National Aeronautics and
Space Administration

EXPLORE SCIENCE

NASA's Small Spacecraft Strategic Plan for Science, Human Exploration, and Technology Development

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Chair, Small Spacecraft Coordination Group
Science Mission Directorate
NASA Headquarters

June 2019 **Goddard Planetary CubeSats Symposium**

Aug. 4, 1971 – Apollo 15 Particles and Fields Subsatellite (PFS-1) released from the Service Module prior to Lunar Orbit Departure

Apollo 15 Subsatellite

- Met objectives to study the plasma, particle, and magnetic field environment of the Moon and map the lunar gravity field
- Operated for 6 months prior to electronics failures
- Supported Explorer 35's finding that the Moon acts as a physical barrier to the solar wind creating a "hole" in the flow of charged particles
- Mass of 35.6 kg with 3 instruments: magnetometer, S-band transponder, and charged particle detector
- Astronauts David Scott, Alfred Worden, and James Irwin

Courtesy: NASA Space Science Data Center Catalog

Congratulations

SIMPLEX Small Satellite Concept Finalists (Planetary Science)

- Daniel Scheeres. U of Colorado. Janus: Reconnaissance Missions to Binary Asteroids
- Rob Lillis. University of California Berkeley. EscaPADE: Escape and Plasma Acceleration and Dynamics Explorer
- Bethany Ehlmann. California Institute of Technology. Lunar Trailblazer: Detect and Map Water on Lunar Surface

SMEX Missions to Study Our Sun, Its Effects on Space Weather (Heliophysics)

- Craig DeForest. Southwest Research Institute Boulder. PUNCH: Polarimeter to Unify the Corona and Heliosphere
- Craig Kletzing University of Iowa. TRACERS: Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites

