

National Aeronautics and
Space Administration



ESTO
EARTH SCIENCE TECHNOLOGY OFFICE

2021 Small Spacecraft Virtual Forum

NASA Earth Science Division SmallSats: Constellations and Technology Validation via SmallSats/CubeSats

Sachidananda Babu Technology Validation Program Manager
sachi.babu@nasa.gov

Pamela Millar, ESTO Program Director

Robert Bauer, ESTO Deputy Program Director



Earth Science Technology Program Elements

ESTO manages, on average, 120 active technology development projects. Most are funded through the primary program lines below. Over 800 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



12 projects awarded in 2020

*Solicitations planned in FY22, and FY24
Average selection rate: 16.4%*

In-Space Validation of Earth Science Technologies (InVEST)

On-orbit technology validation and risk reduction for small instruments and instrument systems.



Four projects selected in FY18

Solicitation open in FY21

*Solicitations planned in FY24 and FY27
Average selection rate: 18.3%*

Instrument Incubator Program (IIP)

Earth remote sensing instrument development from concept through breadboard and demonstration

19 projects awarded in FY19

Solicitation open in FY21

*Solicitations planned in FY23 and FY25
Average selection rate: 23.2%*



Advanced Information Systems Technology (AIST)

Innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products

22 projects awarded in FY18

Solicitation open in FY21

Solicitations planned in FY23, and FY25

Average selection rate: 19.3%



Decadal Incubation

Maturation of observing systems, instrument technology, and measurement concepts for Planetary Boundary Layer and Surface Topography and Vegetation observables through technology development, modeling/system design, analysis activities, and small-scale pilot demonstrations

*Two Study Teams selected in FY20
Solicitations planned in FY21 and FY24*

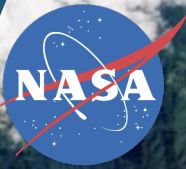




A Flexible, Science-driven Strategy

- Competitive, peer-reviewed proposals enable selection of best-of-class technology investments
- Risks are retired before major dollars are invested: a cost-effective approach to technology development and validation
- Successful partnering establishes leveraging opportunities
- This approach has resulted in:
 - a portfolio of emerging technologies that will enhance and/or enable future science measurements
 - a growing number of infusion successes into science campaigns, instruments, applications, ground systems, and missions

ESTO Enables – Science Selects



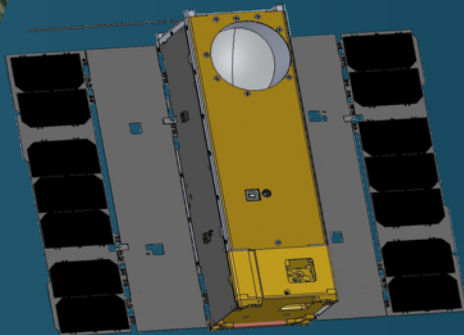
ESTO InVEST 2012 Program

U-Class Satellites Advancing TRLs for Future Earth Science Measurements

MiRaTA

MIT / MIT-LL

Launched: July 2017



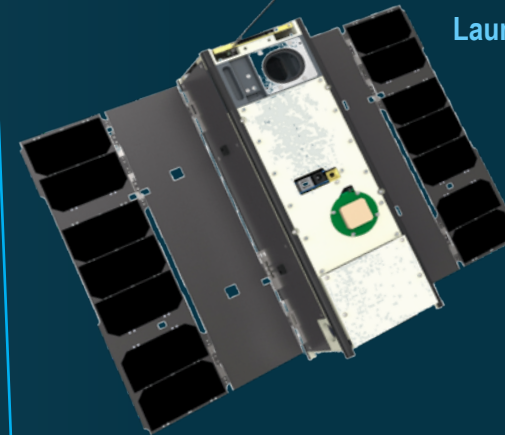
3 Frequency Radiometer and GPSRO

Validate new microwave radiometer and GPSRO technology for all-weather sounding

IceCube

GSFC

Launched: March 2017



883 GHz submm-Wave radiometer

Validate sub-mm radiometer for space borne cloud ice remote sensing

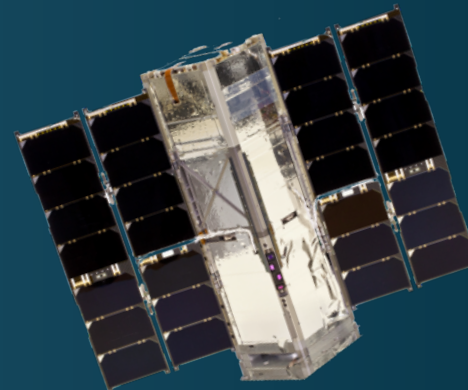
RAVAN

APL

Launched: Nov 2016

Vertically Aligned Carbon Nanotubes (VACNTs)

