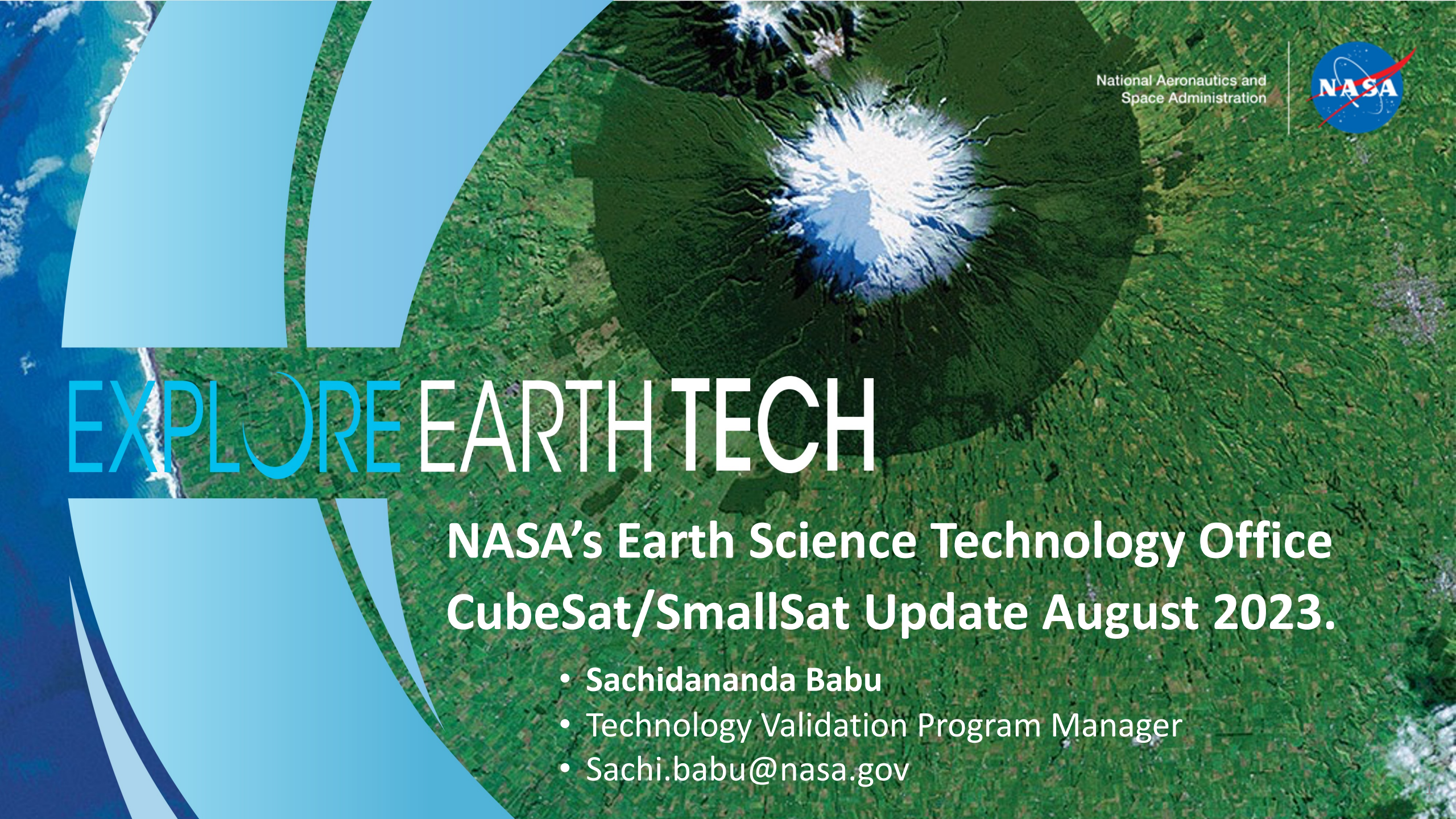
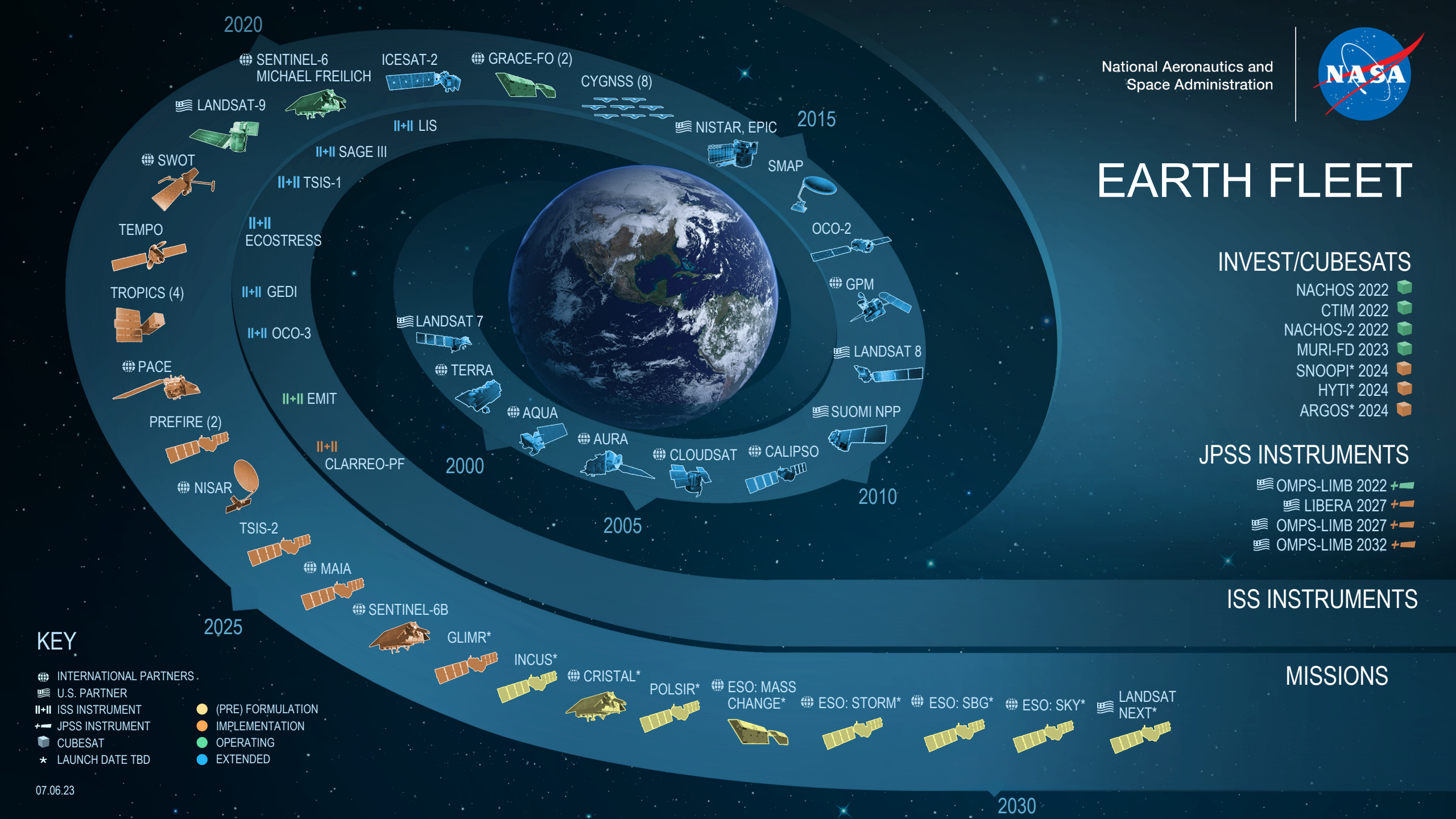
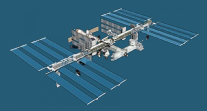


