

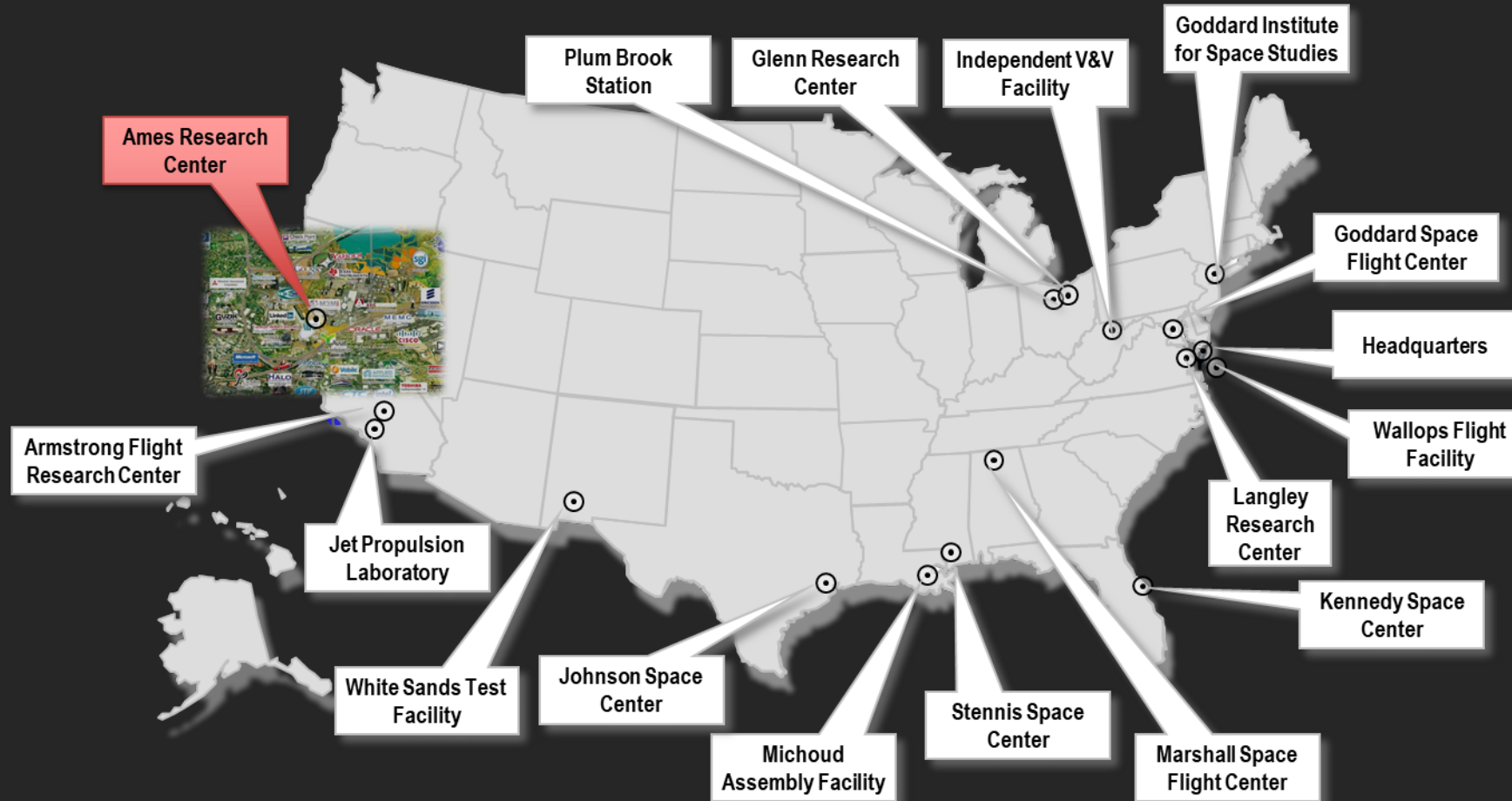


Advanced Exploration Systems (AES) Small Spacecraft Missions

Spanish Small Satellites International Forum
Málaga, Spain

Andres Martinez, Program Executive, Small Spacecrafts
Advanced Exploration Systems (AES) division
HEOMD, NASA Headquarters
February 23, 2022





Spain and U.S.A. - A long history of Spaceflight Partnerships



The Maspalomas Tracking Station – Mercury 1962 – 1963, Gemini 1965 – 1966, and Apollo 1968 - 1972



The Cebrenos Station (1966 – 1983) – Deep Space Station



The Arenosillo Launch Range (from 1966) – Judi-DART sounding rocket



The Robledo de Chavela Station– Received images from Mars transmitted by Mariner 4 – July 1965



Intasat (1974 – 1976) - first Spanish Satellite. Launch provided by NASA on 15 November 1974

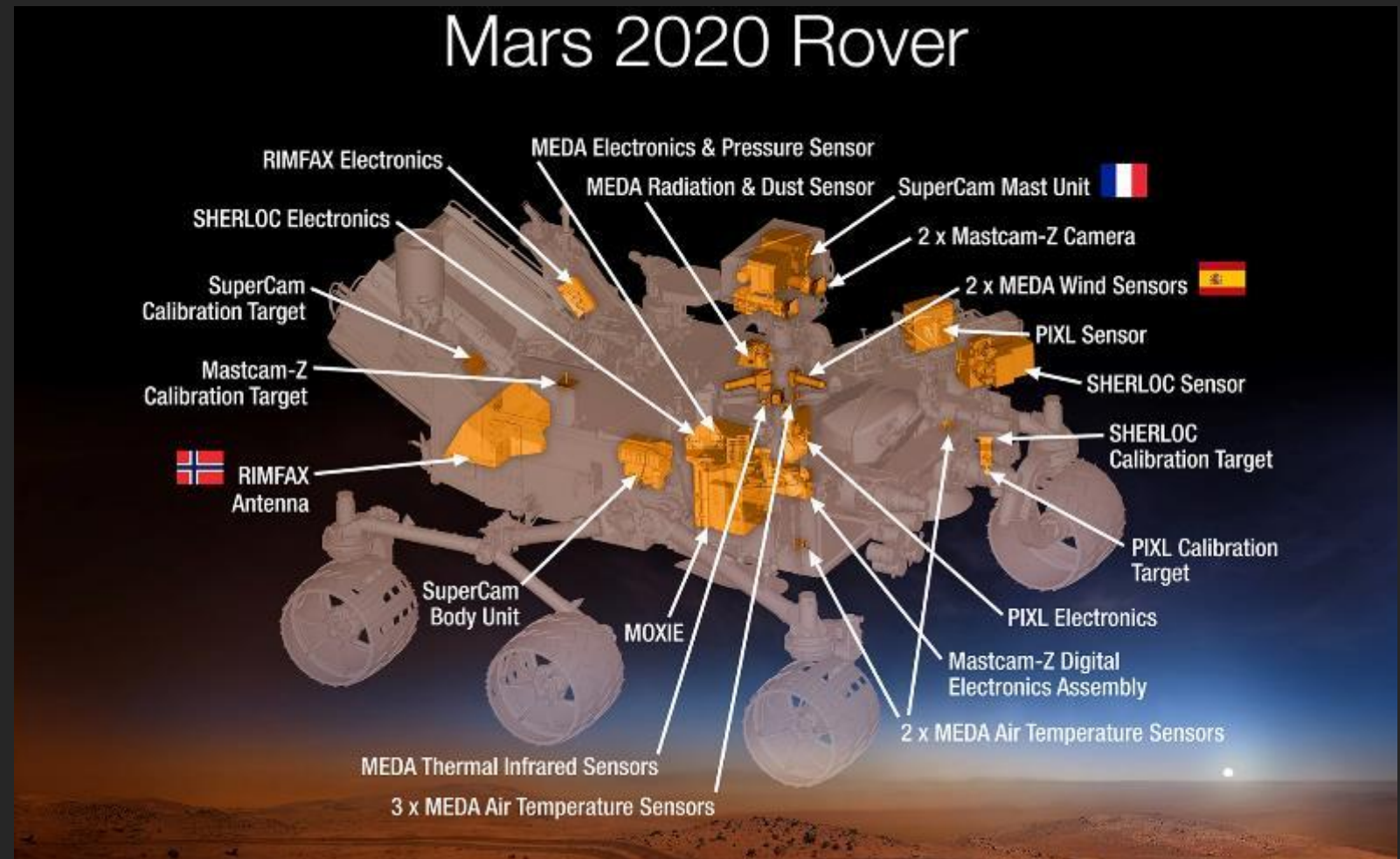


The Space Shuttle Emergency landing (from 1983) at the Spanish Air Force base at Saragoza

1984, the Air Force base at Morón (Seville) was also designated as a base for emergency landings of the Shuttle fleet

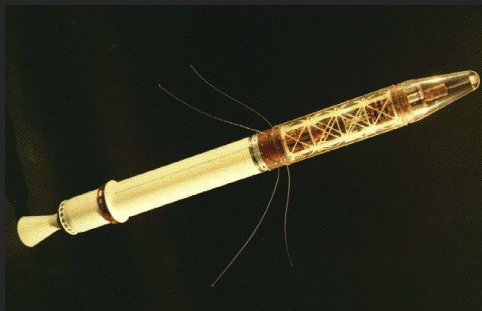
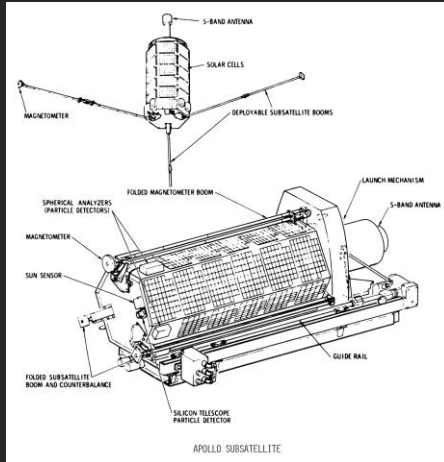
Mars Environmental Dynamics Analyzer (MEDA), a set of sensors that will provide measurements of temperature, wind speed and direction, pressure, relative humidity and dust size and shape.

