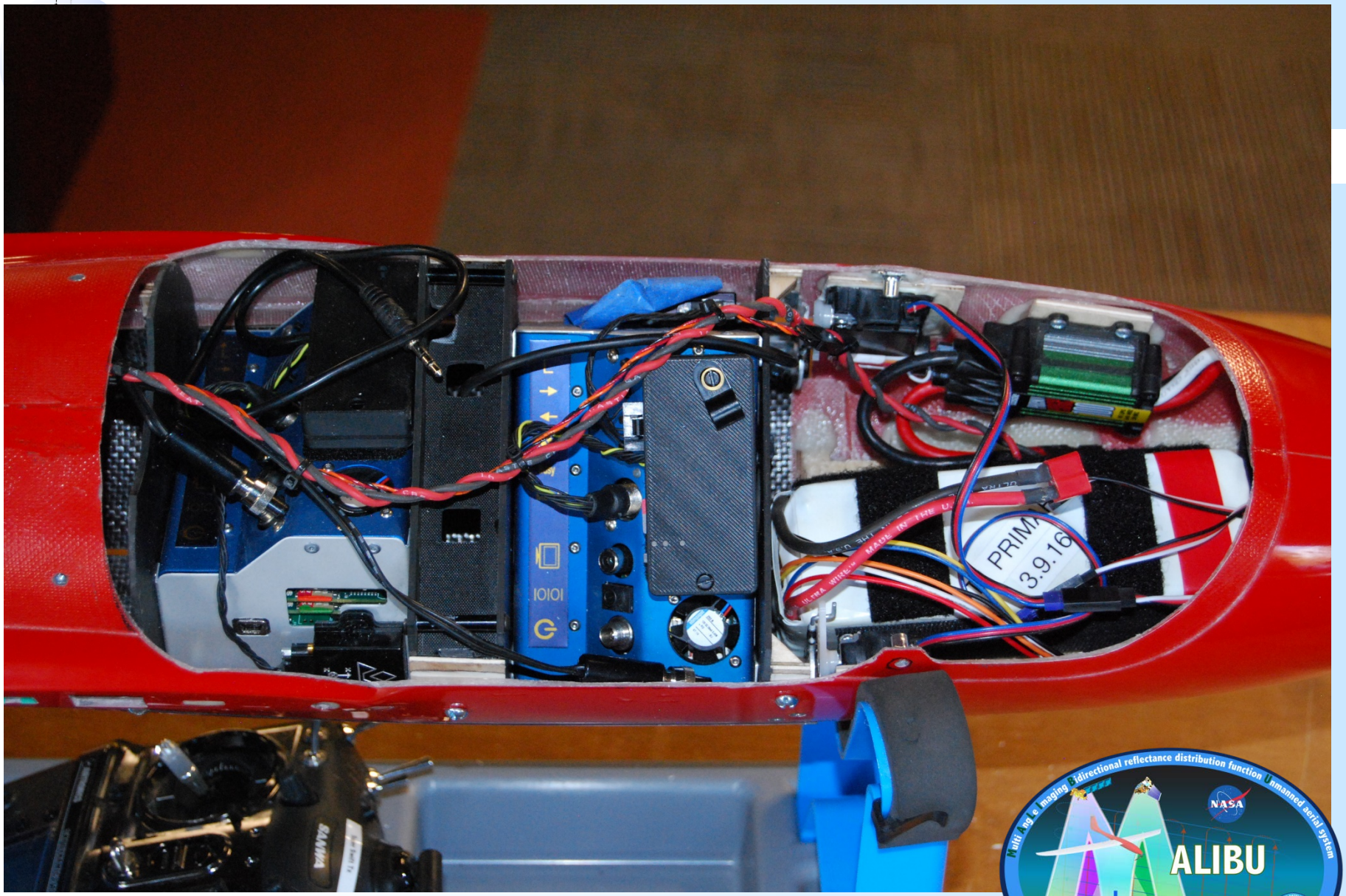
	Copy of UAS Exemption (i.e., this document with all provisions in the previous section followed)
	Proof of liability insurance
	Contact Information
	Aircraft System Limitations (i.e. manuals)

MALIBU Spectral Response

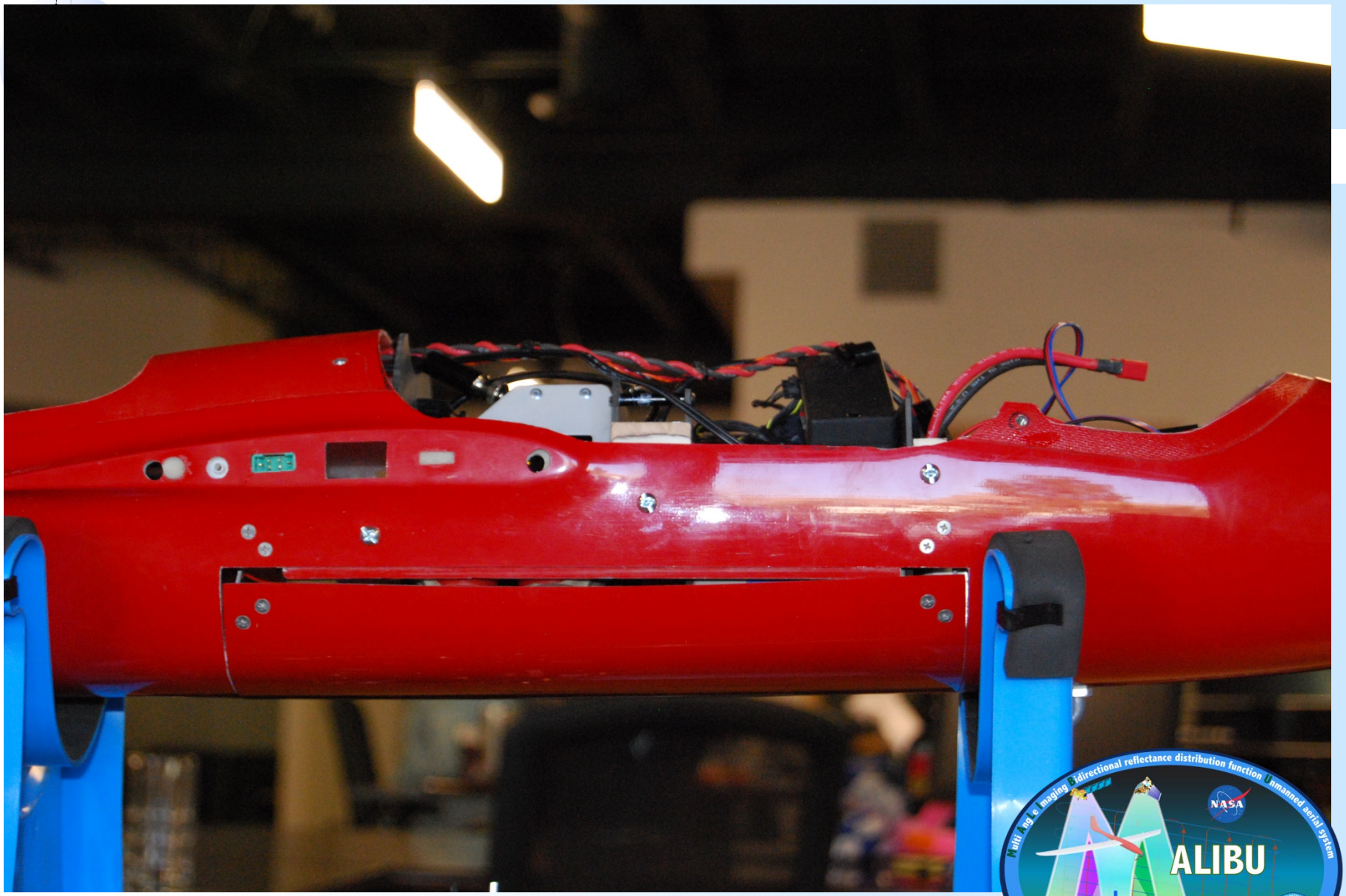


The MALIBU instrument design includes two Tetracam optical units matching the optical Land channels of key Land sensors such as Landsat-8 OLI, Sentinel-2 MSI, Sentinel 3-OLCI, Terra/Aqua MODIS, Terra MISR, and Suomi-NPP/JPSS VIIRS.

