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Associate Administrator
@Dr_ThomasZ

July 25, 2017

NEXUS OF SCIENCE & HUMAN EXPLORATION

INTEGRATED PORTFOLIO
SMD has a high impact, integrated and multi-faceted portfolio

COMBINED EFFORT ACROSS TOPICAL AREAS
SMD science discipline areas interrelate to HEOMD with many synergies

HUMAN ATTENDANT SCIENCE FUTURE OPPORTUNITIES
SMD utilizes ISS and will identify science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure

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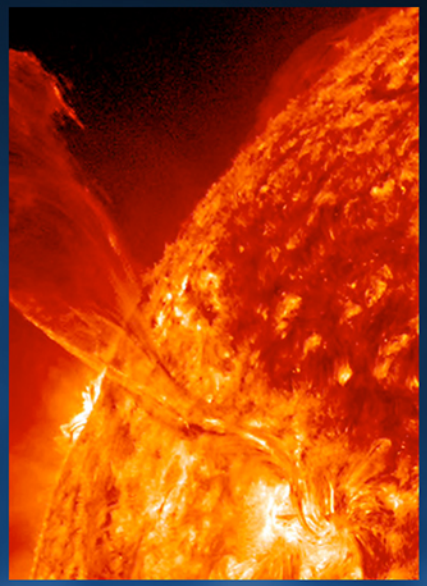
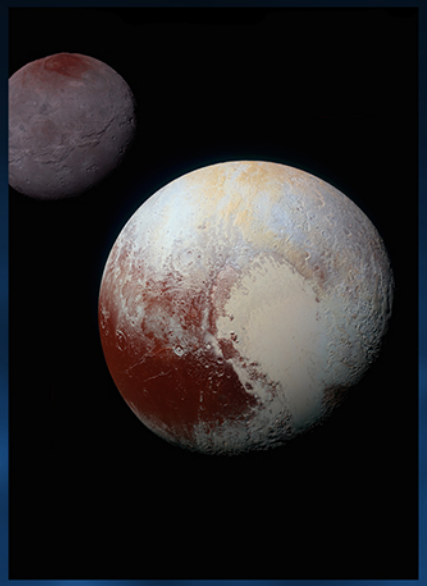
NASA SCIENCE MISSION DIRECTORATE



HELIOPHYSICS

EARTH SCIENCE



PLANETARY SCIENCE

ASTROPHYSICS

Innovation & Discovery

An Integrated Program Enabling Great Science

SCIENCE BY THE NUMBERS

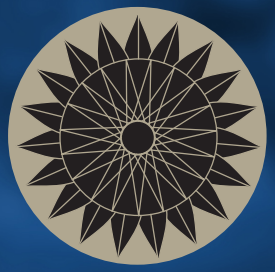
Spacecraft
104 missions
87 spacecraft

CubeSats
17 science missions
11 technology demonstrations

Balloon Payloads
13 science payloads
13 piggyback/ student payloads

Sounding Rocket Flights
14 science missions
3 technology/ student missions

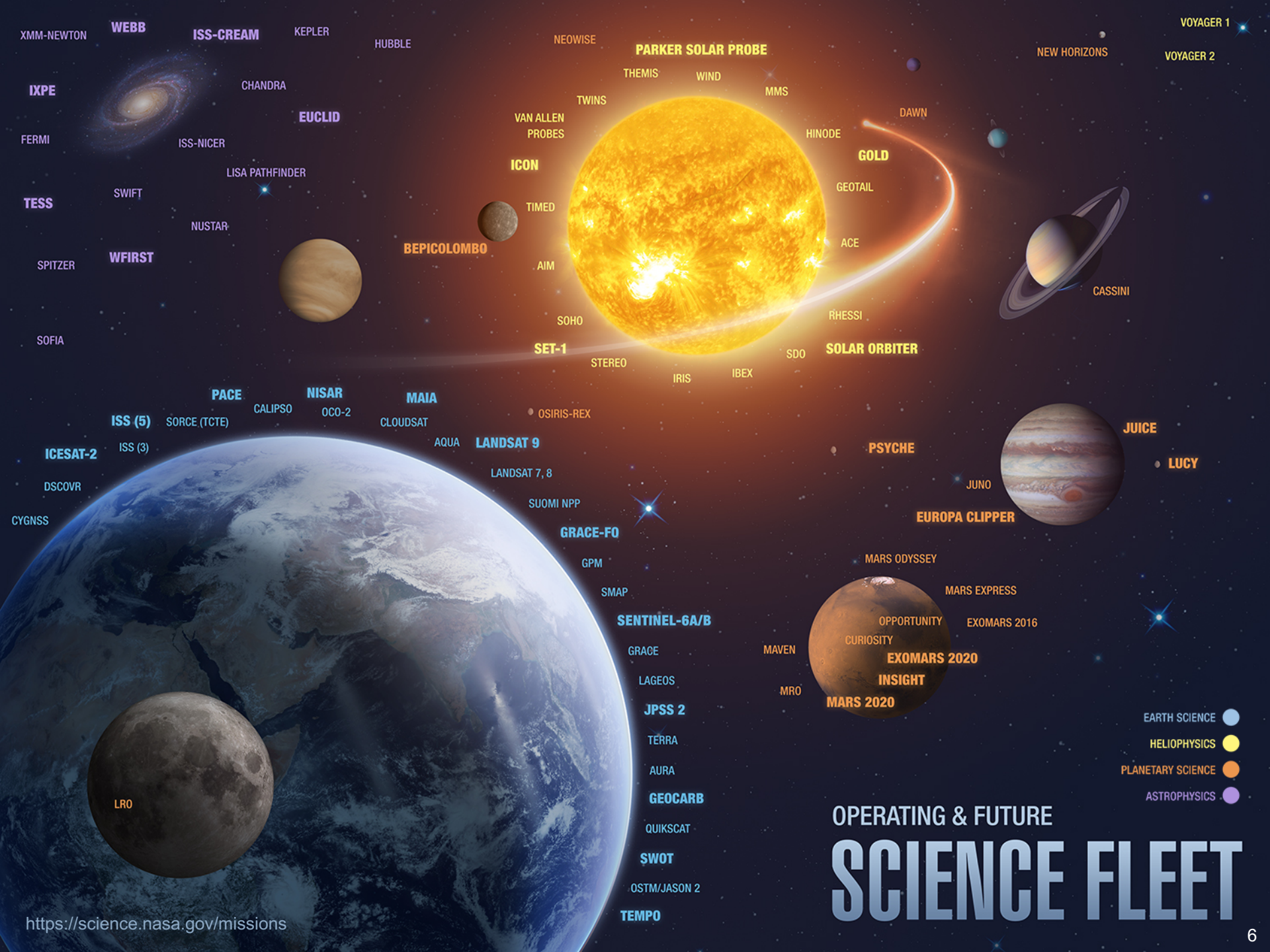
Earth-Based Investigations
25 major airborne missions
8 global networks



Technology Development
~$400M invested annually

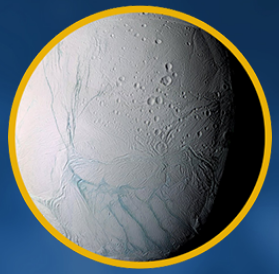
Research
10,000+ U.S. scientists funded
3,000+ competitively selected awards
~$600M awarded annually

As of June 7, 2017

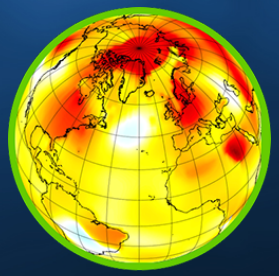

XMM-NEWTON
WEBB
ISS-CREAM
KEPLER
HUBBLE
NEOWISE
PARKER SOLAR PROBE
VOYAGER 1
VOYAGER 2
NEW HORIZONS
IXPE
CHANDRA
THEMIS
WIND
MMS
TWINS
VAN ALLEN PROBES
EUCLID
DAWN
HINODE
GOLD
FERMI
ISS-NICER
ICON
LISA PATHFINDER
GEOTAIL
SWIFT
TESS
TIMED
NUSTAR
BEPICOLOMBO
ACE
SPITZER
WFIRST
AIM
CASSINI
SOHO
RHESSI
SOFIA
SET-1
SDO
SOLAR ORBITER
STEREO
IRIS
IBEX
PACE
NISAR
MAIA
CALIPSO
OCO-2
CLOUDSAT
OSIRIS-REX
ISS (5)
SORCE (TCTE)
JUICE
ICESAT-2
ISS (3)
AQUA
LANDSAT 9
PSYCHE
LUCY
DSCOVR
LANDSAT 7, 8
JUNO
SUOMI NPP
CYGNSS
EUROPA CLIPPER
GRACE-FO
MARS ODYSSEY
GPM
MARS EXPRESS
SMAP
OPPORTUNITY
EXOMARS 2016
SENTINEL-6A/B
CURIOSITY
GRACE
MAVEN
EXOMARS 2020
LAGEOS
INSIGHT
MRO
JPSS 2
MARS 2020
LRO
TERRA
AURA
GEOCARB
QUIKSCAT
SWOT
OSTM/JASON 2
TEMPO
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
OPERATING & FUTURE
SCIENCE FLEET
https://science.nasa.gov/missions