The principal investigator is Jose Rodriguez-Manfredi, Centro de Astrobiologia, Instituto Nacional de Tecnica Aeroespacial, Spain.





Sputnik – OCT 1957
(83.6Kg, 58 cm)



Explorer1 – FEB 1958
(13.97Kg, 205.1 cm, 15.2 cm)

Apollo Program is the deployment of small spacecraft during the Apollo 15 and Apollo 16 missions as the command module left lunar orbit. The Particles and Fields Subsatellite (PFS) series, built by TRW, was designed to study the plasma, particle, and magnetic field environment of the Moon as well as to map the lunar gravity field.

These units were the first small spacecraft released into space from a containerized deployment system.

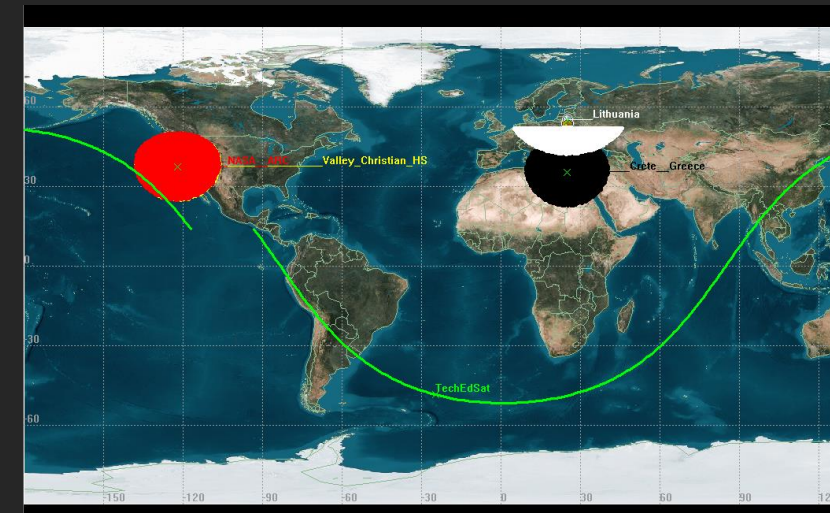
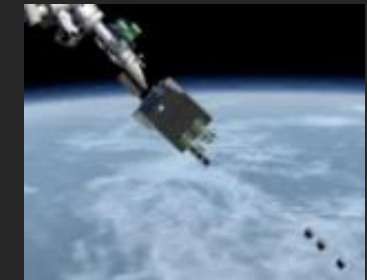
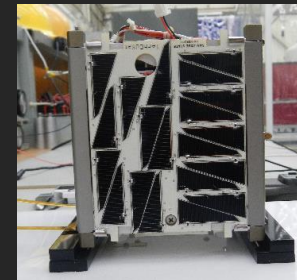
Mission Description

NASA Ames Research Center mentored students from San Jose State University. The mission was to demonstrate:

- 1.) the capabilities of the JAXA J-SSOD aboard the ISS, and be one of the first cubesats to be deployed from the ISS.
- 2.) Iridium and OrbComm inter-satellite communication as a method of eliminating the requirement for a physical ground station in small satellite missions.
- 3.) Ability for engineering students to deliver a flight system to be up-massed to the International Space Station for deployment to space.

Spacecraft Specifications:

- **Mass:** 1.2kg
- **Quantity:** One 1U cubesat
- **Orbit:** 400 km x 400 km @ 51.6 incl.
- **Size:** 10 x 10 x 11 cm
- **Communication:** UHF band
- **Launched:** HTV-4 (JUL 21, 2012)



Mission Description

NASA Ames Research Center, in collaboration with Purdue University, Texas A&M University, and Santa Clara University delivered SporeSat.

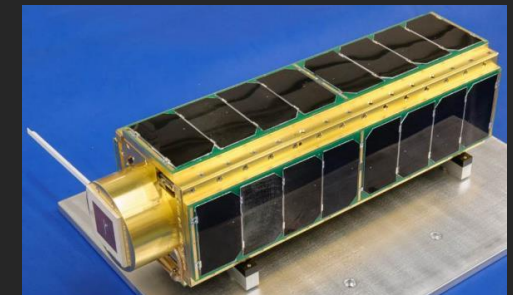
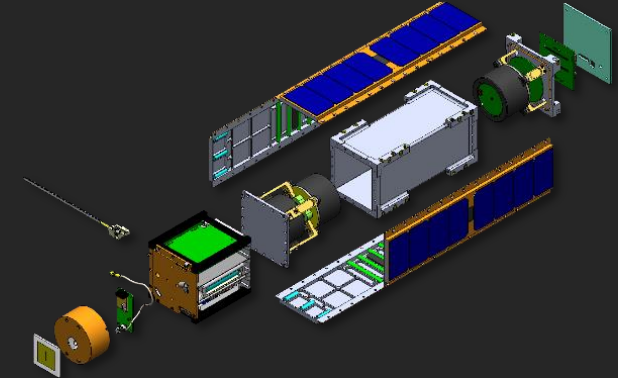
SporeSat was a fundamental space biology science mission in support of human exploration to investigate biophysical mechanisms of plant gravity sensing using a “lab-on-a-chip” experimental approach.

The unicellular germinating *Ceratopteris richardii* fern spore was studied in outer space.

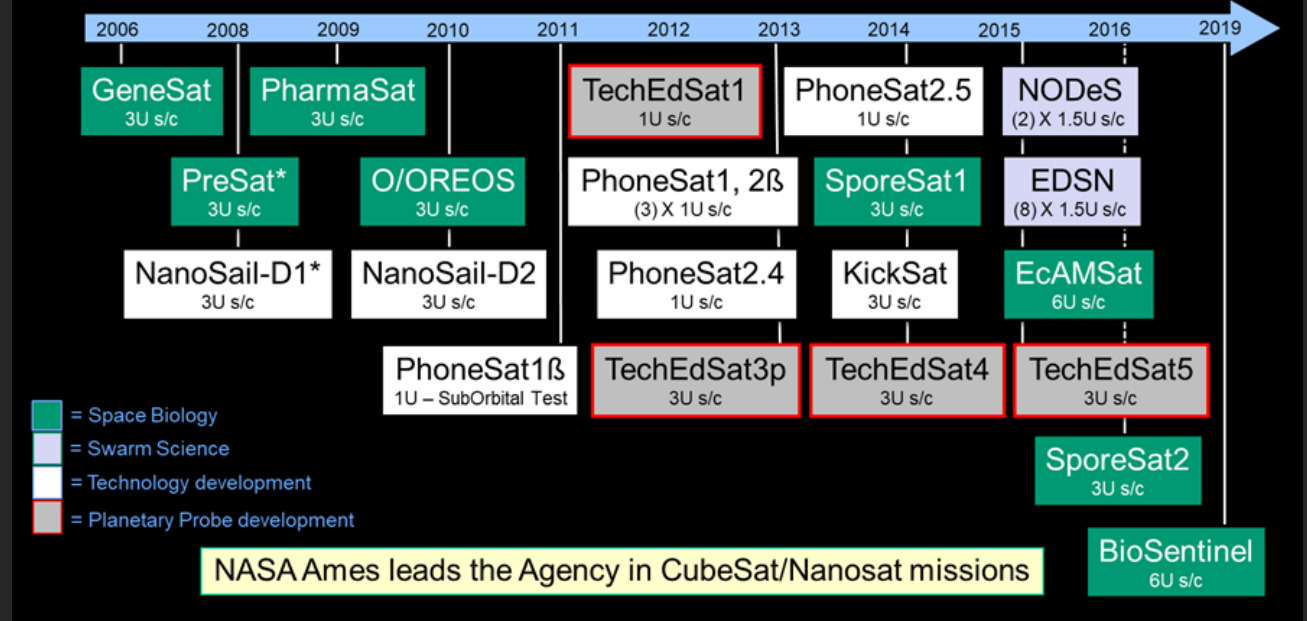
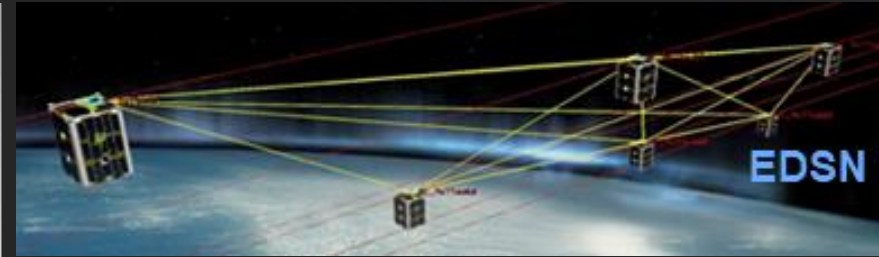
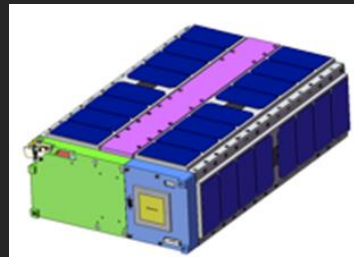
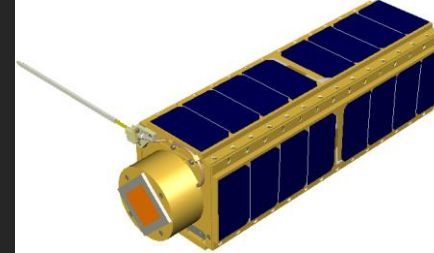
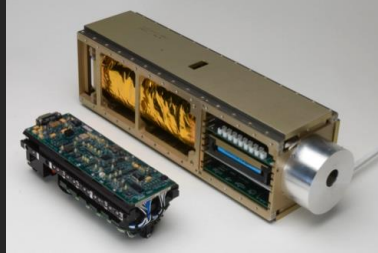
SporeSat was to determine gravity thresholds for calcium ion (Ca^{2+}) channel activation in wild-fern spores.

