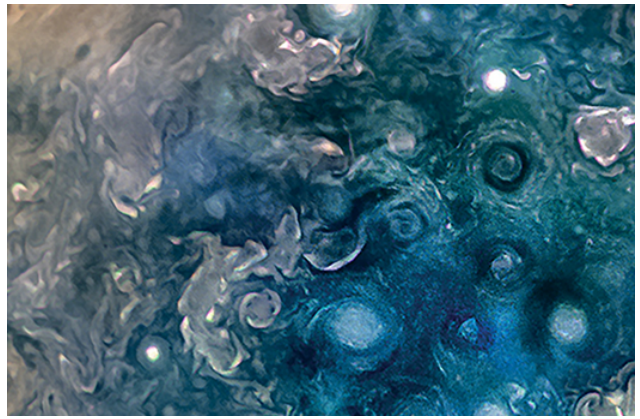
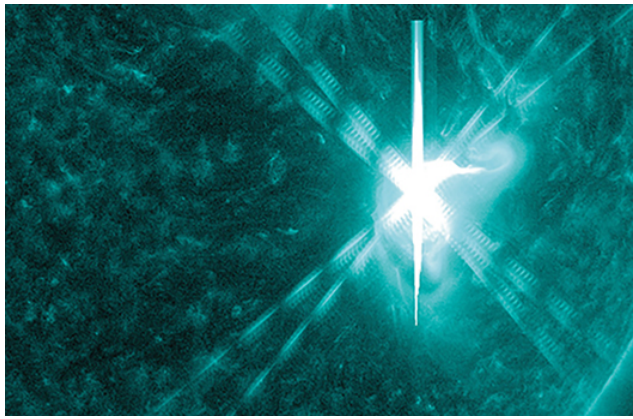
SCIENCE

National Aeronautics and Space Administration



NAS COMMITTEE ON SOLAR AND SPACE PHYSICS

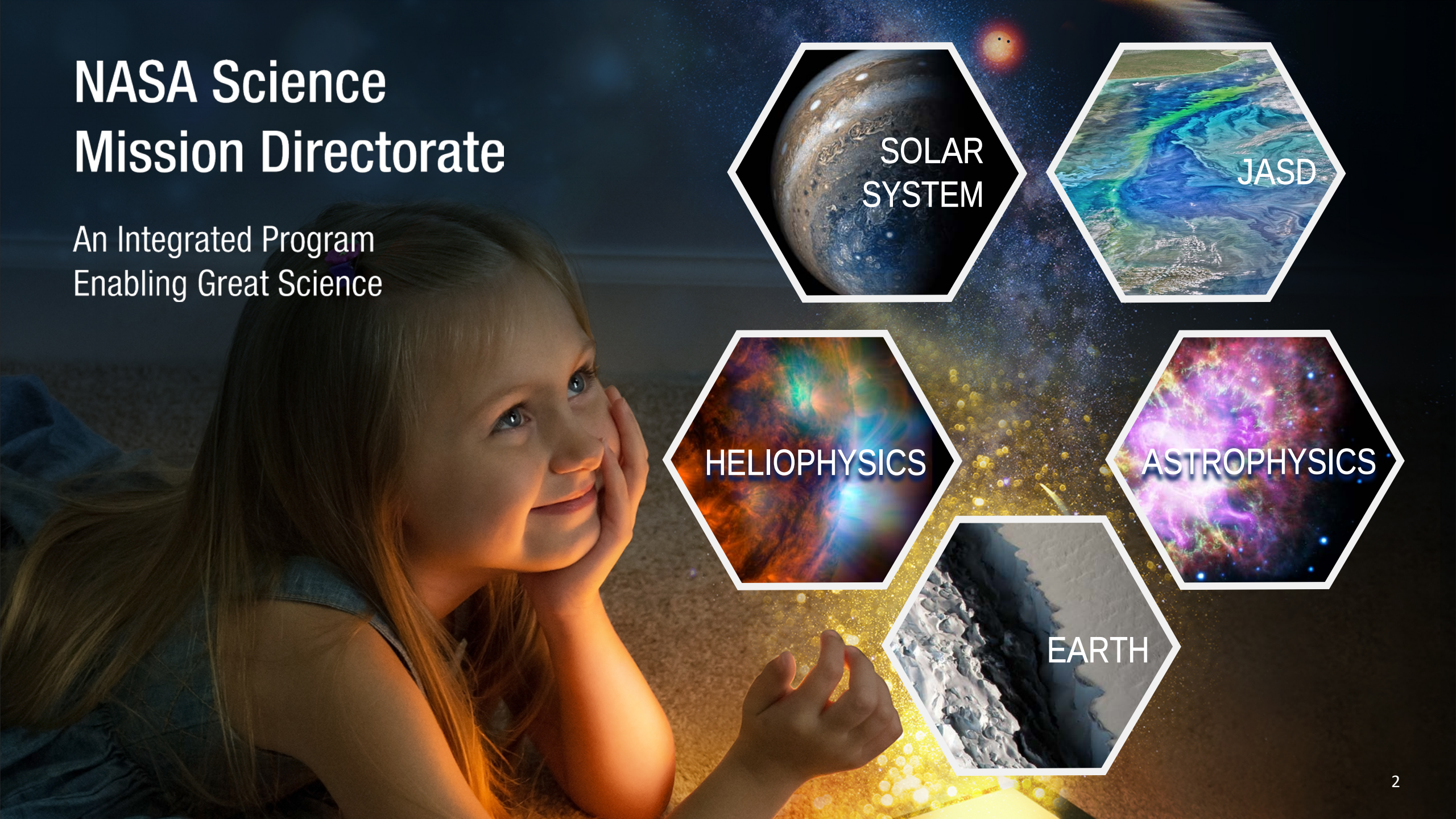
NASA's Perspectives on Small Satellites and Constellations