Demonstrate VACNTs as radiometer absorbing material and calibration standard for total outgoing radiation



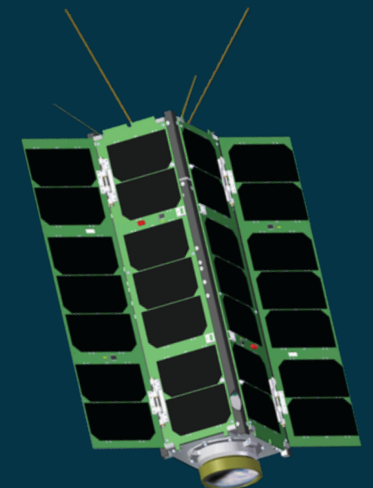
HARP

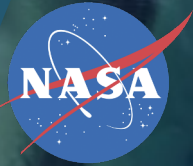
UMBC

Launch to ISS: November 2019

Wide FOV Rainbow Polarimeter

Demonstrate 2-4 km wide FOV hyperangular polarimeter for cloud & aerosol characterization

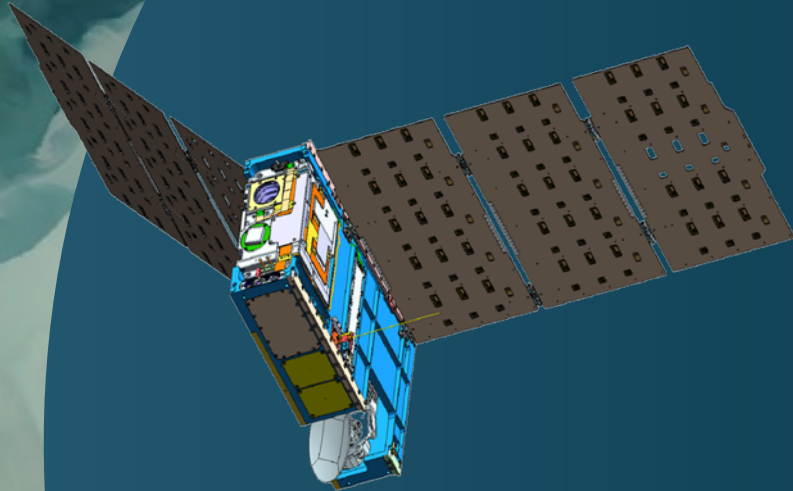




ESTO InVEST 2015 Program / Venture Tech

U-Class Satellites Advancing TRLs for Future Earth Science Measurements

Venture Tech

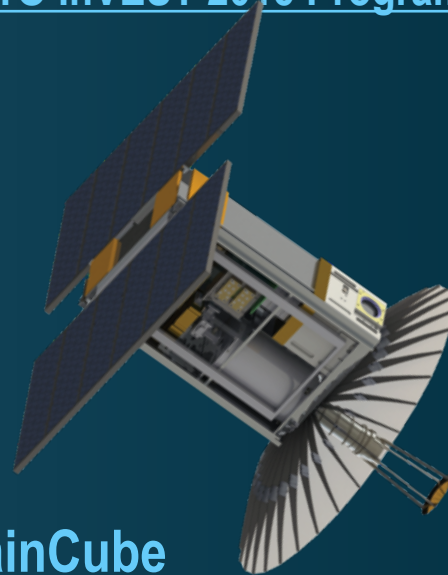


TEMPEST-D

Colorado State University
Launched June 2018

5 Frequency mm-Wave Radiometer
Technology demonstrator measuring the transition of clouds to precipitation

ESTO InVEST 2015 Program



RainCube

Jet Propulsion Lab
Launched June 2018

Precipitation Radar

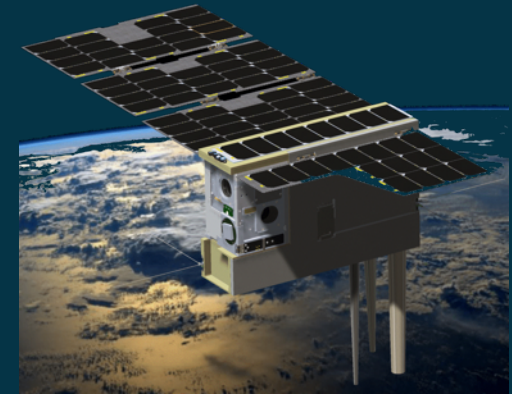
Validate a new architecture for Ka-band radars on CubeSat platform and an ultra-compact deployable Ka-band antenna