NASA's Earth Science Technology Office CubeSat/SmallSat Update August 2023.

- **Sachidananda Babu**
- Technology Validation Program Manager
- Sachi.babu@nasa.gov

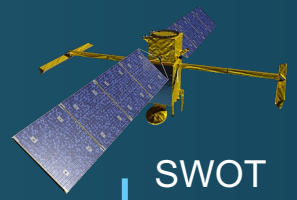

National Aeronautics and Space Administration
NASA
EARTH FLEET
2020
SENTINEL-6 MICHAEL FREILICH
ICESAT-2
GRACE-FO (2)
CYGNSS (8)
LANDSAT-9
LIS
NISTAR, EPIC
2015
SAGE III
SWOT
TSIS-1
SMAP
TEMPO
ECOSTRESS
OCO-2
TROPICS (4)
GEDI
GPM
LANDSAT 7
OCO-3
LANDSAT 8
PACE
TERRA
EMIT
SUOMI NPP
PREFIRE (2)
AQUA
AURA
CLOUDSAT
CALIPSO
CLARREO-PF
2000
2010
NISAR
2005
TSIS-2
MAIA
SENTINEL-6B
2025
GLIMR*
INCUS*
CRISTAL*
POLSIR*
ESO: MASS CHANGE*
ESO: STORM*
ESO: SBG*
ESO: SKY*
LANDSAT NEXT*
2030
INVEST/CUBESATS
NACHOS 2022
CTIM 2022
NACHOS-2 2022
MURI-FD 2023
SNOOPI* 2024
HYTI* 2024
ARGOS* 2024
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
OMPS-LIMB 2027
OMPS-LIMB 2032
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
(PRE) FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED
07.06.23

Recent and Upcoming Earth Science Launches

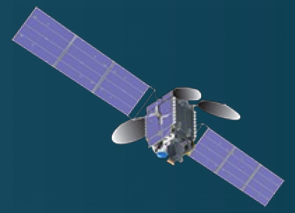


EMIT (ISS)

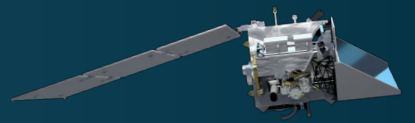
OMPS-Limb
(JPSS-2/NOAA)



SWOT



TEMPO*

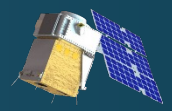


PACE****

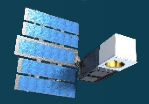
2022 **2023** **2024**

July November December January April May January February May June

CTIM-FD

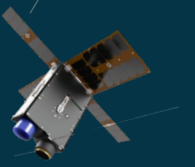


MURI
(hosted on
YAM-5)

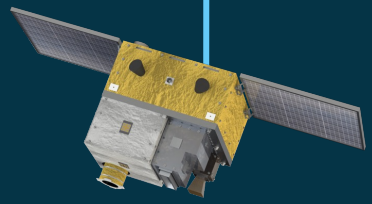


TROPICS 2, 3**

SNOOPI***



HyTI*****



ARGOS

*Agency LRD March 2023
**Agency LRD November 2023
***Launch Date NET February 2024
****Agency LRD January 2024
*****Launch Date NET June 2024