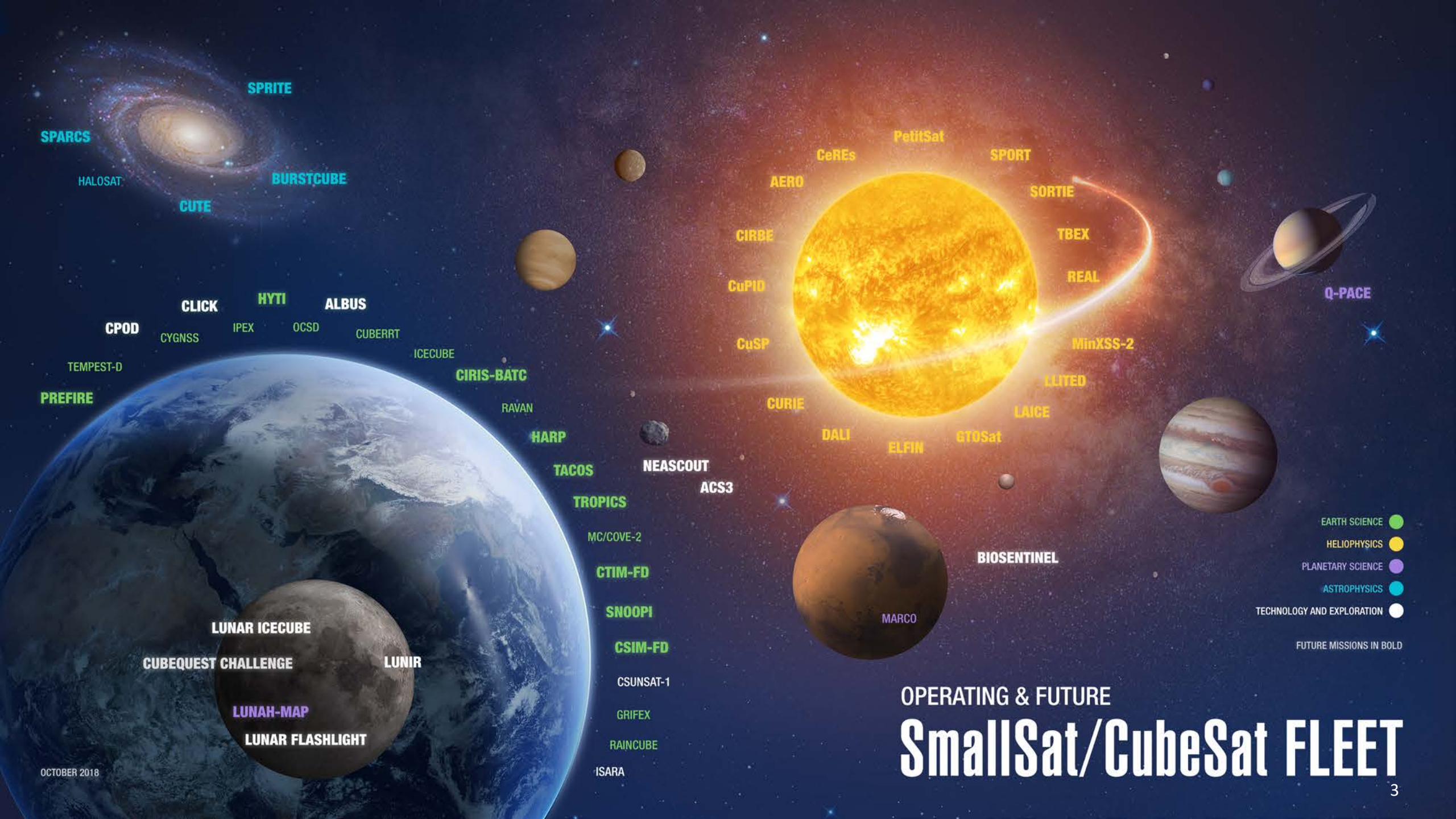
Dr. Charles D. Norton
Special Advisor, Small Spacecraft Missions
Science Mission Directorate, NASA

October 1, 2018

NASA Science Mission Directorate

An Integrated Program
Enabling Great Science

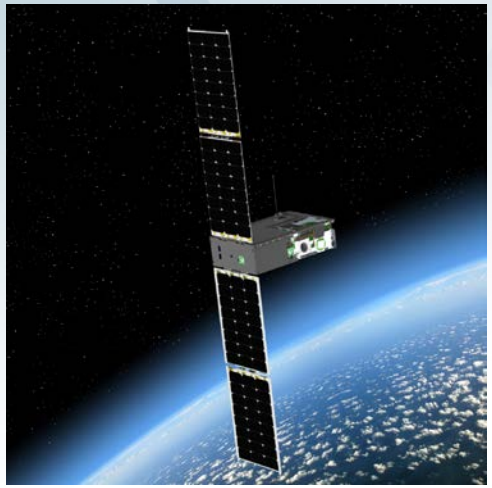



SPRITE
SPARCS
HALOSAT
BURSTCUBE
CUTE
CLICK
HYTI
ALBUS
CPOD
CYGNSS
IPEX
OCSD
CUBERRT
ICECUBE
TEMPEST-D
CIRIS-BATC
PREFIRE
RAVAN
HARP
TACOS
NEASCOUT
ACS3
TROPICS
MC/COVE-2
CTIM-FD
SNOOPI
CSIM-FD
CSUNSAT-1
GRIFEX
RAINCUBE
ISARA
LUNAR ICECUBE
CUBEQUEST CHALLENGE
LUNIR
LUNAH-MAP
LUNAR FLASHLIGHT
OCTOBER 2018
PetitSat
CeREs
SPORT
AERO
SORTIE
CIRBE
TBEX
CuPID
REAL
CuSP
MinXSS-2
LLITED
CURIE
LAICE
DALI
GTOSat
ELFIN
Q-PACE
BIOSENTINEL
MARCO
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
TECHNOLOGY AND EXPLORATION
FUTURE MISSIONS IN BOLD
OPERATING & FUTURE
SmallSat/CubeSat FLEET

Why Small Spacecraft Matter

- Increases the pace of exploration and discovery, at lower cost, allowing for higher risk tolerance
- Leverages NewSpace industry capabilities through commercial partnerships
- Enables new scientific discoveries via constellations providing increased spatial and temporal coverage
- Advances new technologies for future missions
- Mitigates strategic knowledge gaps and provides an increasingly capable platform to precede human explorers to the Moon, Mars, and other destinations
- Lowers barriers to entry for new investigators and ideas

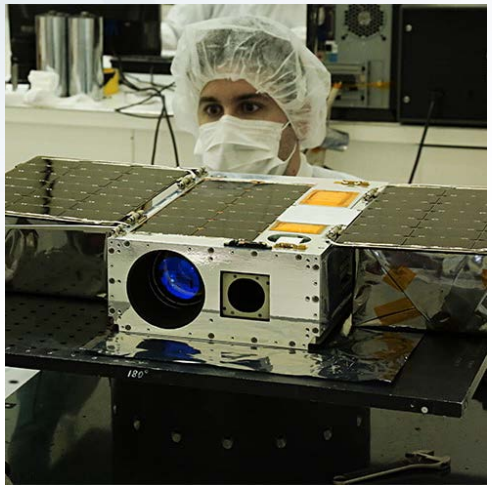
Small Missions Advance NASA Science & Technology



