National Aeronautics and Space Administration

EXPLORE

NASA Small Spacecraft Strategic Plan and Thinking Beyond Low Earth Orbit

Interplanetary Small Satelllite Conference

Ms. Florence W. Tan
Chair, Small Spacecraft Coordination Group
NASA Headquarters

May 11, 2020

Aug. 4, 1971 Apollo-15 Particles and Fields Subsatellite

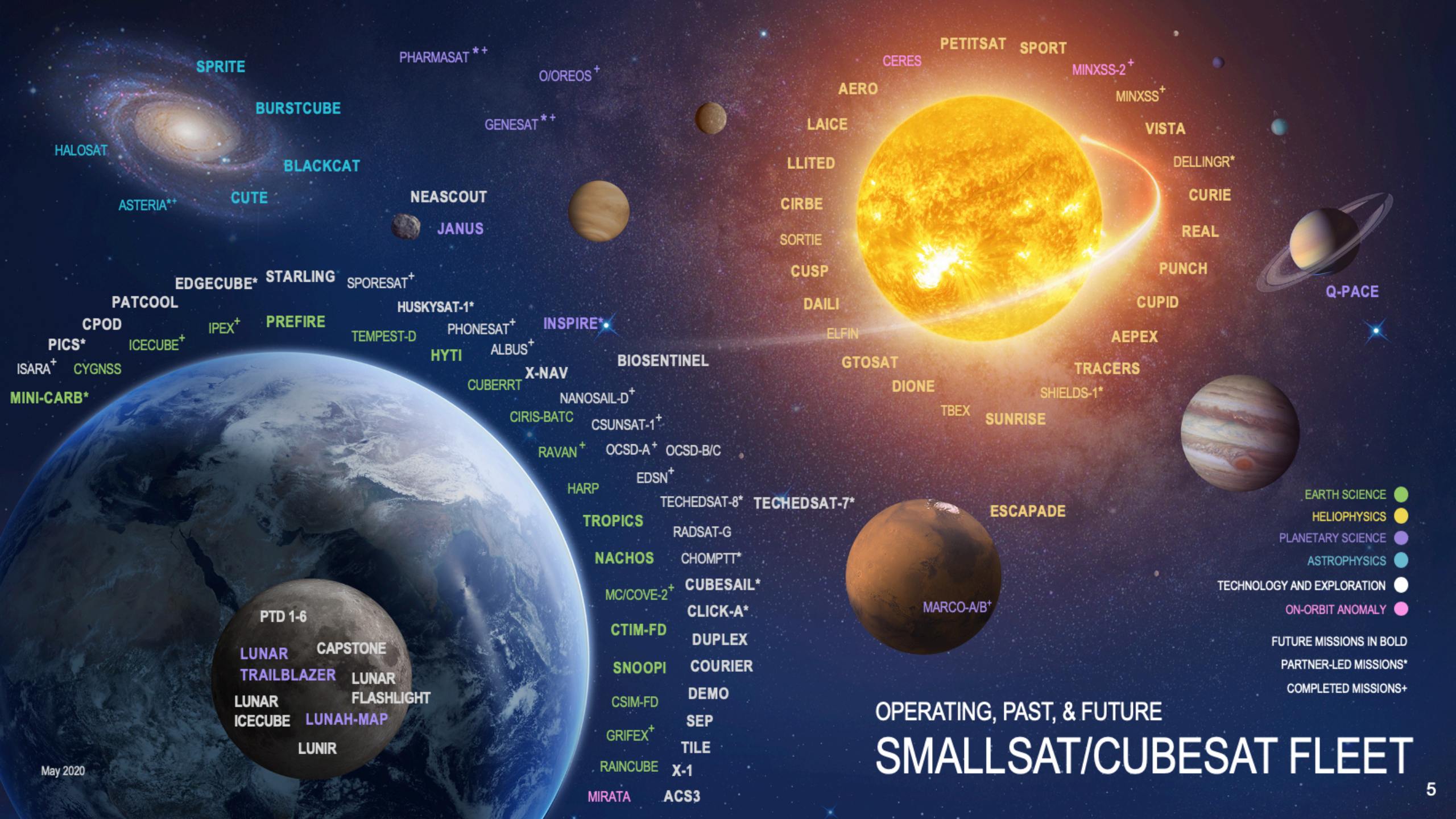
Courtesy: NASA Space Science Data Center Catalog

Apollo Subsatellites

Met objectives to study the plasma, particle, and magnetic field environment of the Moon and to map the lunar gravity field

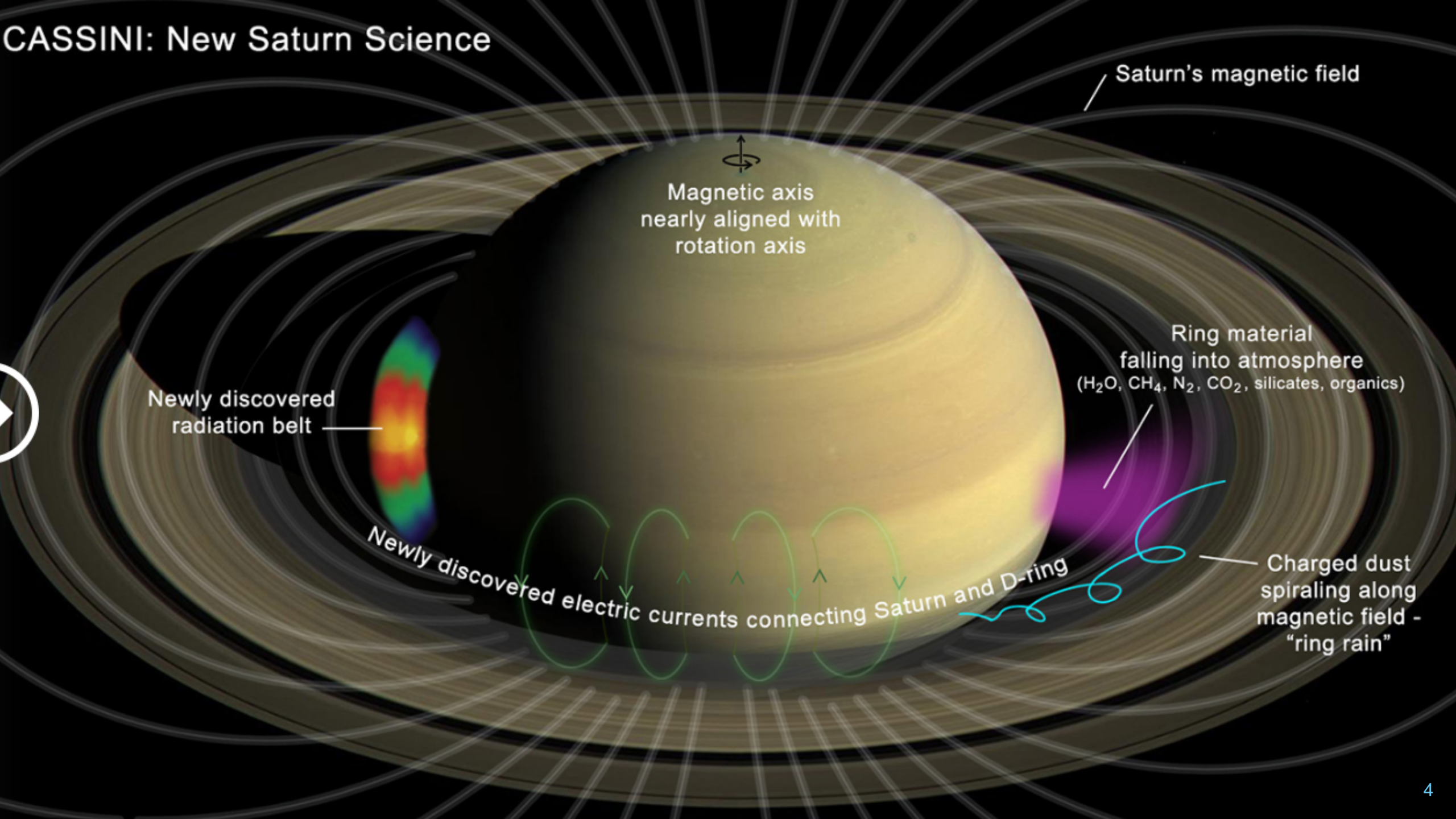
Mass of 35.6 kg carrying 3 instruments: magnetometer, S-band transponder, and charged particle detector