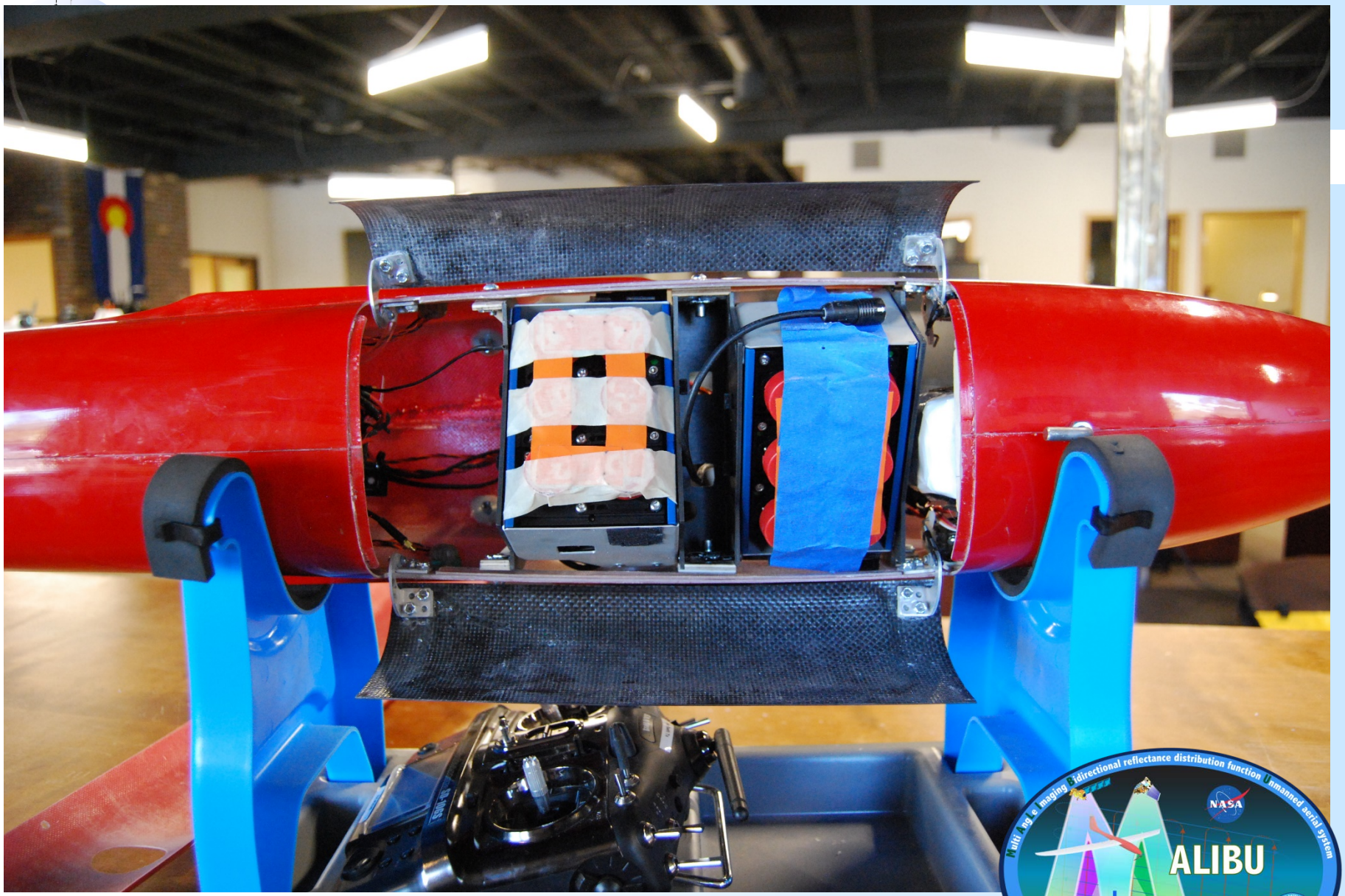

Multi Angle Imaging Bidirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center


PRIM
3.9.16


Multi-Angle imaging BiDirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center

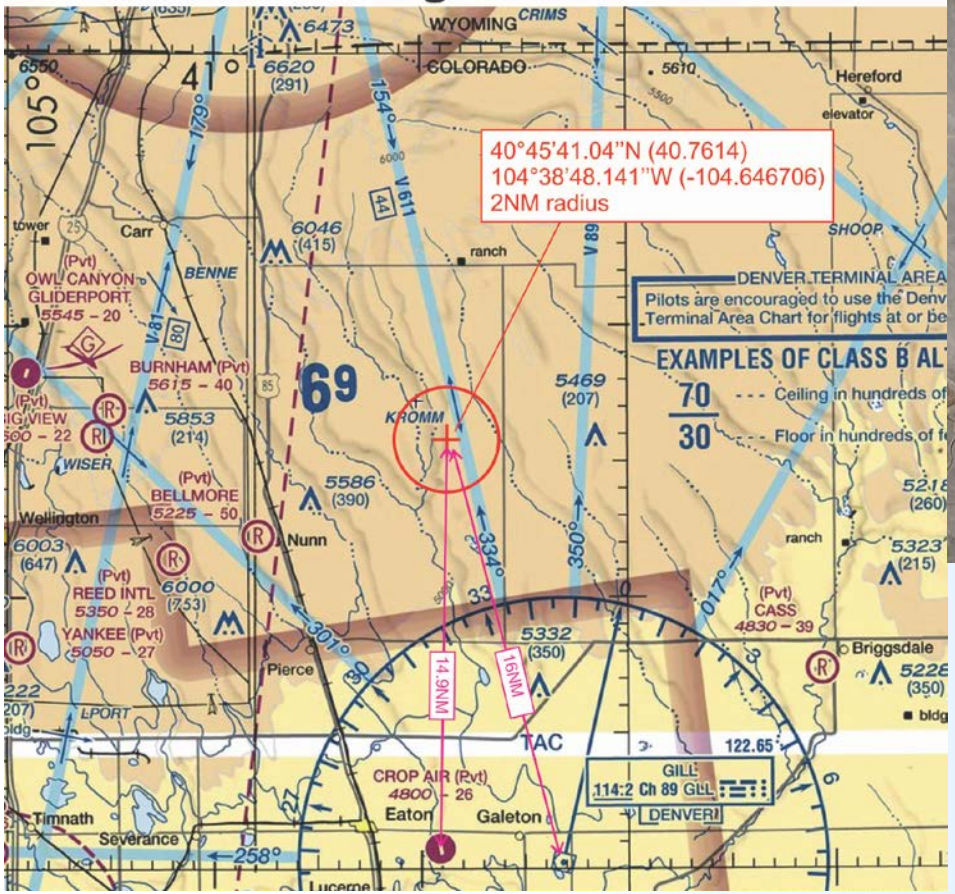


Multi Angle imaging Bidirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center


Multi Angle Imaging Bidirectional reflectance distribution function Unmanned aerial system
NASA
ALIBU
JPSS
NASA - Goddard Space Flight Center

