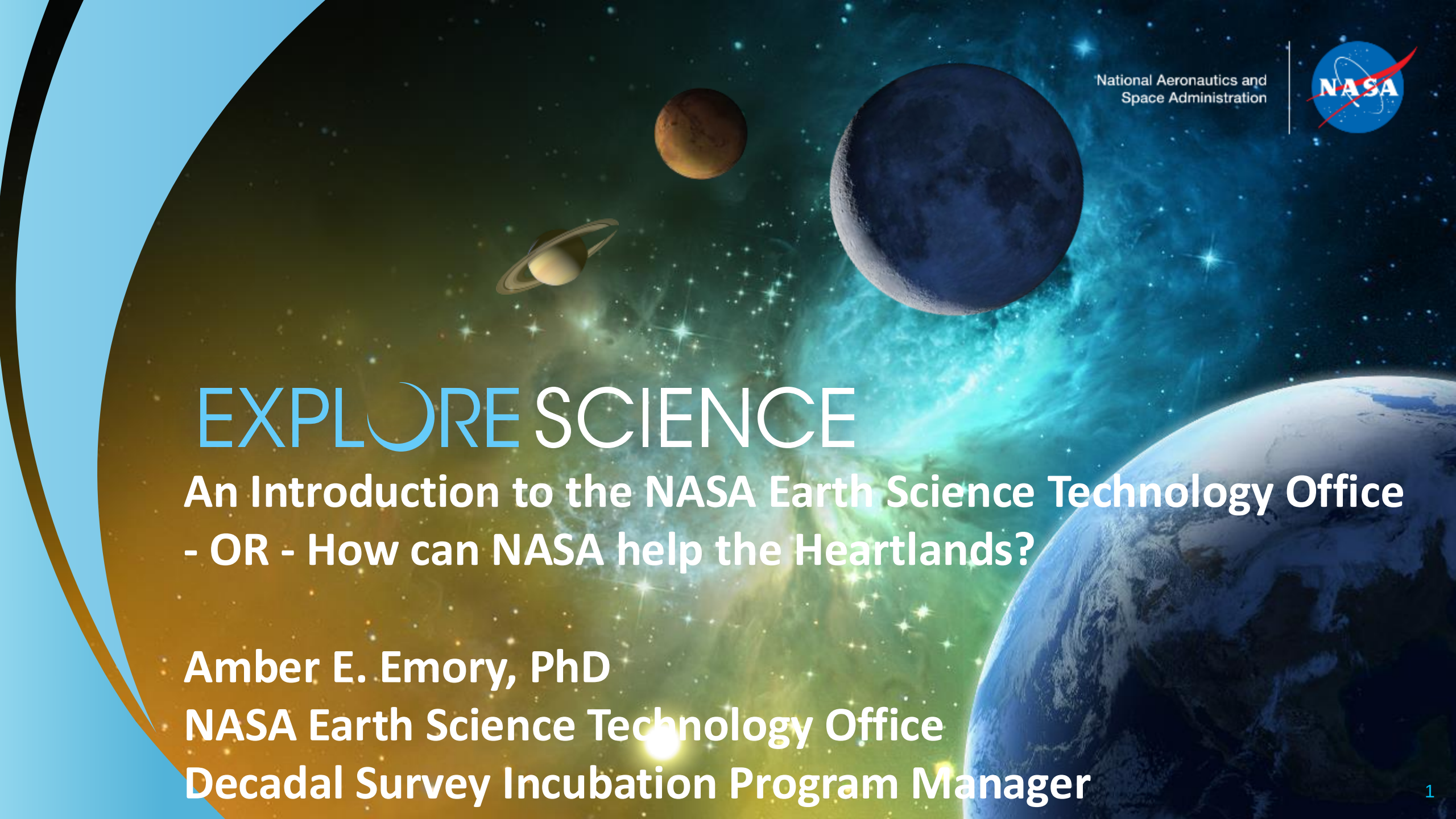


EXPLORE SCIENCE

An Introduction to the NASA Earth Science Technology Office - OR - How can NASA help the Heartlands?

Amber E. Emory, PhD
NASA Earth Science Technology Office
Decadal Survey Incubation Program Manager

Earth Science Technology Office – Since 1998

ESTO leads technology development activities for the Earth Science Division. Through a science-driven competitive process it enables the next generation of instruments and information systems that advance our ability to study the Earth.