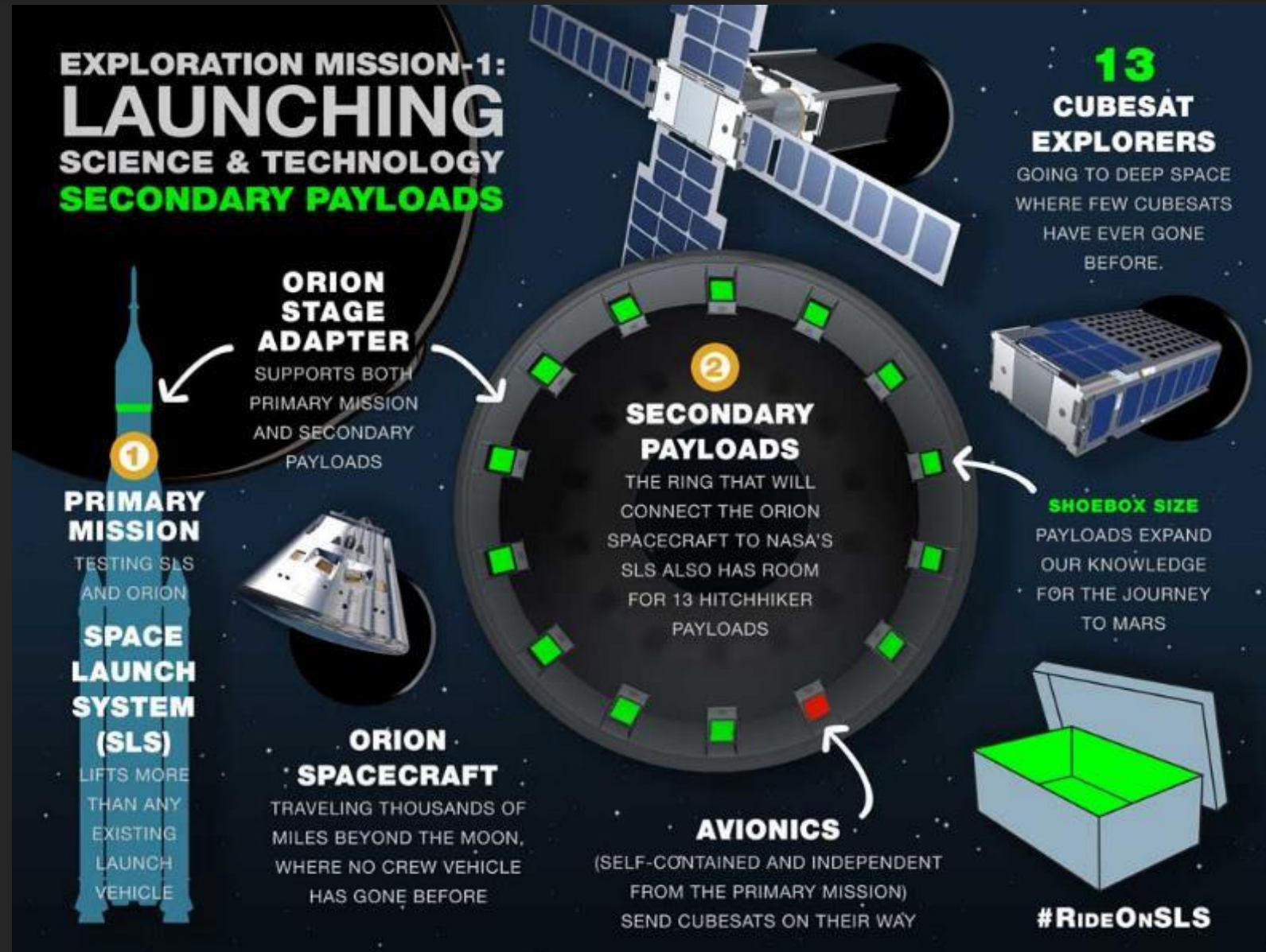
Spacecraft Specifications:

- **Mass:** 5.2kg
- **Quantity:** One 3U cubesat
- **Orbit:** 350 km x 350 km @ 51.6 incl.
- **Size:** 10 x 10 x 30 cm
- **Communication:** UHF, and S band
- **Launched:** SpaceX-3 (April 2014)