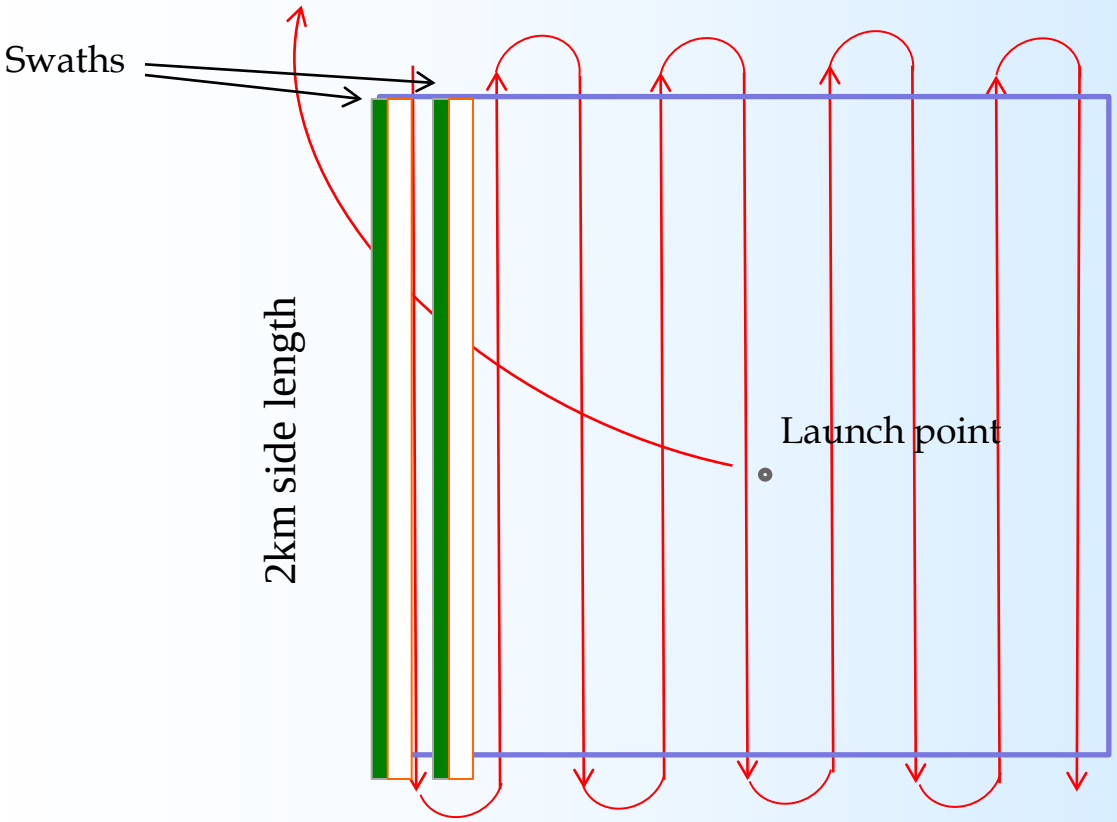
MALIBU Test Flights – (6/29/16 – 7/1/16) (Pawnee National Grasslands, CO)