ESTO comprises four main program lines:

- **ATIP** ◉ Advanced Technology Initiatives Program
- **IIP** ◉ Instrument Incubator Program
- **AIST** ◉ Advanced Information Systems Technology
- **DSI** ◉ Decadal Survey Incubation

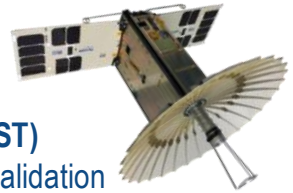
Earth Science Technology Program Elements

ESTO manages, on average, 138 active technology development projects. Over 900 projects have completed since 1998.

Advanced Technology Initiatives: ACT and InVEST

Advanced Component Technologies (ACT)
Critical components and subsystems for advanced instruments and observing systems
Next Solicitations in *FY25*
Average award: $1.2M (2-3 years)

FireTech - NEW
New observation and predication capabilities for understanding and managing wildfires.



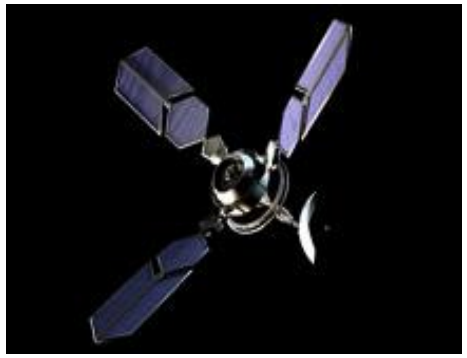
In-Space Validation of Earth Science Technologies (InVEST)
On-orbit technology validation and risk reduction for small instruments and instrument systems.

Next Solicitation in *FY24*
Average award: $3-6M (3 years)

Instrument Incubator Program (IIP)

Innovative remote sensing instrument development from concept through breadboard and demonstration.
- Average award IDD: $1.5M per year over 3 years. (instrument dev & demo)
- Average award ICD: $750K over 1.5 years (Instrument concept demo)
- Average award ITM: New: $2.5M over 2 years (Instrument Tech maturation, starting with IIP-23)

Next Solicitation *in FY23*
Average award: $4.5M (3 years)



Advanced Information Systems Technology (AIST)

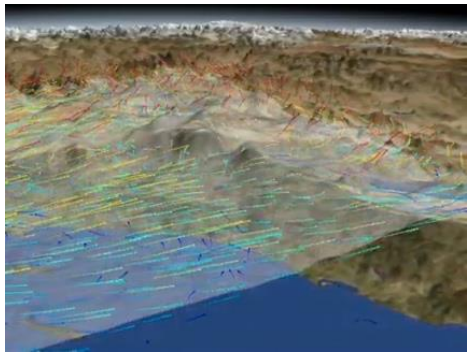
Innovative information systems for: new measurement collection through distributed sensing; Science missions ROI optimization; agile Science investigations; integrated information frameworks for mirroring Earth systems evolution and what-if scenarios.

Next Solicitation *in FY23*
Average award AET (Advanced & Emerging Technology): $650k per year over 2-3 years.
Average award EST (Early-Stage Technology): $600k total over 1.5 years