NASA SCIENCE

AN INTEGRATED PROGRAM

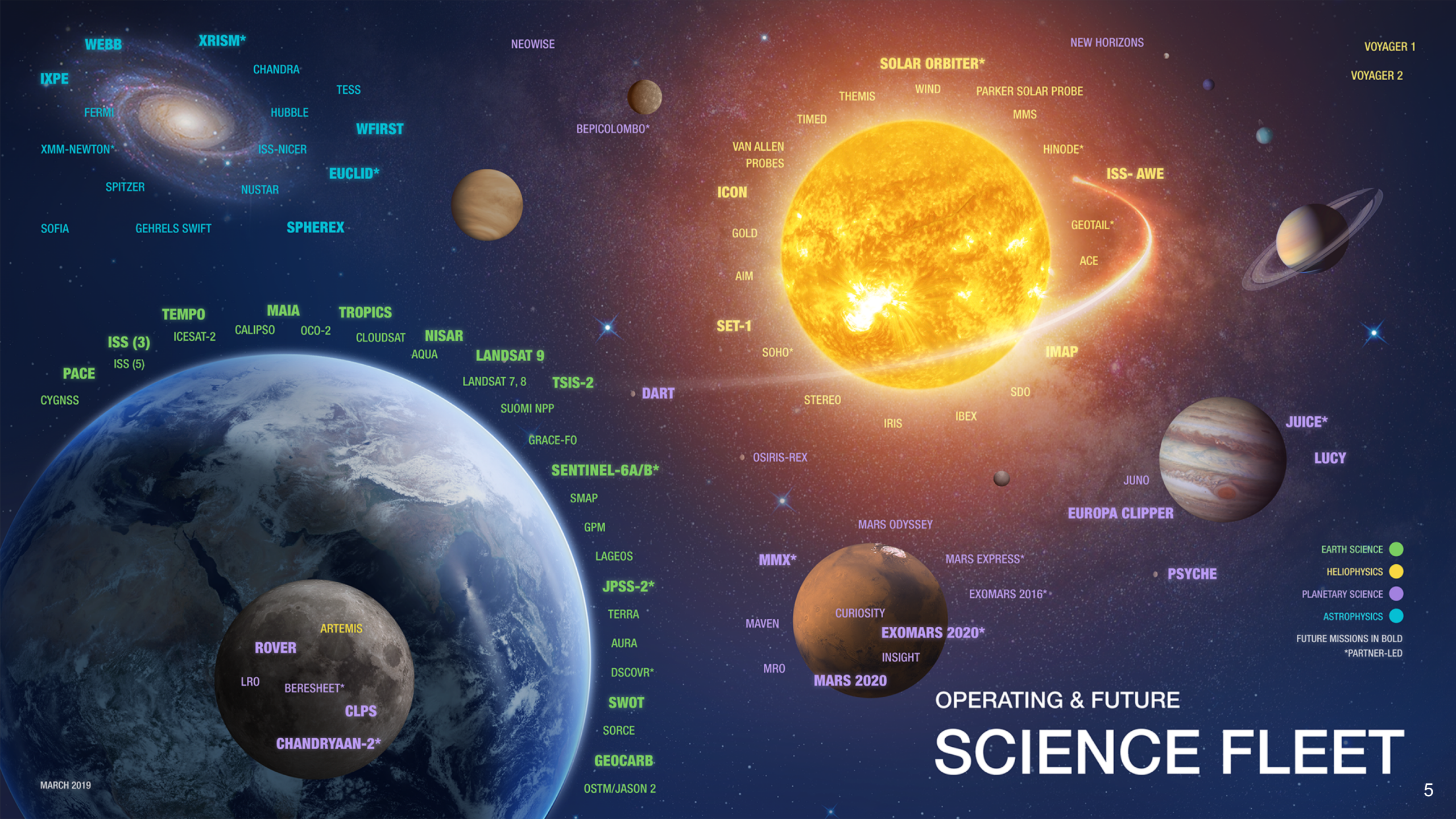
Joint Agency Satellite Division

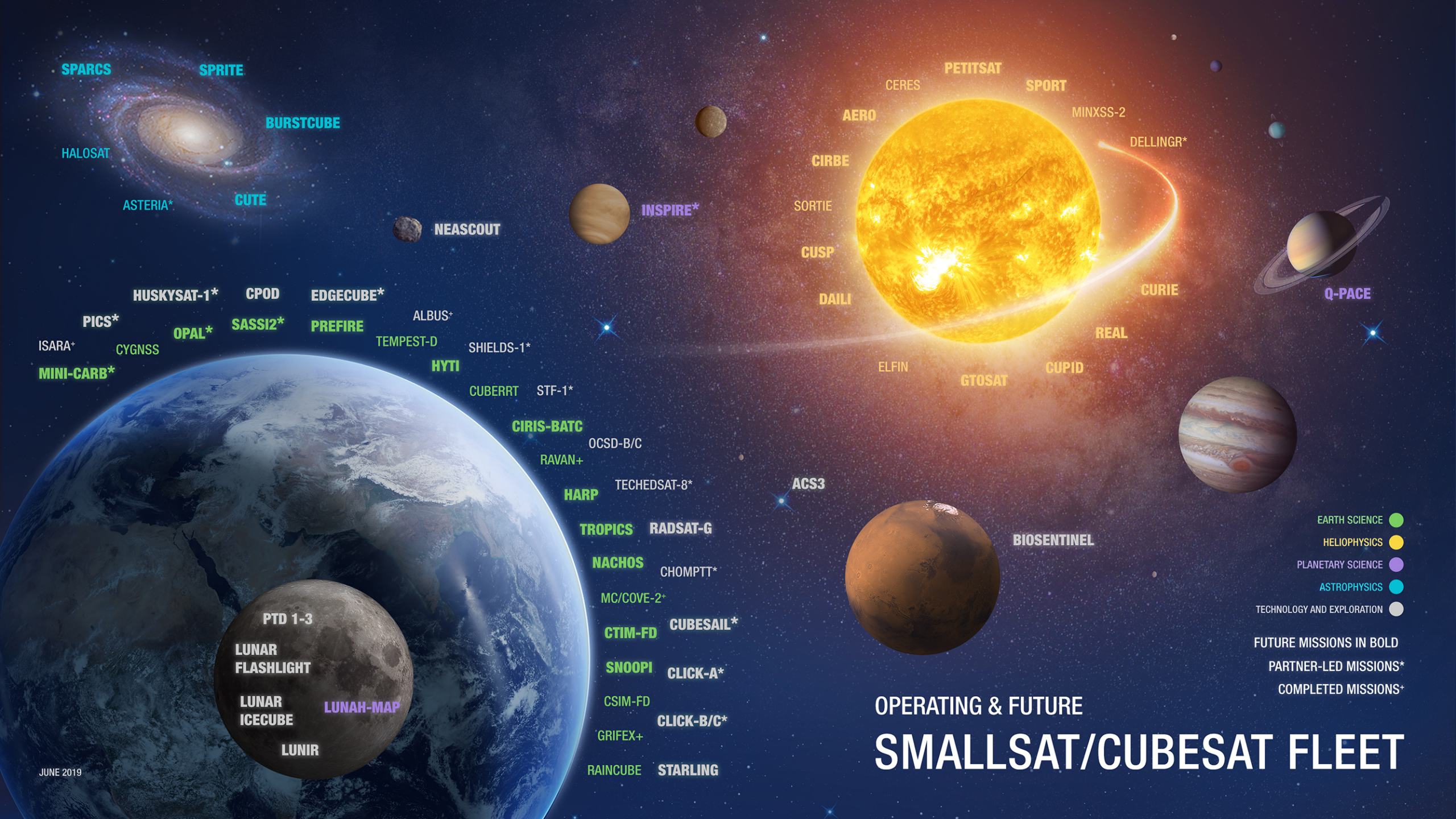
Planetary Science

Astrophysics

Earth Science

Heliophysics


WEBB
XRISM*
IXPE
CHANDRA
TESS
FERMI
HUBBLE
WFIRST
XMM-NEWTON*
ISS-NICER
EUCLID*
SPITZER
NUSTAR
SOFIA
GEHRELS SWIFT
SPHEREX
NEOWISE
BEPICOLOMBO*
SOLAR ORBITER*
NEW HORIZONS
VOYAGER 1
VOYAGER 2
THEMIS
WIND
PARKER SOLAR PROBE
TIMED
MMS
VAN ALLEN PROBES
HINODE*
ICON
ISS- AWE
GOLD
GEOTAIL*
ACE
AIM
SET-1
SOHO*
IMAP
SDO
STEREO
IRIS
IBEX
OSIRIS-REX
JUICE*
LUCY
JUNO
EUROPA CLIPPER
TEMPO
MAIA
TROPICS
ICESAT-2
CALIPSO
OCO-2
CLOUDSAT
NISAR
ISS (3)
AQUA
LANDSAT 9
ISS (5)
PACE
LANDSAT 7, 8
TSIS-2
DART
CYGNSS
SUOMI NPP
GRACE-FO
SENTINEL-6A/B*
SMAP
GPM
LAGEOS
JPSS-2*
TERRA
AURA
DSCOVR*
SWOT
SORCE
GEOCARB
OSTM/JASON 2
ARTEMIS
ROVER
LRO
BERESHEET*
CLPS
CHANDRYAAN-2*
MARS ODYSSEY
MMX*
MARS EXPRESS*
PSYCHE
EXOMARS 2016*
CURIOSITY
MAVEN
EXOMARS 2020*
INSIGHT
MRO
MARS 2020
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
FUTURE MISSIONS IN BOLD
*PARTNER-LED
OPERATING & FUTURE
SCIENCE FLEET
MARCH 2019