KEY SCIENCE THEMES

Discovering the Secrets of the Universe



Searching for Life Elsewhere

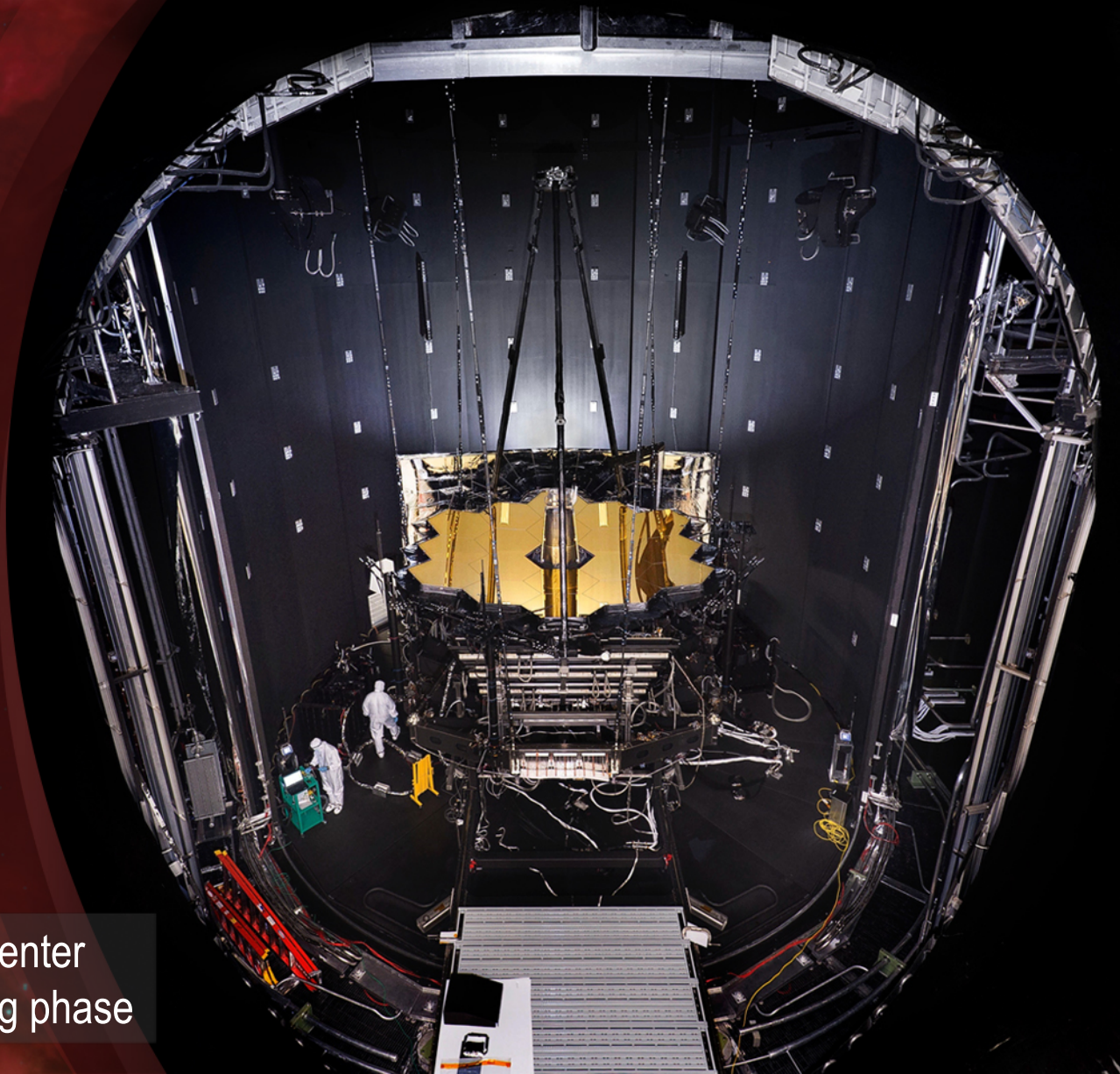


Safeguarding and Improving Life on Earth

DISCOVERING THE SECRETS OF THE UNIVERSE

Webb

The James Webb
Space Telescope



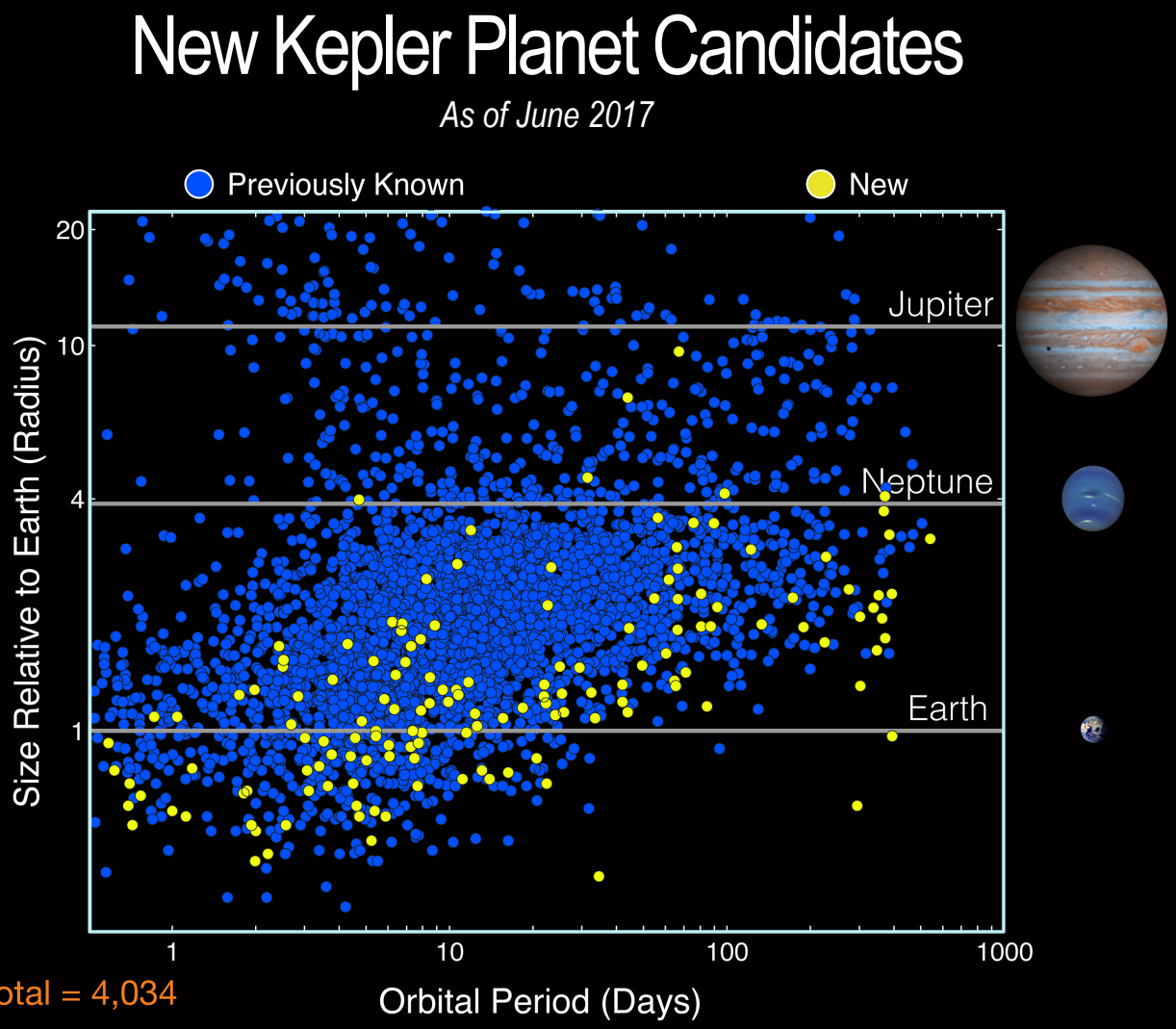
WEBB at Johnson Space Center
for cryogenic-vacuum testing phase