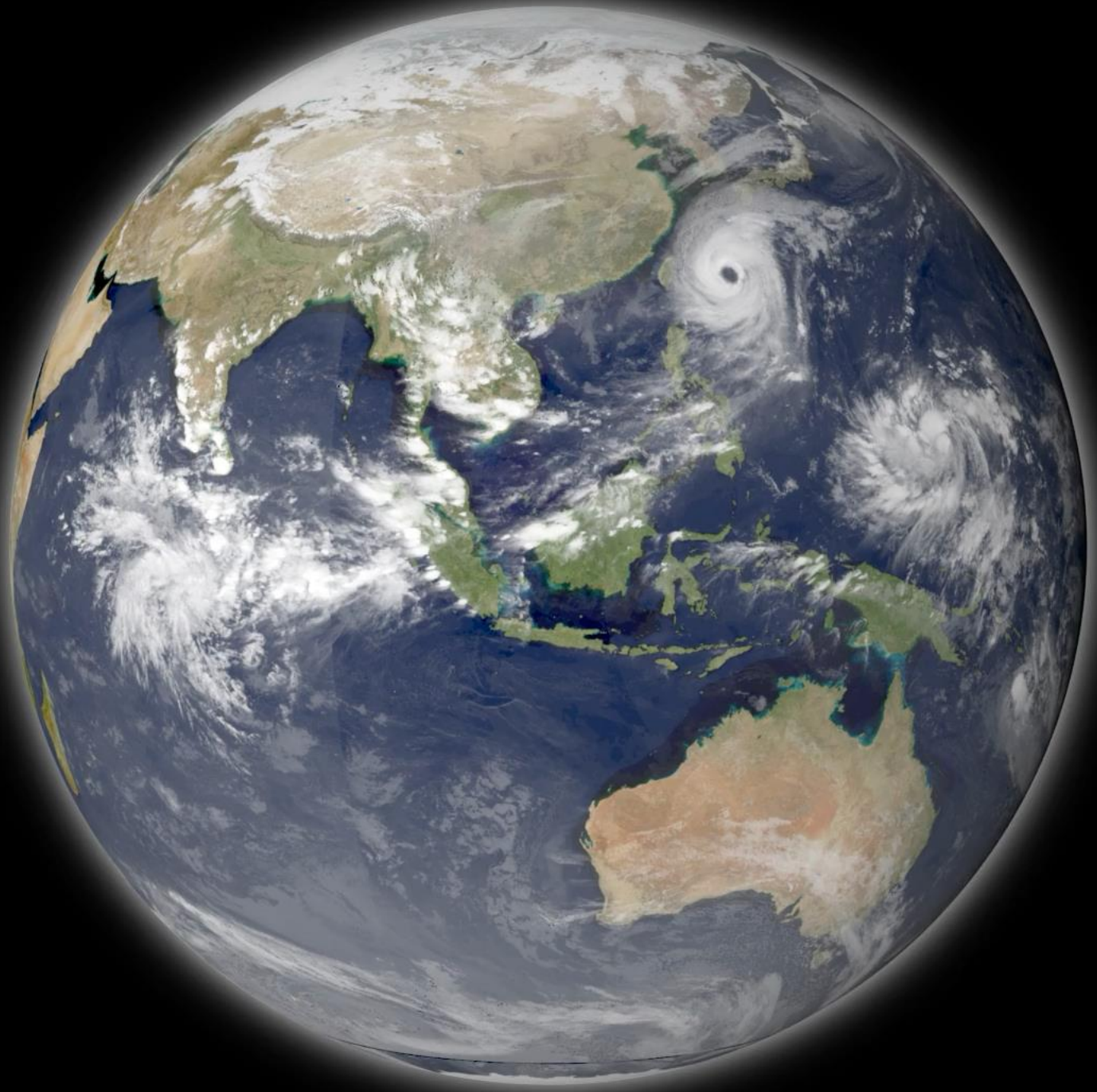
Decadal Survey Incubation (DSI)

Maturation of observing systems, instrument technology, and measurement concepts for Planetary Boundary Layer (PBL) and Surface Topography and Vegetation (STV) to accelerate readiness for implementation in the next decade. Managed in partnership with R&A
- Avg tech award: $1.5M/yr for 3 years
- Avg science award: $200k /yr for 3 years
- Average OSSE award: $500k /yr for 2 years