SPARCS
SPRITE
BURSTCUBE
HALOSAT
ASTERIA*
CUTE
NEASCOUT
INSPIRE*
HUSKYSAT-1*
CPOD
EDGECUBE*
PICS*
OPAL*
SASSI2*
PREFIRE
ALBUS+
ISARA+
CYGNSS
TEMPEST-D
SHIELDS-1*
MINI-CARB*
HYTI
CUBERRT
STF-1*
CIRIS-BATC
OCSD-B/C
RAVAN+
TECHEDSAT-8*
HARP
TROPICS
RADSAT-G
NACHOS
CHOMPTT*
MC/COVE-2+
CTIM-FD
CUBESAIL*
SNOOPI
CLICK-A*
CSIM-FD
CLICK-B/C*
GRIFEX+
RAINCUBE
STARLING
PTD 1-3
LUNAR FLASHLIGHT
LUNAR ICECUBE
LUNAH-MAP
LUNIR
JUNE 2019
PETITSAT
CERES
SPORT
AERO
MINXSS-2
DELLINGR*
CIRBE
SORTIE
CUSP
DAILI
CURIE
Q-PACE
REAL
ELFIN
CUPID
GTOSAT
ACS3
BIOSENTINEL
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
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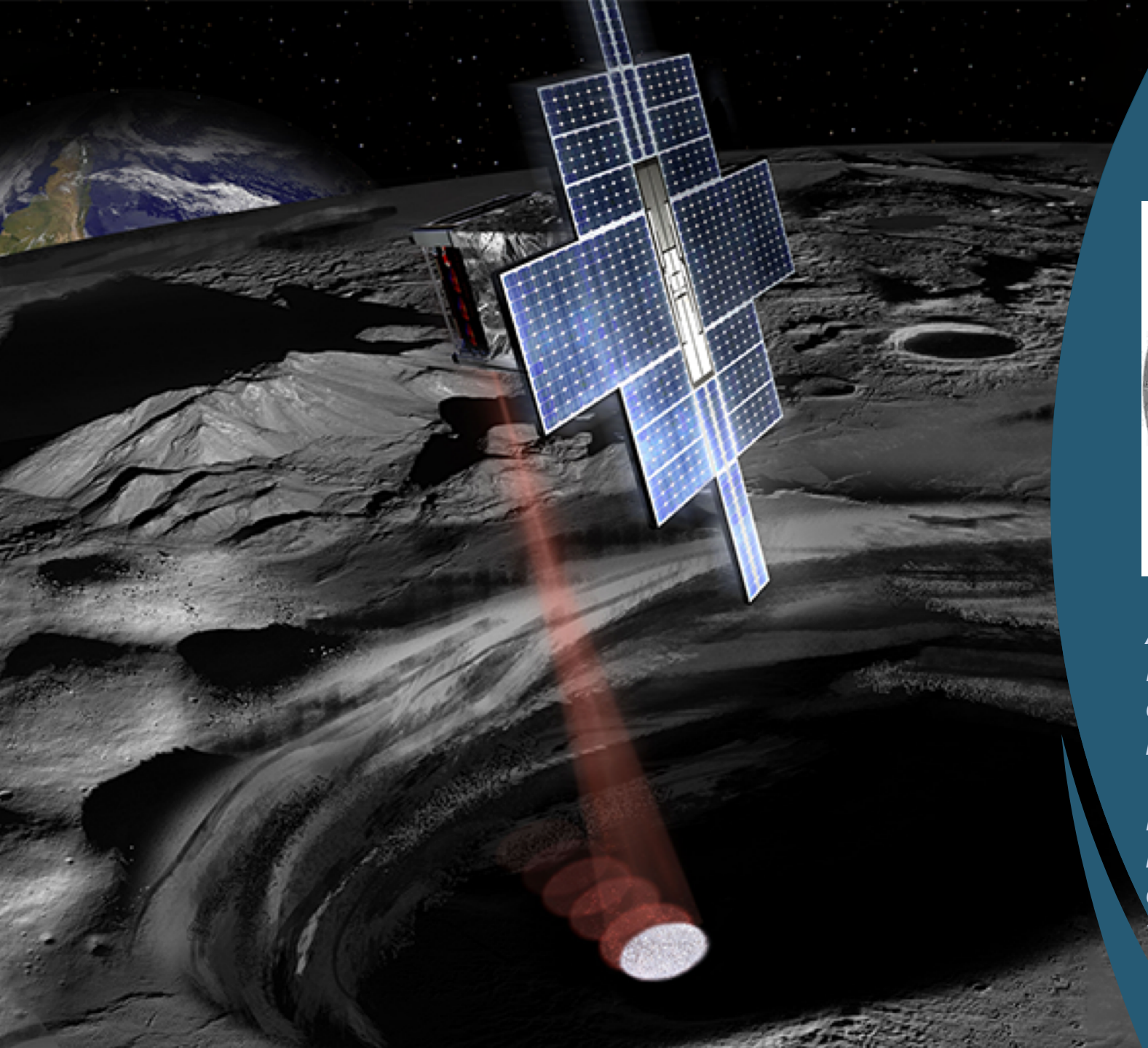
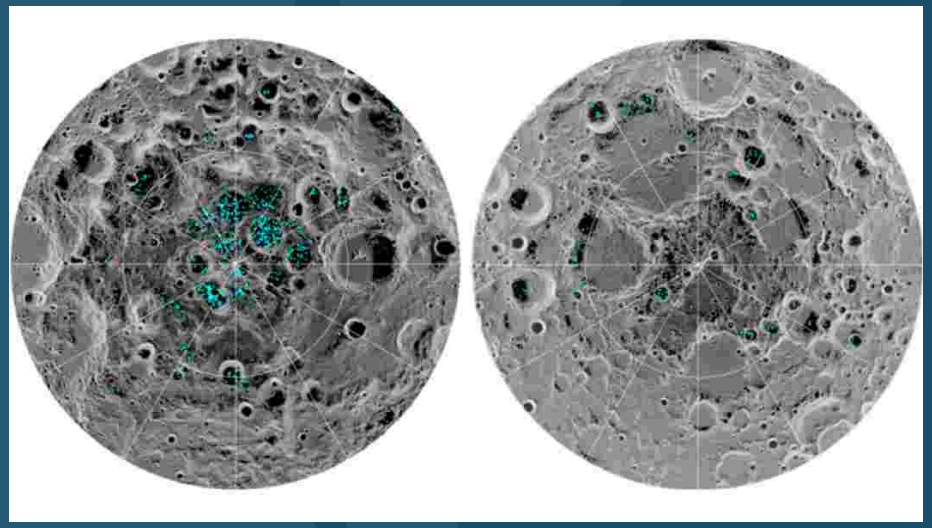
TECHNOLOGY AND EXPLORATION
FUTURE MISSIONS IN BOLD
PARTNER-LED MISSIONS*
COMPLETED MISSIONS+
OPERATING & FUTURE
SMALLSAT/CUBESAT FLEET



Lunar Flashlight



Aug. 21, 2018 – Distribution of surface ice at Moon's south pole (left) and north pole (right), detected by NASA's Moon Mineralogy Mapper instrument, aboard India's Chandrayaan-1.

Lunar Flashlight will use an active multiband reflectometer based receiver with NIR lasers to detect and characterize water/ice and other volatiles addressing strategic knowledge gaps.