05.18.23

Earth Science Division: SmallSat Missions & Investment, 2010-2023

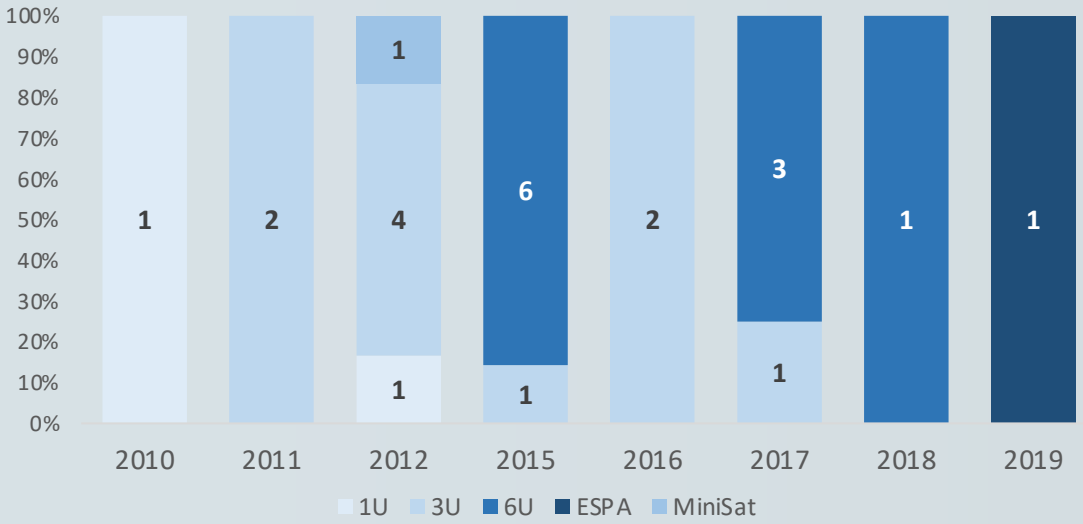
EXPLORE EARTH TECH

28 TOTAL MISSIONS *Over 12 Years*

- **10** COMPLETED
- **6** IN IMPLEMENTATION
- **3** OPERATION
- **3** CANCELLED/FAILED

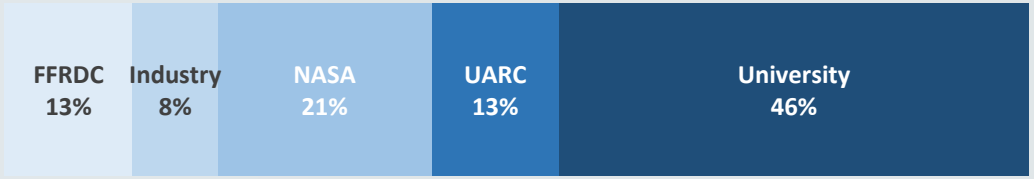
$442M TOTAL INVESTMENT *Over 11 Years*

Earth Science Missions: *Trended Mission Size*

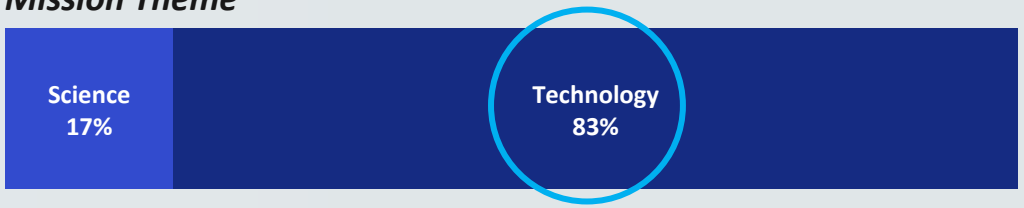


Hosted payloads are not included in data shown.

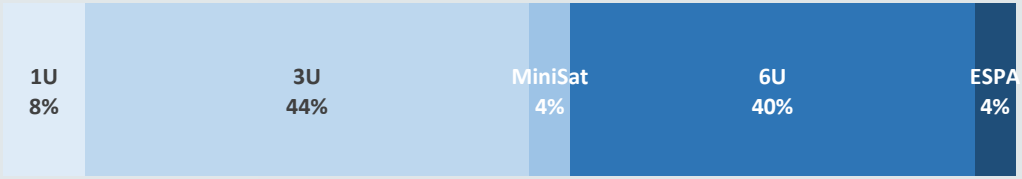
Sponsoring Organization



Mission Theme



Spacecraft Size



Constellations

Constellations include two or more spacecraft.