David Scott, Alfred Worden, and James Irwin



OPERATING, PAST, & FUTURE

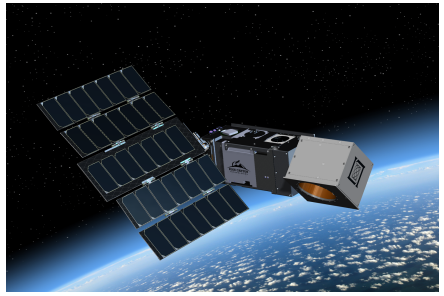
SMALLSAT/CUBESAT FLEET


CASSINI: New Saturn Science
Saturn's magnetic field
Magnetic axis
nearly aligned with
rotation axis
Ring material
falling into atmosphere
(H_2O, CH_4, N_2, CO_2, silicates, organics)
Newly discovered
radiation belt
Newly discovered electric currents connecting Saturn and D-ring
Charged dust
spiraling along
magnetic field -
"ring rain"

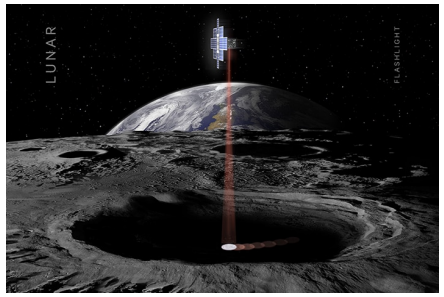
Small Spacecraft Coordination Group

Formed and chartered by the APMC to advise the SMD, STMD, and HEOMD Associate Administrators on strategy to guide cross-agency initiatives, policies, and programmatic scope

National Academies and NASA Reports Impact SmallSat/CubeSat Strategy



Science
New Observation Methods



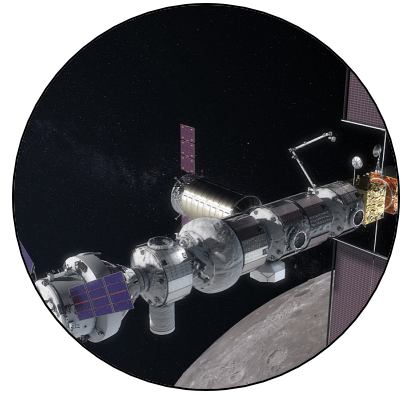
Exploration
Strategic Knowledge Gaps

Technology
Spacecraft Subsystems

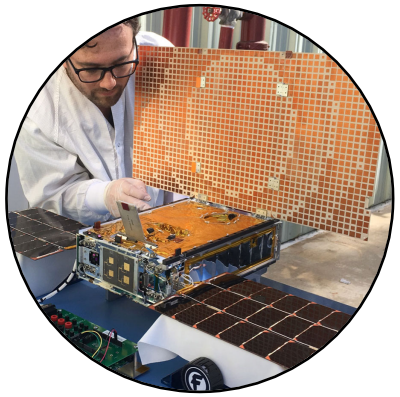
NASA Small Spacecraft Strategic Plan

An integrated and coordinated strategy supporting the NASA Strategic Plan

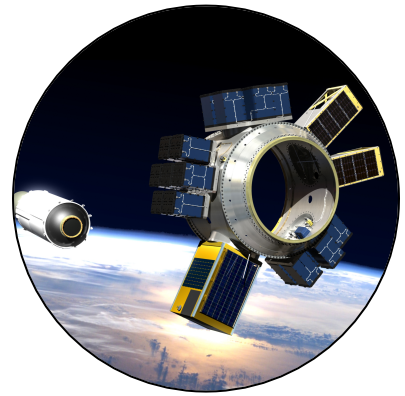
High Priority Science



Support to Human Exploration



Disruptive Technology Innovation



Regular Access to Space

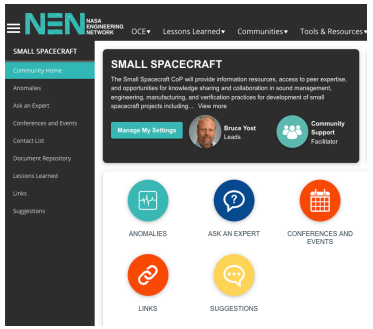
https://www.nasa.gov/smallsat-institute

SMD SmallSat/CubeSat Implementation Plan

Guidance on Early Career Training, Focused Science/Technology Demos, and Strategic Investments for Decadal-Class Science

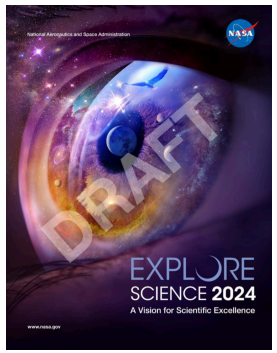
Mission Reliability
Anomaly reporting process/database via NEN

Education/Training
Re-established Community of Practice supporting PIs



Constellation Missions
Assess commercial options for high data rate global telecom services

ESPA Development
Broaden solicitations and establish rideshare policies



Focus Areas

- **Mission Reliability**: Addresses how lack of reliable systems impacts risk to technology maturation and science objectives
- **Constellation Missions**: Addresses highest priority NAS CubeSat report recommendations essential to new and unique science observations
- **ESPA-Class Mission Development**: Addresses need to accelerate ESPA and propulsive-ESPA capabilities enabling decadal survey measurements
- **Education and Training**: Addresses community training objectives increasing likelihood of achieving mission success

Reviewed alignment with both the NASA (2018) and SMD Draft (2024) strategic plans

NASA Access to Space Workshop

Feb 24-26, 2020 – Applied Physics Laboratory, Johns Hopkins University JHU/APL

Obtain community input from scientific, commercial industry, and programmatic leaders on ESPA-class payload pipeline development supporting NASA SMD's rideshare policy

SMD's Rideshare Policy Briefed to Community

SMD SmallSat Solicitation Analysis

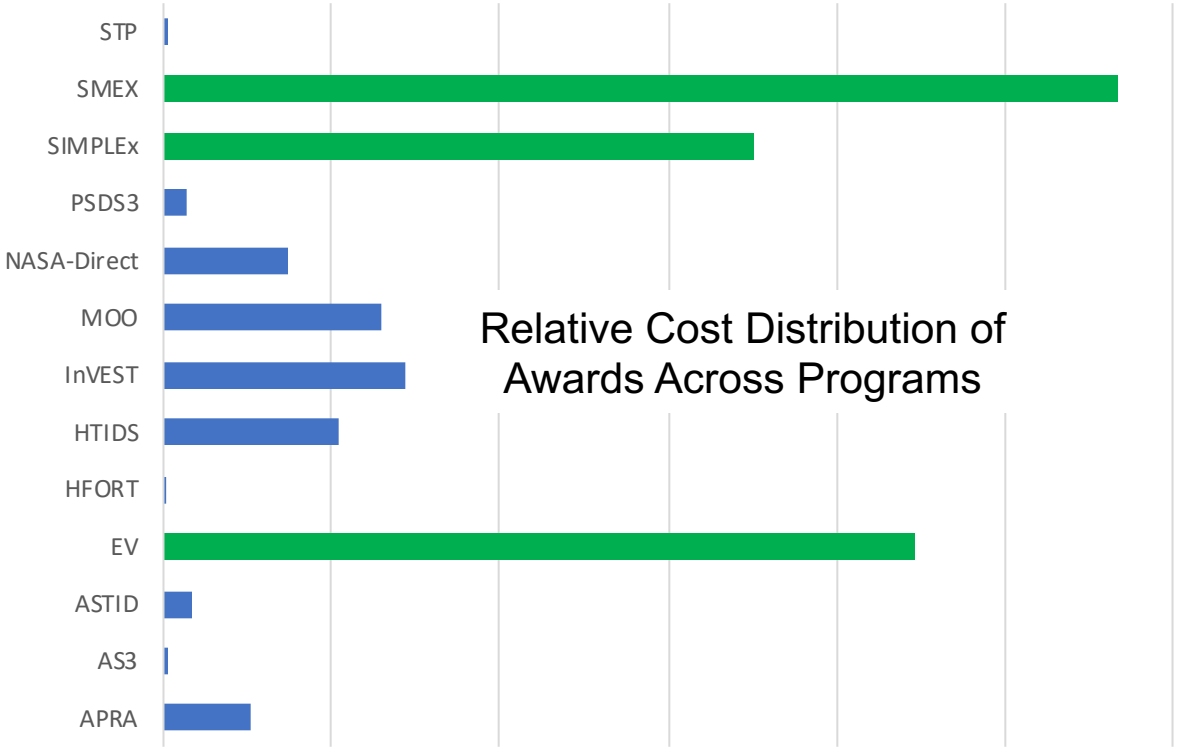
Quick Look – Statistics Based on PI Awarded Institution