CSIM-FD

Compact Solar Spectral Irradiance Monitor

Single 6U CubeSat at 1/10th (mass) and 1/20th (volume) of prior SORCE SIM instrument for understanding how solar variability impacts Earth's climate

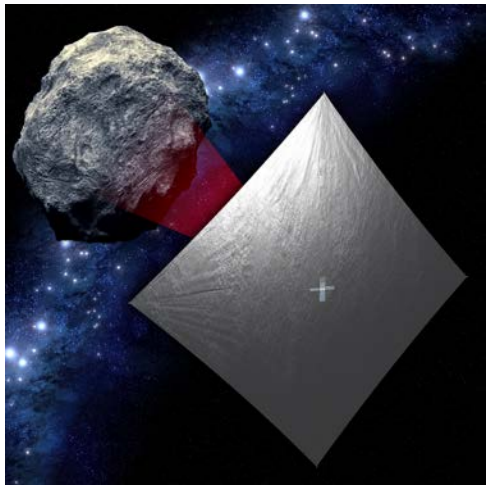


ASTERIA

Arcsecond Space Telescope

Achieved < 0.5 arcsecond RMS and <0.01 K thermal control for precision photometry while verifying known transit of super-Earth 55 Cancri-e enabling exoplanet research

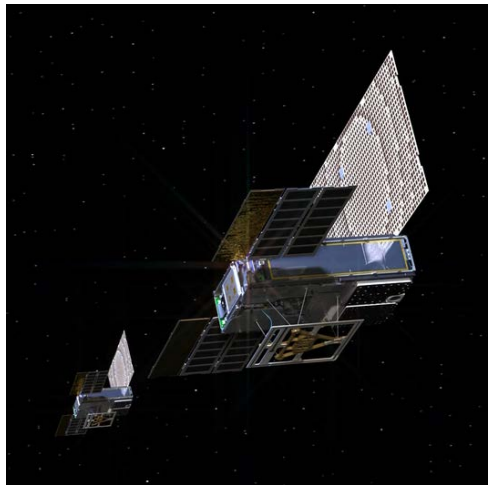
2018 SmallSat Mission of the Year



NEAScout

Near Earth Asteroid Scout

Single 6U CubeSat reconnaissance mission to image a near-Earth asteroid determining regional morphology, regolith properties, spectral class and other features, to close strategic knowledge gaps for potential human/robotic exploration missions



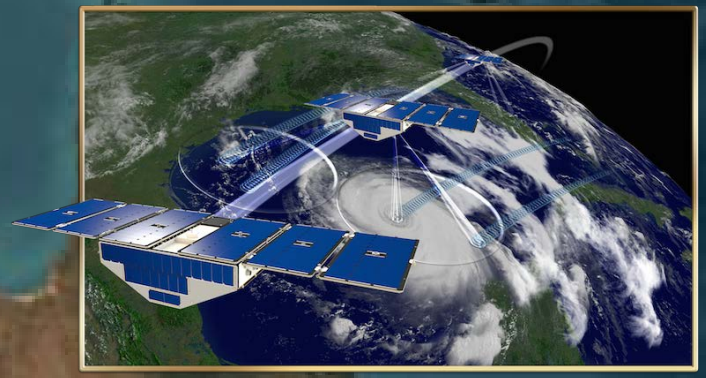
MarCO

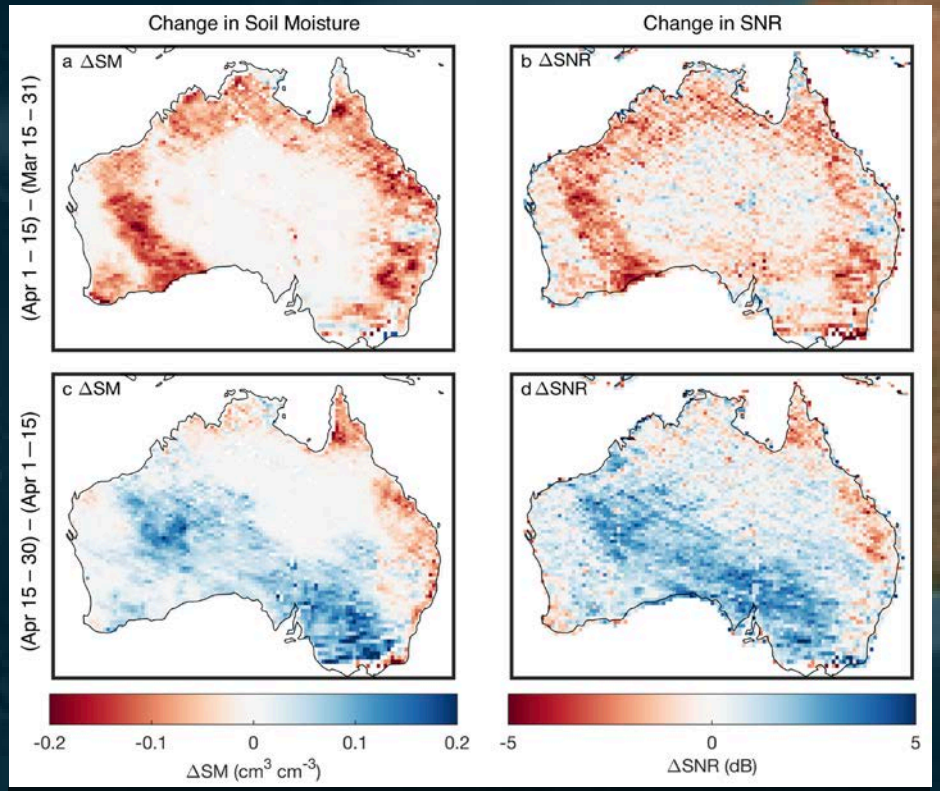
Mars Cube One

Two independent 6U CubeSats testing various deep space technologies, in a non-interference manner, relaying telemetry from the Mars InSight EDL sequence