* Data as of April 2023

Earth Science Flight Opportunities

Open solicitation/In review | Completed solicitation

Mission	Mission Type	Release	Selection	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	Completed KDP-F
EVI-3 (MAIA & TROPICS)	Class C LEO Hosted Instrument & Class D CubeSat Constellation	2015	2016	MAIA Delivery 2022; TROPICS Launch 2022
EVM-2 (GeoCarb)	Class D Geostationary Hosted Instrument	2015	2016	Launch TBD
EVI-4 (EMIT & PREFIRE)	Class C ISS-hosted Instrument & Class D Twin CubeSats	2016	2018	Delivery NLT 2021
EVS-3 (ACTIVATE, DCOTSS, IMPACTS, Delta-X, SMODE)	5 Suborbital Airborne Campaigns	2017	2018	4 in deployment. Delta-X is in post-deployment phase.
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 (INCUS)	Full Orbital	2020	2021	Launch ~2026
EVI-6 (PolSIR)	Polarized Submillimeter Ice-cloud Radiometer on 2 identical Cubesats	2022	2023	Delivery NLT 2027
ESE	Explorer Mission	2022	2024	Launch ~2029 & ~2031
EVC-2	Continuity Measurements	2023	2024	Delivery NLT 2028
EVS-4	Suborbital Airborne Campaigns	2023	2024	N/A
ESE	Explorer Mission	2024	2026	Launch TBD
EVI-7	Instrument Only	2024	2025	Delivery NLT 2030
EVM-4	Full Orbital	2024	2025	Launch ~2030
EVC-3	Continuity Measurements	2026	2027	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)

ESE *(NEW)*
Medium-size instruments and missions
(~2 years)

07.31.23

Polarized Submillimeter Ice-cloud Radiometer (PolSIR)

The investigation consists of two identical CubeSats

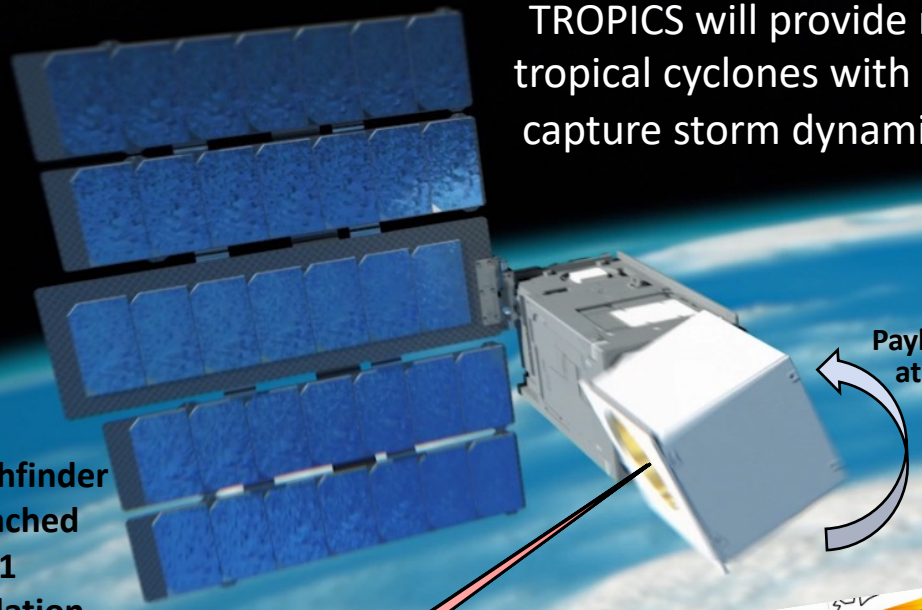
- each small satellite is just a little over a foot tall
- - flying in orbits separated by three to nine hours. Over time, these two instruments will observe the clouds' daily cycle of ice content.