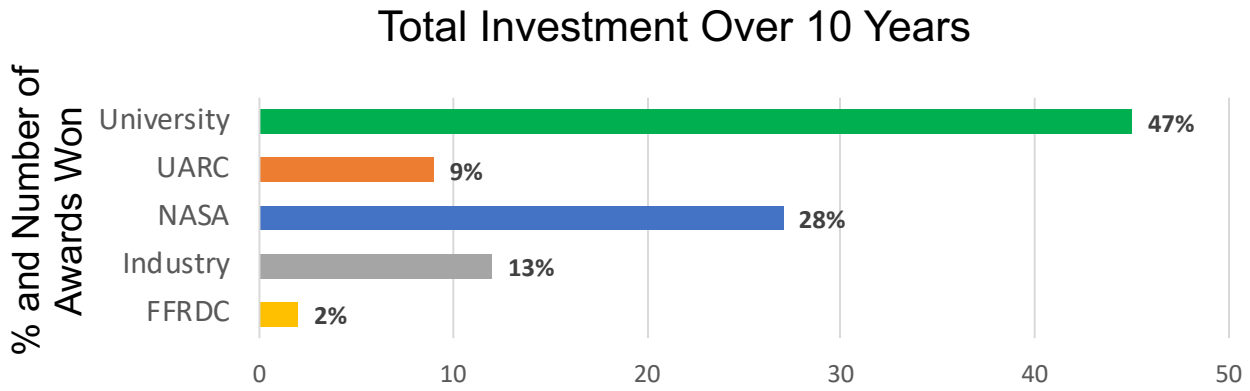
95 Awards

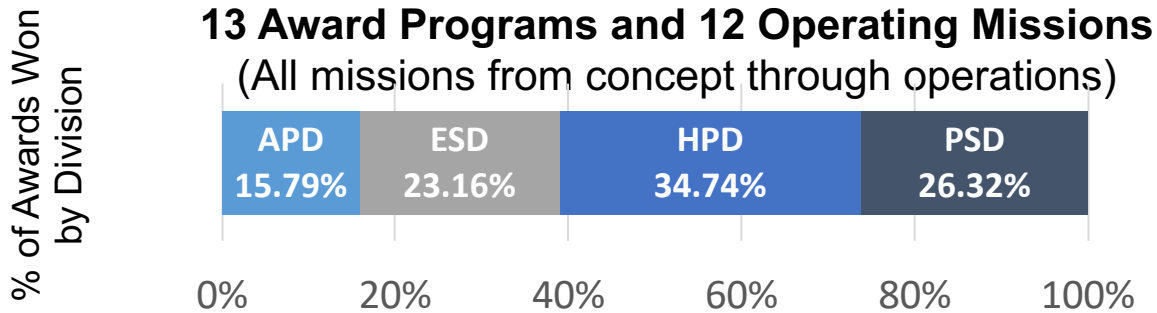
Total Number of Competed Awards

2016 – 2019

NASA Wins SmallSat Mission of the Year

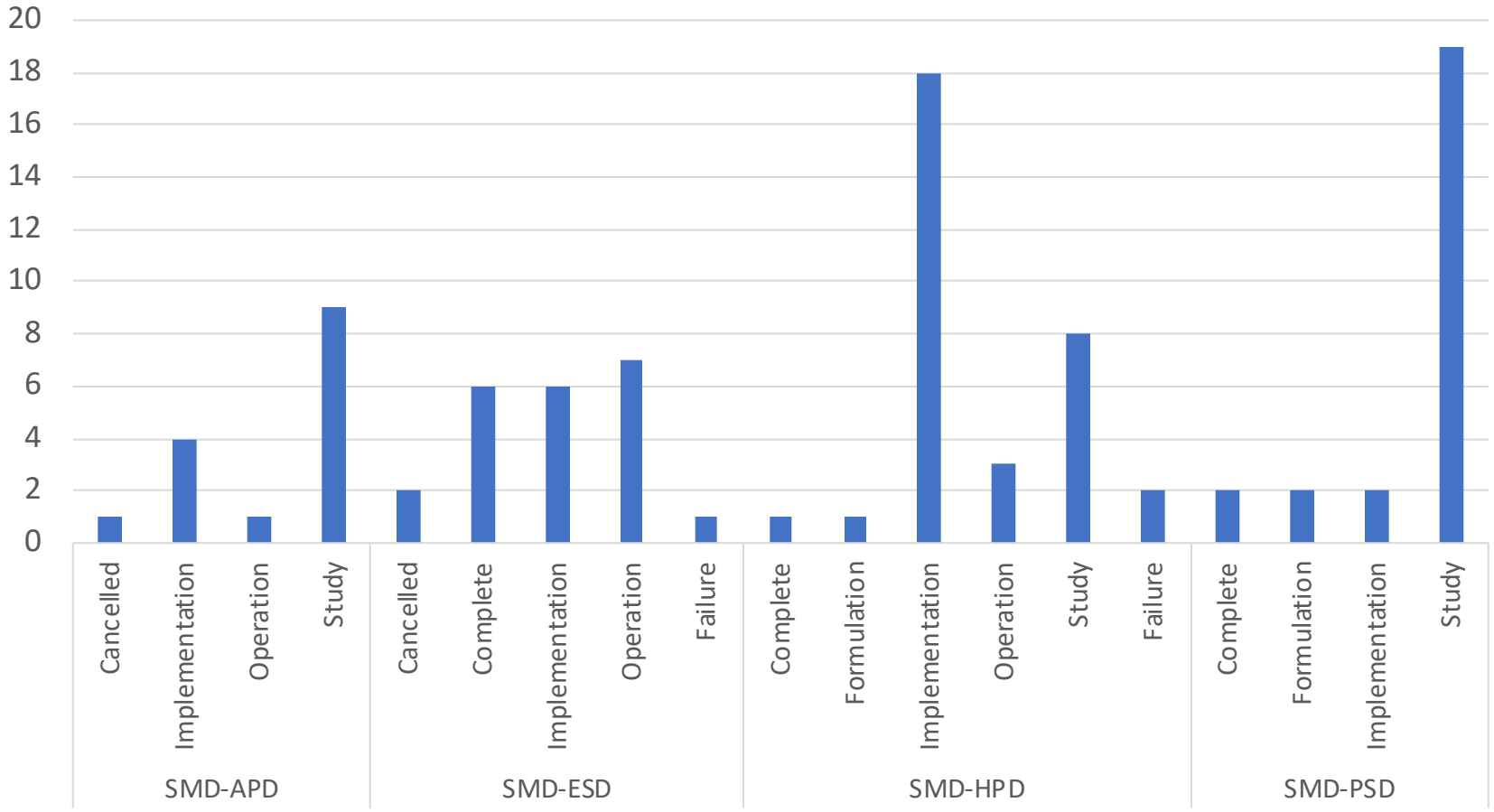






SMD SmallSat/CubeSat Solicitation Analysis

Distribution of SMD Awards Across Divisions by Mission Development Stage

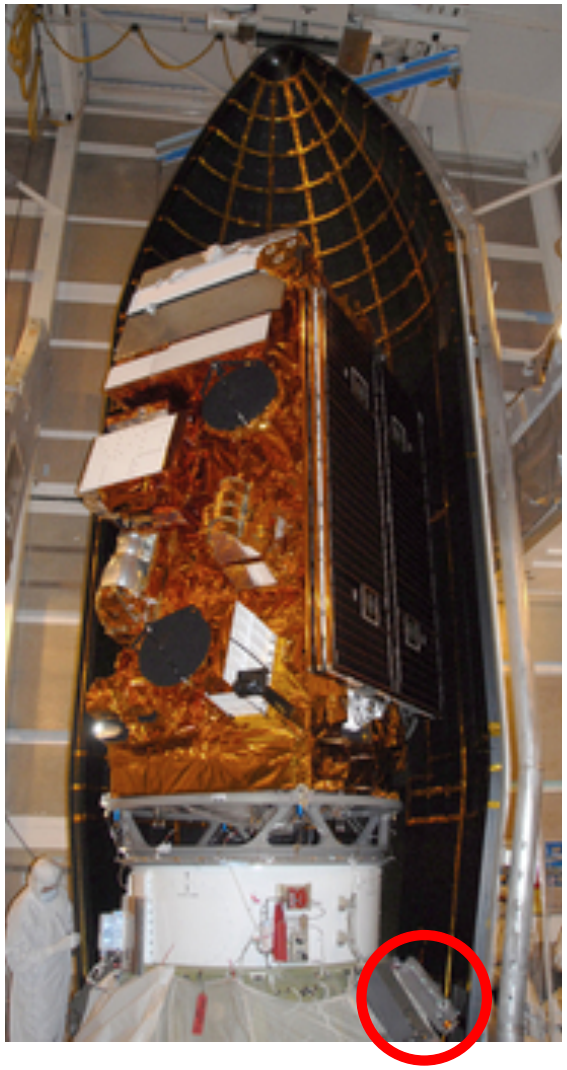


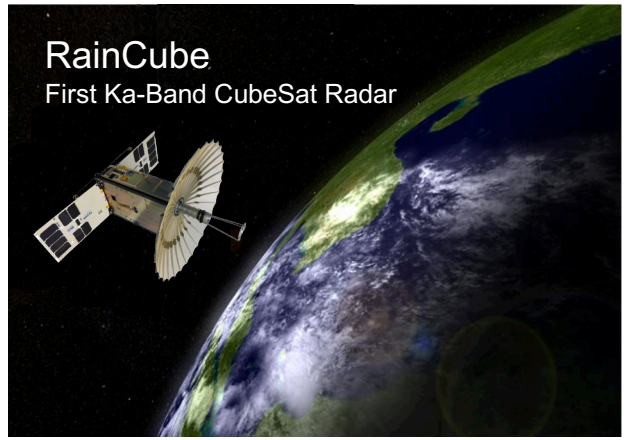
SMD-APD	**15**
Cancelled	1
Implementation	4
Operation	1
Study	9
SMD-ESD	**22**
Cancelled	2
Complete	6
Implementation	6
Operation	7
Failure	1
SMD-HPD	**33**
Complete	1
Formulation	1
Implementation	18
Operation	3
Study	8
Failure	2
SMD-PSD	**25**
Complete	2
Formulation	2
Implementation	2
Study	19
Grand Total	**95**

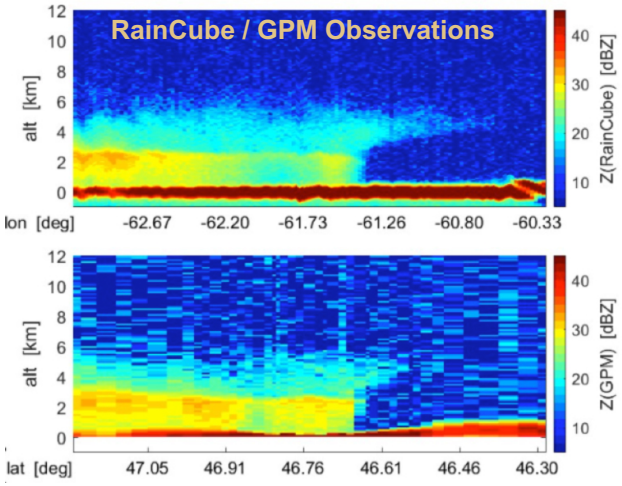
Number of missions in study, formulation, implementation, operation, complete, failure and cancellation status

Fundamentals of Small Spacecraft

CubeSats, SmallSats, ESPA, Integration and Launch