CubeRRT

The Ohio State University
Launched: June 2018

Radiometer RFI

Demonstrate wideband RFI mitigating backend technologies vital for future spaceborne microwave radiometers

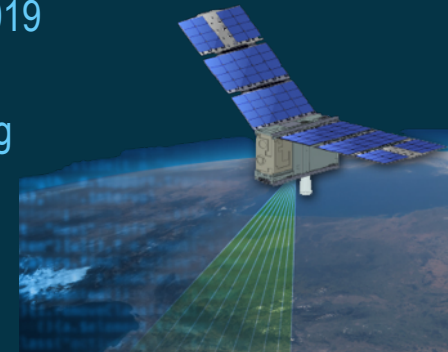


CIRiS

Ball Aerospace
Launch to ISS: December 2019

Infrared Radiometer

Validate an uncooled imaging infrared (7.5 μm to 13 μm) radiometer designed for high radiometric performance from LEO



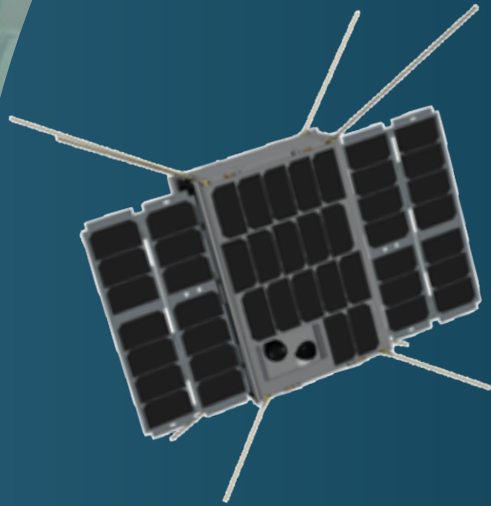


ESTO InVEST 2017 Program

U-Class Satellites Advancing TRLs for Future Earth Science Measurements

SNoOPI

Purdue University

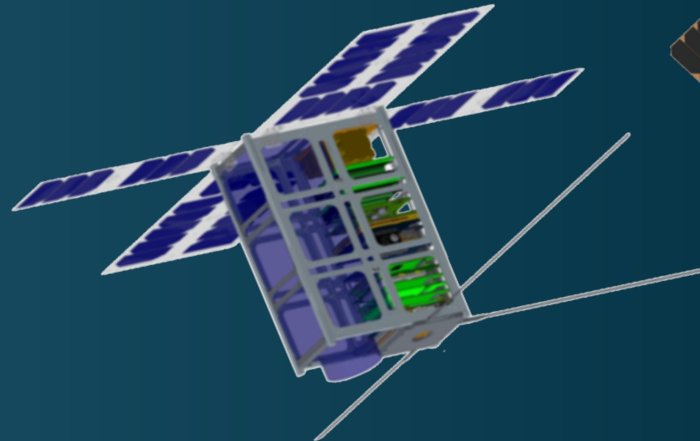


SigNals of Opportunity: P-band Investigation

Demonstrate measurement of the reflection coefficient and phase of land surface reflections from P-band communication satellite signals of opportunity

HyTI

University Of Hawaii

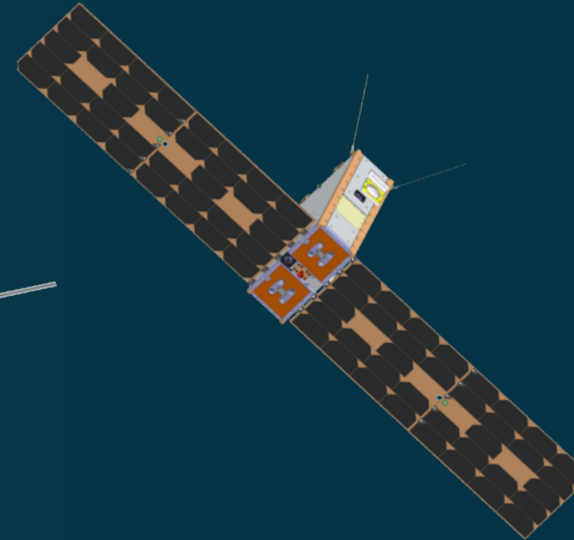


Hyperspectral Thermal Imager

Demonstrate a 6U CubeSat based LEO thermal infrared (TIR) hyperspectral imager with agile on-board processing