TROPICS: Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

William J. Blackwell (MIT LL), Principal Investigator Scott A. Braun (NASA GSFC), Project Scientist

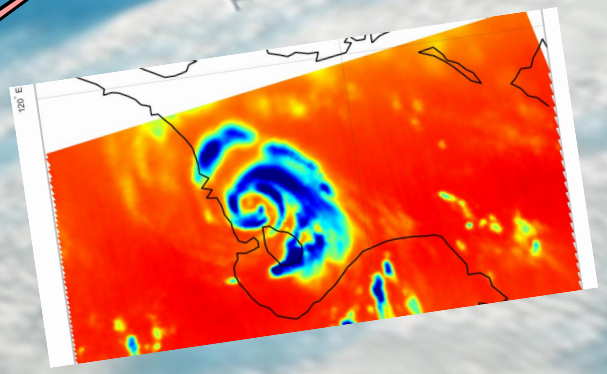
Science Mission Directorate
Earth Venture Program
EVI 3

TROPICS will provide microwave observations of tropical cyclones with <60 minute revisit to better capture storm dynamics and improve forecasting



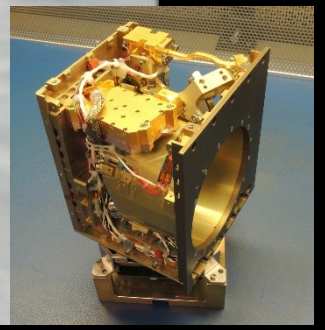
Payload scans at 30 RPM

TROPICS Pathfinder satellite launched June 30, 2021
Four constellation vehicles launched May 2023