Jan. 2019 – Near-collocated measurements of vertical rain reflectivity profiles from RainCube (top) and GPM's Ka-band radar (bottom). RainCube points Nadir while GPM scans along-track

“Ingenuity is what allows people to accomplish amazing things and it allows us to expand our horizons to the edges of the universe”
Vaneeza Rupani, 11th Grader, Alabama

Evolution of SmallSats
(Past 5 Years)

Growth and establishment of commercial flight systems

Expansion of measurement capability from innovative miniaturized instruments

Increased design space of measurement opportunities

Diversity of options for access to space (dedicated launch, and containerized/ESPA rideshare)

Emerging Launch Capabilities Beyond LEO

Rideshare and Direct Inject Vehicle Development

Industry transition to higher capability launch vehicles will provide greater opportunities

Partnerships, via multi-mission or secondary payload manifests, will be essential to the future of beyond LEO science and exploration

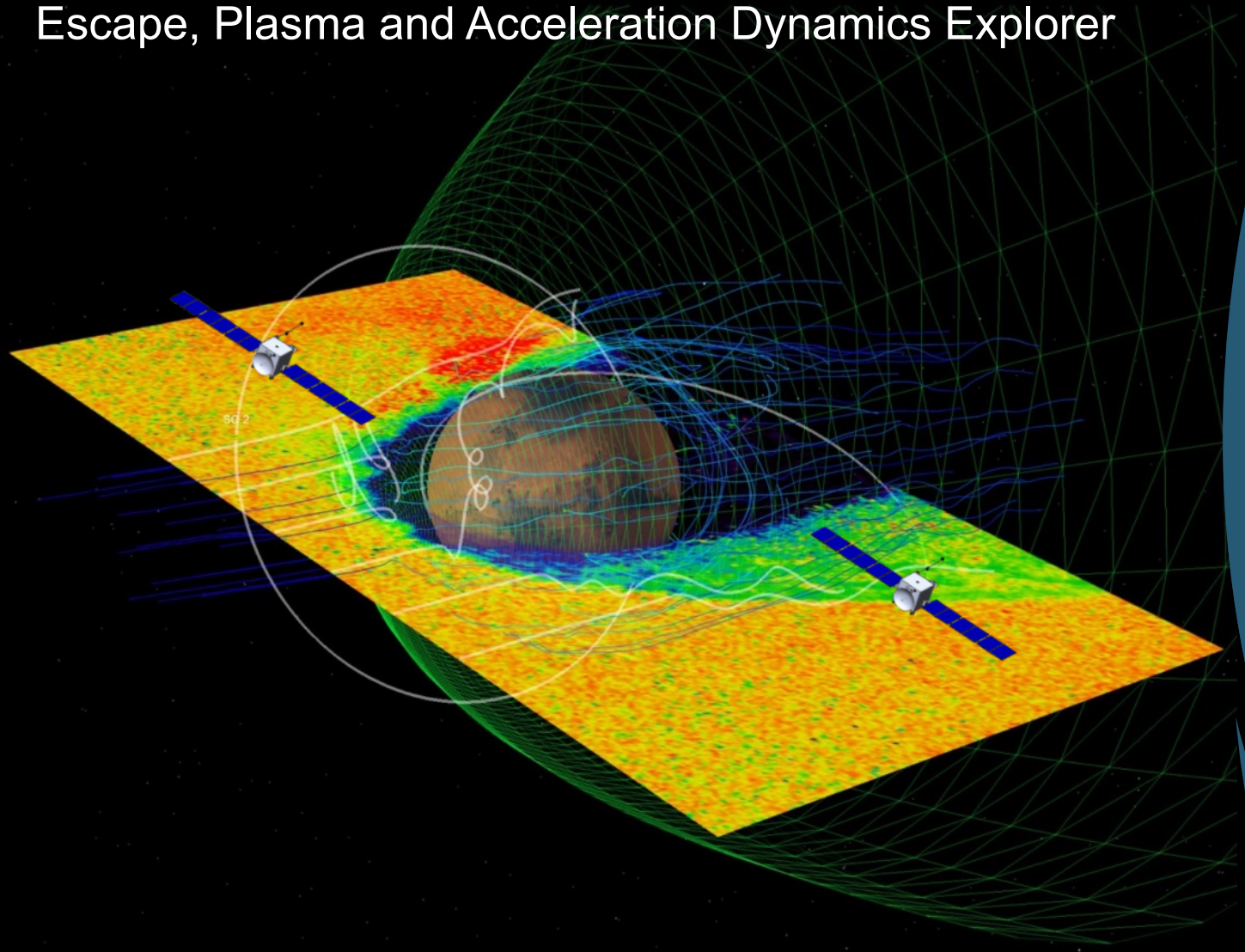
Future launch vehicles will drive greater innovation in mission design and science return