DISCOVERING THE SECRETS OF THE UNIVERSE

Juno

Detecting Turbulent Cyclones
on Jupiter's South Pole

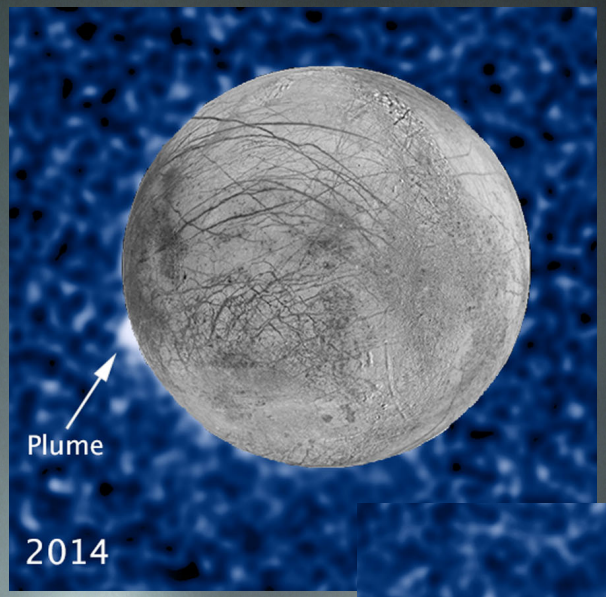
SEARCHING FOR LIFE ELSEWHERE



SEARCHING FOR LIFE ELSEWHERE

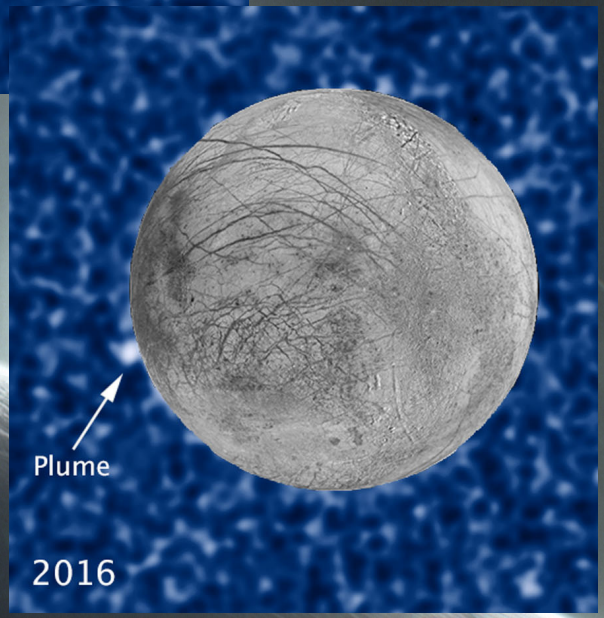
Cassini

Diving through plumes from Saturn's Moon Enceladus



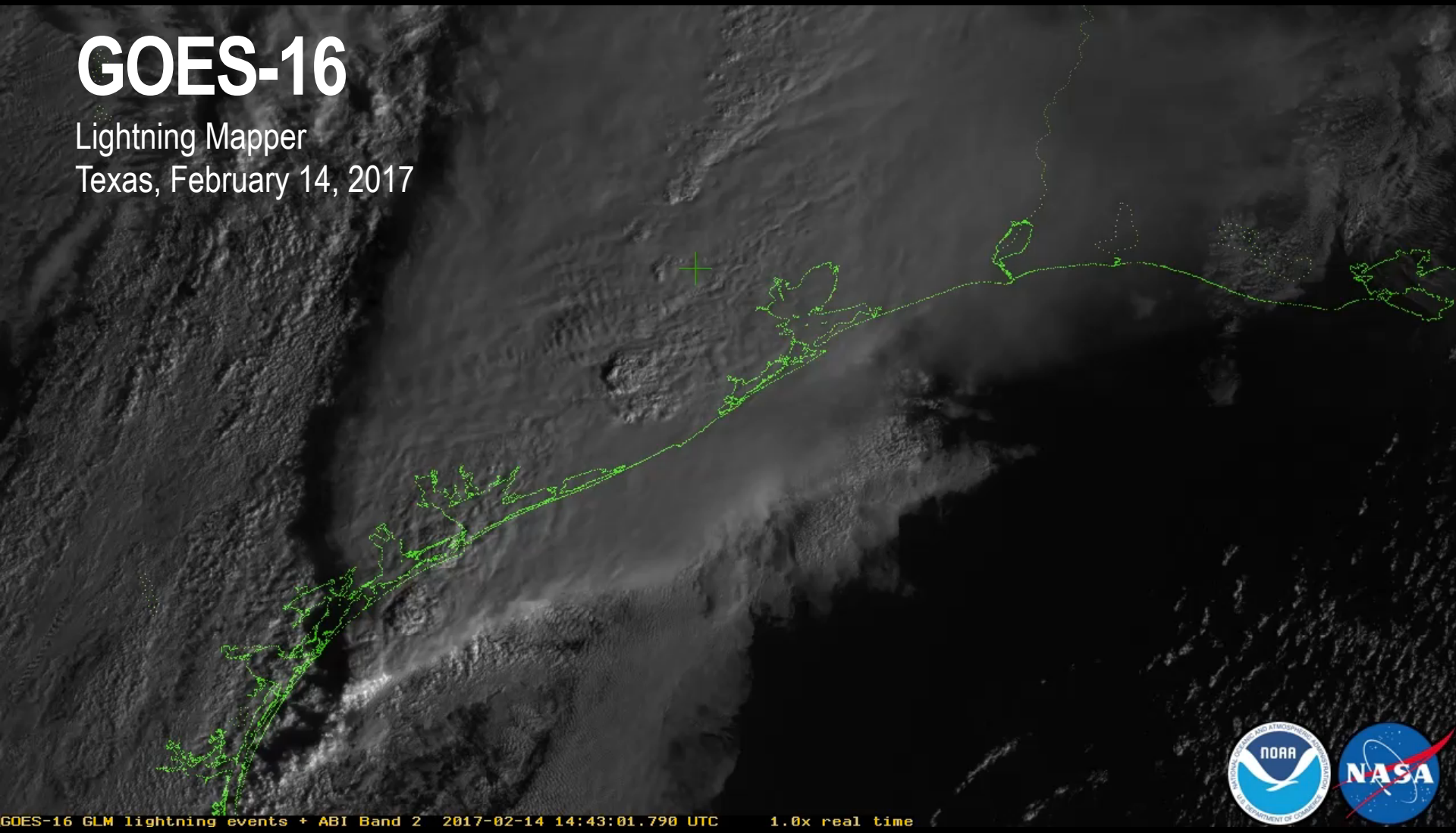
Hubble

Plumes on Jupiter's Moon Europa



Artistic Rendering

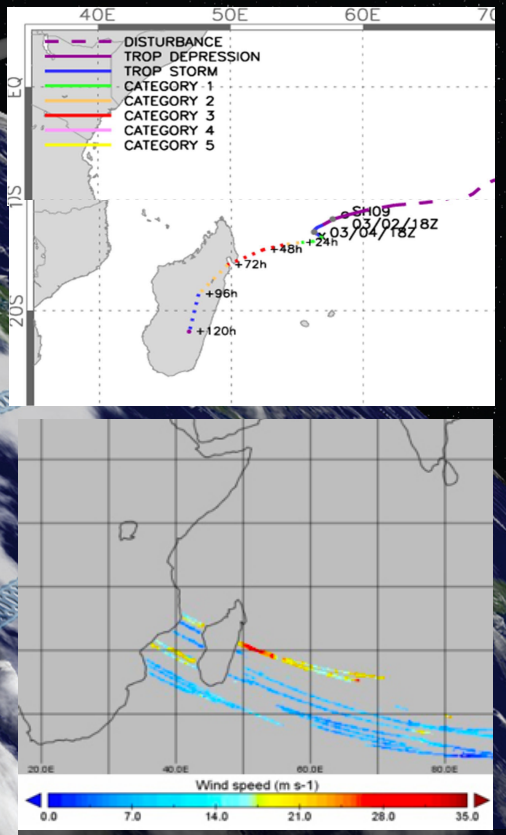
SAFEGUARDING AND IMPROVING LIFE ON EARTH