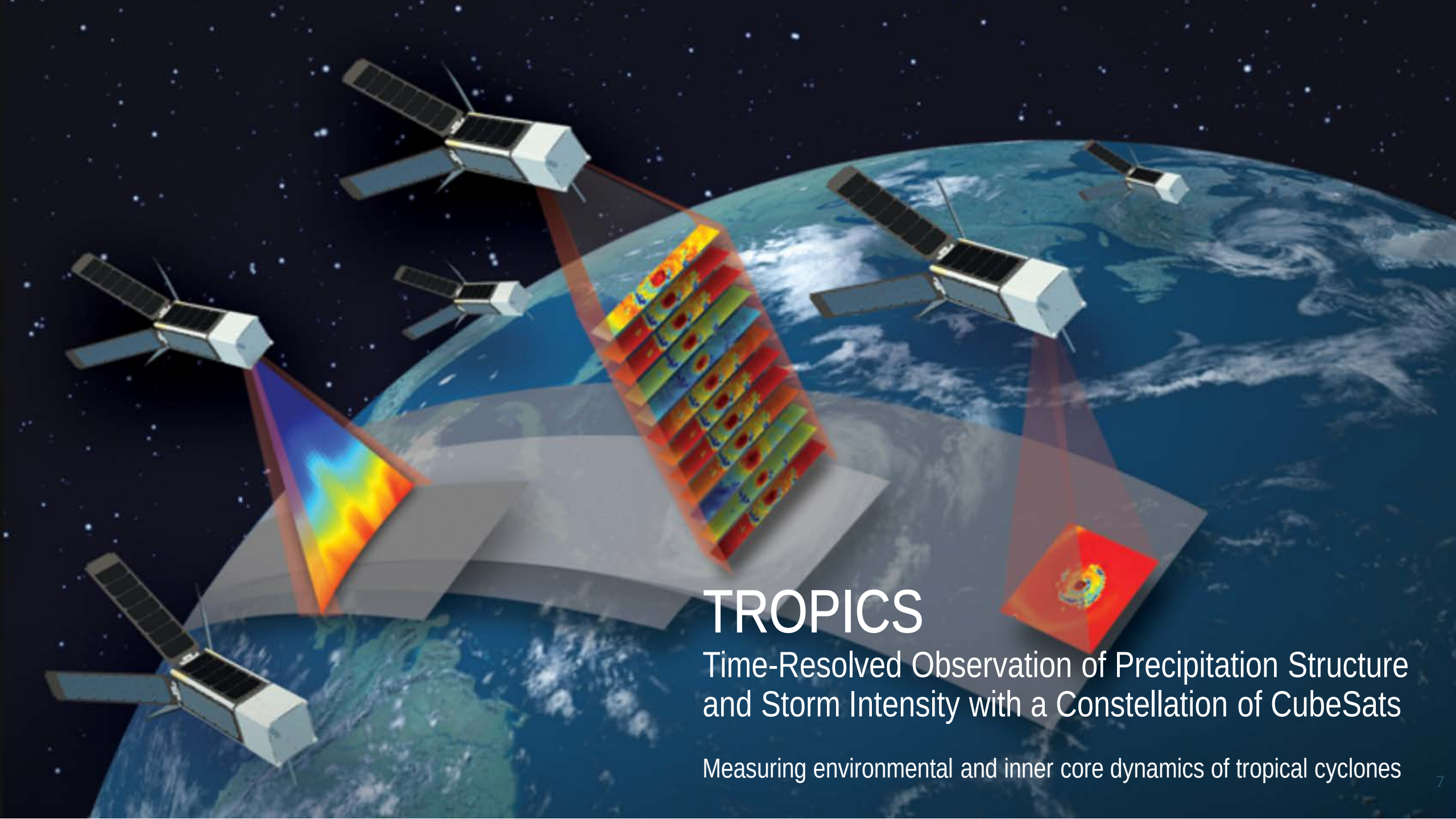
CYGNSS

Land Hydrology Opportunistic Measurement Near-Surface Soil Moisture





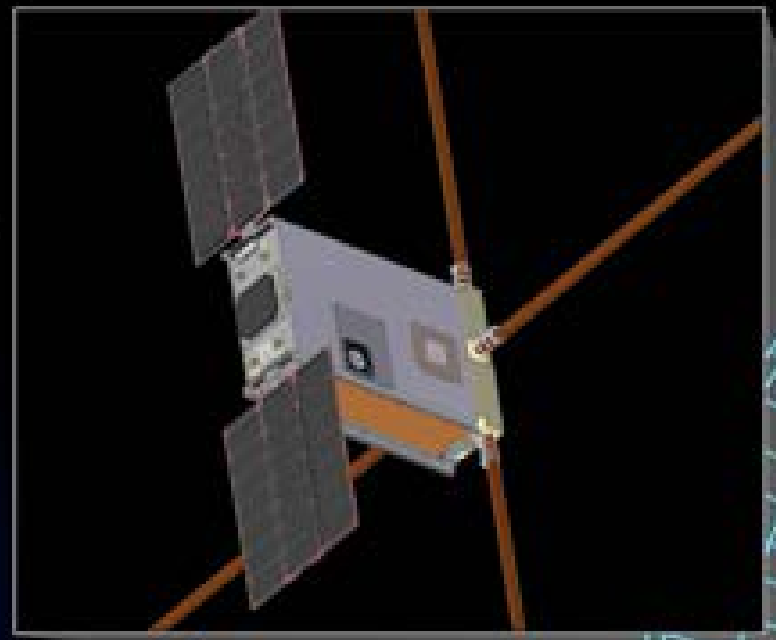
June 8, 2018 – Nature Scientific Reports: Change in mean SMAP soil moisture compared to change in CYGNSS SNR