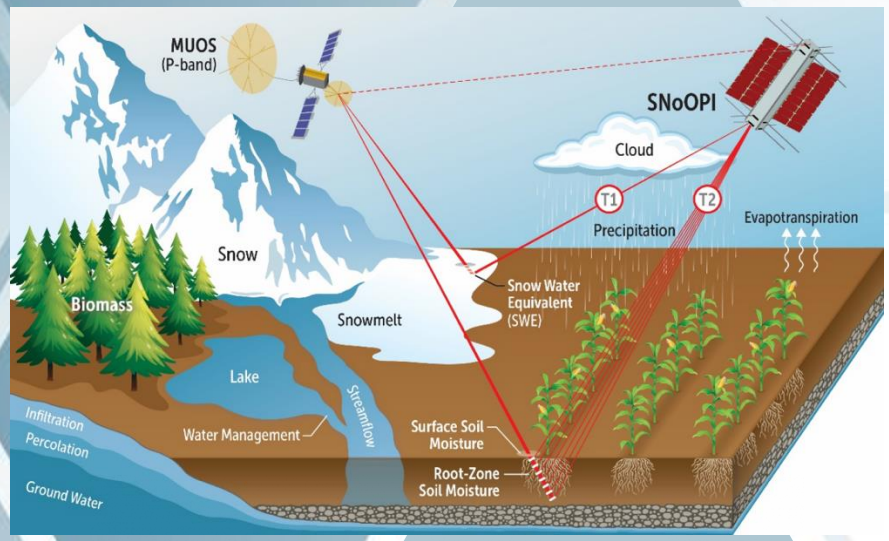
Next Solicitation *in FY24*

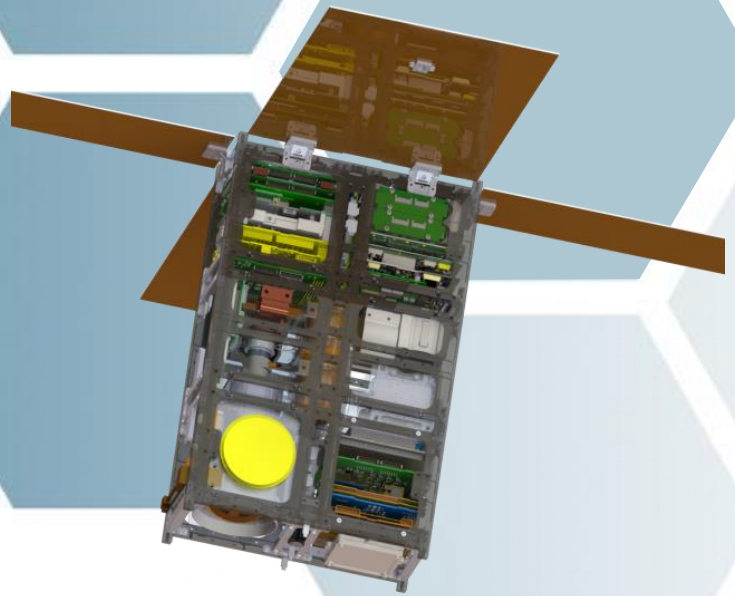


How does NASA advance technology to understand precipitation, soil moisture, temperature, dew point, vegetation, etc?



Technology Advancements for Soil Moisture and Evapotranspiration





SNOOPI (Signals of Opportunity P-band Investigation) is a 6U CubeSat mission that will demonstrate and validate the in-space use of P-band (240-380 MHz) signals of opportunity to measure **root zone soil moisture** and **snow water equivalent**.

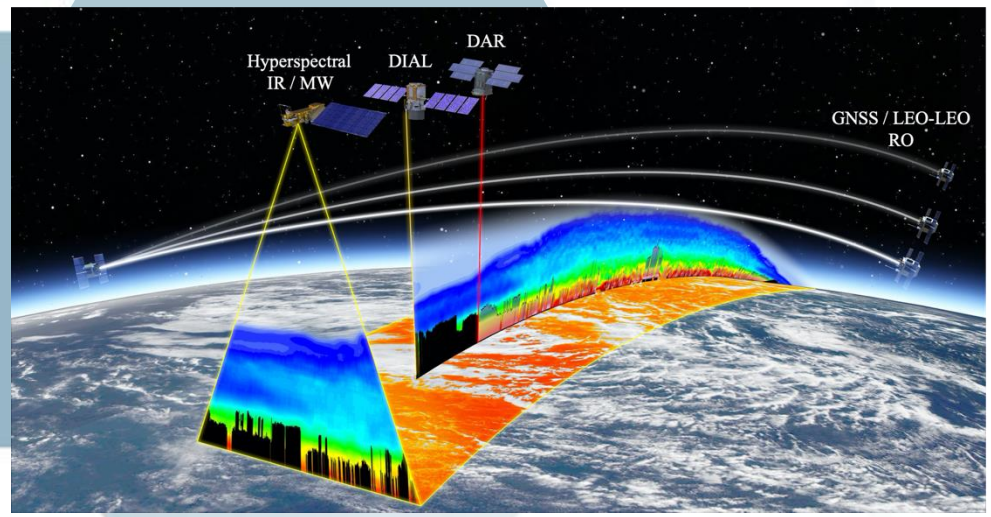
HyTI (Hyperspectral Thermal Imager) is a 6U CubeSat demonstration mission that will enable the next generation of high spatial, spectral, and temporal resolution thermal infrared (TIR) imagery acquisition from low Earth orbit.

Both CubeSats will launch to the ISS NET March 12, 2024.