International cooperation must also be pursued to extract the most science from various beyond LEO targets

Image Courtesy: eBaum's World

ESCAPADE

Escape, Plasma and Acceleration Dynamics Explorer



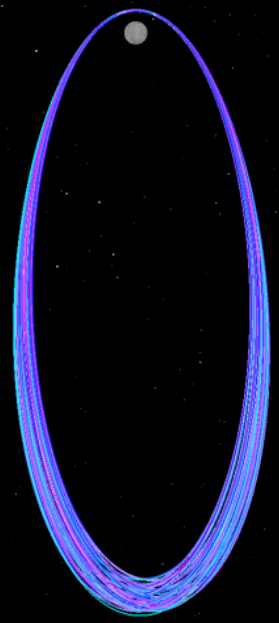
SpaceX Falcon Heavy Rideshare with PSYCHE
Image Courtesy: Robert Lillis, Shannon Curry, et. al

Martian SmallSats

Understanding how solar wind momentum and energy flows throughout Mars' magnetosphere to drive ion and sputtering escape shaping Mars' climate evolution

MarCO's interplanetary transit and radio occultation experiment paves the way for future Mars planetary atmosphere SmallSat science measurements

Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment



Near Rectilinear Halo Orbit (NRHO)

CAPSTONE

STMD/HEOMD mission to test autonomous relative navigation for Gateway and other lunar missions

Verify NRHO orbital dynamics, and demonstrate novel low-energy transfers to cislunar space

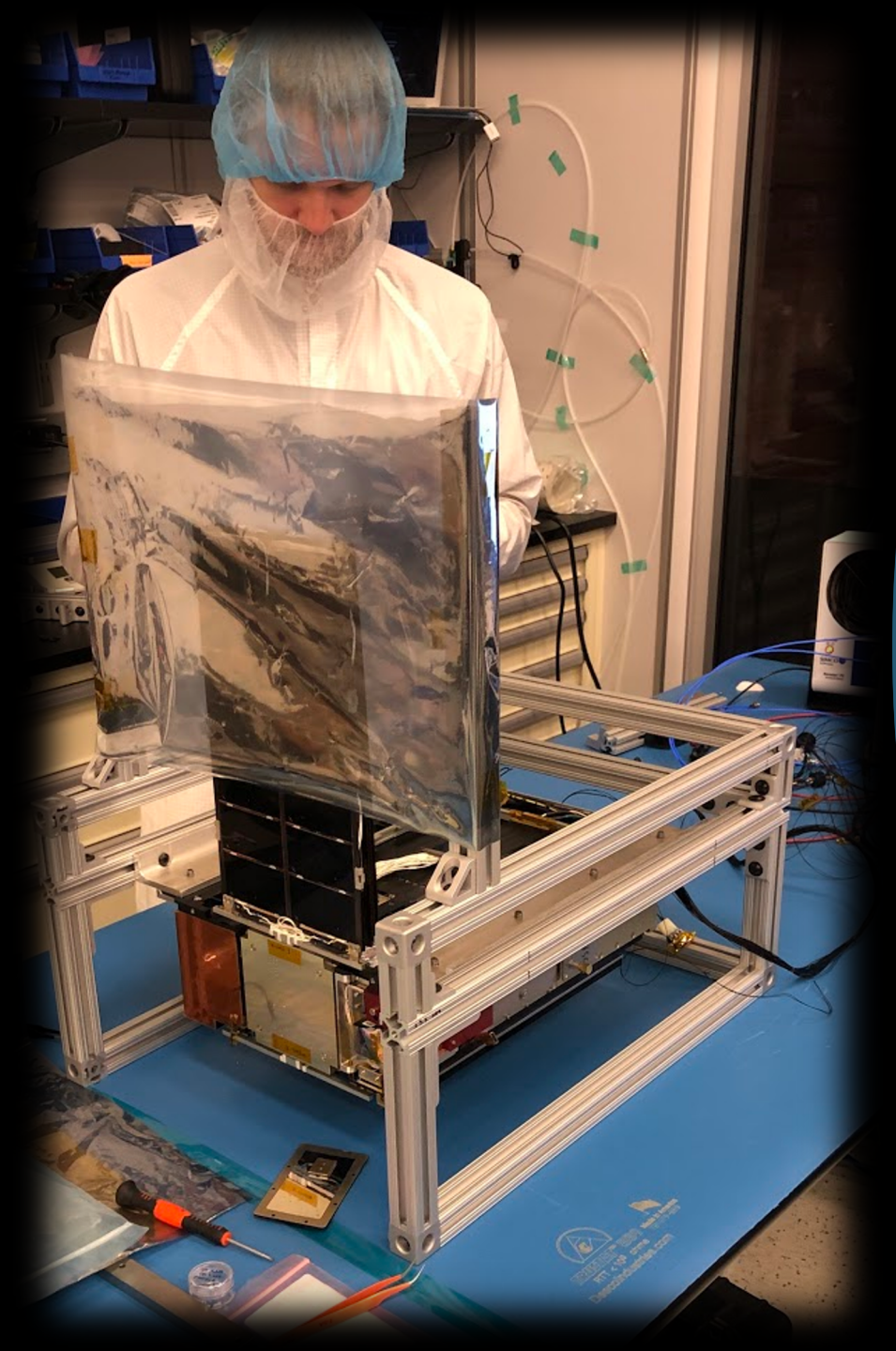
Execute a cislunar mission in under $30M (including launch) and in under 3 years

Manifest for launch aboard a booster Electron from Rocket Labs in early 2021

Advanced SPACE

Tyvak A Terran Orbital Corporation

ROCKET LAB

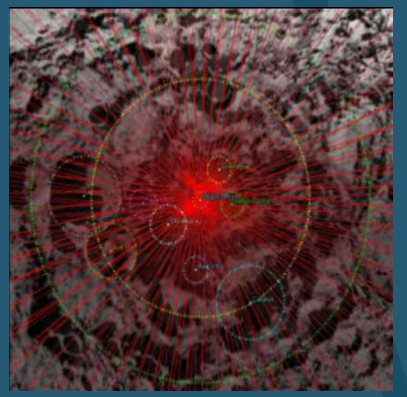


One of
13 CubeSats planned
to be launched
with Artemis-1 in 2021

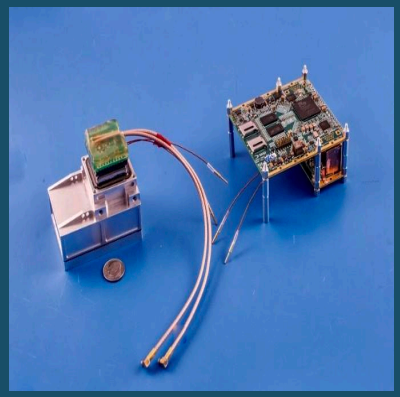
LunaH-Map

Lunar Polar Hydrogen Mapper

Improve scientific understanding of how water is created and spread throughout the Solar System