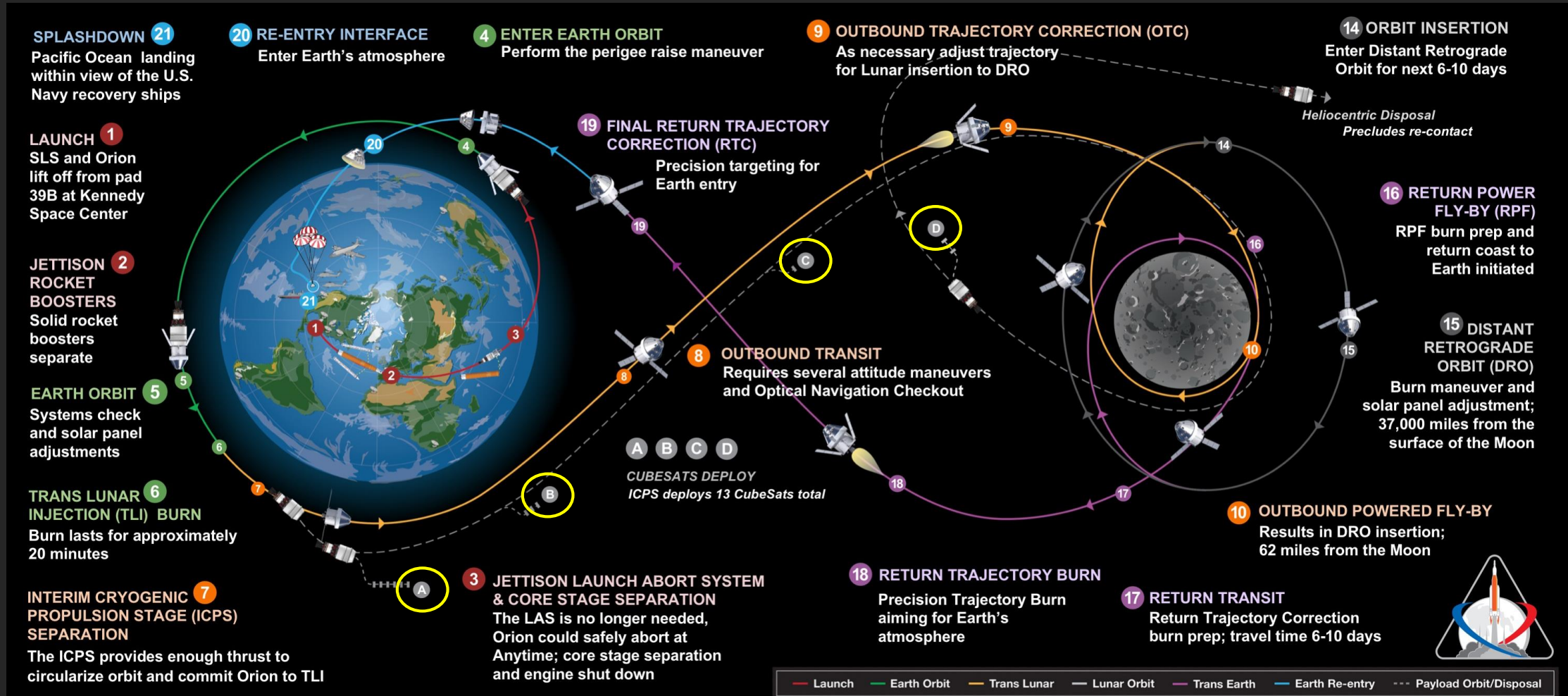


NASA Ames Research Center - Small Satellites





The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport

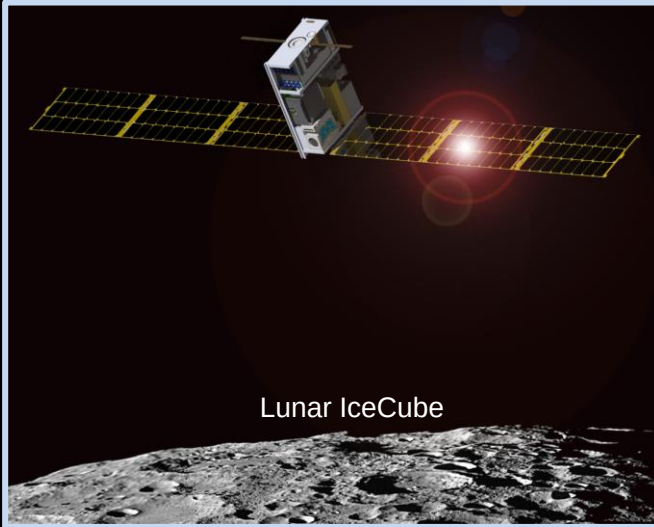


Total distance traveled: 1.3 million miles – Mission duration: 25.5 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

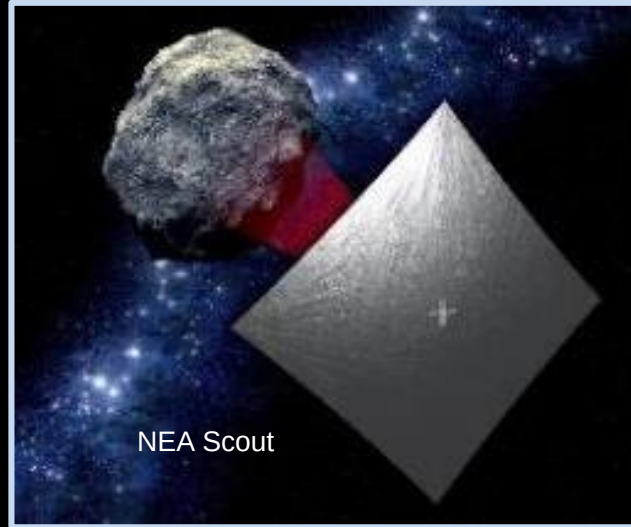
AES Artemis Small Spacecraft Missions



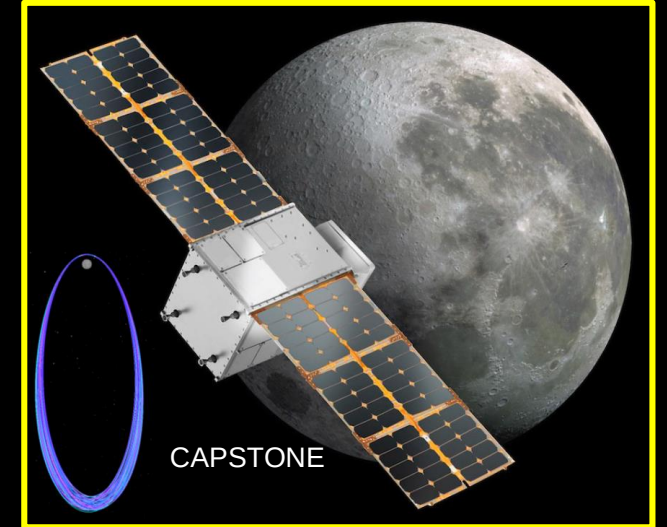
LunIR



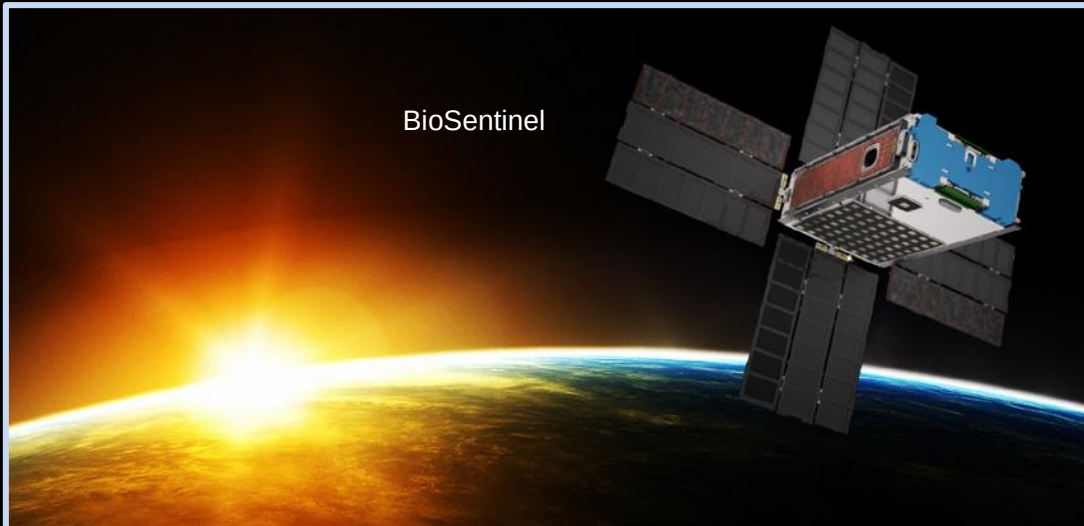
Lunar IceCube



NEA Scout



CAPSTONE



BioSentinel

Enabling interplanetary research with small spacecraft platforms

MarCO Demonstrations:

- Downlink Using X-Band Feed and DSN Equipment
- Downlink Using X-Band Feed and MarCO Receiver System
- OMSPA Using X-Band Feed and Custom SDR-based Multiple Receiver System

First Opportunistic Multiple Spacecraft Per Antenna (OMSPA) Demonstration with a CubeSat

Deep Space Station 17

Develops an operational capability to support Artemis-1 SmallSat missions

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.

LRO Demonstrations:

- Routinely Tracking LRO at S-Band
- Intermediate Frequency (IF) Systems and DSN Downlink Equipment (DCO, DTT) Verified
- LRO Telemetry Blocks Sent Directly from DSS-17 to JPL DSSC over the NASA Mission Backbone - verifying DSS-17 Signal Path

First 5 Demodulated Frames from MarCO OMSPA Demonstration on May 6, 2018 from DSS-17:

D. Abraham, Z. Towfic, S. Finley (JPL)
C. Cooper, M. Stratton, R. Kroll (Morehead State)

Mission Ops Center at MSU

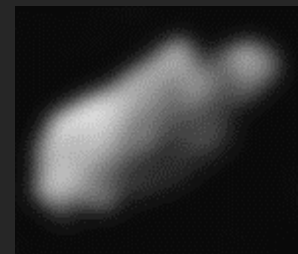
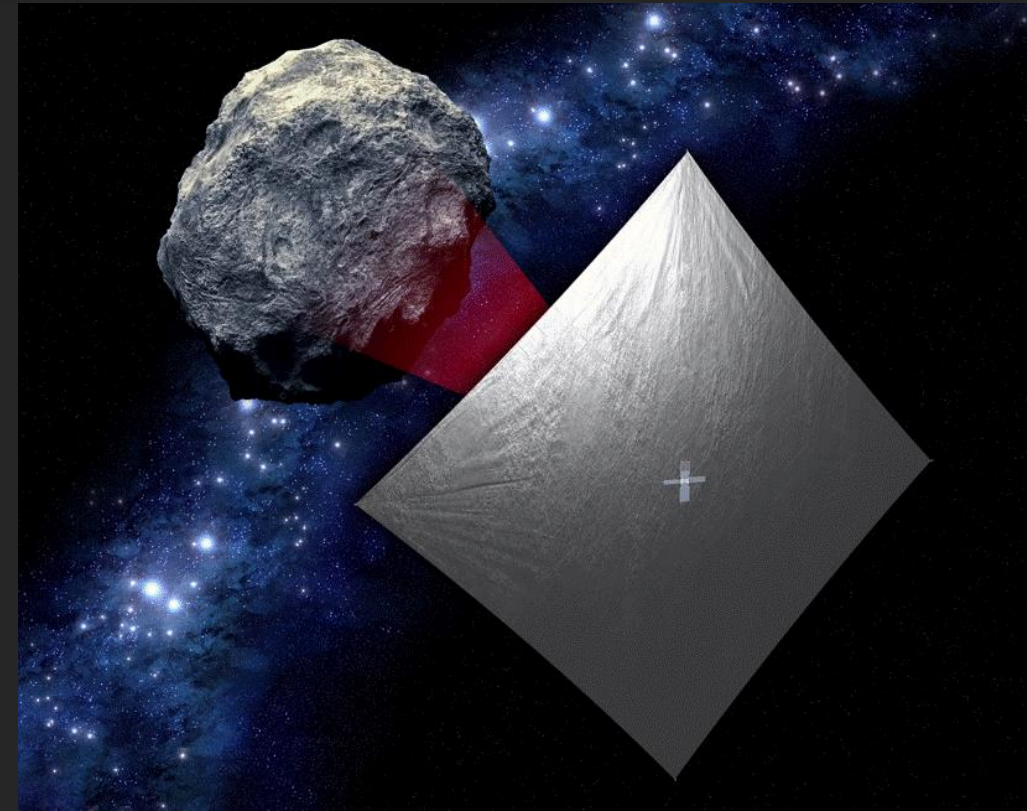
AES Small Spacecraft Missions contribute to key Human Exploration Strategic Knowledge Gaps and to Advance Key Technologies

Why is this project important?