SAFEGUARDING AND IMPROVING LIFE ON EARTH

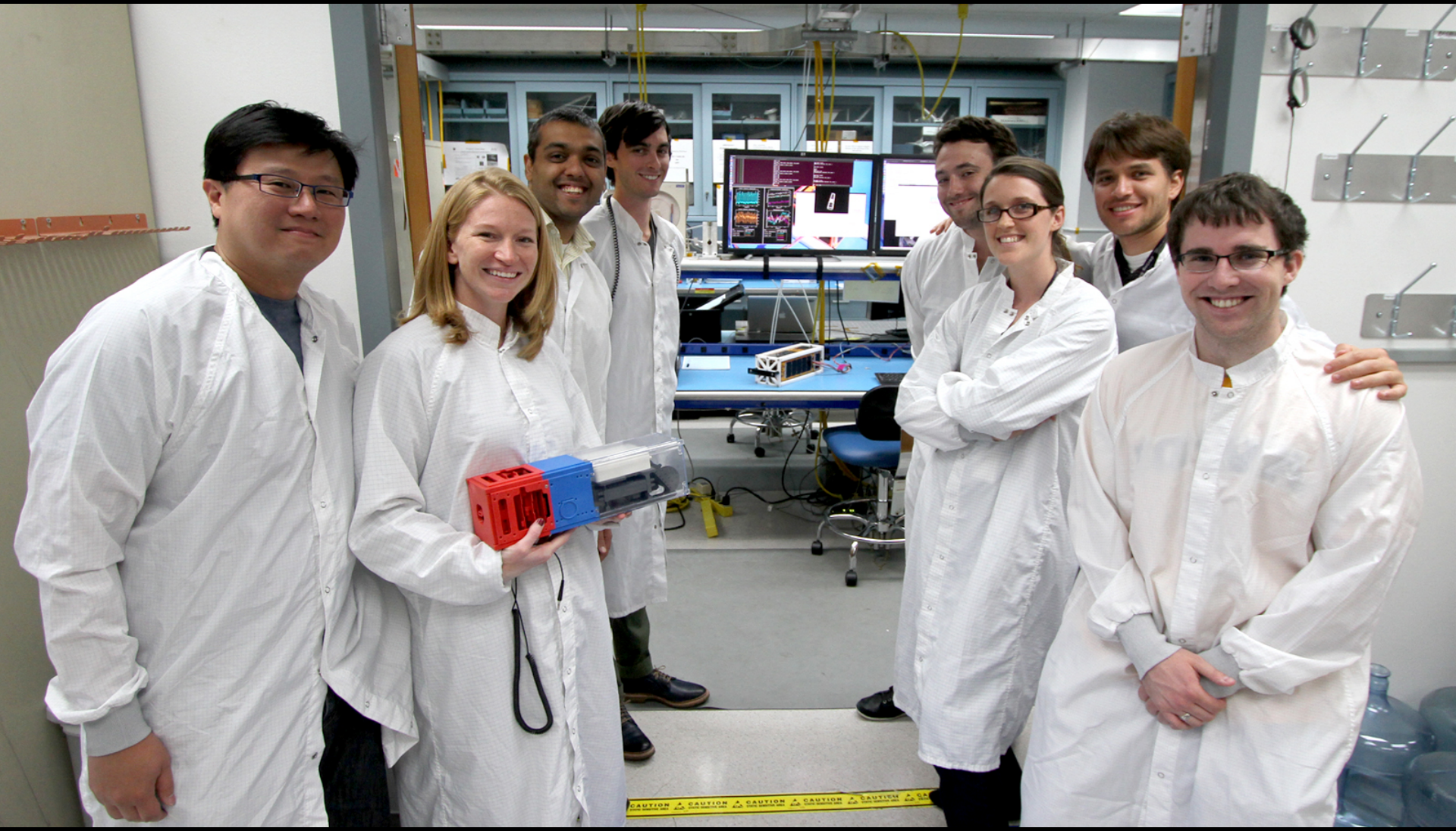
CYGNSS

Measuring the strength of hurricanes



Storm Track and CYGNSS Wind speed measurements from overpasses of Tropical Cyclone Enawo, March 2017

CUBESATS/SMALLSATS: TRAINING OPPORTUNITY



Credit: NASA/JPL-Caltech

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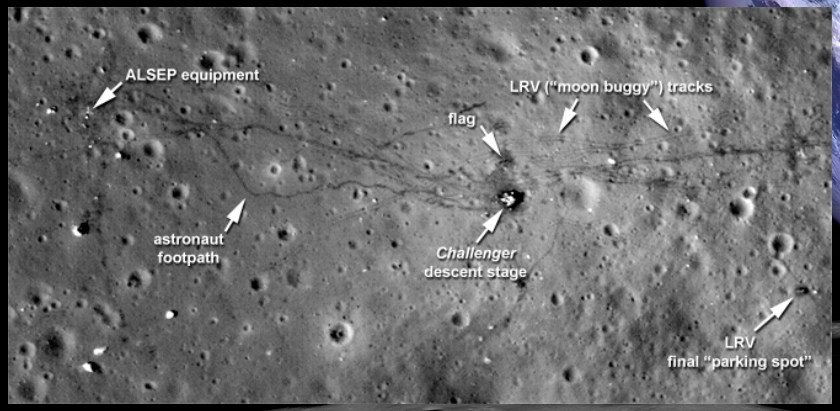
COMBINED EFFORT ACROSS TOPICAL AREAS

- **Lunar Reconnaissance Orbiter**
- **Mars Exploration Program**
  - Mars 2020 Partnership – borne out of current Mars strategy discussions
    - Partnership on HEO/Space Technology Mission Directorate (STMD) instrumentation - Mars EDL Instrumentation (MEDLI-2), Mars Oxygen ISRU Experiment (MOXIE), and Mars Environmental Dynamics Analyzer (MEDA)
  - Working together to study potential future landing sites for crewed missions to Mars
- **Studying space weather and the effect of space radiation on astronauts**
- **Deep Space Optical Communications (DSOC)**
- **Other areas of collaboration**
  - Launch Services
  - Space Communications and Navigation (SCaN)
  - Planetary Protection