Pawnee NGL flight area



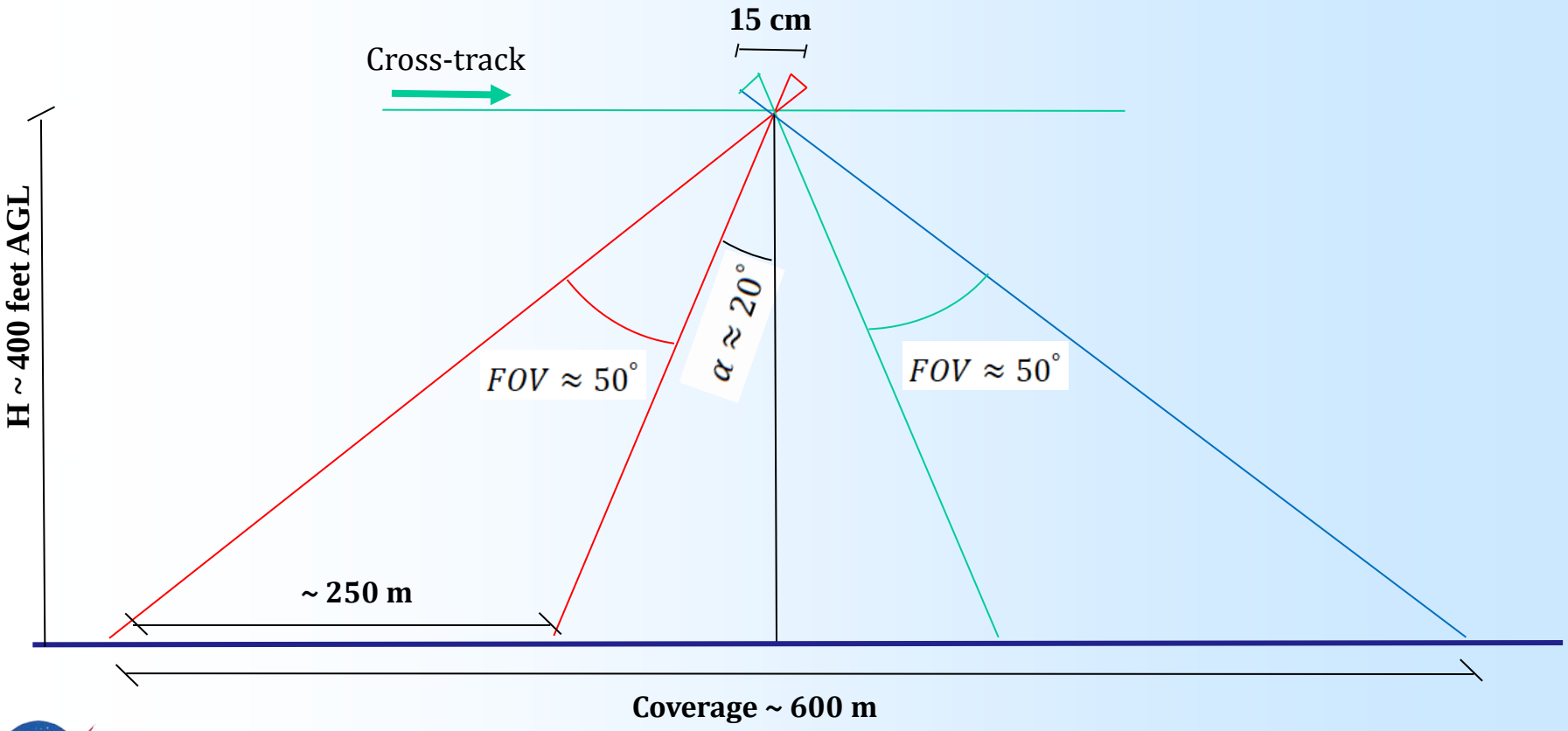
Operations Plan Flight Plan

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



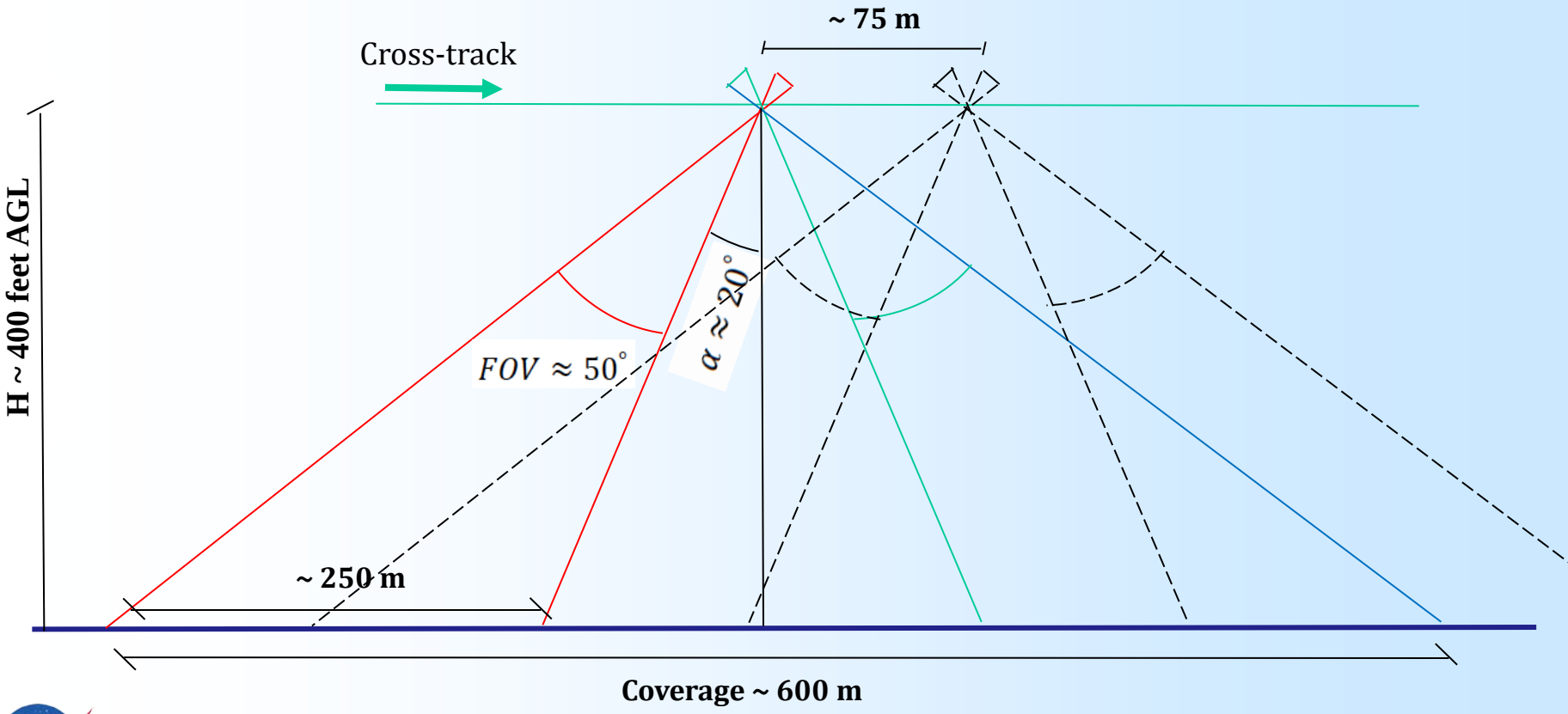
Viewing Geometry: Cross-track

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



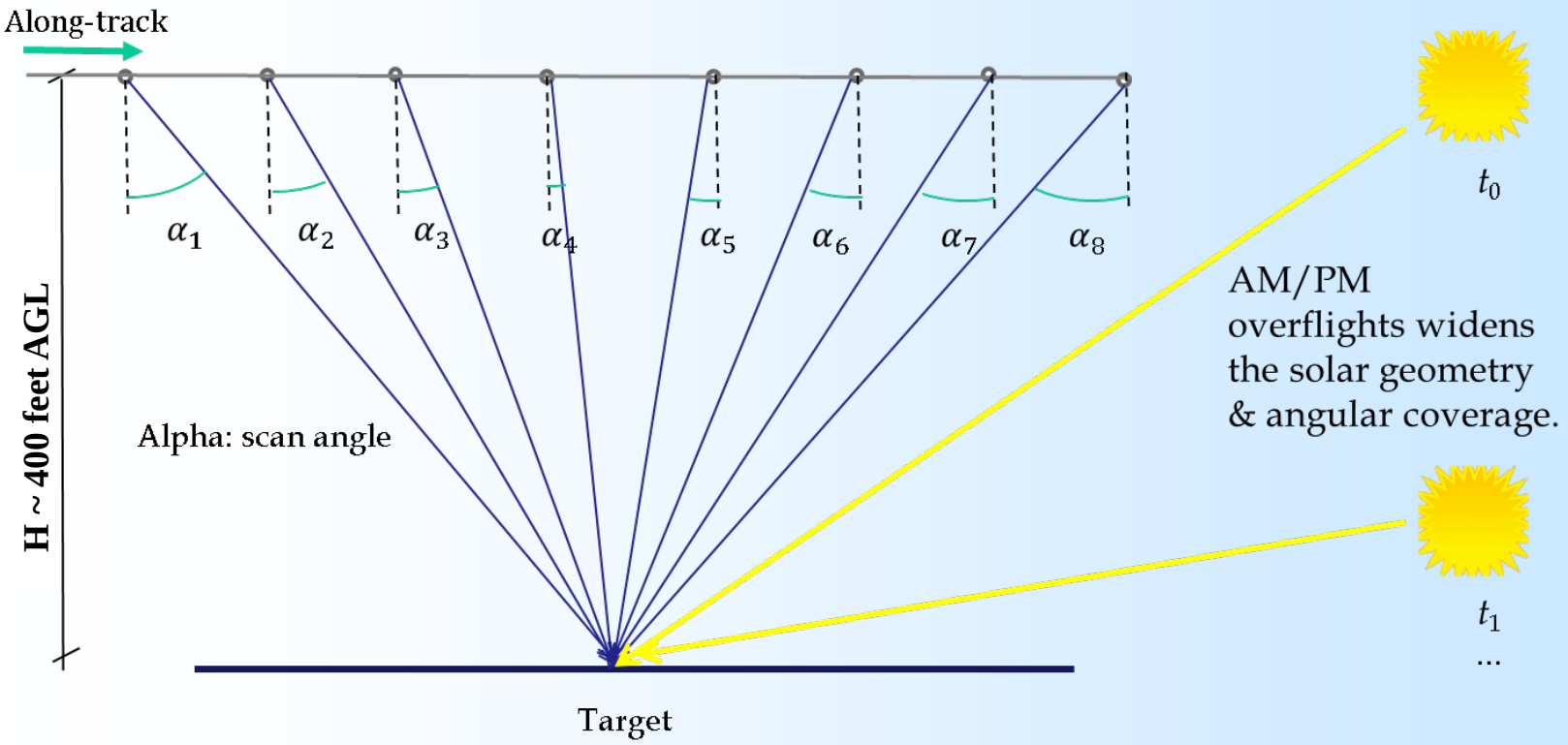
Viewing Geometry: Cross-track