High-resolution microwave data resolves tropical cyclone eye and rain structure

Constellation of Four 3U CubeSats
MIT LL payload; BCT bus; KSAT downlink

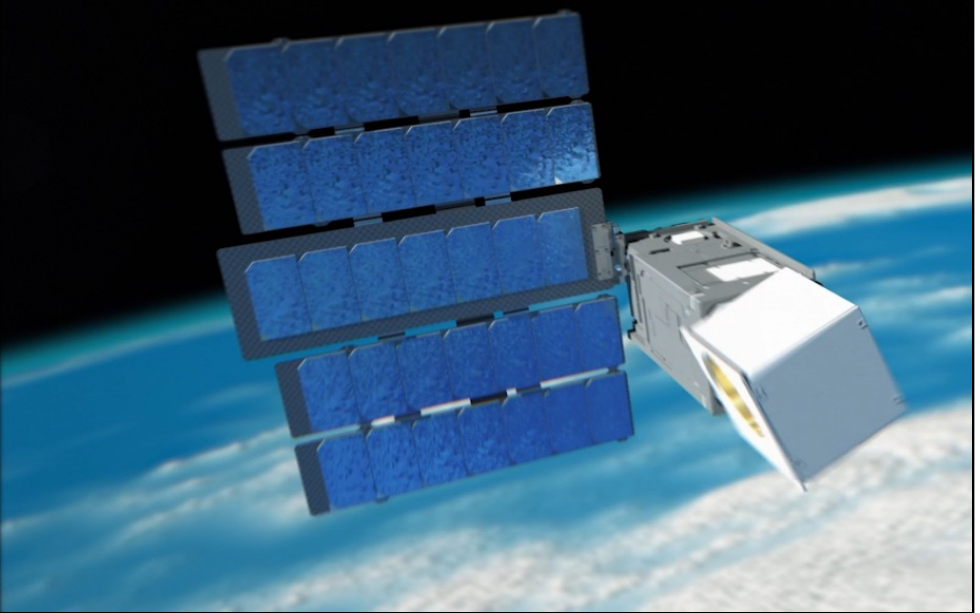


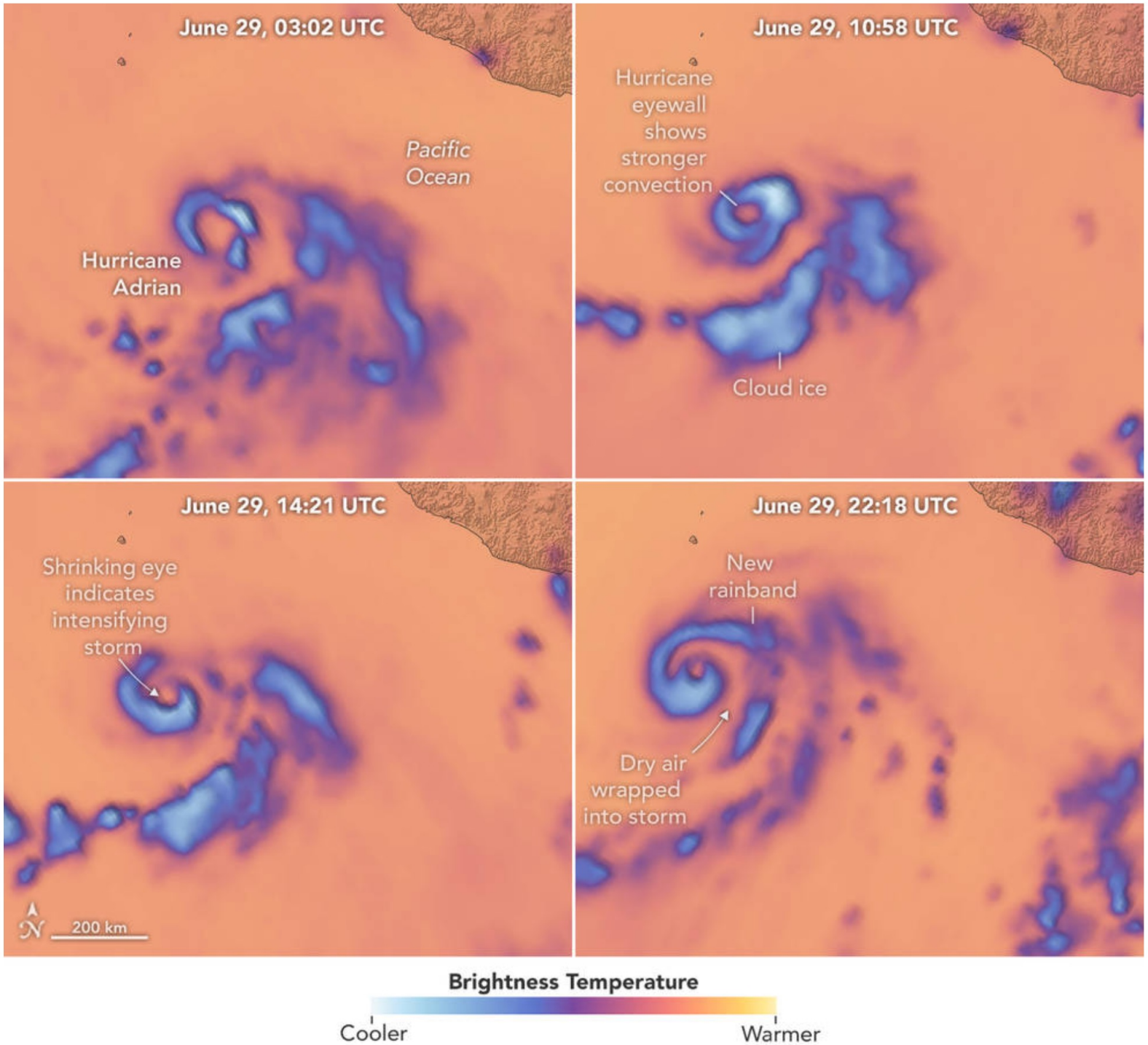
TROPICS Microwave Sounder
12 channels (90-205 GHz)
Temperature, Moisture, Rain Rate

NASA TROPICS

CubeSat Constellation Mission Releases First-Light Data

Four 3U CubeSats, 30° inclination, 550 km
12-channel microwave sounder payload
60-min-revisit tropical cyclone obs





Earth Science Technology Highlight

MURI Instrument Sees First Light

Developed at Leonardo DRS with support from NASA's Earth Science Technology Office, the Multiband Uncooled Radiometer Imager (MURI) instrument has taken first images from orbit.

MURI is testing a new two-band longwave infrared (10.8um and 12.0um) radiometric imager that utilizes an uncooled focal plane array. Thermal infrared data describing Earth's surface temperature is critical for learning more about a host of complex Earth systems, from wildfires to marine ecosystems.

Focal plane arrays typically require bulky, heavy cryogenic coolers. Without those coolers, the MURI instrument is much smaller, lighter, and less power-hungry than traditional radiometers.