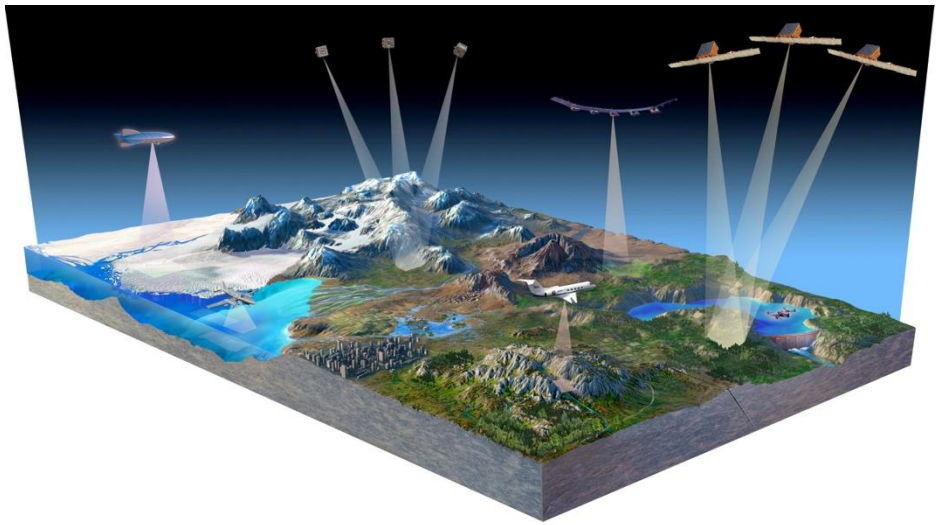
Decadal Survey Incubation Introduction

- The 2017 Decadal Survey recommended the implementation of an Incubation program element intended *to support maturation of mission, instrument, technology, or measurement concepts to address specific high-priority science and applications Targeted Observables (TO's) as needed to enable cost-effective implementation.*
- Focused and sustained attention to establish and mature its associated prospective user communities to make material progress toward maturing both measurement requirements and implementation concepts within this decade.*
- NASA ESD identified ***Planetary Boundary Layer (PBL)*** and ***Surface Topography and Vegetation (STV)*** as the TO's that would be addressed in Incubation.

Notional future PBL Architecture



Notional future STV Architecture



Concluding thoughts:

Food security is national security.

NASA Earth Science satellites and technology capture an enormous amount of data about weather patterns, water, wildfire smoke, cloud cover, soil conditions, vegetation health, air moisture and much more.

We invite you to join us in charting the path forward together. We need to understand community needs and how the data we collect can help benefit humanity.

Back-Up

PBL Incubation Roadmap

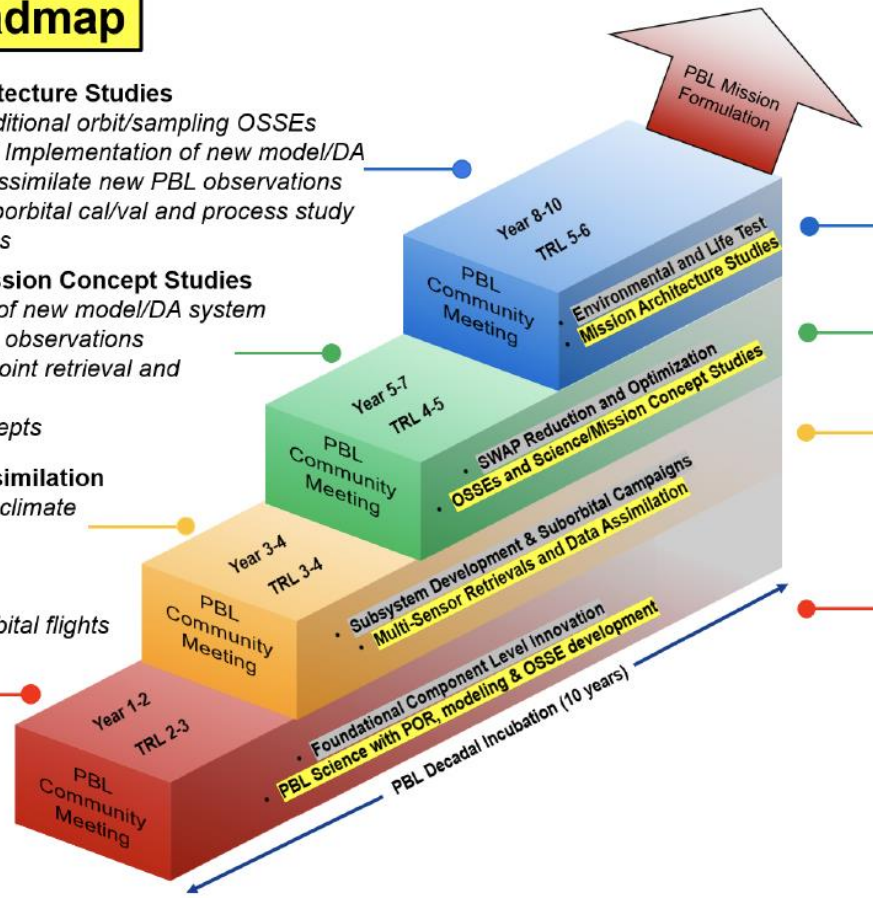
Science Roadmap

Mission Architecture Studies
- *Perform additional orbit/sampling OSSEs*
- *Operational Implementation of new model/DA system to assimilate new PBL observations*
- *Perform suborbital cal/val and process study architectures*