- Serves as a robotic reconnaissance mission to fly by and return data from an asteroid representative of near-Earth asteroids that may one day be human destinations.
- Furthers our scientific understanding of Near Earth Asteroids and Addresses Strategic Knowledge Gaps (SKGs) for future Near Earth Asteroid exploration
- Demonstrates solar sail propulsion for use on future robotic and science exploration and science missions

Project Objectives

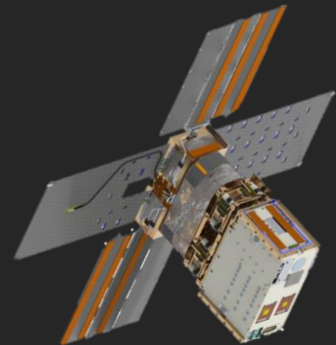
- Image/characterize a NEA during a slow flyby (e.g. 1991VG)
- Enable asteroids as potential destinations for human exploration
- Characterize a candidate NEA with an imager to address key NEO SKG's
- First Solar Sail Navigation and Control to observe an interplanetary body
- Largest non-spin stabilized solar sail
- First use of active translation table to control solar sail
- Full on-board image processing pipeline and analysis, a pathfinder for deep space science autonomy



**Target Reconnaissance
with medium field
imaging**
Shape, spin, and local
environment



**Close Proximity
Imaging**
Local scale morphology,
terrain properties,
landing site survey



Marshall Space
Flight Center



Jet Propulsion Laboratory
California Institute of Technology

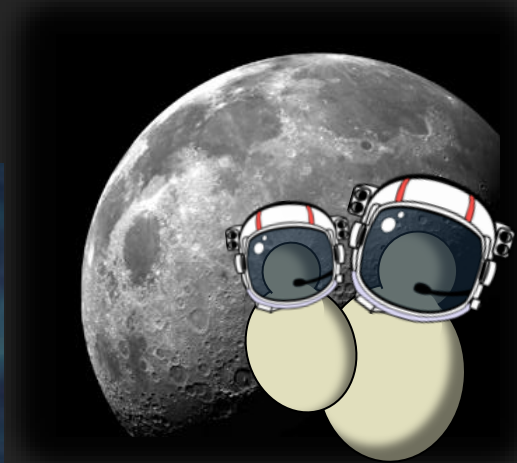
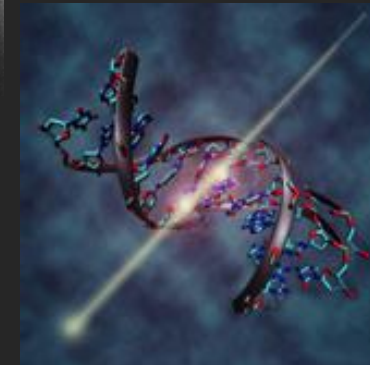
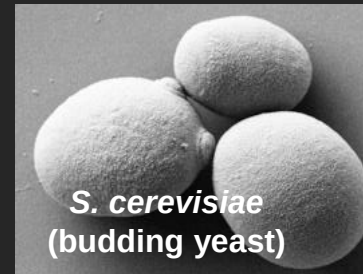
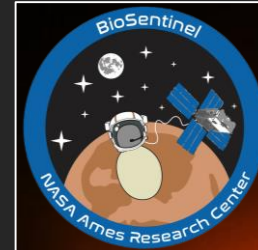
National Aeronautics and Space Administration

Why is this project important?

- BioSentinel is a deep space mission to detect, measure and correlate the impact of space radiation on living organisms over long durations.
- BioSentinel is a free-flyer mission carrying the BioSensor and linear energy transfer (LET) Spectrometer instruments. The BioSensor is a self-contained biology-based radiation sensor using yeast, a simple model organism.
- The yeast cells will receive ionizing radiation in desiccated state and in suspension; the BioSensor measures cell growth and metabolic activity.

Project Objectives

- Develop an instrument with autonomous life support technologies to study the biological effects of the space radiation environment at different orbits
- Study living cells' response to deep-space radiation — work that could help astronauts on future long-duration missions.
- First CubeSat to combine biological studies with autonomous capability & physical dosimetry beyond LEO. Far beyond the protection of Earth's magnetosphere (~0.3 AU from Earth at 6 months; ~40 million km)
- BioSentinel will allow to compare different radiation & gravitational environments (deep space, LEO, lunar surface...)
- Develop a radiation biosensor useful for other missions

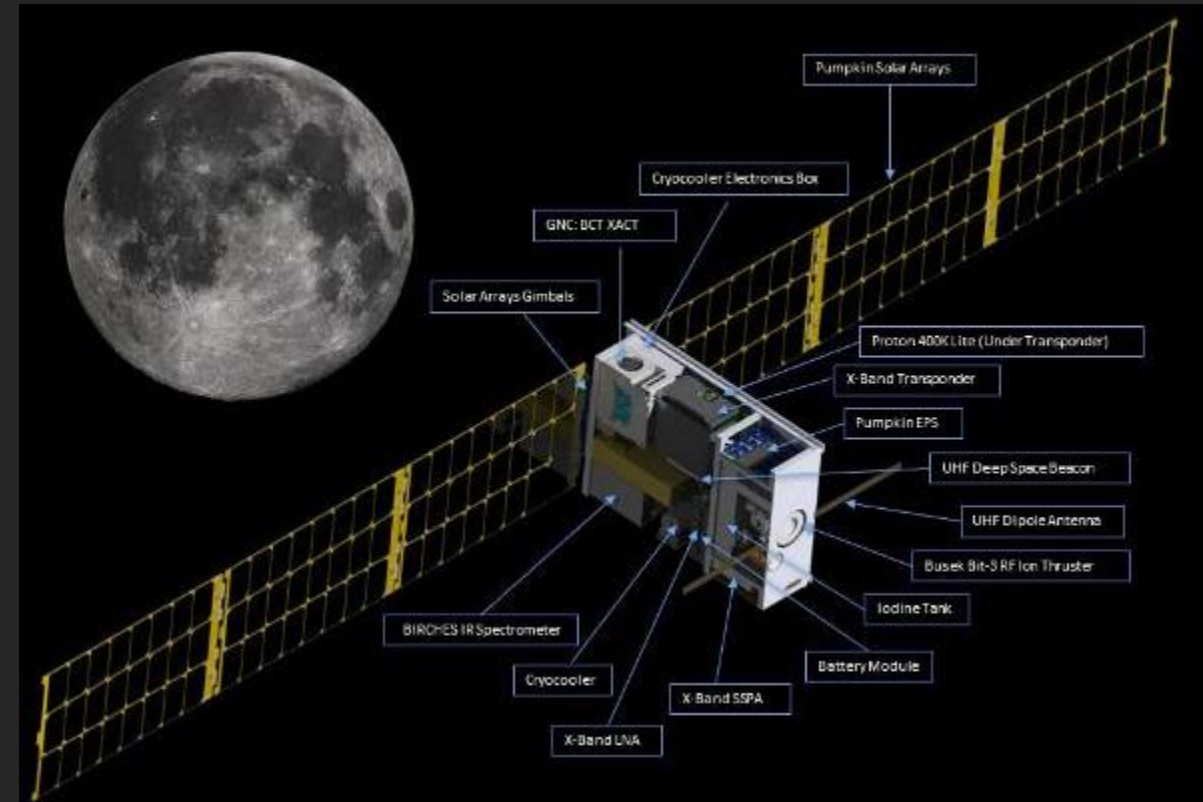


Why is this project important?

- The mission goal is to prospect for water in ice, liquid, and vapor forms and other lunar volatiles from a highly inclined lunar orbit (100 km perilune) using NASA GSFC's BIRCHES infrared (IR) spectrometer: a miniaturized version of the instrument used on OSIRIS REX: OVIERS.
- Potentially lends insight into the location and transport physics of water on the Moon in support of future Human Exploration.