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

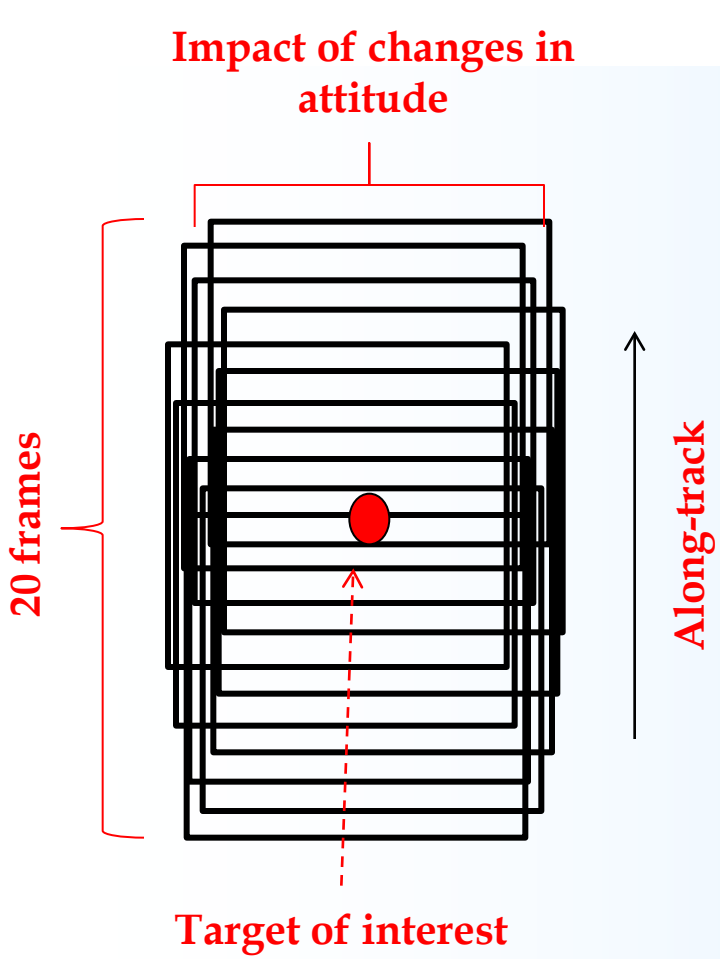


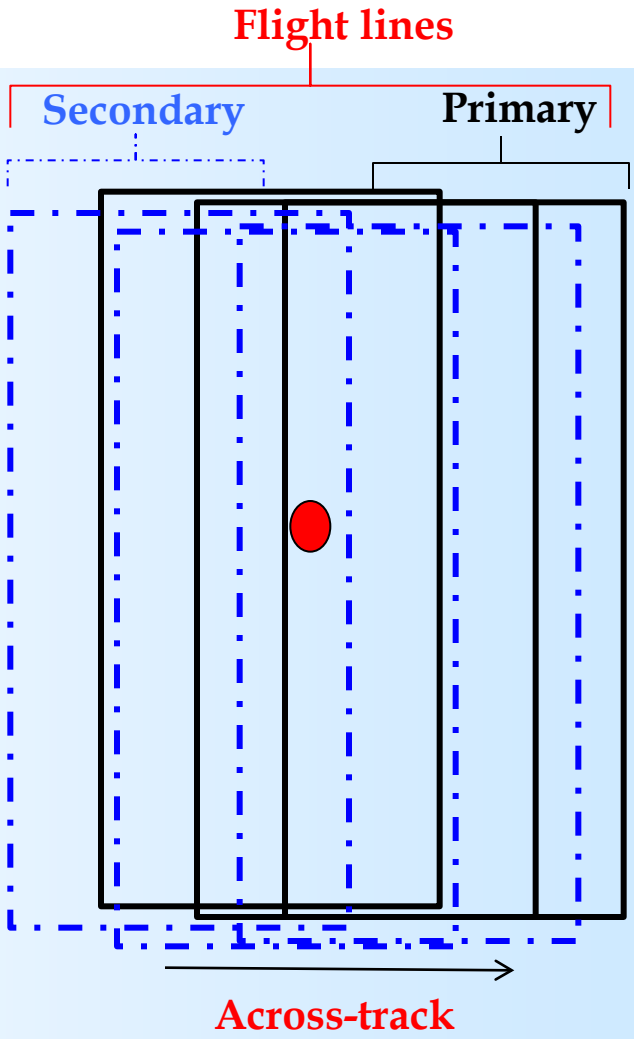
MALIBU Flight Path(cont.)

Overlapping scenes along-track provide multi-angular retrievals.



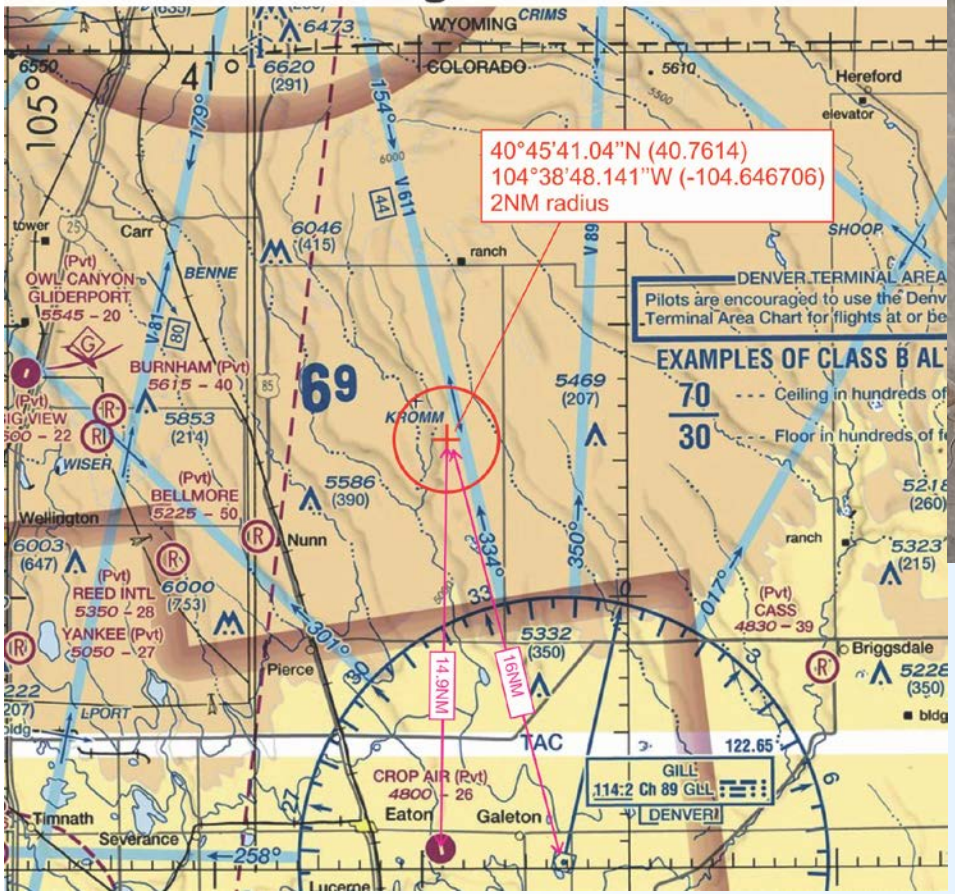
Overlapping Regions





MALIBU Test Flights – (6/28/16 – 7/1/16) (Pawnee National Grasslands, CO)