OSSEs and Science/Mission Concept Studies
- *Finalize development of new model/DA system to assimilate new PBL observations*
- *Combine and finalize joint retrieval and sampling OSSEs*
- *Develop mission concepts*

Multi-Sensor Retrievals and Data Assimilation
- *Refine PBL OSSEs for weather and climate modeling*
- *Implement initial PBL model and DA improvements*
- *Exploit POR and multi-sensor suborbital flights for refined joint retrievals*

PBL Science with POR, modeling & OSSE development
- *Exploit current POR for PBL science (R&A)*
- *Start development of better PBL models, parameterizations and data assimilation*
- *Start development of PBL OSSEs across model architectures*



Technology Roadmap

Environment Testing, Critical Performance Verification
- *Life Testing of transmitters, mechanisms, and coolers*
- *ASIC, PIC test & verification*
- *Thermal Vac. and Vibration Test*

Component Level Hybridization and Optimization
- *Optical/RF hybridization*
- *SWaP reduction*
- *Radiation sensitivity*

Subsystem Development and Deployment
- *Transmitter and receiver subsystem integration*
- *Noise and spectral characterization*
- *Suborbital demonstration, multi-data fusion*
- *Spacecraft accommodation studies*

Foundational Component Technology Innovation
- *Evaluation of emerging measurement techniques*
- *Mature high-power laser and radar sources, integrated photonics, detectors and spectrometers, telescopes and antennas*