Weighing just three pounds, MURI will be capable of gathering infrared data with high precision. During laboratory and airborne testing, MURI gathered infrared data within a margin of error smaller than 1%, which is considered world class for long wave infrared radiometers.

MURI was launched by the SpaceX Transporter 6 on 1/3/23, as one of several hosted payloads within the Loft Orbital YAM5 SmallSat. On orbit operations are planned for at least six months, during which MURI will generate data and imagery that will be compared to Landsat's Thermal Infrared Sensor (TIS).

At right above: MURI captured its 10.8-micron band image in late March, over the Gaza coastline. The black artifacts are relatively colder clouds.
At right below: Google Earth visible image of the area

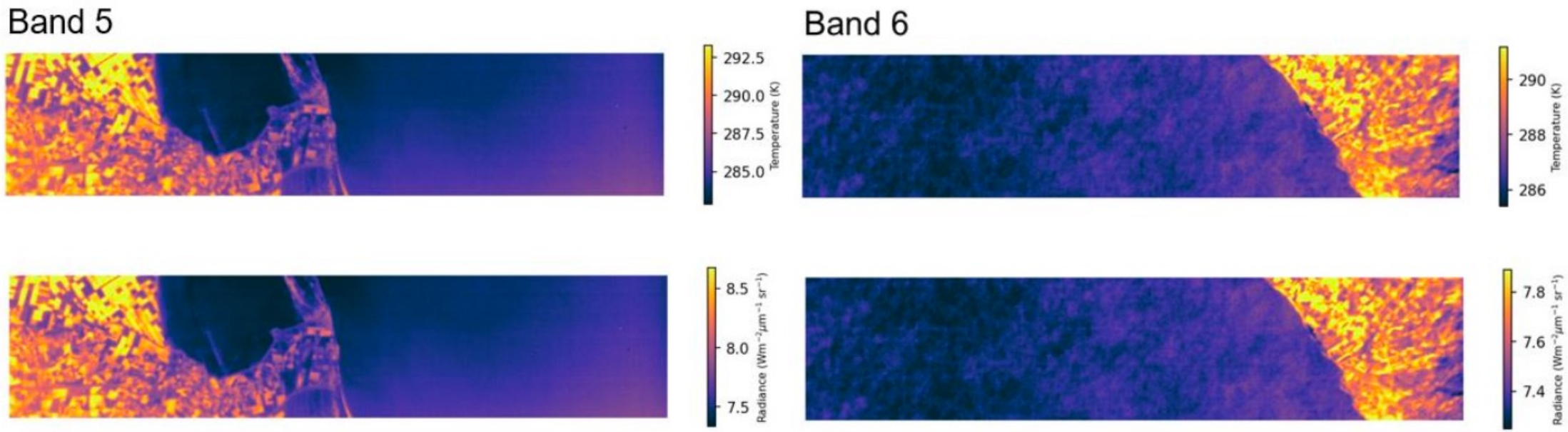
Principal Investigator: Philip Ely, Leonardo DRS

Los Angeles Comparison of MURI SmallSat to LANDSAT 8 TIRS

MURI SmallSat LA Basin July 8, 2023

TIRS Landsat 8 LA Basin May 13, 2013

YAM5/MURI Collect over Italy 04/06/23



Measured Temperature and Radiance Images on Italy Coastlines

Band #	Buoy ID	Buoy Lat.	Buoy Lon.	Measurement distance from Buoy (km)	Buoy Time	MURI Time	Modeled Temp. (K)	Image Temp. (#1) (K)	Image Temp. (#2) (K)	Ave error (K)
5	6903815	43.9123	14.0919	90	04/08/2023 22:33:20	04/06/2023 09:10:33	283.58	284.36	284.54	0.87
6	6903820	39.9299	13.0163	300	04/08/2023 22:33:20	04/06/2023 09:10:33	284.61	285.77	285.87	1.21

Atmospheric Corrected Temperature vs. Truth (Buoy) Data from Images of Italy Collect