C-TIM FD

LASP-Univ of Colorado

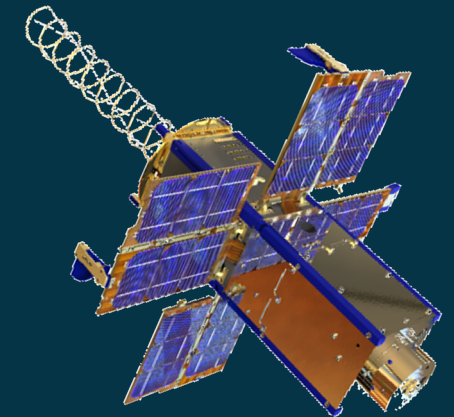


Infrared Radiometer

Validate and demonstrate science performance validate 6U CubeSat system against existing TSIS instrument

NACHOS

Los Alamos National Laboratory



NanoSat Atmospheric Chemistry Hyperspectral Observation System

Compact high-resolution trace-gas hyperspectral imagers, with agile on-board processing

Earth Venture Opportunities

Mission	Mission Type	Release Date	Selection Date	Major Milestone
EVS-1 (EV-1) (AirMoss, ATTREX, CARVE, DISCOVER-AQ, HS3)	5 Suborbital Airborne Campaigns	2009	2010	Completed KDP-F
EVM-1 (CYGNSS)	Class D SmallSat Constellation	2011	2012	Launched Dec. 2016
EVI-1 (TEMPO)	Class C Geostationary Hosted Instrument	2012	2012	Delivered to storage Dec. 2018
EVI-2 (ECOSTRESS & GEDI)	Class C & Class D ISS-hosted Instruments	2013	2014	Launched June & Dec. 2018
EVS-2 (ACT-America, ATOM, NAAMES, ORACLES, OMG, CORAL)	6 Suborbital Airborne Campaigns	2013	2014	CORAL, NAAMES, ORACLES completed KDP-F
EVI-3 (MAIA & TROPICS)	Class C LEO Hosted Instrument & Class D CubeSat Constellation	2015	2016	TROPICS Launch scheduled between Jan. 8 and July 31, 2022,
EVM-2 (GeoCarb)	Class D Geostationary Hosted Instrument	2015	2016	Launch ~2022
EVI-4 (EMIT & PREFIRE)	Class C ISS-hosted Instrument & Class D Twin CubeSats	2016	2018	Delivery NLT 2021
EVS-3 (ACTIVATE, DCOTTS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	Passed Initial Confirmation Review, 2 began deployments
EVI-5 (GLIMR)	Class C Geostationary Hosted Instrument	2018	2019	Delivery NLT 2024
EVC-1 (Libera)	Class C JPSS-Hosted Radiation Budget Instrument	2018	2020	Delivery NLT 2025
EVM-3	Full Orbital	2020	2021	Launch ~2026
EVI-6	Instrument Only	2021	2022	Delivery NLT 2027
EVC-2	Continuity Measurements	2022	2023	Delivery NLT 2028
EVS-4	Suborbital Airborne Campaigns	2023	2024	N/A
EVI-7	Instrument Only	2024	2025	Delivery NLT 2030
EVM-4	Full Orbital	2024	2025	Launch ~2030
EVC-3	Continuity Measurements	2025	2026	Delivery NLT 2031
EVS-5	Suborbital Airborne Campaigns	2027	2028	N/A

EVS
Sustained sub-orbital investigations (~4 years)

EVM
Complete, self-contained, small missions (~4 years)

EVI
Full function, facility-class instruments Missions of Opportunity (MoO) (~3 years)

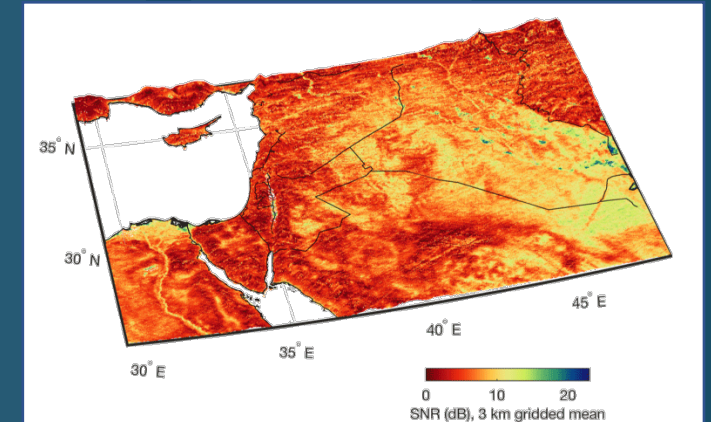
EVC
Complete missions or hosted instruments targeting “continuity” measurements (~3 years)