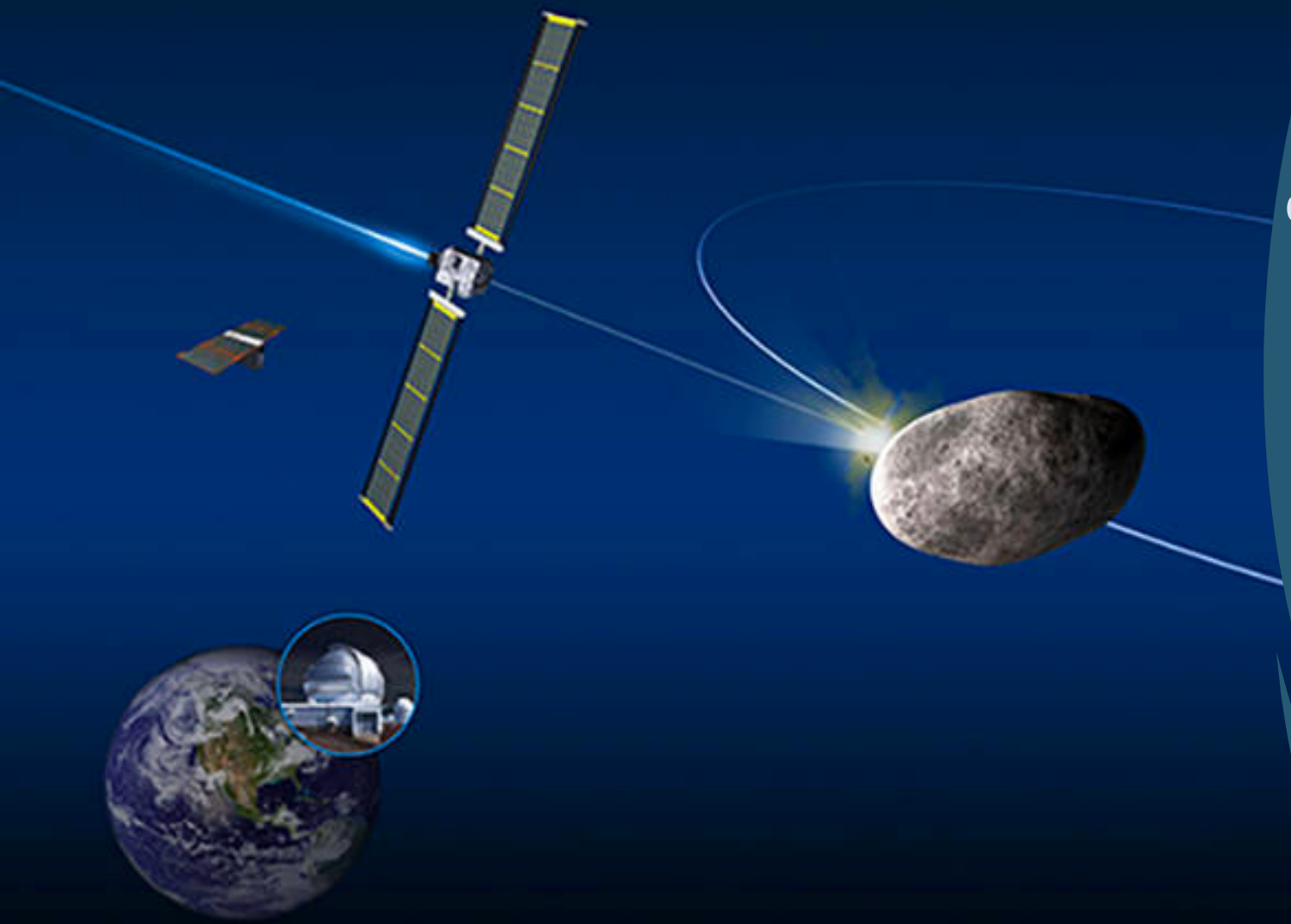
Orbit ground track shown for entire 60 (Earth) day science phase (141 passes)



Mini-NS is comprised of 8 neutron sensitive modules (above left) and 2 electronics board assemblies (above right)

PI: Craig Hardgrove University of Arizona
LunaHmap will map the abundance of hydrogen down to one meter within the permanently shadowed regions (PSRs) throughout the South Pole

First Planetary Defense Technology Demonstration to Collide with Asteroid in 2022



DART

Double Asteroid Redirection Test

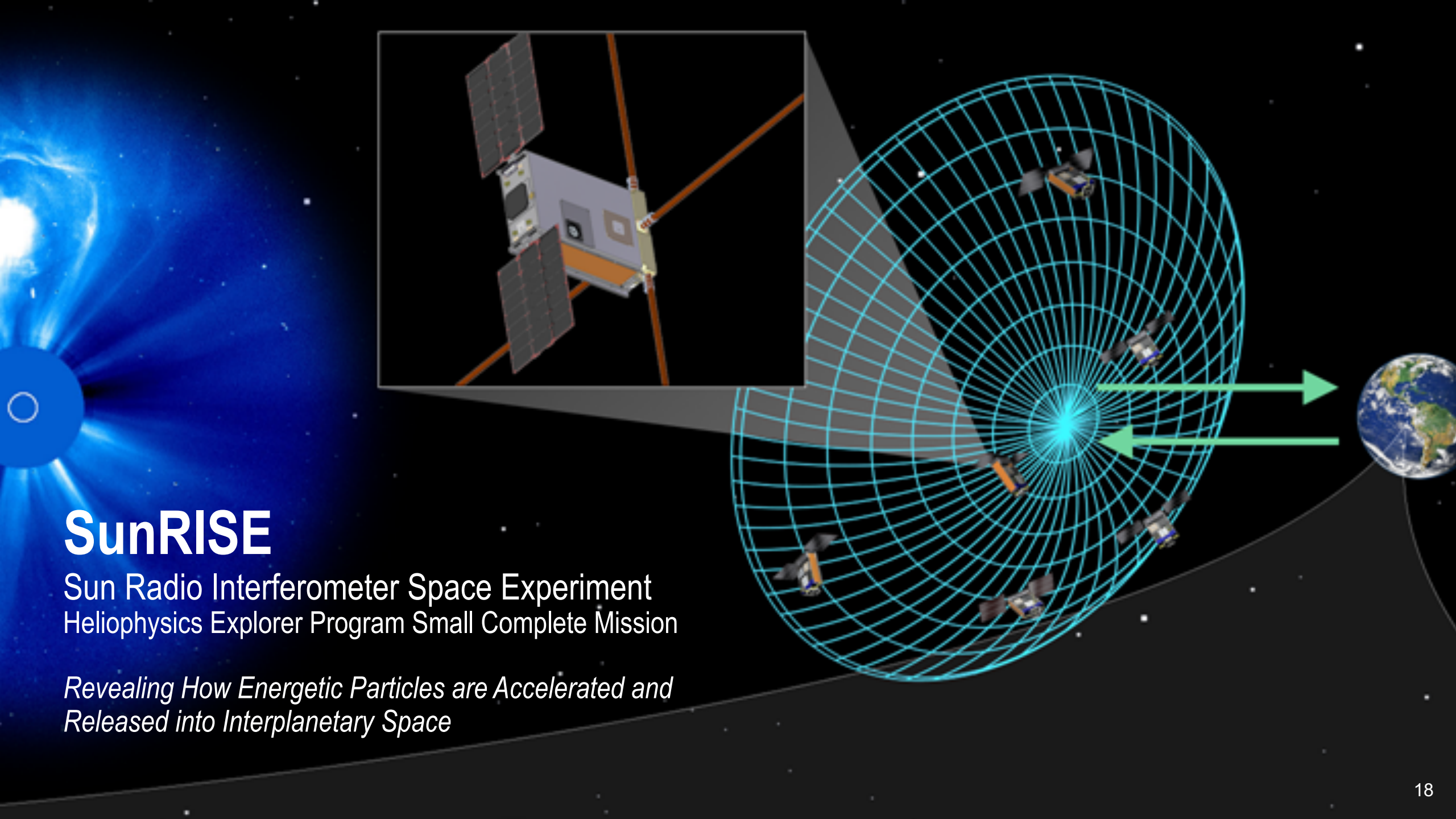
Demonstrate the kinetic effects of crashing an impactor spacecraft into an asteroid moon for planetary defense purposes