LUNAR RECONNAISSANCE ORBITER

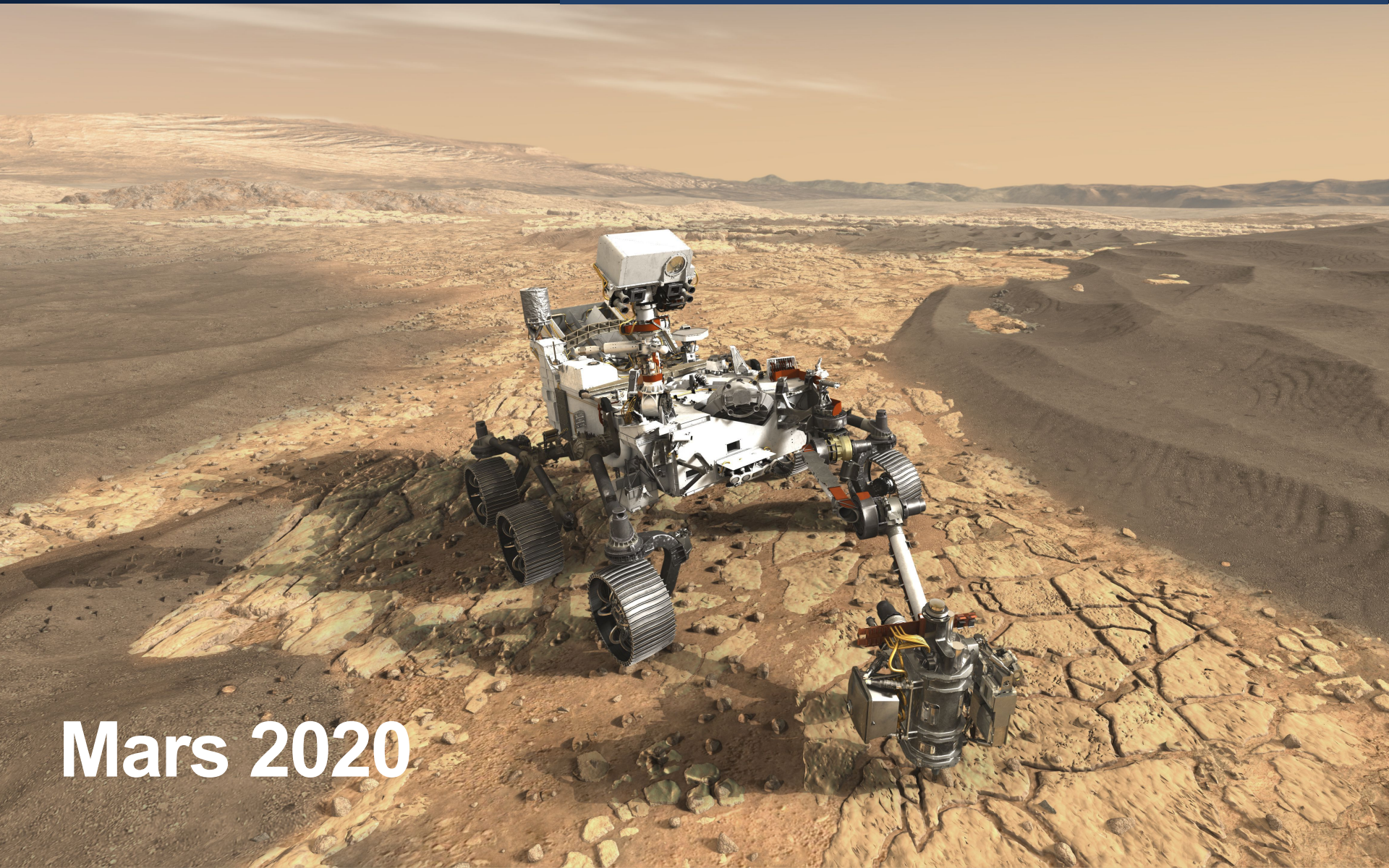


LRO's look at the Apollo 17 Landing Site

LRO

In orbit around the moon

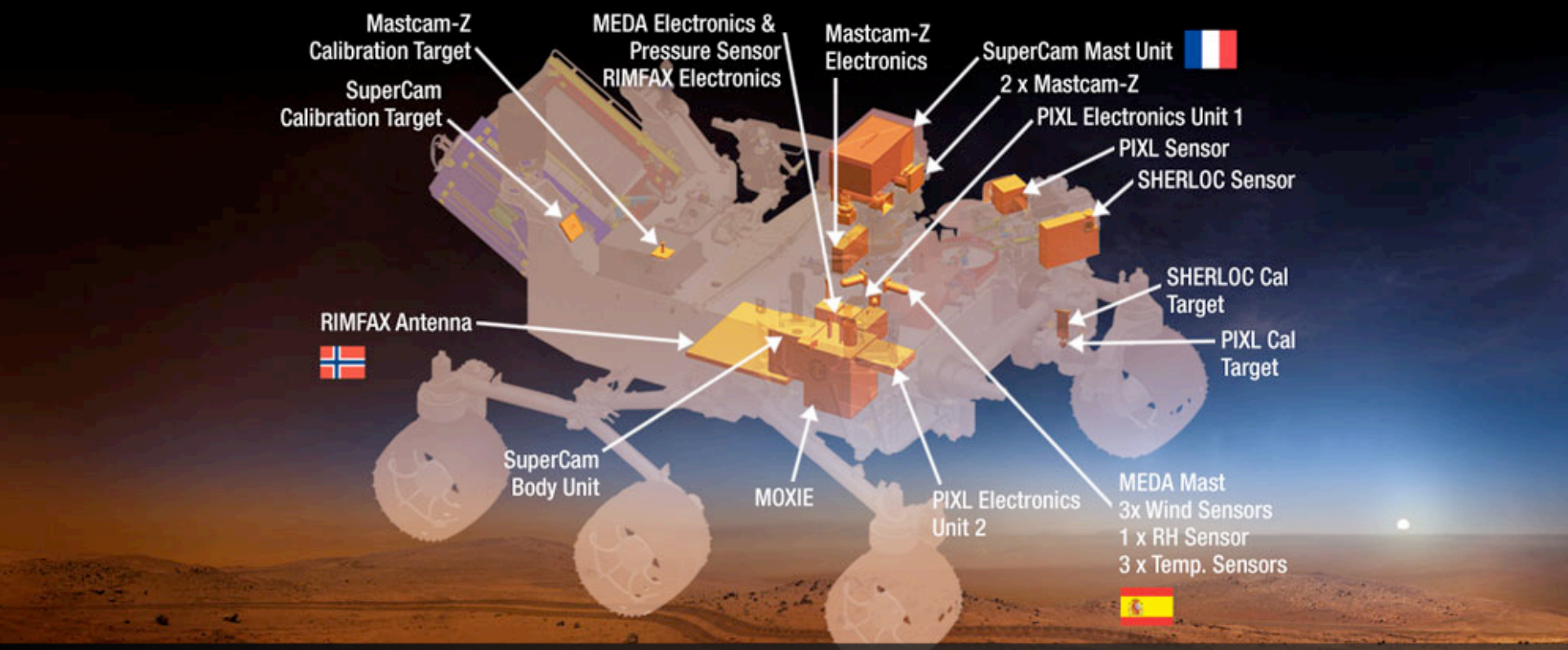
MARS EXPLORATION PROGRAM



Mars 2020

MARS ATMOSPHERIC CONDITIONS

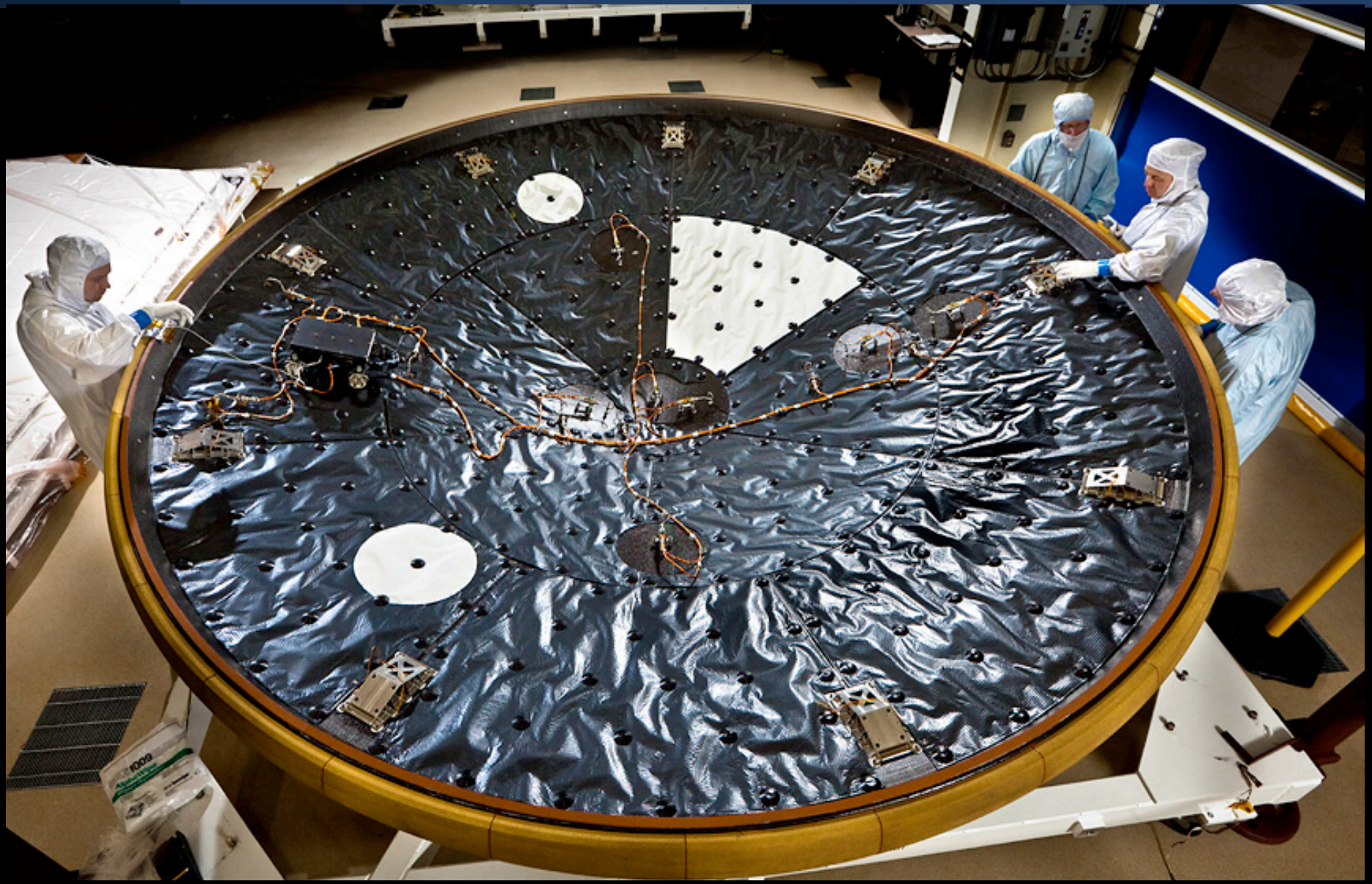
MARS ROVER 2020



MOXIE demonstrate the production of oxygen from the Mars atmosphere to enable in-situ propellant production for future human missions

MEDA surface weather station contributed by Spain that will measure temperature, pressure, relative humidity, winds, and dust.