Project Objectives

- Prospect for water in ice, liquid, and vapor forms and other lunar volatiles from a low-perigee, inclined lunar orbit using NASA GSFC's BIRCHES - IR spectrometer.
- Demonstrates enabling technologies for exploration of the Solar System with small satellites, including an innovative RF Ion engine combined with a low energy trajectory to achieve lunar capture. The Busek BIT-3 uses solid-state iodine as the propellant generating significant Δv (1.3 km/s)
- Precision Ranging HW and Processes
- Operate in a near rectilinear halo orbit (NRHO) around the Moon

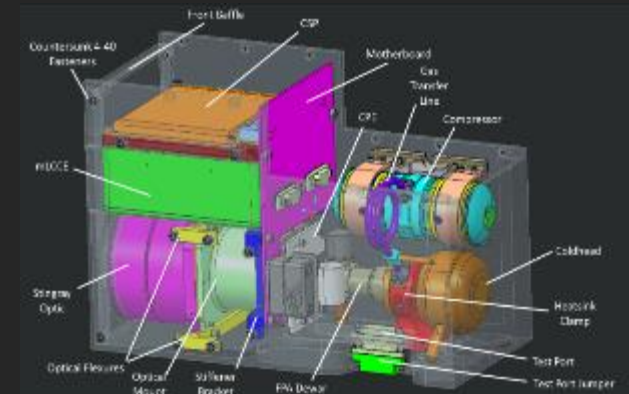
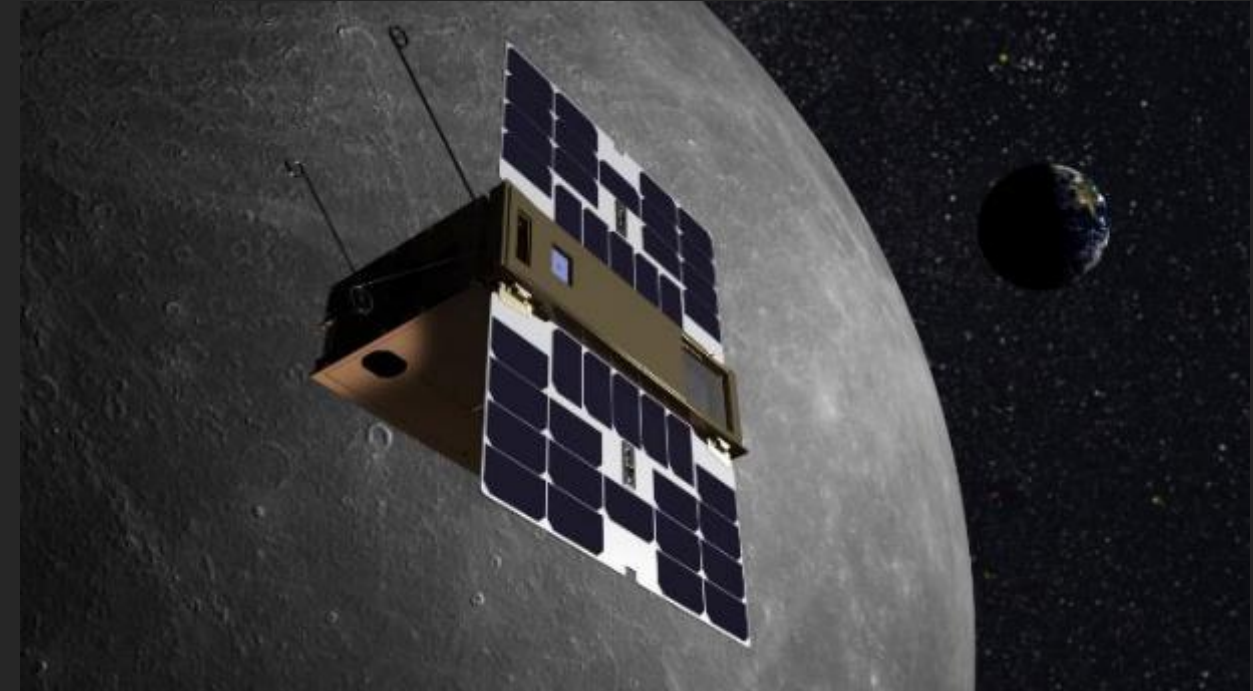


Why is this project important?

- LunIR will observe the lunar surface and characterize things like material composition, thermal signatures and future potential landing sites. What that translates to at its core? Looking for water on the moon!
- LunIR will accomplish its mission by completing a flyby of the Moon. The spacecraft will continue then collecting data to address NASA's knowledge gaps related to transit and long-duration exploration to Mars and beyond.

Project Objectives

- Pathfinder small satellite mission hosting a mid-wave Infra-Red (MWIR) sensor. During lunar flyby, LunIR will collect and downlink surface imagery. The MWIR sensor system includes an integrated micro-cryocooler and a high temperature nBn-based 1 Megapixel focal plane.
- LunIR hosts a visible wavelength camera that will be used for on-board navigation processing using the moon
- Data from both will be used for post-processing applicability toward a low Size, Weight and Power (SWaP) common sensor suite for relative navigation.





Why is this project important?

- Serves as a test-case for other non-NASA ground stations to provide auxiliary deep space navigation and tracking support for small spacecraft missions.
- Ground segment support for Artemis, Moon to Mars, and Beyond!
- Provides operational capability to support Artemis 1 CubeSat missions in the 2021 timeframe:

Artemis Missions Supported by DSS-17 at MSU:			
Lunar IceCube	LunIR	CAPSTONE	LunaH Map
BioSentinel	NEA Scout	Lunar Flashlight	CuSP

Project Objectives

- Expand DSN capabilities by utilizing non-NASA assets to provide communication and navigation services to small spacecraft missions to the Moon and inner solar system
- Provide operational capability to support Artemis SmallSat missions
- Enable interplanetary research with small spacecraft platforms

Enabling interplanetary research with small spacecraft platforms

MarCO Demonstrations:

- Downlink Using X-Band Feed and DSN Equipment
- Downlink Using X-Band Feed and MarCO Receiver System
- OMSPA Using X-Band Feed and Custom SDR-based Multiple Receiver System

First Opportunistic Multiple Spacecraft Per Antenna (OMSPA) Demonstration with a CubeSat

Develops an operational capability to support Artemis-1 SmallSat missions

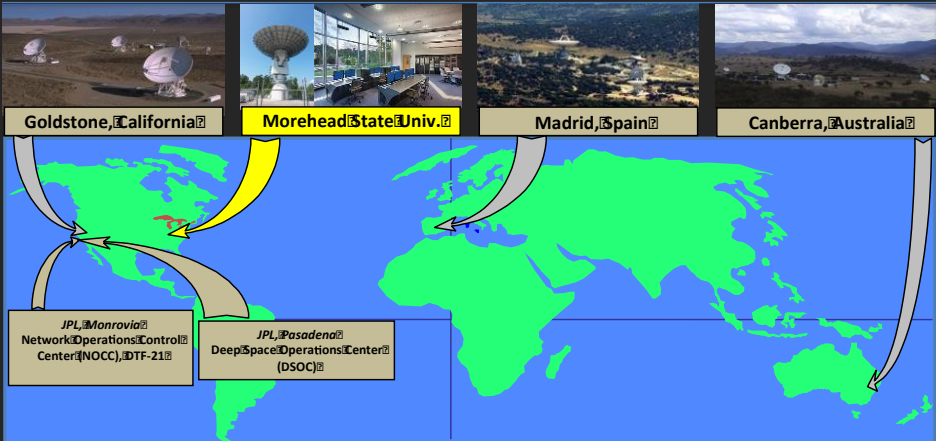
LRO Demonstrations:

- Routinely Tracking LRO at S-Band
- Intermediate Frequency (IF) Systems and DSN Downlink Equipment (DCO, DTT) Verified
- LRO Telemetry (Blocks Sent Directly from DSS-17 to JPL DSOC over the NASA Mission Backbone- verifying DSS-17 Signal Path)

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.

First 5 Demodulated Frames from MarCO OMSPA Demonstration on May 6, 2018 from DSS-17
D: Abraham, Z. Towfic, S. Finley (JPL)
C: Cooper, M. Stratton, R. Kirk (Morehead State)