Tech Demo:

Demonstrate the STMD developed NASA Evolutionary Xenon Thruster (NEXT-C) solar electric propulsion system as part of its in-space propulsion

Demonstrate the STMD developed Low Intensity Low Temperature (LILT) Transformational Array Solar Panel Module

Image Didymos asteroid with DART's onboard DRACO imager and ride-along CubeSat, the Italian Space Agency's LICIACube

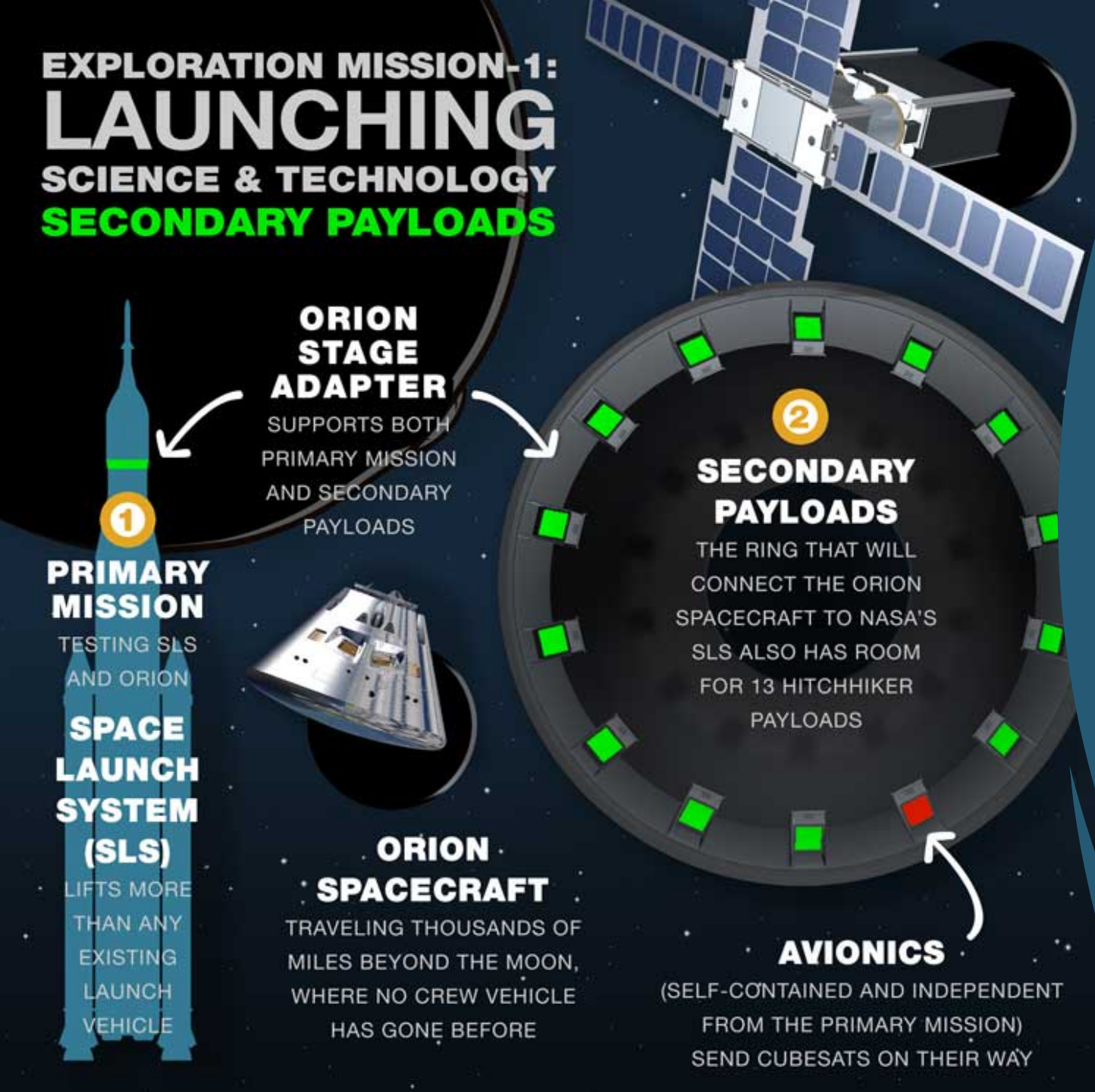


SunRISE

Sun Radio Interferometer Space Experiment

Heliophysics Explorer Program Small Complete Mission

Revealing How Energetic Particles are Accelerated and Released into Interplanetary Space



Launch and Rideshare

Updated SMD ESPA-Class Rideshare Policy

SMD Single Point-of-Contact for Rideshare Activities

SLS Artemis-1

Commercial Rideshare Business is Evolving

SpaceX, Nanoracks, ASTRA, ArianeSpace, and ESPA bus vendors are incorporating costs of commercial rideshare as part of their business models

Telecom as a Service

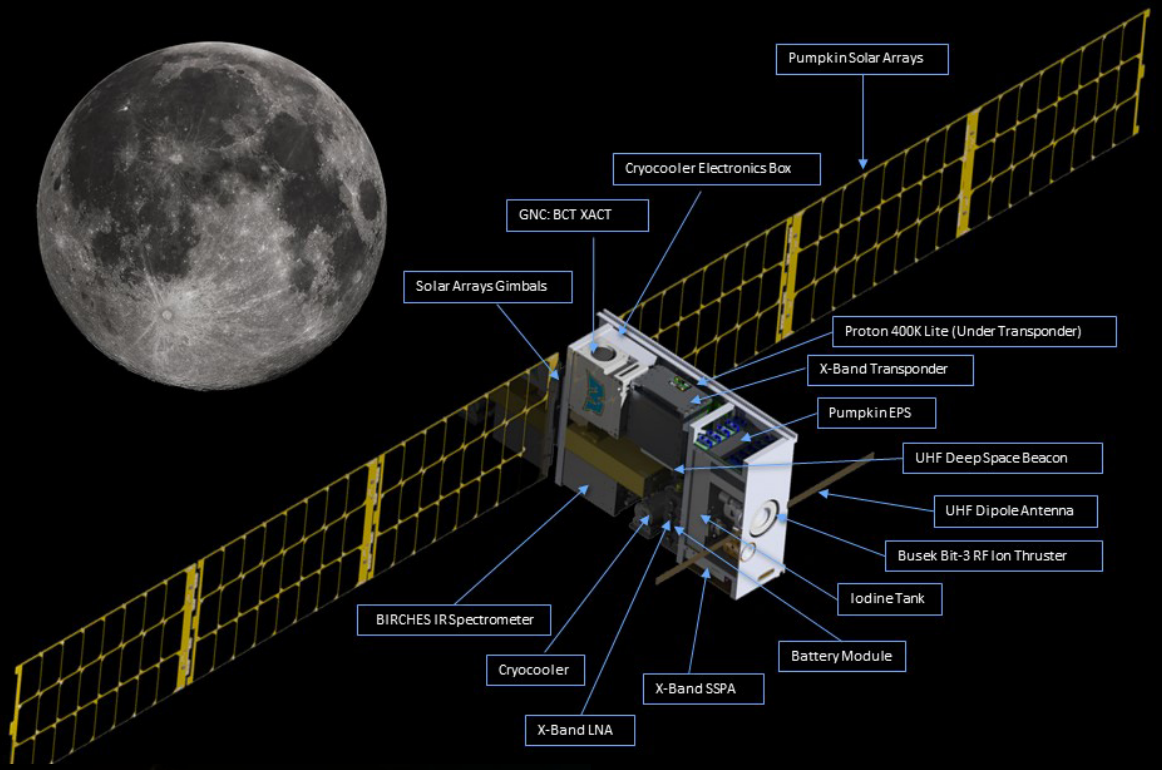
Enabling interplanetary research with small spacecraft platform

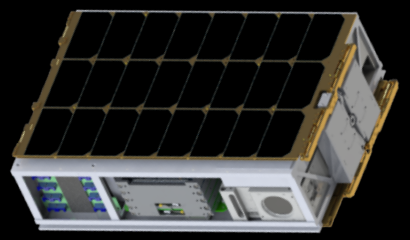
Expands DSN capabilities by utilizing non-NASA assets to provide communication and navigation services to small spacecraft missions to the Moon and inner solar system

Develops an operational capability to support Artemis-1 SmallSat missions

Center at MSU

One of 13 CubeSats planned to be launched with Artemis 1 in 2021





Lunar IceCube

HEOMD mission to improve scientific understanding of the role of external sources, internal sources, and micrometeorite bombardment in the formation, trapping, and release of water on the moon.