ADDRESSING STRATEGIC KNOWLEDGE GAPS

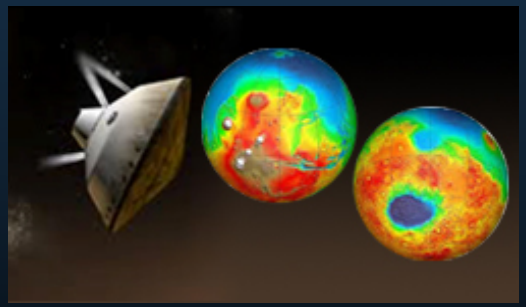


MARS SCIENCE & EXPLORATION: LEARNED

ORBITAL ENVIRONMENT AND OPERATIONS

- Deep space navigation
- Orbit transfer near low-gravity bodies
- Gravity assist
- Aero-braking
- Gravitational potential
- Mars' moons characteristics
- ISRU potential

CAPTURE, EDL & ASCENT



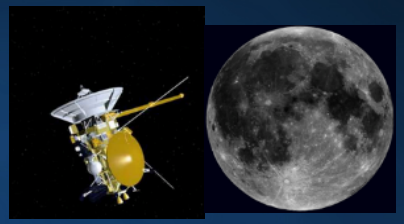
- Spatial/temporal temperature variability
- Density and composition variability
- Storm structure, duration and intensity
- 1 mT payload
- ~10 km accuracy

SURFACE OPERATIONS

- Water once flowed and was stable
- Global topography: elevation and boulder distributions
- Remnant magnetic field
- Dust impacts on solar power/ mechanisms
- Radiation dose
- Global resource distribution
- Relay strategies, operations cadence

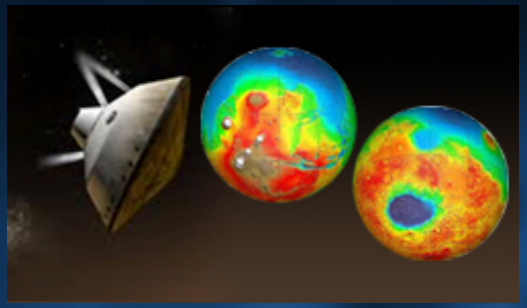
MARS SCIENCE & EXPLORATION: TO LEARN

ORBITAL ENVIRONMENT AND OPERATIONS



- Return flight from Mars to Earth
- Autonomous rendezvous & docking
- ISRU feasibility
- Resource characterization of Mars moons
- High-power SEP

CAPTURE, EDL & ASCENT

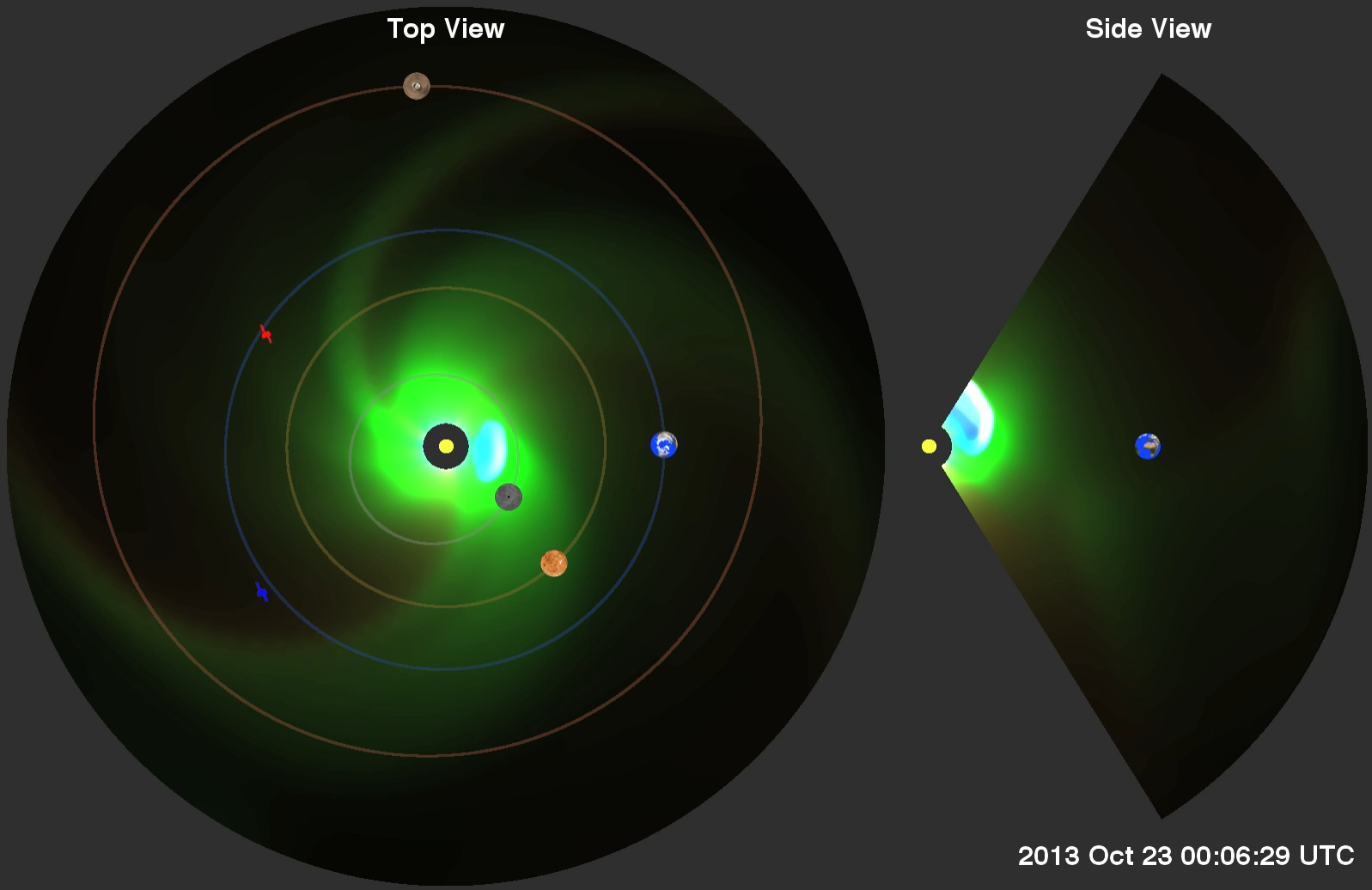


- Ascent from Mars
- Large mass EDL
- Precision EDL
- Aero-capture
- Site topography and roughness
- Long-term atmospheric variability

SURFACE OPERATIONS

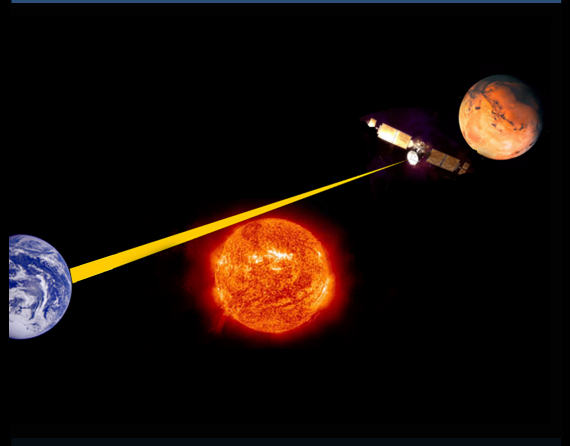
- Landing site resource survey
- Dust effects on human health, suits & seals
- Rad/ECLSS in Mars in environment
- Power sufficient for ISRU surface navigation

STUDYING SPACE WEATHER AND EFFECTS OF SPACE RADIATION ON ASTRONAUTS



CCMC model of multiple coronal mass ejections (CMEs)

FURTHERING DEEP SPACE COMMUNICATIONS

CONCEPT	TECHNOLOGY	IMPLEMENTATION
		
Psyche Mission	Deep Space Optical Communications (DSOC)	Next Generation Deep Space Missions

Enabling Technology *Technology demonstration of DSOC near Psyche*

Result *Greatly increasing communications bandwidth to enable more rapid data and information streaming*