Pawnee NGL flight area



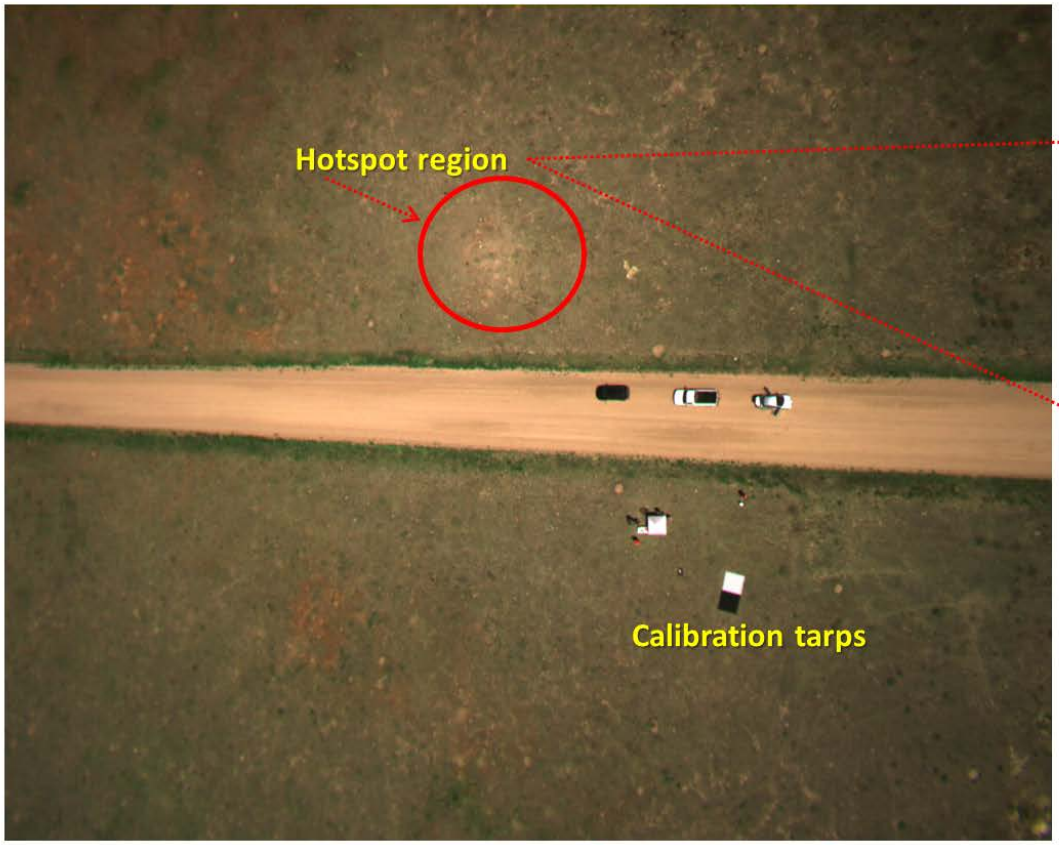
MALIBU Field Campaign at Pawnee

Play Video and hope that it works…

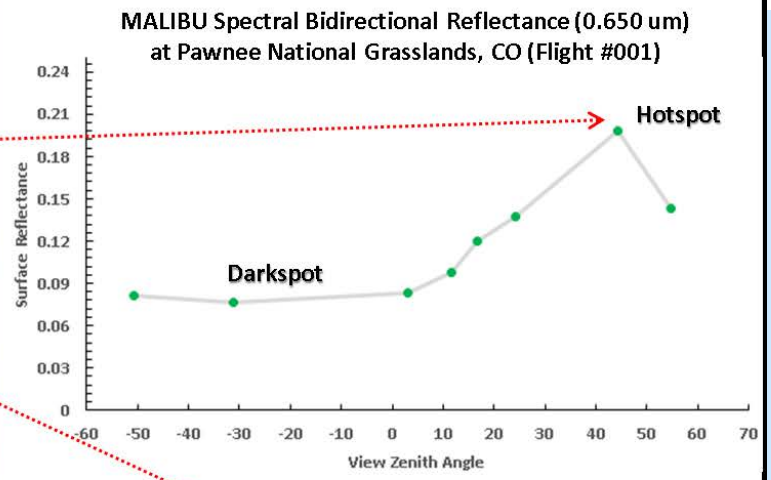
https://youtu.be/Vd8c-4rXQOo

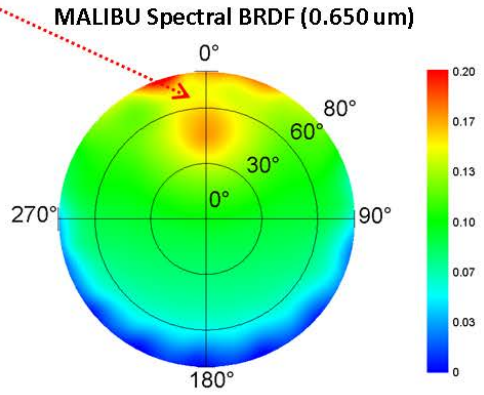
[Back Up File: MALIBU_Test_Flights_Pawnee_National_Grasslands_001-003.mp4]

First Light BRDF Products

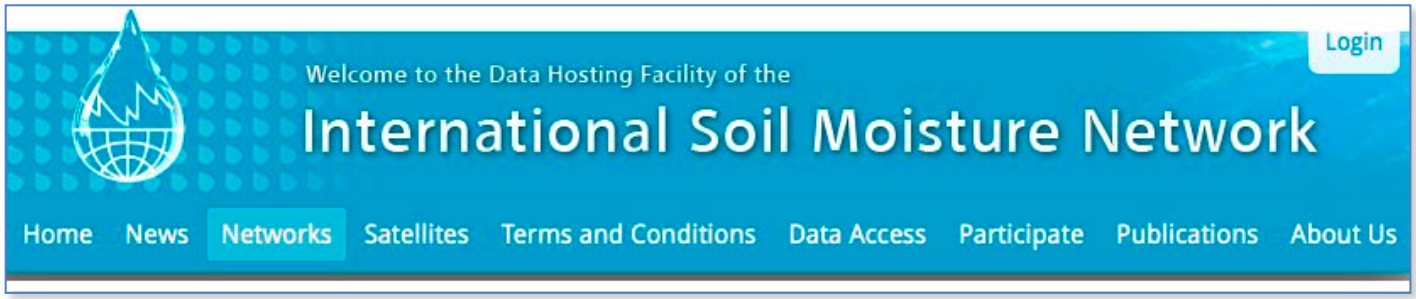


MALIBU True Color Surface Reflectance Composite (Red: 0-0.3; Green 0-0.3; Blue 0-0.3)





Fiducial Reference Data Sets



LTER

FLUXNET
A Global Network

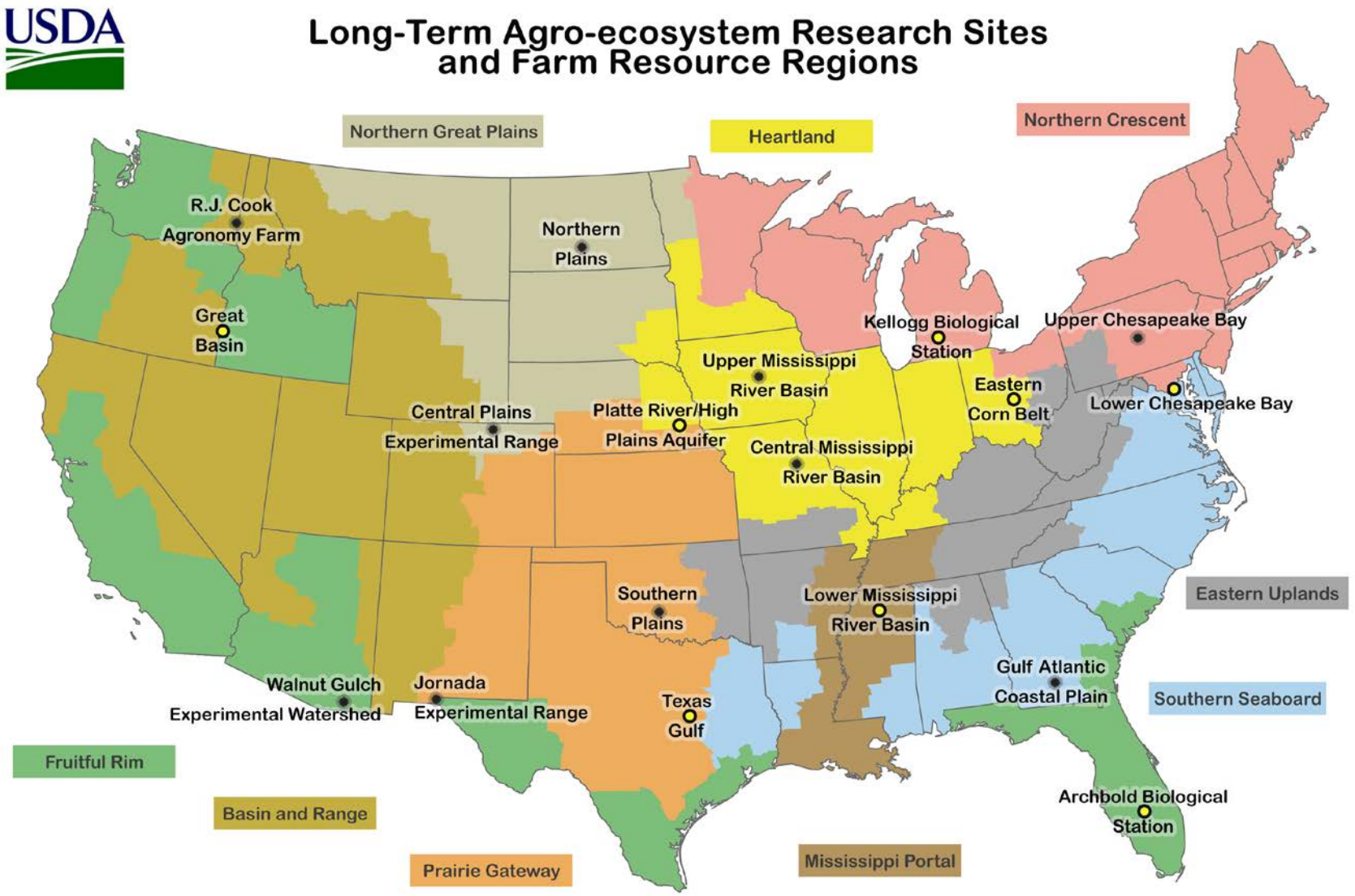
AERONET
AEROSOL ROBOTIC NETWORK

neon® Data
The National Ecological Observatory Network Data Portal

ABoVE
ARCTIC BOREAL VULNERABILITY EXPERIMENT

US Climate Reference Network

Fiducial Reference Data Sets: Key Players



NASA POCs (Pierre Guillevic, Brad Doorn, Chris Justice)
Full List of Organizations:
http://www.ars.usda.gov/SP2UserFiles/Program/211/LTAR%20Collaborators%20alphbetical%20FINAL.pdf