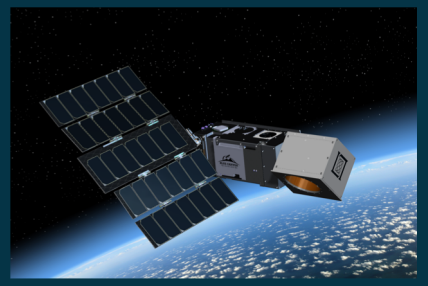
Small Spacecraft Coordination Group

Formed to advise the SMD, STMD, and HEOMD AAs on strategy to guide cross-agency initiatives, policies, and programmatic scope

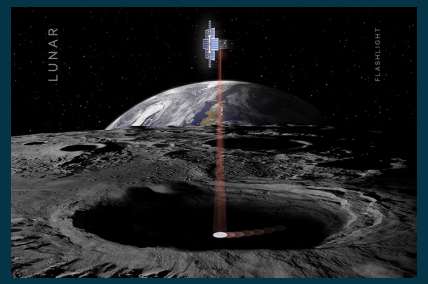
Integrated Small Spacecraft Strategic Plan

Release at SmallSat 2019

NASA Strategic Plan



Science
New Observation Methods



Exploration
Strategic Knowledge Gaps

Technology
Spacecraft Subsystems

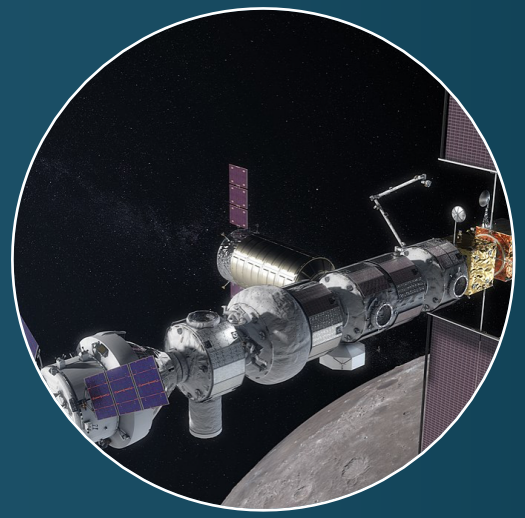
Small Satellites Align with NASA Strategic Objectives

NASA 2018 Strategic Plan Framework

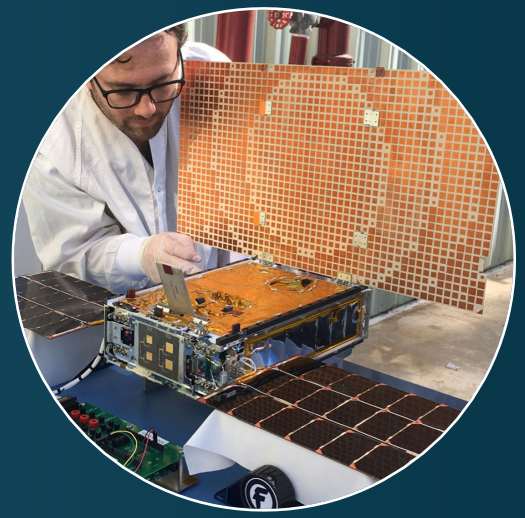
Theme	Strategic Goal	Strategic Objective
DISCOVER	Expand Human Knowledge Through New Scientific Discoveries	1.1: Understand the Sun, Earth, Solar System, and Universe 1.2: Understand Responses of Physical and Biological Systems to Spaceflight
EXPLORE	Extend Human Presence Deeper Into Space and to the Moon for Sustainable Long-Term Exploration and Utilization	2.1: Lay the Foundation for America to Maintain a Constant Human Presence in Low Earth Orbit Enabled by a Commercial Market 2.2: Conduct Exploration in Deep Space, Including to the Surface of the Moon
DEVELOP	Address National Challenges and Catalyze Economic Growth	3.1: Develop and Transfer Revolutionary Technologies to Enable Exploration Capabilities for NASA and the Nation 3.2: Transform Aviation Through Revolutionary Technology Research, Development, and Transfer 3.3 Inspire and Engage the Public in Aeronautics, Space, and Science
ENABLE	Optimize Capabilities and Operations	4.1: Engage in Partnership Strategies 4.2: Enable Space Access and Services 4.3: Assure Safety and Mission Success 4.4: Manage Human Capital 4.5: Ensure Enterprise Protection 4.6: Sustain Infrastructure Capabilities and Operations

Small Spacecraft Agency Integrated Strategic Plan

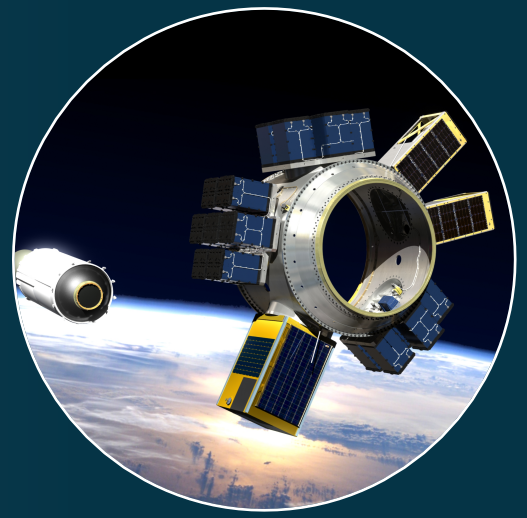
High Priority Science



Support to Human Exploration



Disruptive Technology Innovation



Regular Access to Space

An integrated and coordinated strategy supporting the NASA strategic plan objectives of Discover, Explore, Develop, Enable