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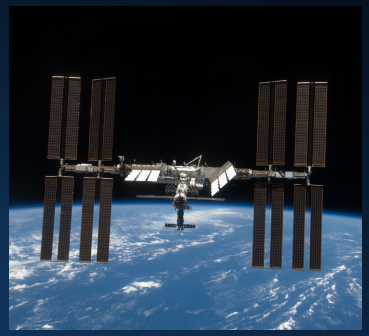
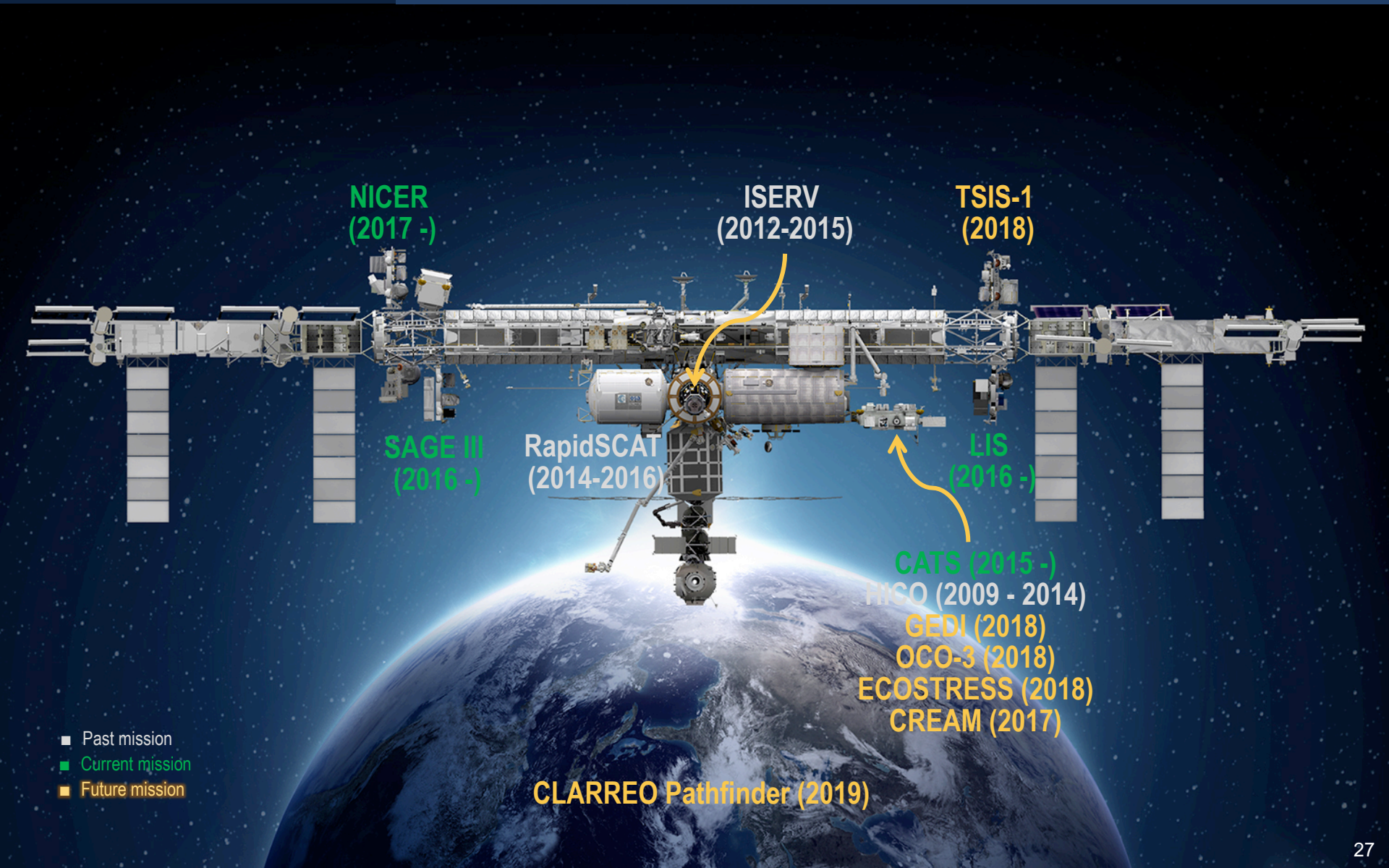


Science instruments on the International Space Station (ISS)

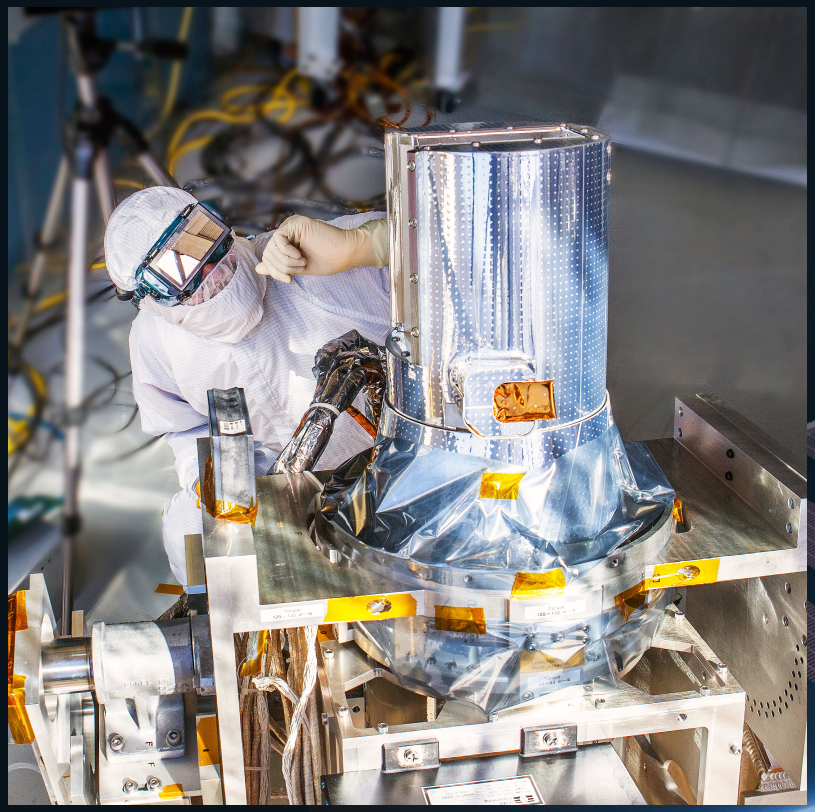
Space Launch System relevance to outer worlds (e.g. Europa)

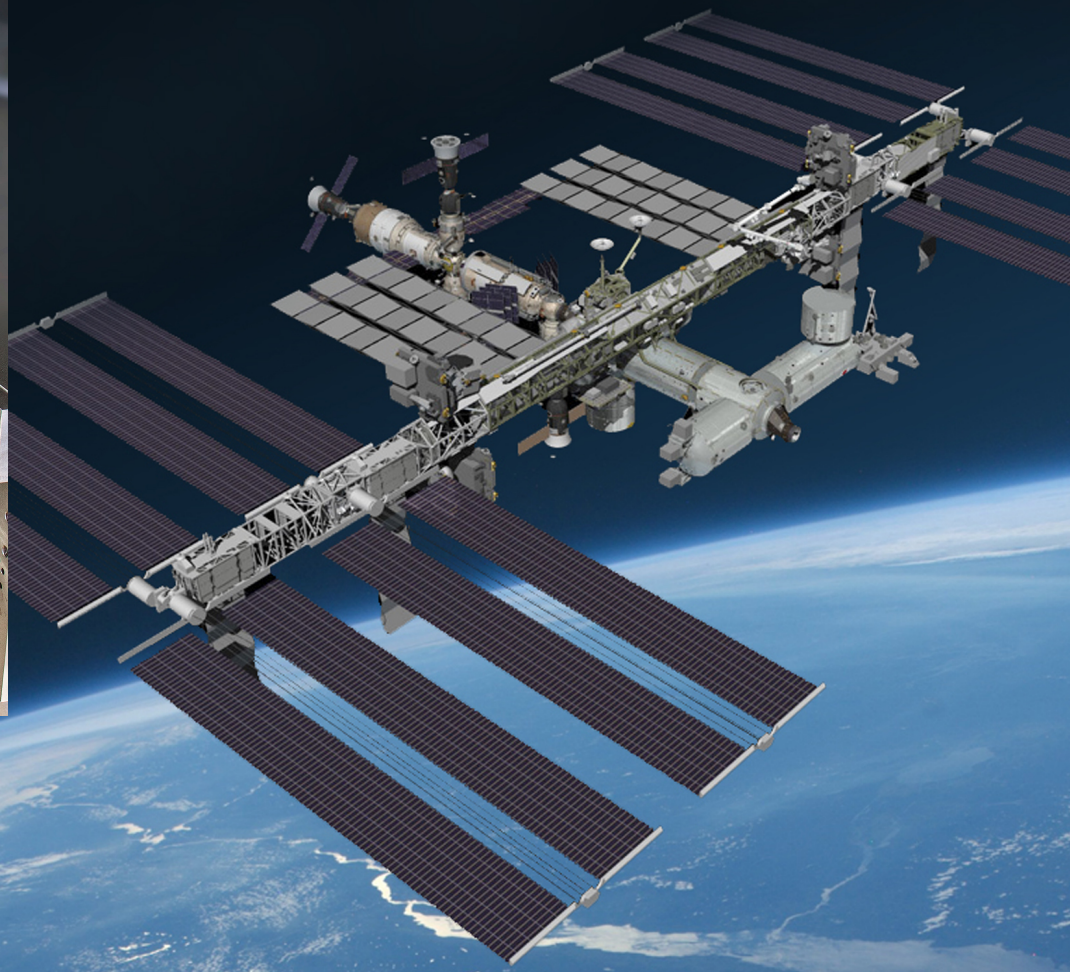
Potential collaboration on satellite and telescope assembly and servicing