CEOS LPV Focus Areas and Co-leaders *ECV

Snow Cover*, Sea Ice	Thomas Nagler (ENVEO, Austria)	Tao Che (Chinese Academy of Sciences)
Surface Radiation (Reflectance, BRDF, Albedo*)	Crystal Schaaf (U Mass Boston)	Alessio Lattanzio (EUMETSAT)
Land Cover* and Land Use Change	Pontus Olofsson (Boston University)	Martin Herold (Wageningen University, NL)
Above Ground Biomass*	**Vacant**	**Vacant**
FAPAR*	Arturo Sanchez (University of Alberta)	Nadine Gobron (JRC, IT)
Leaf Area Index*	Oliver Sonnentag (University of Montreal)	Stephen Plummer (ESA)
Fire* (Active Fire, Burned Area)	Luigi Boschetti (University of Idaho)	Kevin Tansey (University of Leicester, UK)
Land Surface Temperature* (LST and Emissivity)	Simon Hook (NASA JPL)	Jose Sobrino (University of Valencia, SP)
Soil Moisture*	Tom Jackson (USDA ARS)	Wolfgang Wagner (Vienna Univ of Technology, AT)
Land Surface Phenology	Matt Jones (Oregon State University)	Jadu Dash (U Southhampton)
Vegetation Index	Tomoaki Miura (University of Hawaii)	Marco Vargas (NOAA/NESDIS/STAR)

CEOS-LPV's Core Mission

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

Instrument Teams

VIIRS Land

MODIS Land

Discipline Teams

NOAA

NASA

USGS

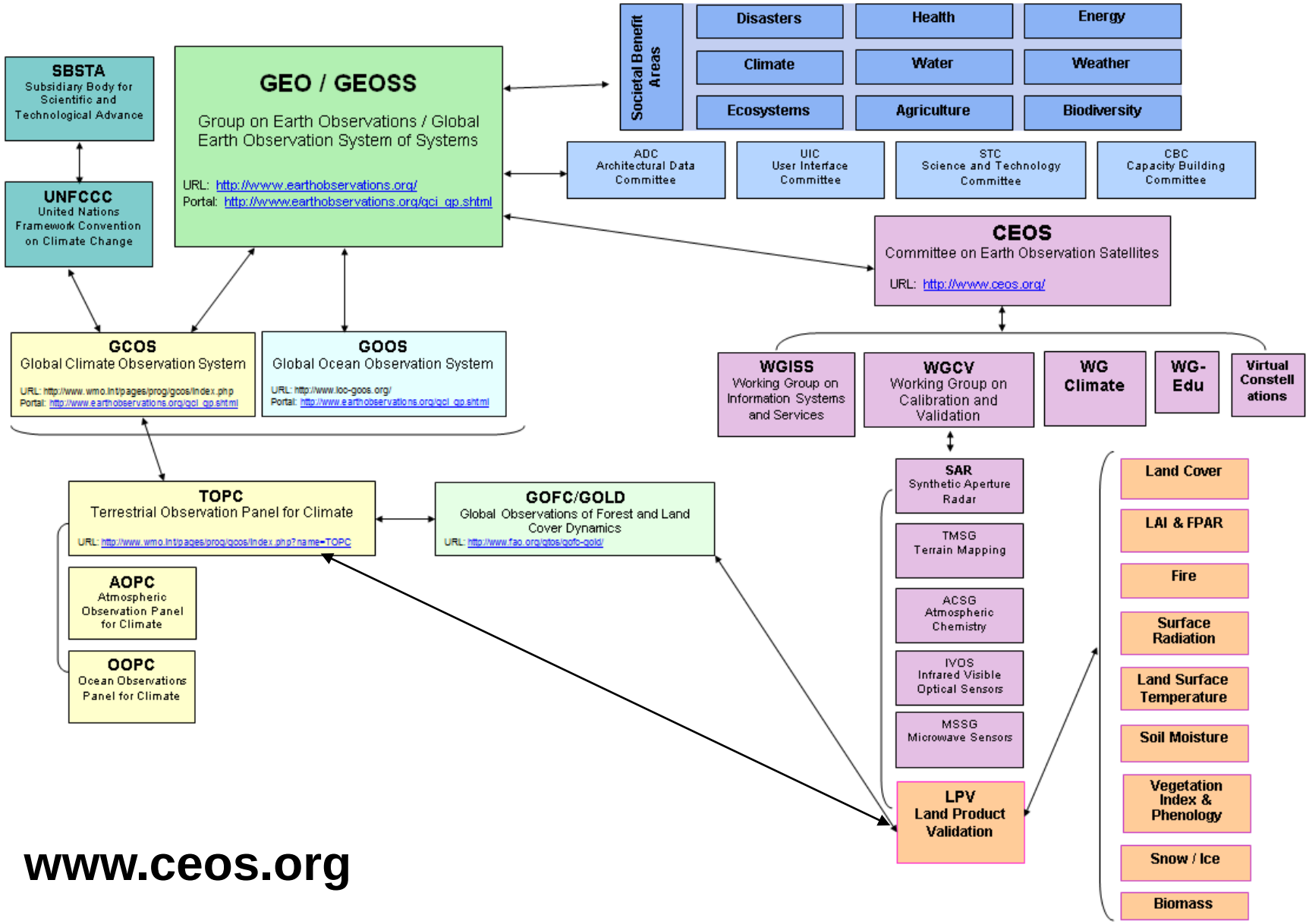
esa

EUMETSAT

CEOS Working Groups and Associates

To integrate across LPV Focus Areas, CEOS Space Agencies, and the Land Discipline & Instrument Teams.

International Programs concerned with Terrestrial Earth Observations

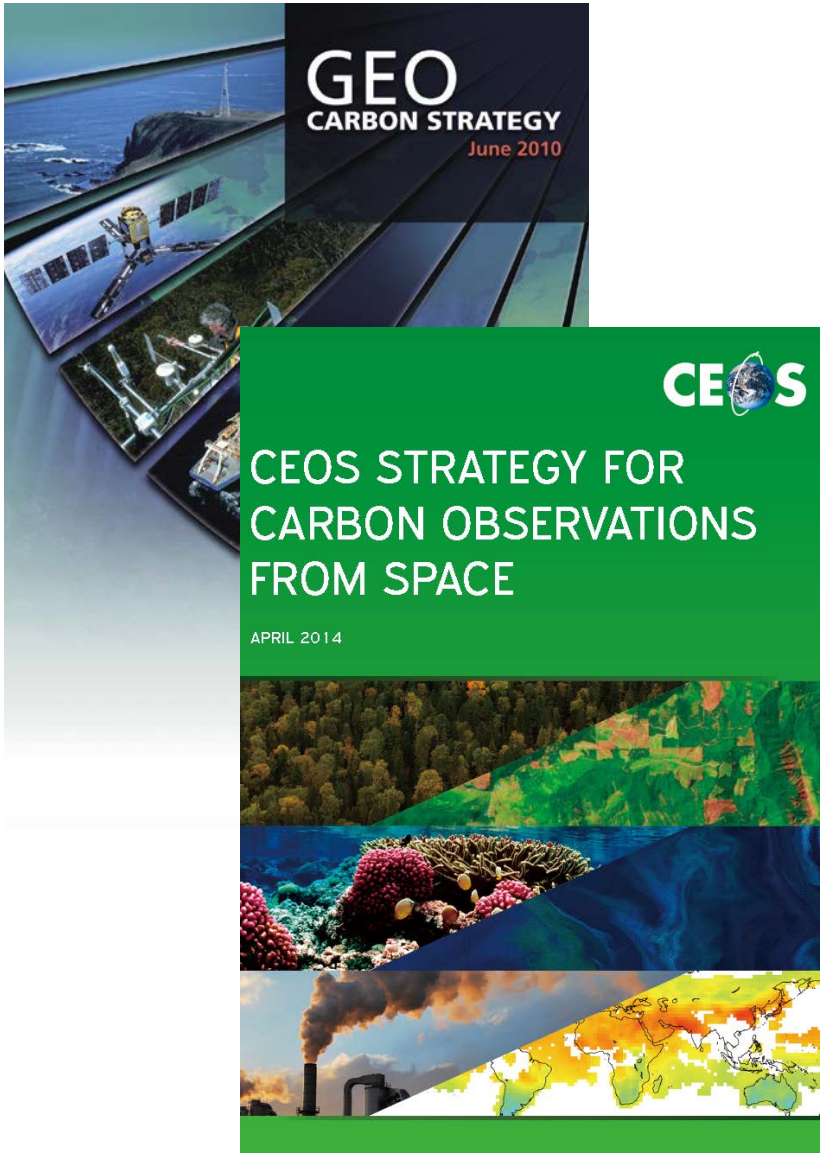


www.ceos.org

Key CEOS Carbon Actions

- **Carbon Action 7:** "Improve and ***expand upon the availability of the in-situ observations needed for the calibration and validation of satellite land data products used for carbon science***".