Tech Demo: Perform DTN flight validation during cruise to the moon which serves as a precursor to the NEN's and DSN's implementations of DTN
Downlink to the ESA Kourou ground station to test interoperability

PI: Ben Malphrus Moorhead State University
Lunar IceCube will investigate the distribution of water and other volatiles as a function of time of day, latitude, and regolith age and composition.

Jet Propulsion Laboratory
California Institute of Technology

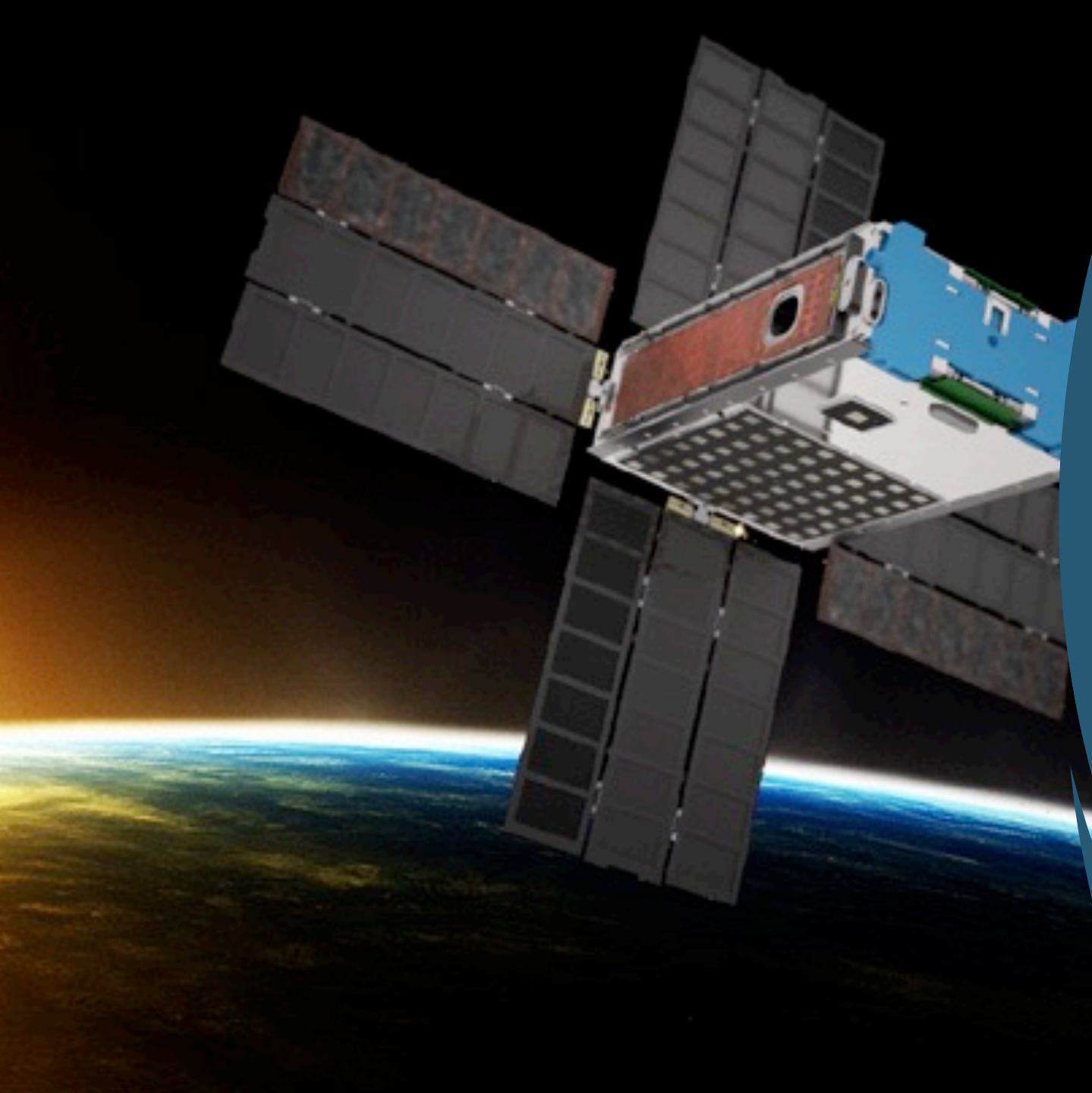
ESPA-Class Payload Pipeline Development

Ingredients exist to develop and sustain ESPA-class missions

- Novel science targets
- Technology maturation opportunities
- Broad community support

Greatest community interest focused on AO process adaptations

- Speed of solicitation process
- Direct solicitation with primary missions
- Vista-specific solicitations that await matching launch opportunities



ESPA-Class Focused Technology Needs

Mission Design Tools for New Observing Systems

Propulsive ESPA Technology

Propulsion for ESPA Spacecraft

Autonomy for Constellation Formation and Maintenance

Relay and Space-to-Space Telecom Infrastructure

Information Systems Needs

Data Science and Analytics

Autonomous constellation operations, observation planning, data fusion, and execution

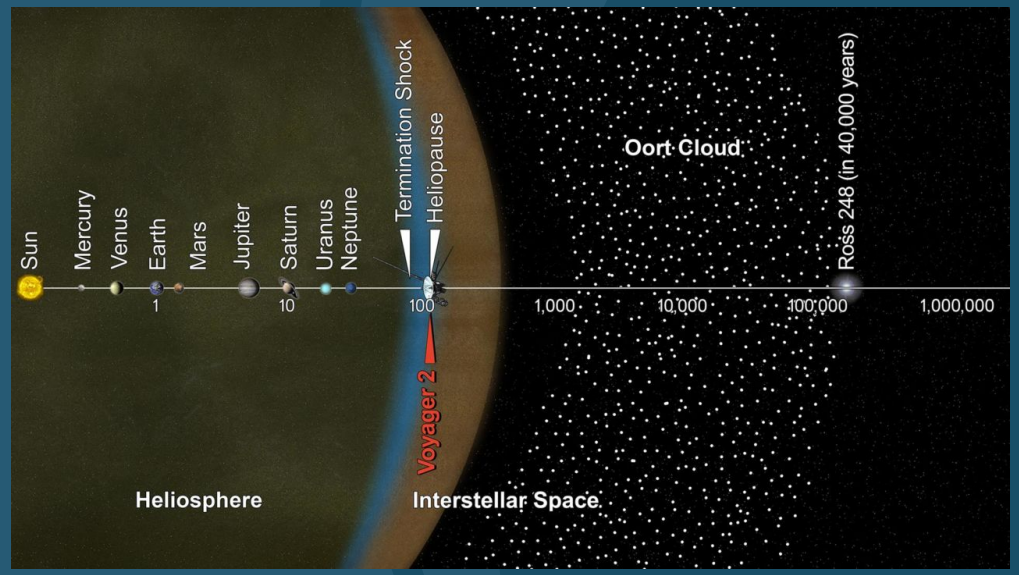
Distributed science data system management

Technology for flight system design verification and validation

Analysis of mission design-trade options

Interstellar Missions

Beyond Voyager



Opportunity to study material from beyond the heliosphere

Utilizes small thrusters for attitude and trajectory correction

New technologies could reduce travel time to <40 years

Voyager 1 (2012) and 2 (2018) cross the heliopause entering interstellar space

Future of SmallSats

SmallSats for sustained decadal-class observations

Data products from large/small missions become indistinguishable

New insights from multi-instrument constellation data fusion and analytics

Cooperative synergies among large and small missions

International cooperation on key community science measurements

Costs will keep rising, but plateau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