Mission Ops Center at MSU

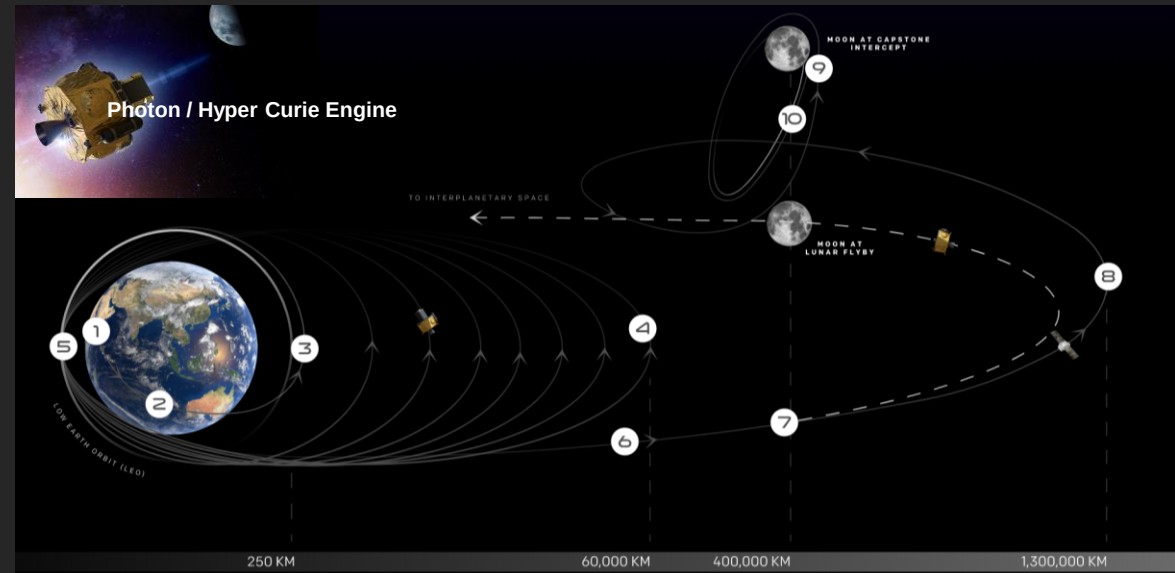
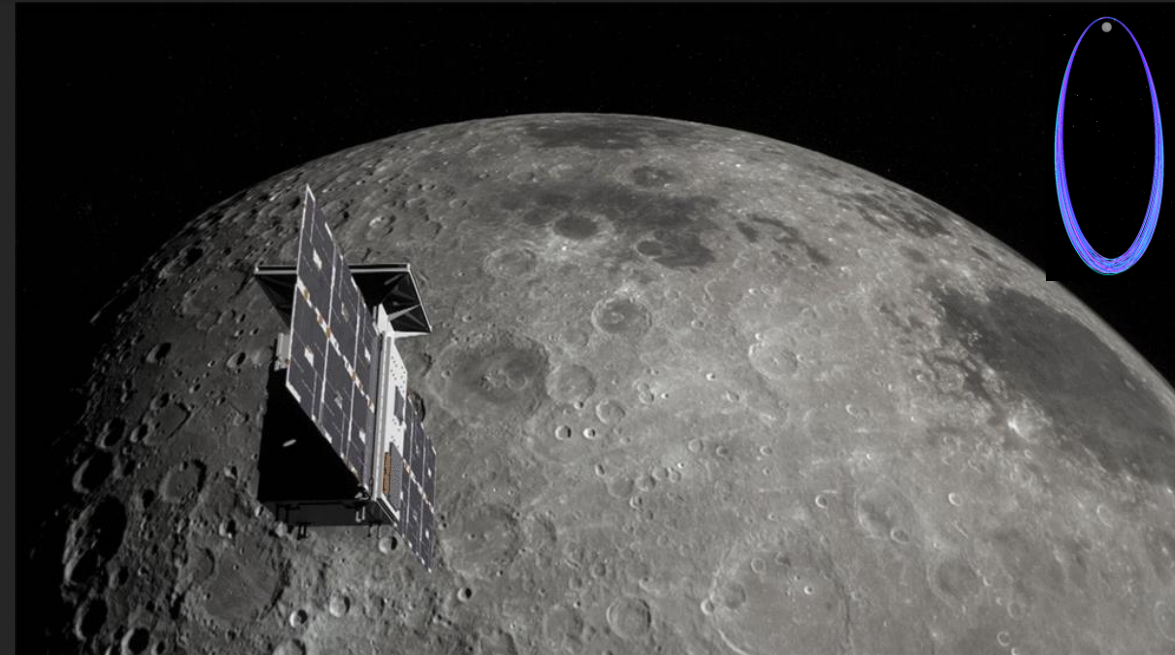


Why is this project important?

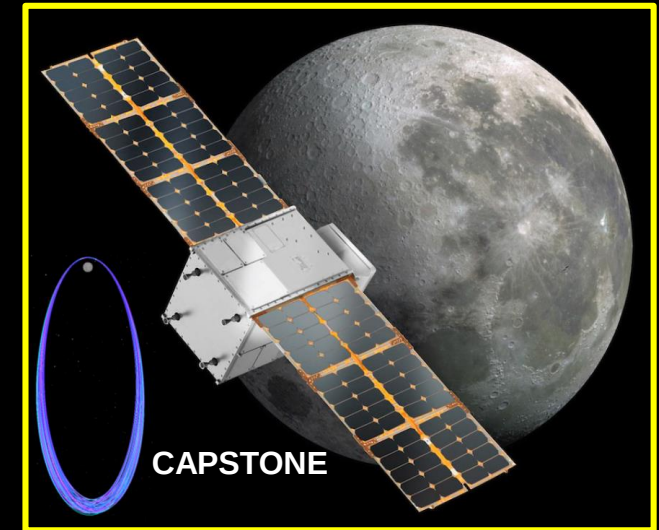
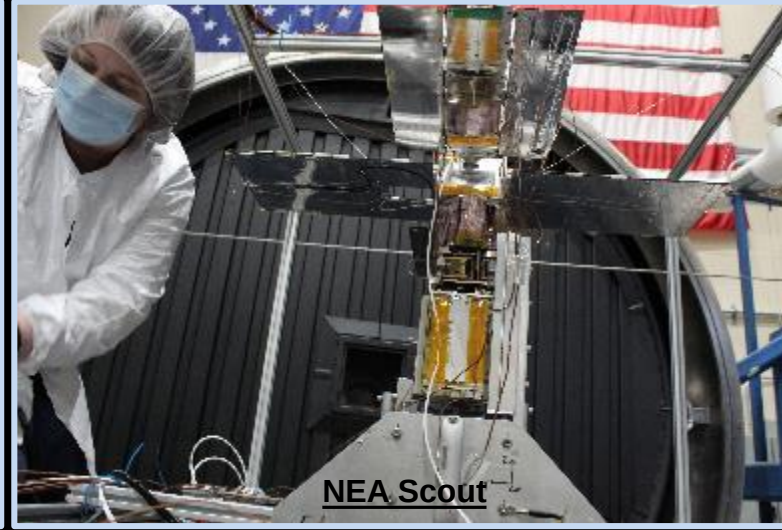
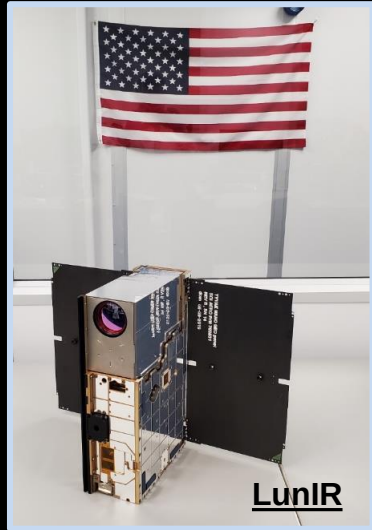
- The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) is expected to be the first spacecraft to operate in a near rectilinear halo orbit (NRHO) around the Moon. In this unique orbit, the CubeSat will rotate together with the Moon as it orbits Earth and will pass as close as 1,000 miles and as far as 43,500 miles from the lunar surface.
- Following a three-month trip to the Moon, CAPSTONE will enter a near rectilinear halo orbit, which is a highly elliptical orbit over the Moon's poles, to verify its characteristics for future missions and conduct a navigation demonstration with NASA's Lunar Reconnaissance Orbiter.

Project Objectives

- Verify** the characteristics of a cis-lunar near rectilinear halo orbit NRHO/three-body Earth-Moon Operations for future spacecraft. Demonstrate entering and maintaining this unique orbit.
- Demonstrate** the Cislunar Autonomous Positioning System's (**CAPS**) ability to generate spacecraft-to-spacecraft navigation services that allow future spacecraft to determine their location relative to the Moon without relying exclusively on tracking from Earth. CAPSTONE spacecraft **communicates** with LRO to **demonstrate** relative measurements and components of autonomous navigation system
- Pathfinder – Document operational experience and lessons learned for insertion into and operation in a lunar NRHO. Mitigate technical risks of NRHO operations and validate navigation and stationkeeping analysis and simulation and directly transfer that experience and lessons to **inform NASA Gateway** planning activities.
- Demonstrate **one way ranging** using chip scale atomic clock (CSAC) integrated with IRIS radio.



AES Artemis Small Spacecraft Missions – Ready!



Deep Space Station 17

Enabling interplanetary research with small spacecraft platforms

MarCO Demonstrations:

- Downlink Using X-Band Feed and DSN Equipment
- Downlink Using X-Band Feed and MarCO Receiver System
- OMSPA Using X-Band Feed and Custom SDR-based Multiple Receiver System

First Opportunistic Multiple Spacecraft Per Antenna (OMSPA) Demonstration with a CubeSat

LRO Demonstrations:

- Routinely Tracking LRO at S-band
- Intermediate Frequency (IF) Systems and DSN Downlink Equipment (DSO, DTT) Verified
- LRO Internally Blocks SDR Capacity from DSS-17 to JPL DSO over the NASA Mission Backbone - verifying DSS-17 Signal Path

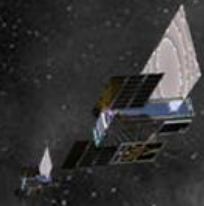
Develops an operational capability to support Artemis-1 SmallSat missions

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.