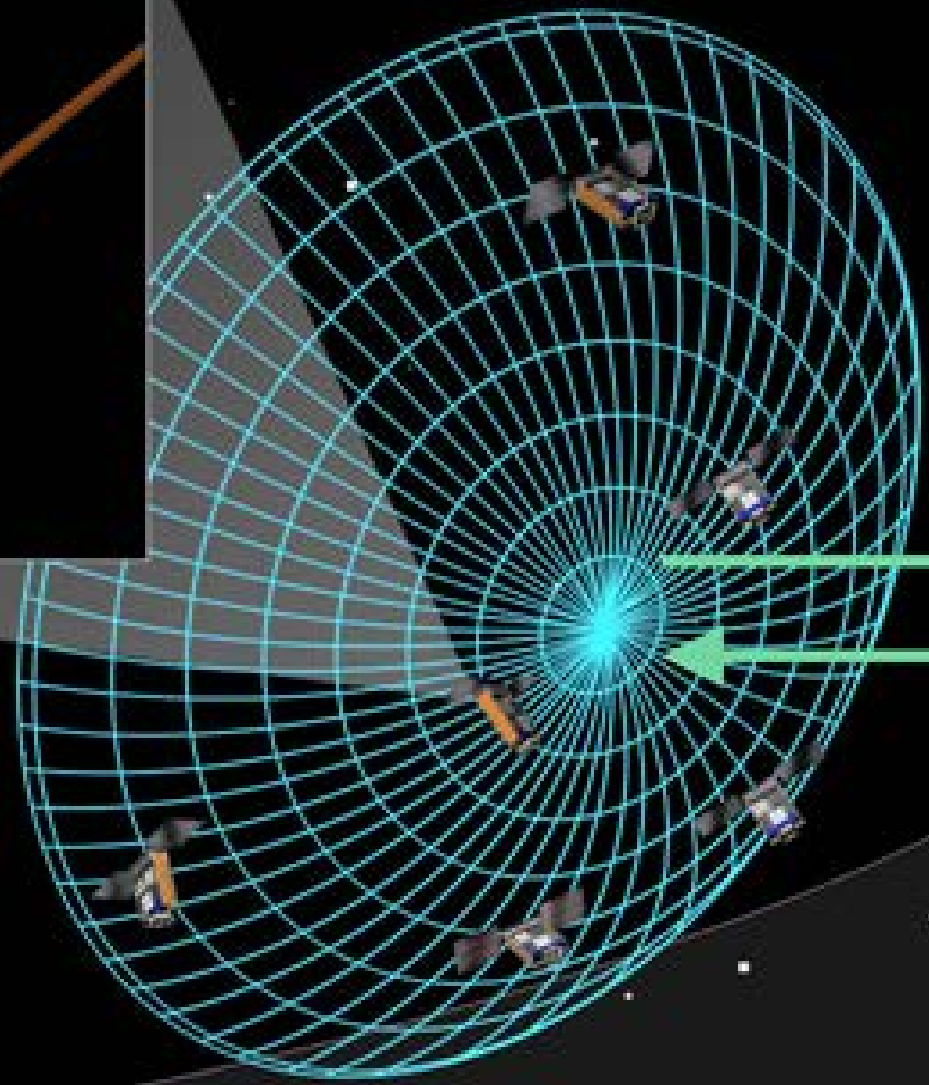


TROPICS

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

Measuring environmental and inner core dynamics of tropical cyclones





SunRISE

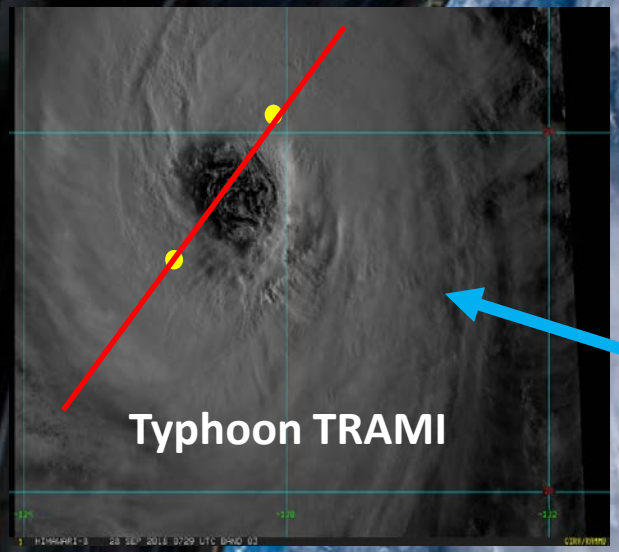
Sun Radio Interferometer Space Experiment

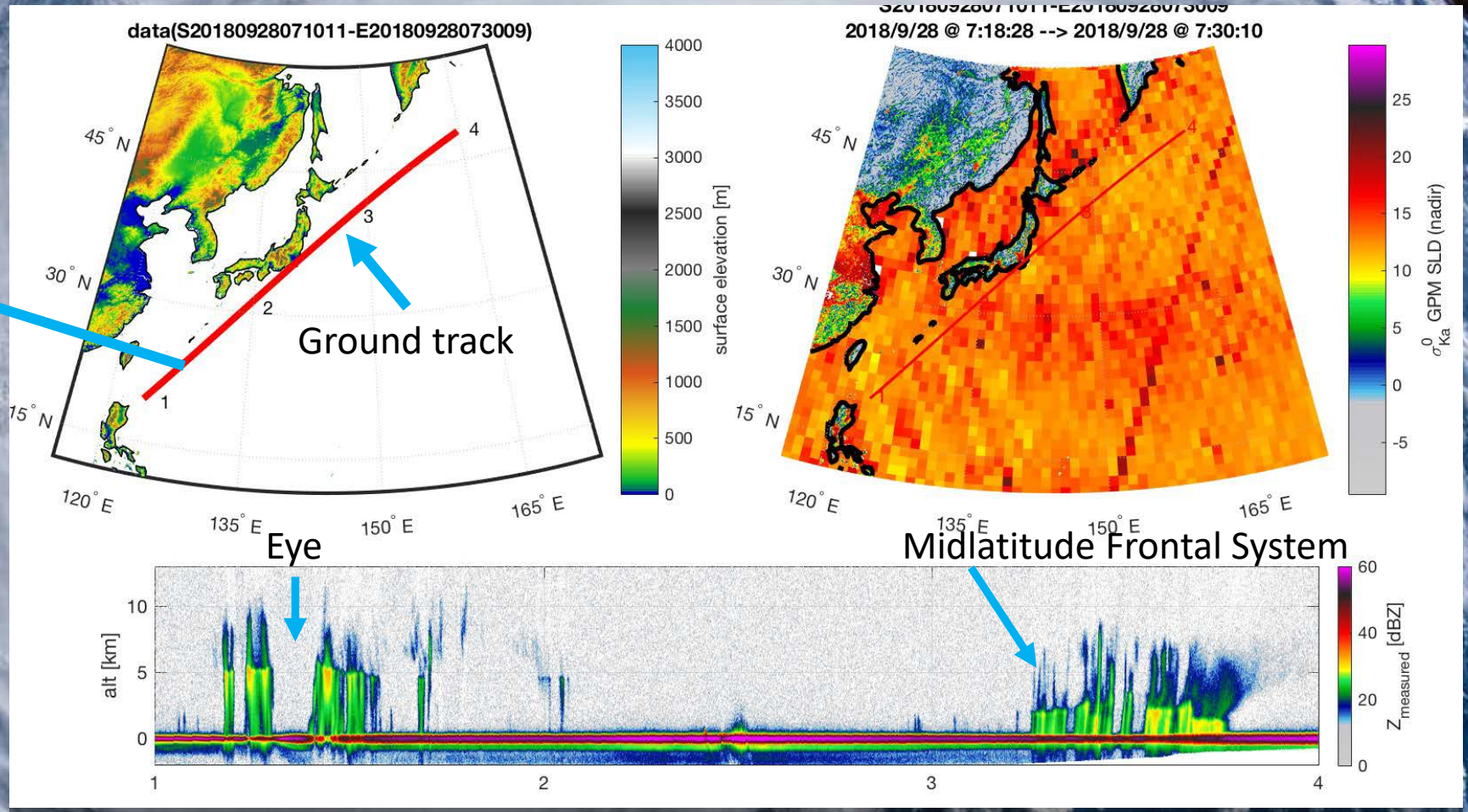
Heliophysics Explorer Program Small Complete Mission