High Priority Science Strategy

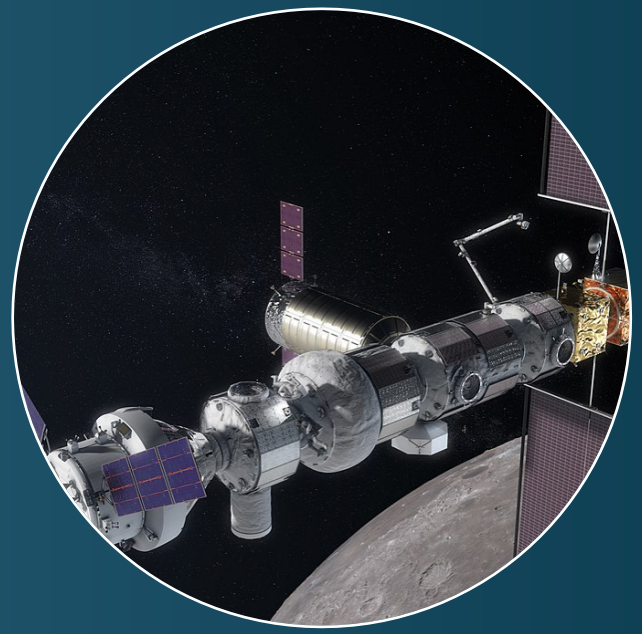
Develop a focused approach to new technology development and launch services that enables unique scientific observations

Actively partner on services and capabilities that enable multipoint spacecraft measurements

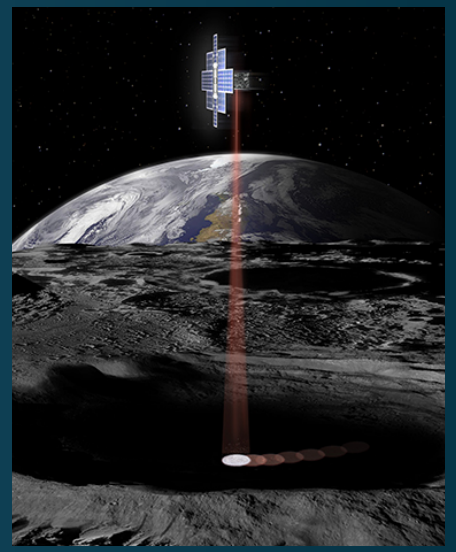
Educate the wider scientific community on technology and launch capabilities for decadal survey−class science and exploration initiatives

NASA should tailor technologies and launch services to unique capabilities of small spacecraft, with educational and commercial partnerships, to enable innovative science

Support to Human Exploration Strategy



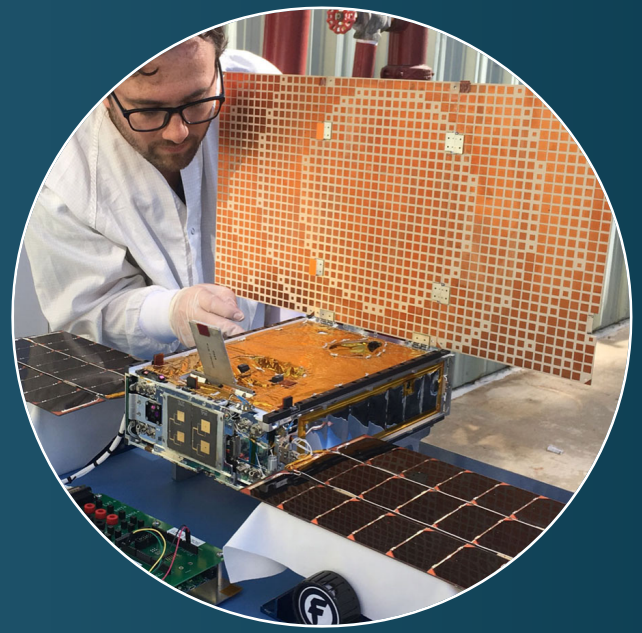
Actively partner with industry on capabilities and services for affordable small spacecraft missions to the Moon and Mars to support human exploration



Ensure that scientific and exploration activities in cis-lunar space involving humans and small spacecraft are coordinated, mutually beneficial and complementary

NASA should join with industry to leverage their advances and economic interests in cis-lunar space while developing reliable flight systems to enable our exploration objectives

Disruptive Technology Innovation Strategy



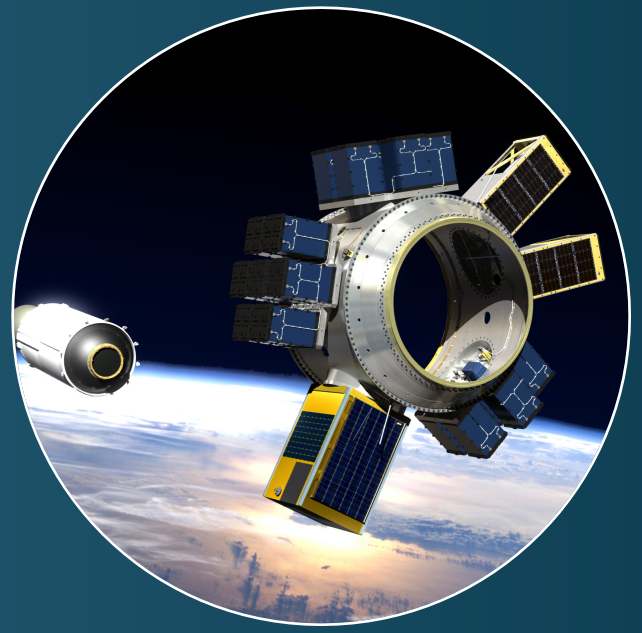
Collaborate on risk reduction activities involving innovative commercial spacecraft and systems

Partner with industry and academia to aggressively adapt innovative emerging technology capabilities to meet NASA's unique needs

Foster innovation, agile development practices, and embrace higher risk throughout the agency via missions and flight demonstrations

NASA should work directly with industry and academia on risk reduction while maintaining a culture of innovation, risk tolerance, and rapid development at lower cost

Regular Access to Space Strategy



Coordinate access-to-space opportunities for NASA's small spacecraft

Develop new methods to increase flexibility in space access destinations, capability, and manifesting, while preserving core capabilities.