First 5 Demodulated Frames from MarCO OMSPA Demonstration on May 6, 2018 from DSS-17
D. Alvarado, Z. Toetic, S. Folley (JPL)
C. Conrad, M. Stettin, R. Alric (Northwest State)

Mission Ops Center at MSU

HEOMD/AES Deep Space SmallSats: Deep Space Station 17 (DSS-17)

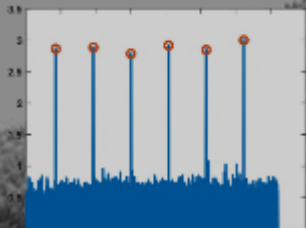


Enabling interplanetary research
with small spacecraft platforms

MarCO Demonstrations:

- Downlink Using X-Band Feed and DSN Equipment
- Downlink Using X-Band Feed and MarCO Receiver System
- OMSPA Using X-Band Feed and Custom SDR-based Multiple Receiver System

First Opportunistic Multiple Spacecraft Per Antenna (OMSPA) Demonstration with a CubeSat



First 5 Demodulated Frames from MarCO OMSPA
Demonstration on May 6, 2018 from DSS-17,

D. Abraham, Z. Towfic, S. Finley (JPL)

C. Conner, M. Stratton, R. Kroll (Morehead State)

Develops an operational
capability to support Artemis-1
SmallSat missions

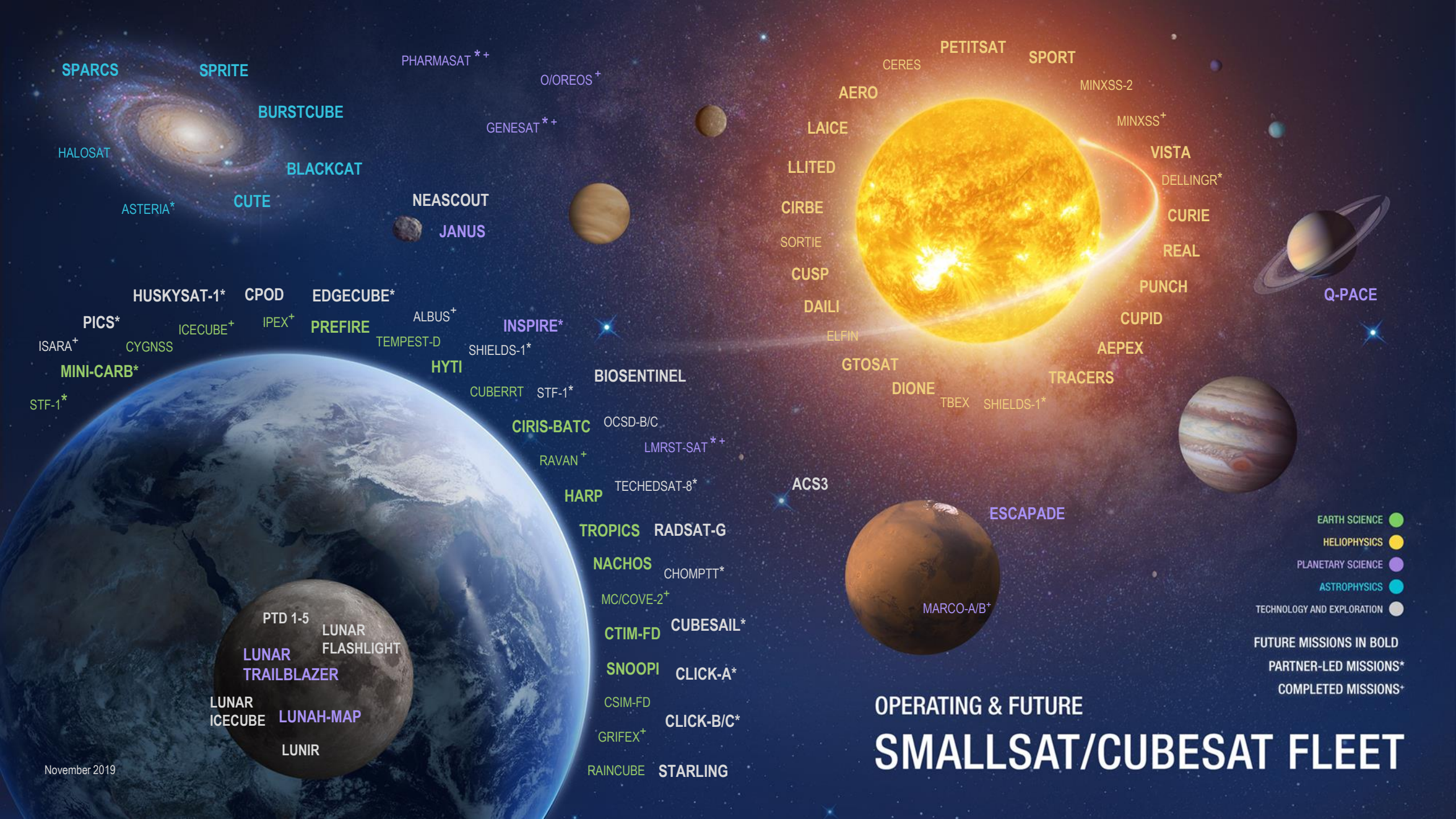
Expands DSN capabilities by utilizing non-NASA
assets to provide communication and navigation
services to small spacecraft missions to the
Moon and inner solar system.

LRO Demonstrations:

- Routinely Tracking LRO at S-band
- Intermediate Frequency (IF) Systems and DSN Downlink Equipment (DCD, DTT) Verified
- LRO Telemetry Blocks Sent Directly from DSS-17 to JPL DSOC over the NASA Mission Backbone- verifying DSS-17 Signal Path



Mission Ops Center at MSU



SPARCS

SPRITE

PHARMASAT^{**}

O/OREOS⁺

PETITSAT

SPORT

BURSTCUBE

HALOSAT

BLACKCAT

GENESAT^{**}

AERO

MINXSS-2

ASTERIA^{*}

CUTE

NEASCOUT

JANUS

LAICE

MINXSS⁺

VISTA

DELLINGR^{*}

LLITED

CIRBE

SORTIE

CUSP

DAILI

ELFIN

GTOSAT

DIONE

TBEX

SHIELDS-1^{*}

CURIE

REAL

PUNCH

CUPID

TRACERS

AEPEX

Q-PACE

HUSKYSAT-1^{*}

CPOD

EDGE CUBE^{*}

PICS^{*}

ICECUBE⁺

IPEX⁺

PREFIRE

ALBUS⁺

INSPIRE^{*}

TEMPEST-D

SHIELDS-1^{*}

HYTI

CUBERRT

STF-1^{*}

BIOSENTINEL

OCSD-B/C

LMRST-SAT^{**}

CIRIS-BATC

RAVAN⁺

TECHDSAT-8^{*}

HARP

ACS3

ESCAPADE

TROPICS

RADSAT-G

NACHOS

CHOMPTT^{*}

MC/COVE-2⁺

CTIM-FD

CUBESAIL^{*}

SNOOPI

CLICK-A^{*}

CSIM-FD

CLICK-B/C^{*}

GRIFEX⁺

RAIN CUBE

STARLING

PTD 1-5

LUNAR

FLASHLIGHT

LUNAR

TRAILBLAZER

LUNAR

ICECUBE

LUNAH-MAP

LUNIR

EARTH SCIENCE

HELIOPHYSICS

PLANETARY SCIENCE

ASTROPHYSICS

TECHNOLOGY AND EXPLORATION

FUTURE MISSIONS IN BOLD

PARTNER-LED MISSIONS^{*}

COMPLETED MISSIONS⁺

OPERATING & FUTURE

SMALLSAT/CUBESAT FLEET

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

Small Spacecraft Integrated Strategic Plan



Small Spacecraft Virtual Institute: <https://www.nasa.gov/smallsat-institute>

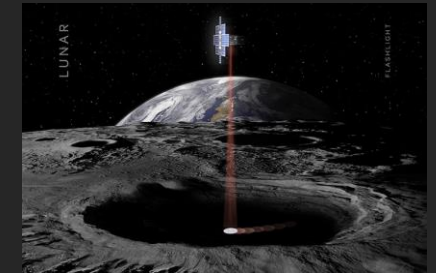
SSCG Focus Areas

- Strategy and Implementation
- Safety, Mission Assurance, & Reliability
- Services and Infrastructure
- Launch Accommodation and Rideshare
- Cybersecurity and Enterprise Protection
- Commercial Partnerships & New Space
- International Relationships and Outreach



Science

New Observation Methods



Exploration

Strategic Knowledge Gaps



Technology

Spacecraft Subsystems



NASA

Thank you!

EXPLORE
with us



You are the Artemis Generation - Connect with us



Andres Martinez

Program Executive, Small Spacecrafts,
Advanced Exploration Systems division,
Human Exploration and Operations Mission
Directorate at NASA Headquarters in
Washington, D.C.



[@NASAArtemis](https://twitter.com/NASAArtemis)



[@NASAArtemis](https://www.instagram.com/NASAArtemis)



[@NASAArtemis](https://www.facebook.com/NASAArtemis)

Learn more about Artemis at nasa.gov/artemis



blogs.nasa.gov/artemis

Sign up for NASA updates at nasa.gov/subscribe

Thank you!