Open solicitation - In Review
Completed solicitation

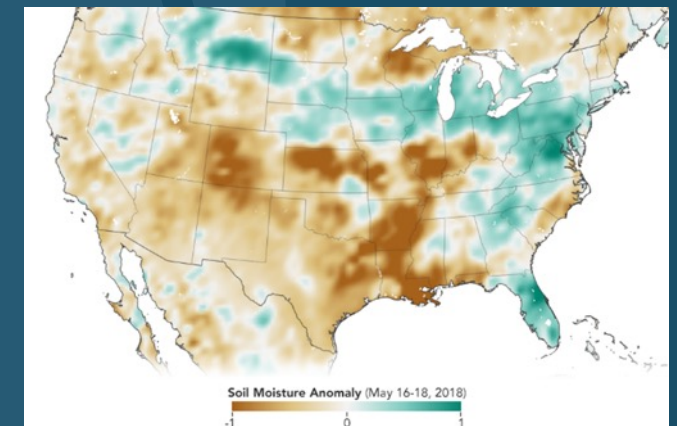
8 Smallsats exploiting Global GNSS network to measure sea surface winds to improve Hurricane forecasts

Over land it can measure soil moisture and flooding

CYGNSS and SMAP



Nov 2018 – CYGNSS constellation high resolution SNR map identifies flooded regions in central and northern Iraq