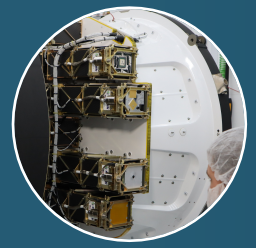
Identify and address regulatory roadblocks to streamline processes impacting space access for our NASA partners

NASA has a leading role and must continue to develop policy and procedures to support compatible payloads on emerging launch platforms

SSCG Focus Areas and Selected Future Products/Policies

1 - Strategy and Implementation

2 - S&MA, Reliability, Technical Excellence



3 - Launch Accommodation and Rideshare

4 - Services and Infrastructure

5 - Cybersecurity and Enterprise Protection

6 - Commercial Partnerships and New Space

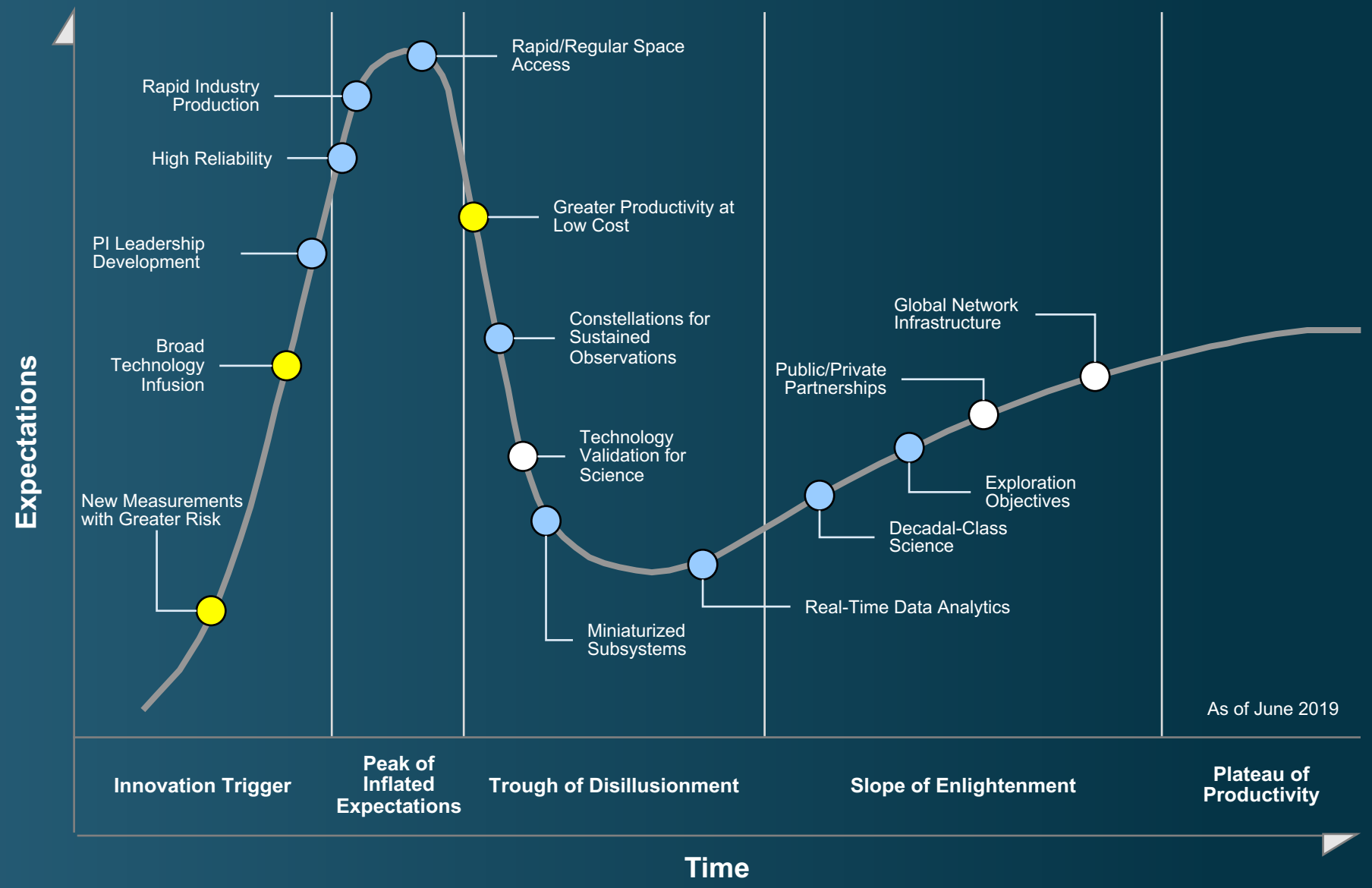
7 - International Relationships and Outreach

Sample Products/Policies to be released or completed	
Area 1	NASA SmallSat Technology and Science Mission Concept Workshop
Area 2	NASA Engineering Network Community of Practice Mission Anomaly Database
Area 2	Community Class-D Mission Assurance Requirements
Area 3	Federated NASA Mission and Rideshare Information Database (via Virtual Institute)
Area 3	ESPA-Class and High-Priority Launch Manifest Policy
Area 4	Community Telecom and Ground Station Services
Area 5	Spacecraft Telecom Encryption Policies
Area 6	Public/Private/Government Partnership Opportunities

Engaging the Community for Mission Success

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

Gartner Based SmallSat Hype Cycle



Years to mainstream adoption

- less than 2 years
- 2 to 5 years
- 5 to 10 years
- more than 10 years
- obsolete before plateau

This chart is a composite, derived from Gartner published Hype Cycles.

The particular combination and comparison of items made here has not been reviewed by Gartner

EXPLORE
with us

Backup

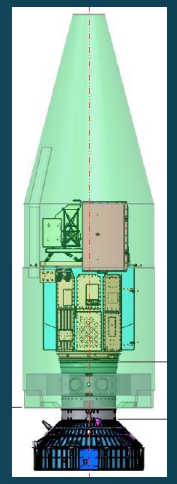
2019 CSLI Selections

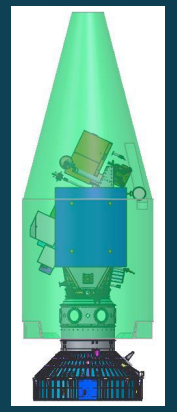
16 Missions Selected from Round 10 Solicitation

To date:
176 CubeSats missions from 39 states
- 91 CubeSats launched
- 43 CubeSats manifested
- 53 CubeSats unmanifested (only 17 of which are 2019 flight-ready)

Future Rideshare Accommodations

In addition to ISS and CRS flight accommodations
- Rideshare on 4 SMD Primary missions
- SLS accommodations