Revealing How Energetic Particles are Accelerated and Released into Interplanetary Space

RainCube Observing Typhoon Trami

First fully operational precipitation radar September 11, 2018



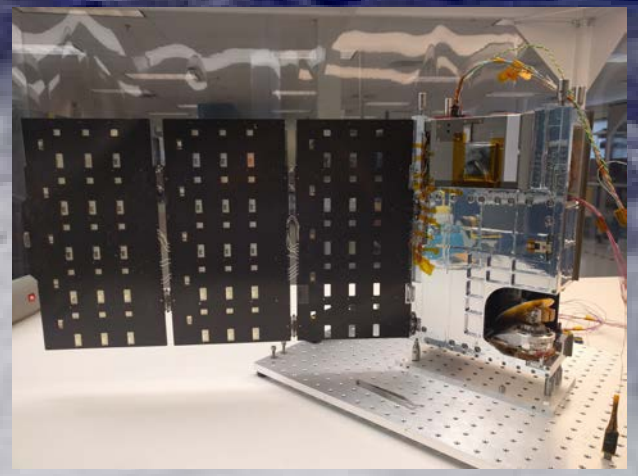


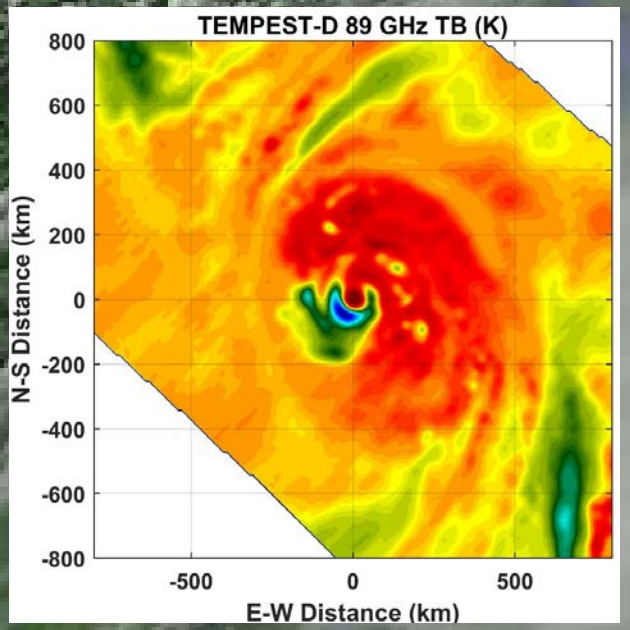
Vertical profile of radar reflectivity measurements of the observed stratiform rain together with ocean surface reflectivity measurements with deep convective tower approximately 9km high

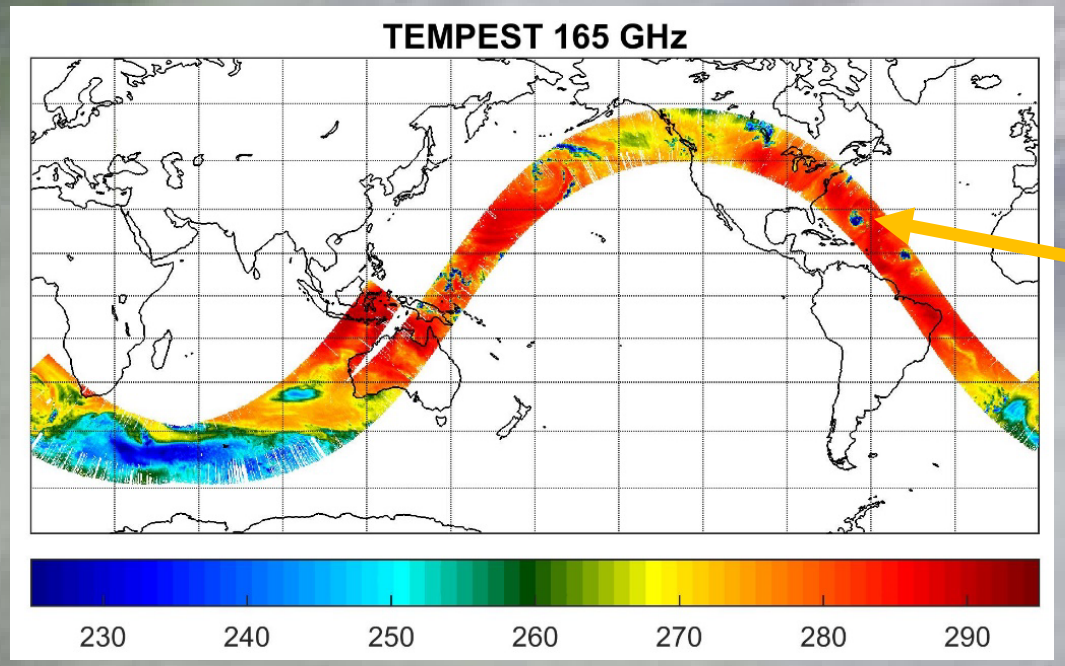
TEMPEST-D: First Light

Millimeter-wave radiometry for temporal evolution of tropical storms

- Observed Hurricane Florence on first full swath-width orbit on 9/11/18
- 89 GHz brightness temperature of Florence sensitive to clouds, precipitation, water vapor and strong convection (Left)
- 165 GHz brightness temperature of Florence images convection around inner core through ice scattering signature (Right)