Planned Solicitations

FY22 FY23 FY24 FY25 FY26 FY27 FY28

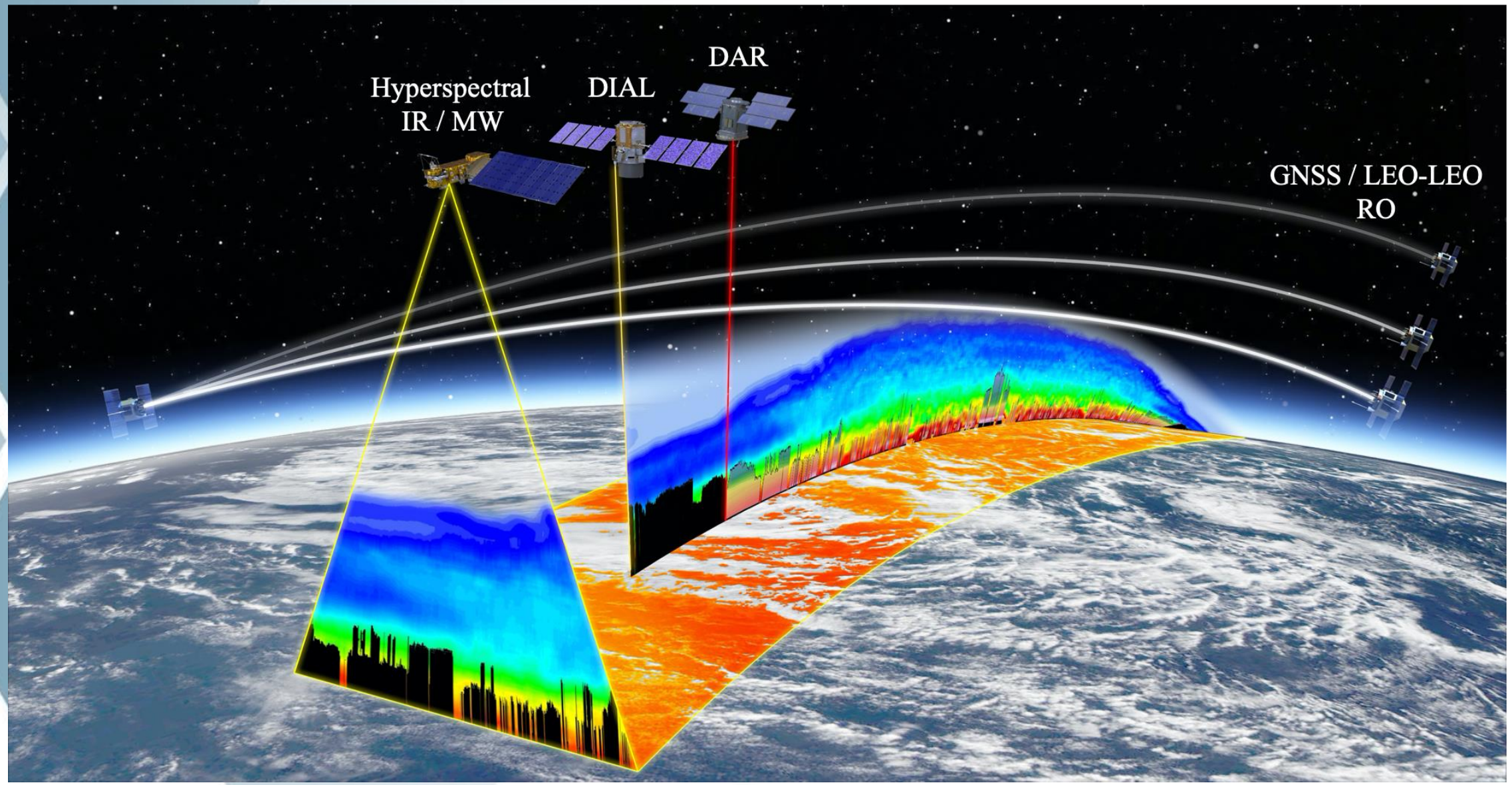
DSI Q3 Q2

PBL Incubation Ideal End-state

For PBL to become a Designated Observable for the next Decadal Survey (2027) by developing an affordable, intelligent, and integrated path to space for the next decade that meets key scientific needs.

Intelligent – Integrated - Affordable

NASA's Unique Contribution to the Space-Based Architecture – Synergistic Retrievals



Measurement Techniques and Relative Maturity

Method	Observable(s)	~ PBL Profile Resolution Vertical x Horizontal (PBLH Horiz. Resolution)		Coverage	Conditions	Maturity (space)	
		Current	Emerging			Current	Emerging
Hyperspectral Infrared Sounder	T, q, PBLH, composition, cloud and surface properties (winds from GEO or constellation)	1x14 km (10 km)	1x1 km (1 km)	Large swath, daily global coverage	Clear sky, through tenuous cloud, between broken clouds		
Multi-spectral & Hyperspectral Microwave Sounder	T, q, cloud, precipitation and surface properties (winds from GEO or constellation)	2x40 km (NA)	2x5 km (NA)	Large swath, daily global coverage	All sky (except in heavy precipitation), cloud clearing/combined with IR	Multi-spectral	Hyper-spectral
Backscatter Lidar	Attenuated backscatter, PBLH	(1 km)	(1 km)	Small footprint, line of sight, weekly-monthly revisit	Clear sky, through tenuous cloud, between broken clouds		
Differential Absorption Lidar (DIAL)	q, TPWV, PBLH, attenuated backscatter (aerosol/cloud)	NA	0.2x75 km (1 km)	Small footprint, line of sight, weekly-monthly revisit	Clear sky, through tenuous cloud, between broken clouds	NA	
Raman Lidar	T, q, TPWV, PBLH, aerosol backscatter and extinction	NA	0.2x75 km (1 km)	Small footprint, line of sight, weekly-monthly revisit	Clear sky, through tenuous cloud, between broken clouds	NA	
Differential Absorption Radar (DAR)	In-cloud q, inferred in-cloud T, TPWV, cloud and surface properties	NA	0.2x100 km	Small footprint, line of sight, weekly-monthly revisit	In-cloud profiling, all sky column (except in heavy precipitation)	NA	
GNSS-RO	Refractivity (combination of T and q), PBLH	0.1x100 km (100 km)	0.1x100km (100 km)	# daily soundings scales with # of satellite pairs	All sky		
LEO-LEO RO	Refractivity (T, q), PBLH	NA	0.1x100km (100 km)	# daily soundings scales with # of satellite pairs	All sky	NA	

DSI Program Leveraging

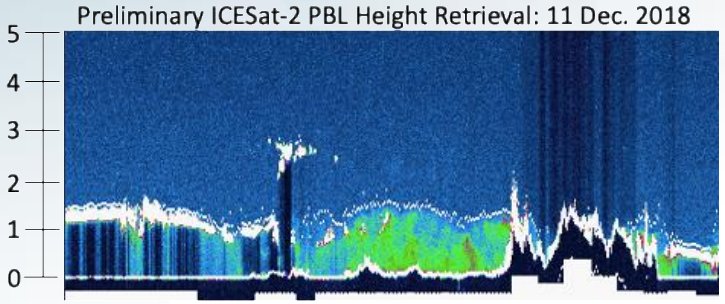
- To expand the number of awards supporting DSI, the program leverages relevant competitively selected awards made in other solicitations by either funding a full award or cost sharing on awards.
  - ❖ IIP
  - ❖ ACT
  - ❖ AIST
  - ❖ FINESST