Landsat-9 (2020) - ESPA

JPSS-2 (2022) - ESPA & LOFTID

SPHEREx (2023) - ESPA
IMAP (2024) - ESPA Grande

PSYCHE (2024) – ESPA

SLS EM-1, 2

Venture Class Launch Service

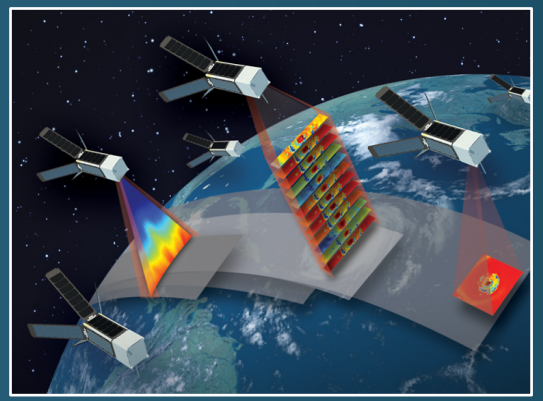
Budgeting $10M- $15M per launch in the AO process

Rocket Lab's Electron LV
- Successful launch 12/16/18
- carrying 10 CubeSat missions for NASA

Virgin Orbit's Launcher One
- Target VCLS launch Sept 2019
- carrying 11 CubeSat missions for NASA

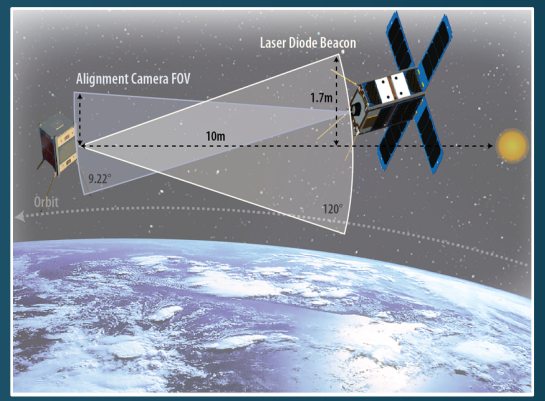
SmallSat Program Opportunities

Investing up to $30M for Earth Science Constellations



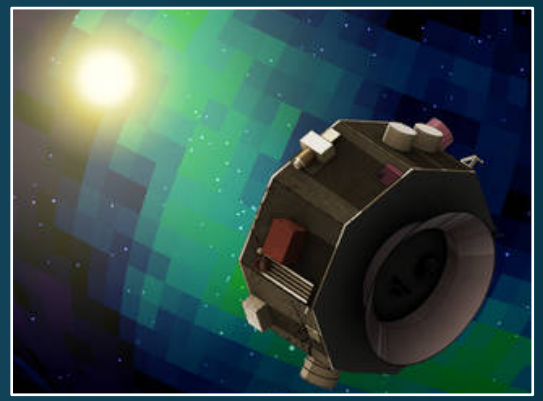
Earth Venture Missions (EVM/EVI) and In-Space Validation of Earth Science Technologies (InVEST)

First Major Investment in Astro SmallSat Missions



Astrophysics Small Explorer (SMEX) and Astrophysics Science SmallSat Studies

Investing up to $65M for ESPA-class Payloads



Heliophysics Technology Demonstration Mission of Opportunity

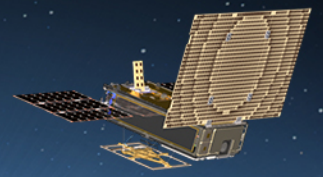
Investing up to $55M in Deep Space SmallSat Missions

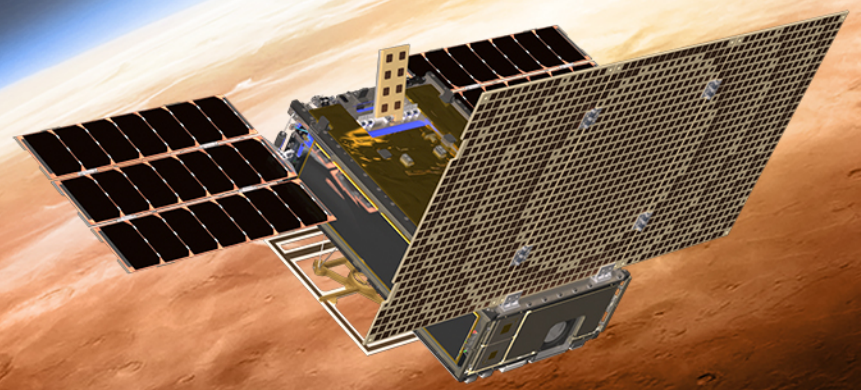
Small Innovative Missions for Planetary Exploration (SIMPLEx)

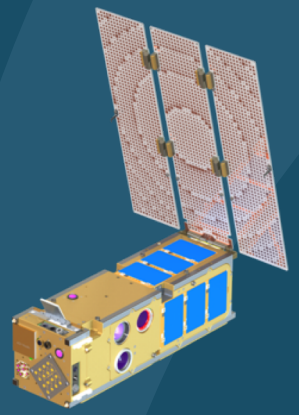
SmallSat/CubeSat commercial engagement opportunities are essential to NASA Science's balanced portfolio, achieving distinct science objectives