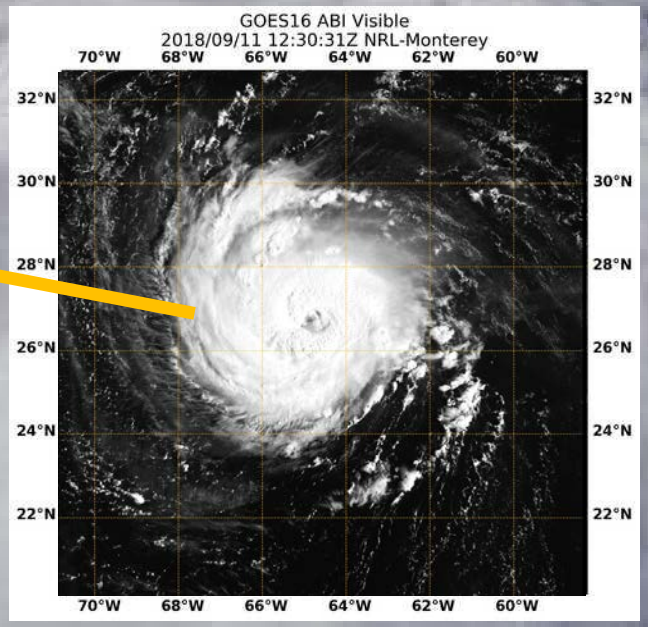






All 5 channels (89, 165, 176, 180, 182 GHz) operational with 165 GHz shown above

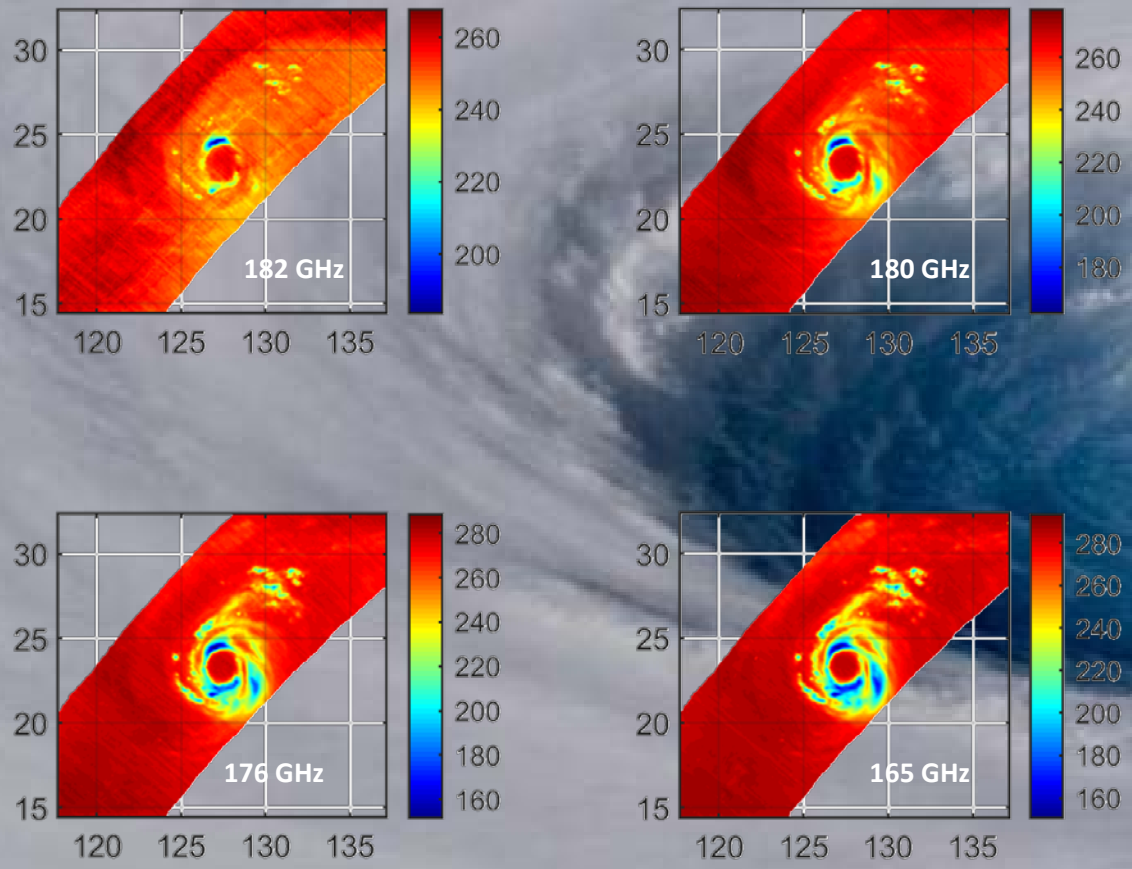
Increasing Rain Intensity



Combined TEMPEST-D/NOAA GOES image of Hurricane Florence

RainCube/TEMPEST-D Observing Typhoon Trami

Spacecraft “constellation” separated by 5 minutes revealing 3D storm structure



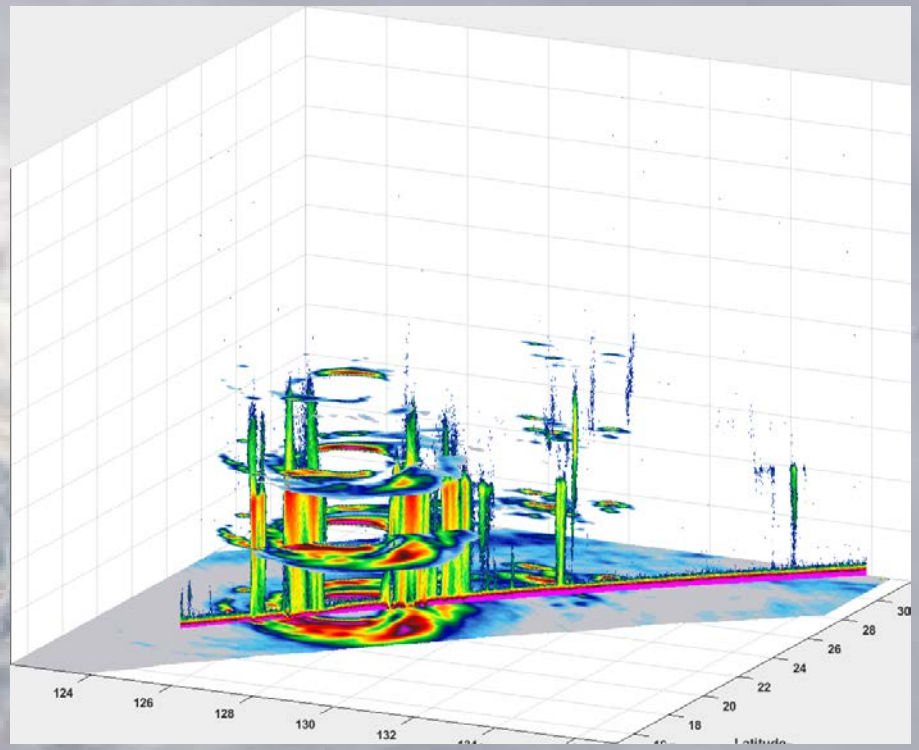
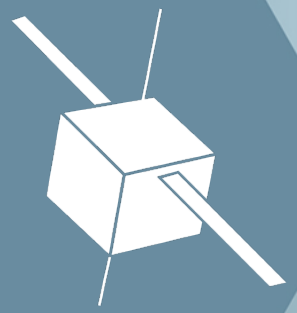