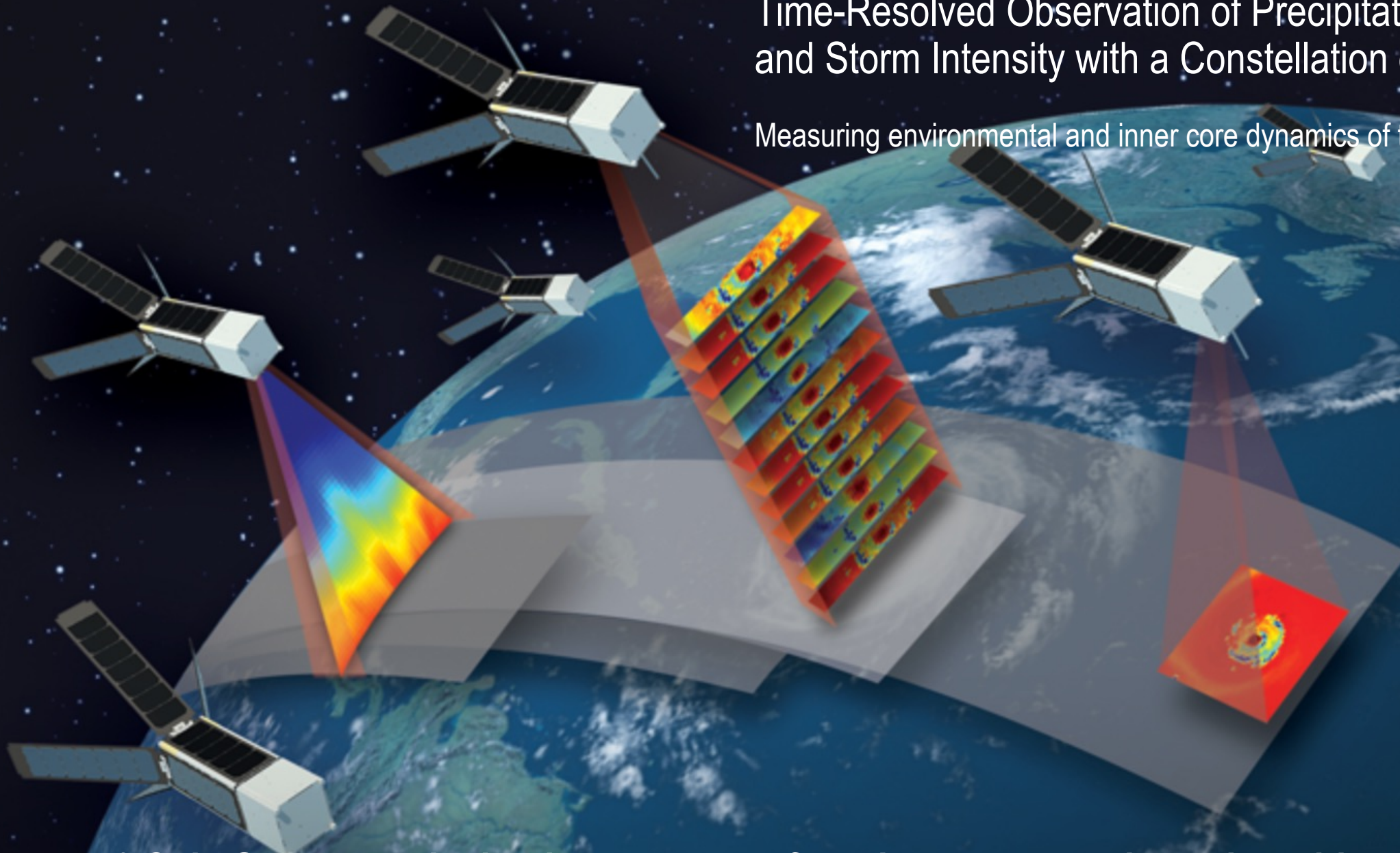


USDA uses SMAP data to report on regional droughts, floods, and crop forecasts

TROPICS

Time-Resolved Observation of Precipitation Structure and Storm Intensity with a Constellation of CubeSats

Measuring environmental and inner core dynamics of tropical cyclones

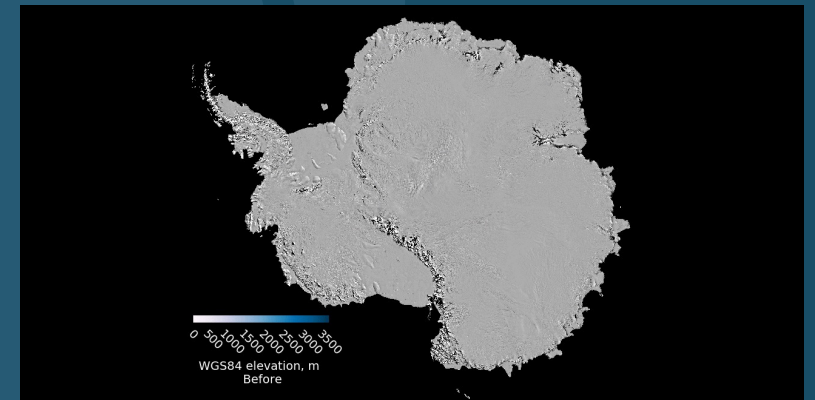


6 CubeSats to study the development of tropical cyclones through rapid-revisit sampling

PREFIRE



Discoveries impact the overall global Earth system, including Greenland ice retreat



Oct. 2018 to Apr. 2019 – 7 months of ICESat-2 observations over Antarctica

CubeSats, SmallSats, and Constellations

Small Satellite Solutions:

- **Venture Class Launch Services:** Investment in new, low-cost (<\$15M/launch), commercial launch vehicles capable of orbiting small payloads to LEO – science control of launch schedule and orbits
- **CYGNSS (Cyclone Global Navigation Satellite System):** Homogeneous tropical constellation of 8 *micro-satellites* using reflected GPS to measure surface winds/air-sea interactions, especially valuable/unique in the precipitation-dominated, dynamic, eyewalls of tropical storms and hurricanes – frequent tropical sampling from 1 orbit plane
- **TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of SmallSats):** Homogeneous tropical constellation of 6 *CubeSats* to measure atmospheric profiles in storms/hurricanes – frequent sampling from 2-3 orbit planes
- **PreFIRE:** 2-satellite CubeSat constellation to measure Far-IR emissions primarily from the Arctic
- **In-Space Validation of Earth Science Technologies (InVEST):** On-orbit *CubeSat-based* technology validation and risk reduction that could not otherwise be fully tested using ground/airborne systems; leading to miniaturized science payload development
 - CSIM/CTIM provide a new SmallSat architecture approach for future TSI and SSI continuity measurements
 - SLI-T instrument development for Landsat-10+, future SLI consideration (6 projects ongoing)
 - Tempest-D and RainCube produced exceptional precipitation measurements of Hurricanes
 - Five CubeSats from InVEST-19 are planned to launch in next 12 months



NASA

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INNOVATE

and

EXPLORE

with us

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Earth Science Technology Office

Contact: sachi.babu@nasa.gov