MarCO

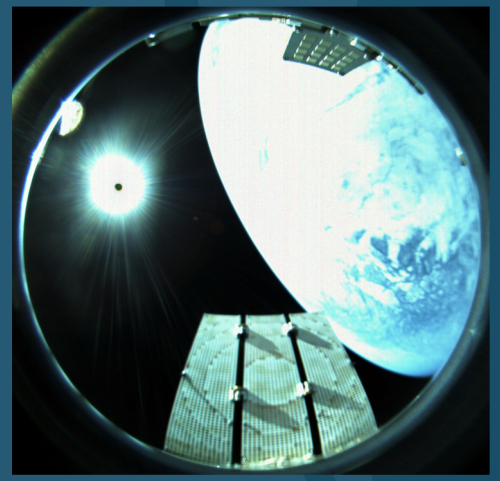
Mars Cube One



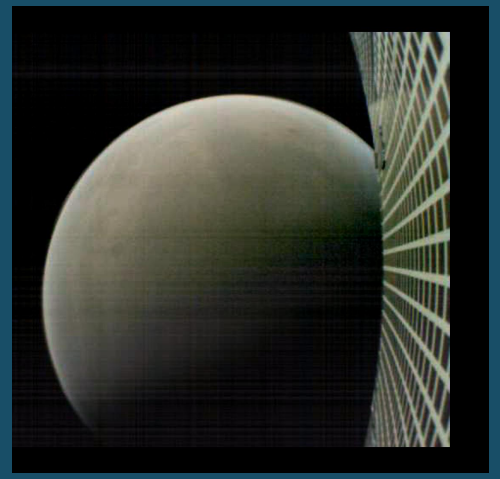




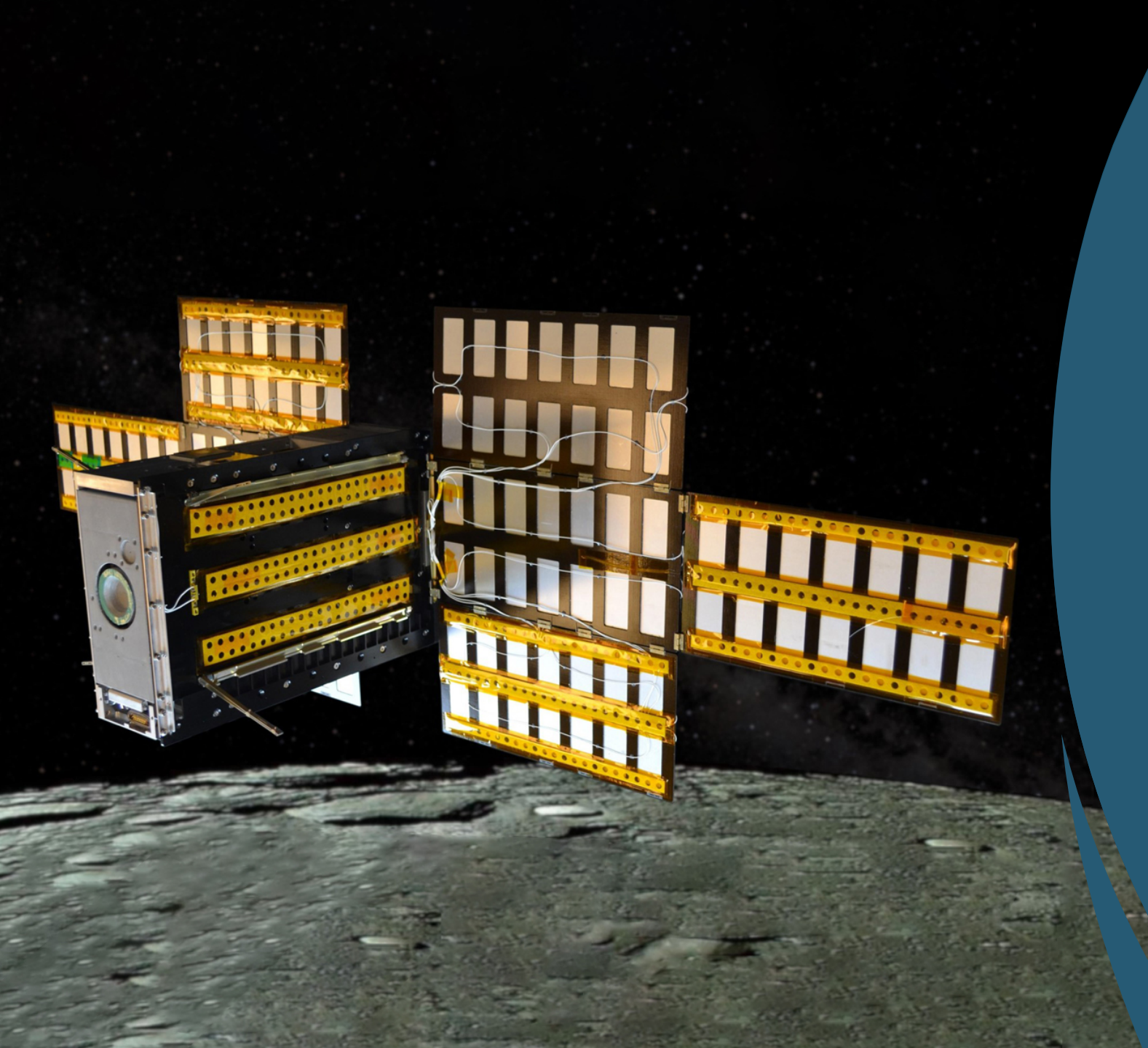
Nov. 2018 – Early adoption of ISARA Reflectarray antenna technology enables MarCO's mission



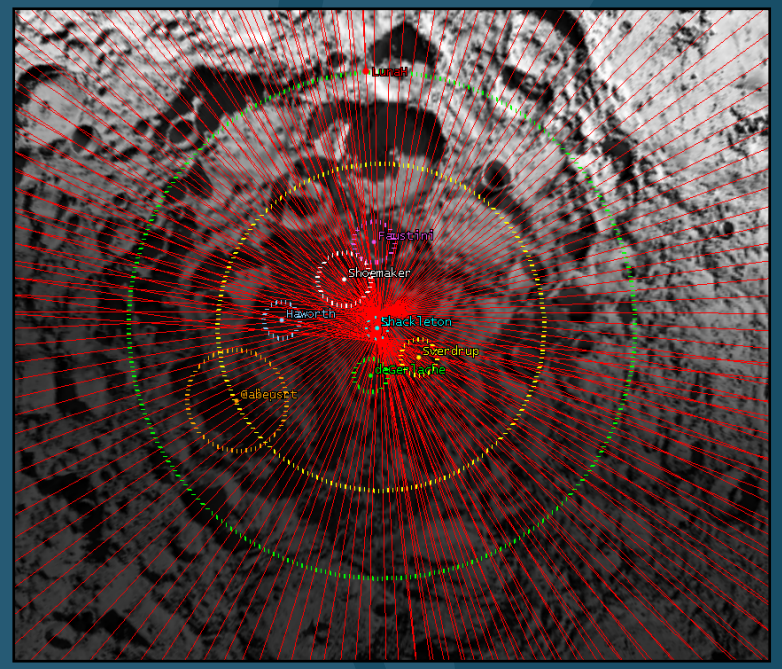
ISARA image showing deployment of Reflectarray antenna and Earth



Nov. 26, 2018 - MarCO-B image of Mars from approximately 4,700 miles away during its flyby



LunaH-Map



Orbit ground track for 60-day science phase: 141 passes over target area, Shackleton Crater