- **Carbon Action 8:** "The ***CEOS WGCV's Land Product Validation (LPV) Subgroup*** will continue its work to validate satellite land data products and ***expand the number of land variables addressed*** as priorities are identified and available resources permit.).



LPV Biomass Focus Area Goals:

Practicality Optimizations:
- 3.4 kg
- 33 second scan
- IP68 waterproof
- Wireless operation

UMB CBL (RIT SICK)	Instrument	RIEGL VZ400
Time-of-flight	Ranging Technique	Time-of-flight
1st and 2nd discrete return	Recorded Data	Multiple discrete return Waveform
0-135 zenith 0-360 azimuth	Scan Configuration	30-130 zenith 0-360 azimuth
905 nm	Wavelengths	1550 nm
0.25 deg 0.50 deg	Angular Resolution	0.04-5.03 mrad zenith 0.04-8.73 mrad azimuth
15 mrad	Beam Divergence	0.35 mrad
1	Laser Class	1
50 Hz	Pulse Rate	100 kHz 300 kHz
3.4 kg	Weight	9.6 kg
40 m	Max. Range	200 m 120 m

Capability Optimizations:
- 0.04 mrad max resolution
- 200 m max range
- Multiple return / waveform

Fusing GLiHT airborne LiDAR (yellow) with the underlying UMB Canopy Biomass Lidar (CBL) (red) provides additional information on the undercanopy structure.

Validation protocols focusing on: (1) core site selection, (2) field sampling (< 4 ha), (3) scaling techniques, and (4) uncertainty quantification of reference measurements.

TOPC-18 Panel & Experts

GCOS • GTOS • WCRP
TOPC Terrestrial Observation Panel for Climate

Land Surface Temperature ECV

Focus Area on Land Surface Temperature and Emmissvity Product Validation

Simon Hook, NASA Jet Propulsion Laboratory, USA
Jose Sobrino, University of Valencia, Spain

Meetings

The Earthtemp initiative 35th EARSeL Symposium Stockholm, Sweden, June 15 to 19. Abstract Deadline is February 2015.

ISRSE36, Berlin, Germany, 11-15 May.

Land Surface Temperature Definition

Land surface temperature (LST) is defined as the temperature derived from a radiative energy balance of a surface and provides the best approximation to the surface skin thermodynamic temperature based on a measure of radiance (Norman and Becker, 1995). LST is also called (directional) radiometric temperature or skin temperature.

Units: The unit of LST is Kelvin [K]. Degree Celsius [°C] is also commonly used.

Land Surface Emissivity Definition

The emissivity of an isothermal, homogeneous emitter is defined as the ratio of the actual emitted radiance to the radiance emitted from a black body at the same thermodynamic temperature (Norman and Becker 1995).

Units: Dimensionless.

Norman, G., and Becker, F. (1995). Terminology in thermal infrared remote sensing of natural surfaces. Agricultural and Forest Meteorology, Volume: 77, Issue: 3-4, Pages: 153-166, DOI: 10.1016/0168-1923(95)02259-Z

Highest Validation Stage Currently Reached for Satellite-Derived Land Surface Temperature and Emissivity Products

Validation stage 1 (LPV validation stage hierarchy) - The highest LPV validation stage reached for satellite-derived land surface temperature and emissivity products. For reaching validation stage 3 and higher, an increased number of global validation sites, covering all surface types, with extended temporal coverage, as well as intercomparison of different LST products are needed.

Land Surface Temperature Validation Methods

Four different methods have been widely used to validate and determine the uncertainties in LST products derived from satellite measurements (Schneider et al., 2012; Guillevic et al., 2014):

Jet Propulsion Laboratory

Driving the Global Climate Observation Agenda

Identify/Review Essential Climate Variables (ECVs) through science panels

Regular review of how these ECV are observed

Develop plans to ensure continuity and improvement of observations

- GCOS follows a 3 phase approach driven by users
- 2015 Status Report started the 3rd assessment cycle with a new Implementation Plan due in Oct 2016 for the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA).

(1st cycle: 1995-1998)

(2nd cycle: 2003-2004-2010)

(3rd cycle: 2015-2016)

WMO IOC UNEP ICSU International Council for Science

19 Essential Climate Variables

Current focus of TOPC is to identify measurable terrestrial key variables that control the physical, biological and chemical processes affecting climate and are indicators of climate change.

Biological/Ecological (6)

Land cover **and Land Use Change**
FAPAR
Leaf area index
Above ground biomass
Soil carbon
Fire disturbance

Hydrological (5)

River discharge
Water use
Ground water
Lakes
Soil moisture

Cryospheric (4)

Snow cover
Glaciers ~~and ice caps~~
Ice sheets and ice shelves
Permafrost

Surface Properties (4)

Albedo
Land surface temperature
Energy fluxes
Anthropogenic greenhouse gases

New, **Revised**, and **Proposed**

11 ECVs are directly linked to MODIS/VIIRS Land Products

Summary of Activities for PY-1 and Challenges Ahead

Agency-Level:

- [*Nickeson*] Maintenance and upkeep of the MODIS/VIIRS-Land websites and validation portal

LPV Subgroup Level:

- [*Guillevic & Wang*] Surface Albedo and LST ECV Protocols (Draft to be completed by end of PY-1)
- [*Guillevic & Camacho*] LPV Status Report (RSE Special Issue) [*in preparation*]
- [*Román, Wang, Pahlevan, and McCorkel*] Field Campaigns (MALIBU-sUAS): Reference data supporting NASA/NOAA/USGS/ESA missions. Deployments at NEON, LTER/LTAR, BSRN, and/or ABoVE sites.
- [*Wang and Gallo*] Land Product Characterization System (LPCS): Integration of MODIS/VIIRS Land Quality Assessment and Validation tools.
- [*Román & Camacho*] Term limits for 9 LPV focus area leads (Dec, 2016)
- [*Nickeson & Román*] AGU'16 Special Session on Land Product Validation Efforts [*submitted*]

CEOS-WG, Plenary, and Higher Level:

- [*Thome*] Upcoming WGCV-41 Plenary:
  - [*Dubayah and Plummer*] CEOS Carbon Actions 7/8: *Formation of LPV AG Biomass Focus area*
    - *Initial Protocols will Focus on Terrestrial Lidar Systems (TLS)*
    - *Identify 3 Priority Core Sites (US, EU, AUSTRALIA) and Support a TLS Intercomparison Study*
- [*Camacho*] 2016 GCOS/TOPC Implementation Plan for UNFCCC COP22 SBSTA-45 *Addressing Orphaned Terrestrial ECVs:*
    - *Fundamental Data Records (Reflectance, BRDF)*
    - *Land Cover & Land Use Change (not just Land Cover)*
    - *Emissivity and Evapotranspiration (not just Land Surface Temperature)*
    - *Higher-level biophysical parameters: LUE, NPP/GPP, Water Content, Pigments*

http://lpvs.gsfc.nasa.gov