SCIENCE INSTRUMENTS ABOARD ISS



CONTINUOUS OBSERVATIONS OF EARTH: OZONE





SAGE III

Monitor Earth's upper atmosphere from ISS vantage point

ISS AS A SCIENCE PLATFORM FOR ASTROPHYSICS

NICER

Revealing the structure, dynamics and energetics of neutron stars aboard ISS

NICER Installation on ISS

Artistic Rendering

SLS ENABLING FUTURE EXPLORATION

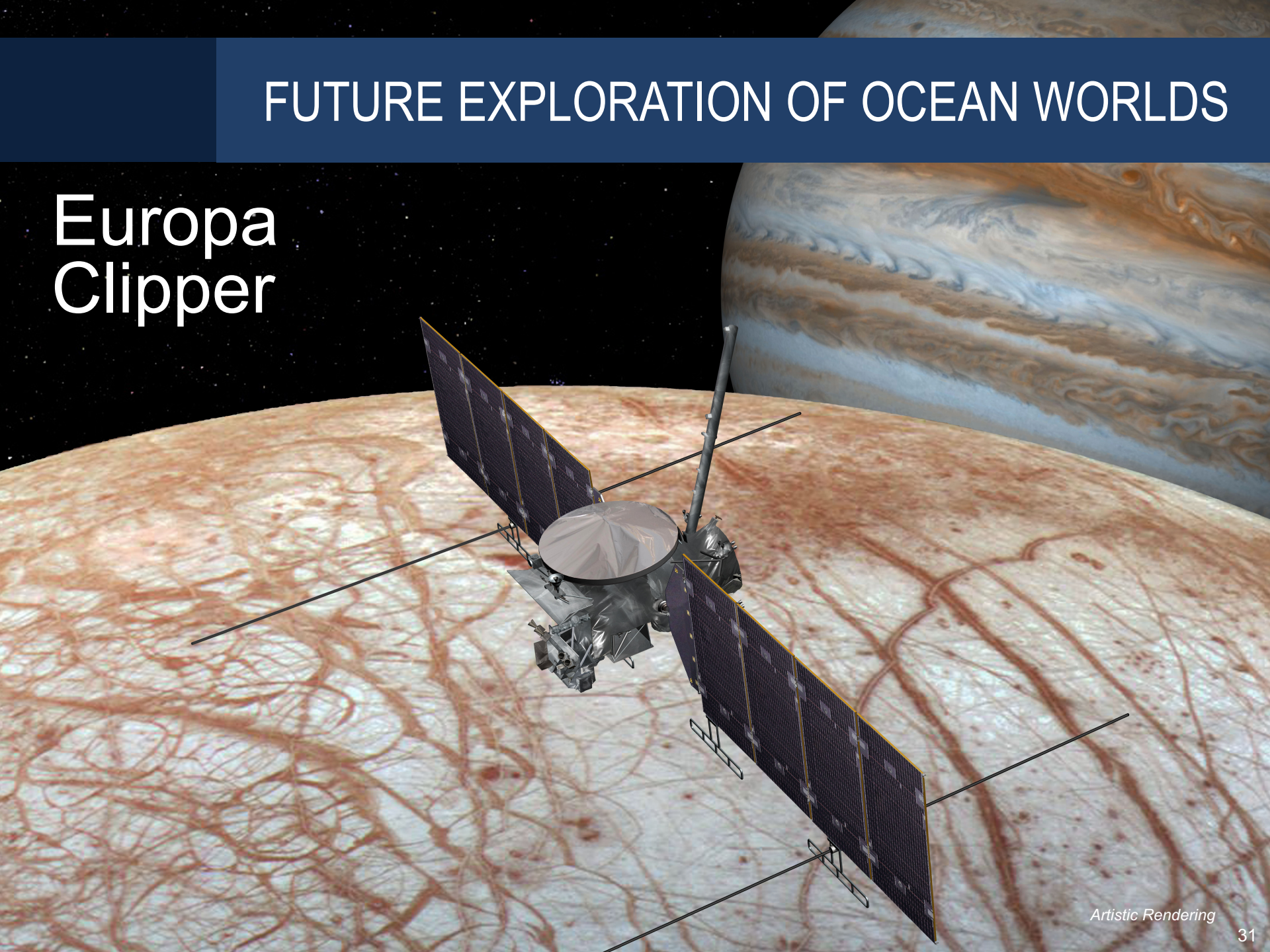
Space Launch System

Enhancing our access to the Outer Solar System

Artistic Rendering

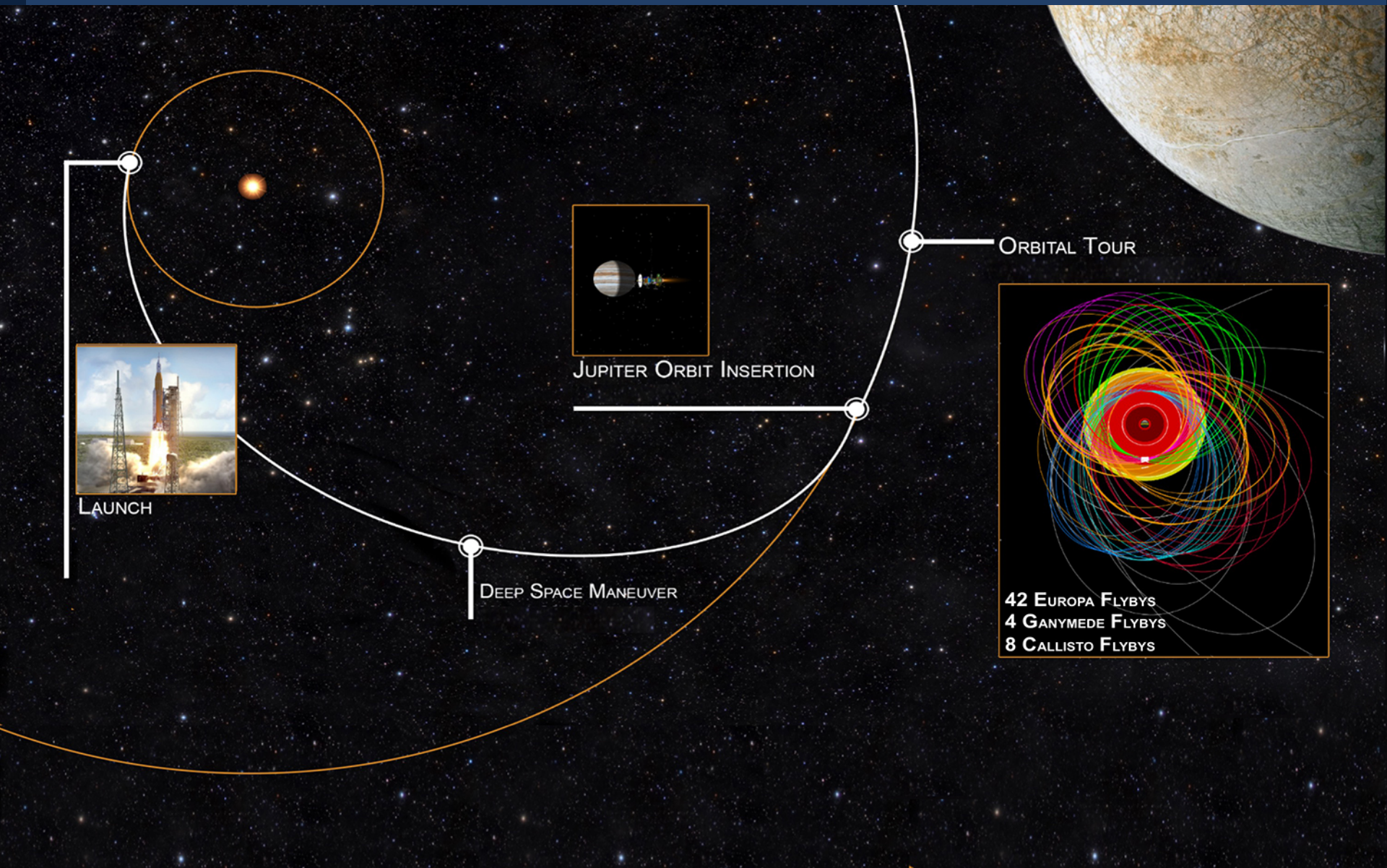
FUTURE EXPLORATION OF OCEAN WORLDS

Europa Clipper



Artistic Rendering

SLS: DIRECT INTERPLANETARY TRAJECTORY EXAMPLE



HUMAN SERVICING OF LARGE TELESCOPES

Hubble

Servicing Mission 4
2009

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