Illustration of complimentary nature of these sensors flow in constellation for observing precipitation



Small Satellite Constellation Data Buy Announced

- Blanket purchase agreements awarded to three companies:
  - Planet – three satellite constellations including 200+ satellites supplying imagery and derived products over the entire Earth
  - DigitalGlobe – operates five satellite constellations that provide very high-resolution (31-50-cm) images
  - Spire – constellation of 48 satellites collecting Radio Occultation soundings and ship reports
- Provides a cost-effective means to augment and complement the suite of Earth Observations
- Acquires data sets, and information products and associated meta-data, through industry partners

CubeSat Launch Initiative Broadens Access to Space

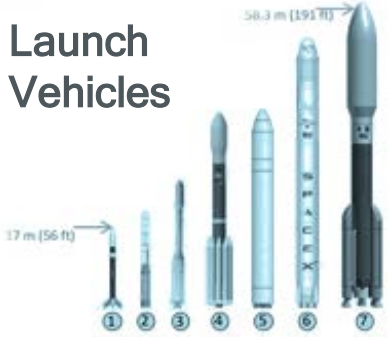
CSLI:

- **PROMOTES** innovative public-private technology partnerships
- **FACILITATES** low-cost technology development
- **STRENGTHENS** NASA and the Nation's future workforce

Launch Providers

	A	B	C	D	E	F	TOTAL BY STATUS
MANIFESTED	3	0	2	4	18	21	48
LAUNCHED	15	13	13	1	17	0	59
TOTAL BY PROVIDER	18	13	15	5	35	21	107

Launch Vehicles



1. SUPER STRYPI
2. MINOTAUR I
3. TAURUS XL
4. DELTA II
5. ANTARES
6. FALCON 9
7. ATLAS V

91 UNIQUE ORGANIZATIONS

71 UNIVERSITIES

155 CUBESAT MISSIONS **SELECTED**

New ESPA-Class Rideshare Policy

- Actively soliciting ESPA-class rideshare scientific payloads
- Directly supports NASA, government, academic, commercial, and international partnerships
- Recognizes future importance of constellation systems and economies of scale enabled by ESPA-class rideshare

RELIC

Low Frequency Radio Astronomy
Constellation Concept

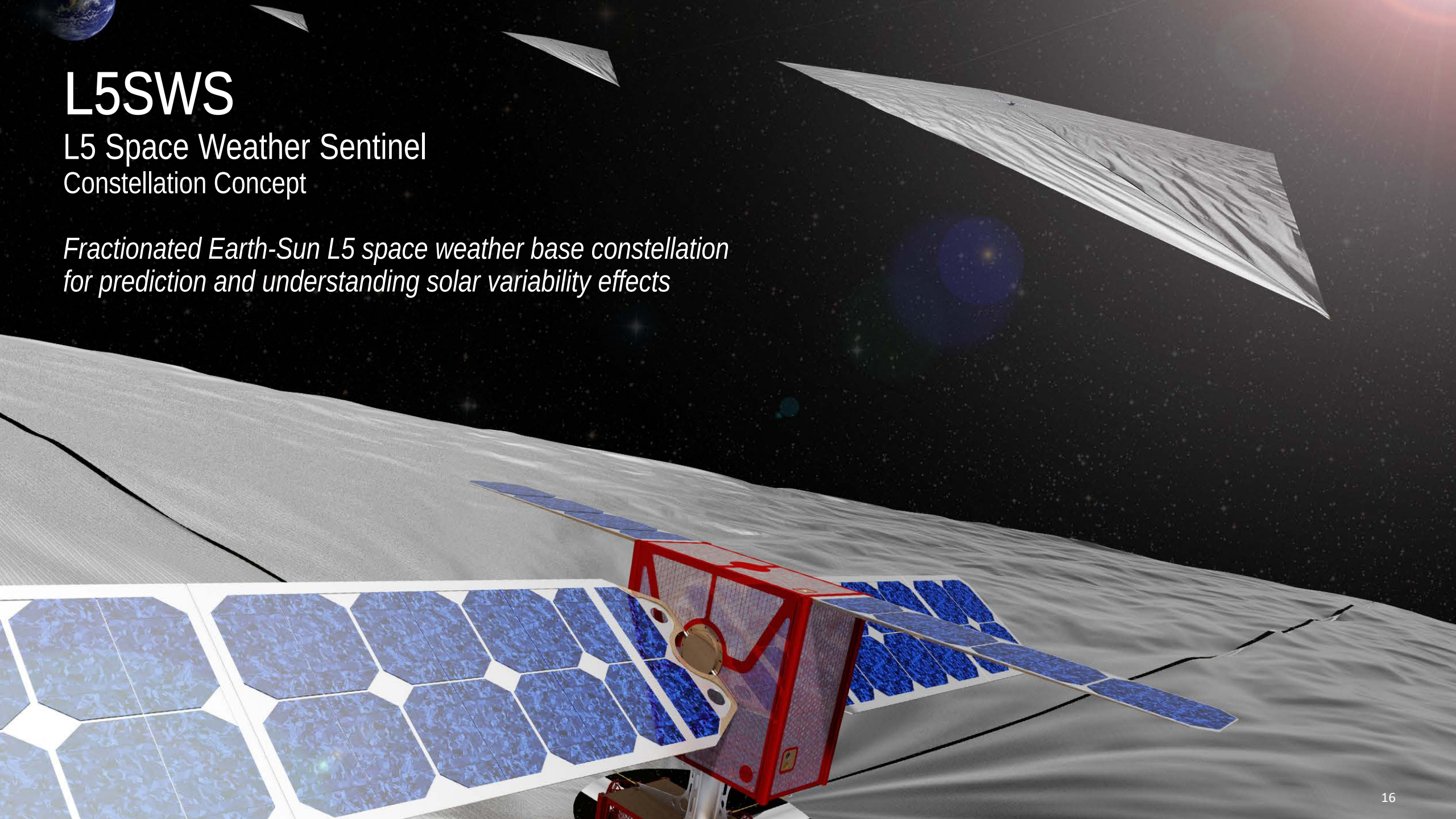
Understanding energy transport from black holes to the intergalactic medium (RELIC)

L5SWS

L5 Space Weather Sentinel

Constellation Concept

Fractionated Earth-Sun L5 space weather base constellation for prediction and understanding solar variability effects




EXPLORE AS
ONE
EXPLORER 1
INSIGHT
PARKER
ICESAT-2
WEBB