- ACT-20: A Compact, High-Power 167-174.8 GHz Traveling Wave Tube Amplifier for Planetary Boundary Layer Differential Absorption Radar; PI: Kenneth Kreischer, Northrop Grumman Systems Corporation
- ACT-20: Ultra-Wideband Photonic Spectrometer for PBL Sensing; PI: Janusz Murakowski, Phase Sensitive Innovations, Inc.
- ATI-QRS-15: H2O, CH4, and HSRL Airborne Lidar Observations (H^3ALO); PI: Amin Nehrir, NASA LaRC
- IIP-21: Flexible Configuration Distributed Synthetic Aperture Digital Beamforming Radar (FlexSAR); PI: Yunling Lou, JPL
- IIP-21: Photonic Integrated Circuits (PICs) in Space: The Hyperspectral Microwave Photonic Instrument (HyMPI); PI: Antonia Gambacorta, NASA GSFC
- IIP-21: HALE InSAR for Continual and Precise Measurement of Earth's Changing Surface; PI: Lauren Wye, Aloft Sensing, Inc.
- AIST-21: A Framework for Global Cloud Resolving OSSE's; PI: Tom Clune, GSFC
- AIST-21: DTAS: A Prototype Digital Twin of Air-Sea Interactions; PI: Allison Gray, University of Washington, Seattle
- FINESST-21: Investigating Arctic coastal erosion through satellite-derived elevation modeling and scalable ICESat-2 bathymetric data fusion; PI: Lori Magruder, UT, Austin
- FINESST-21: Development of a UAV-based integrated ice-penetrating radar system for ice shelf monitoring; PI: Dustin Schroeder, Stanford Univ.

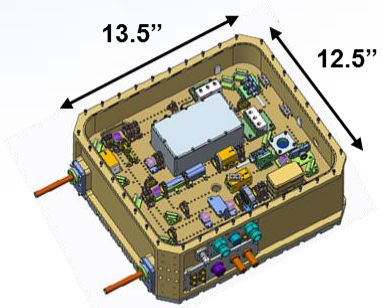
Task Augmentation Activities – FY20

With available remaining budget, ongoing active tasks previously awarded in R&A and ESTO programs were identified that could support goals of PBL and STV.

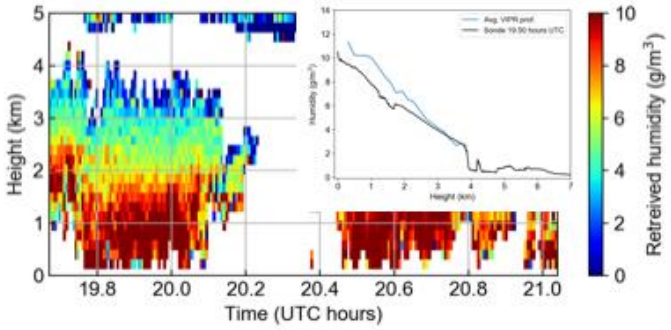
4 active awards from R&A and ESTO programs relevant to PBL were given 1-year augmentations



PBL height

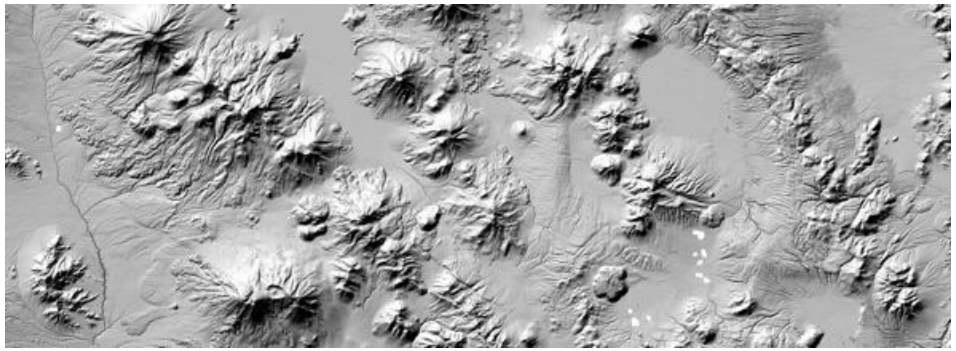


ABLE/HALO Water Vapor DIAL Transmitter



Example of occasional biases in the existing 2 wavelength VIPR system

5 active awards from R&A and ESTO programs relevant to STV were given 1-year augmentations


2x2m EarthDEM example, Altiplano, Bolivia


QUAKES-I Nadir Imager