

National Aeronautics and  
Space Administration



# SCIENCE MISSION DIRECTORATE

**Thomas H. Zurbuchen**  
Associate Administrator  
@Dr\_ThomasZ

July 27, 2017

# SCIENCE & HUMAN EXPLORATION

## **SMD INTEGRATED PORTFOLIO**

Overview of SMD's high impact, integrated and multi-faceted portfolio

## **ROLE OF INNOVATION**

Innovation drives SMD activities, leading to scientific and technological breakthroughs

## **SCIENCE AND HUMAN EXPLORATION NEXUS**

SMD utilizes ISS and sees science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure



# SCIENCE MISSION DIRECTORATE

## SMD INTEGRATED PORTFOLIO

Overview of SMD's high impact, integrated and multi-faceted portfolio

## ROLE OF INNOVATION

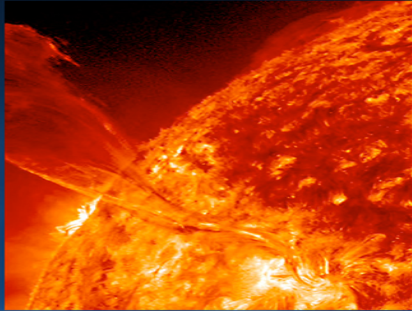
Innovation drives SMD activities, leading to scientific and technological breakthroughs

## SCIENCE AND HUMAN EXPLORATION NEXUS

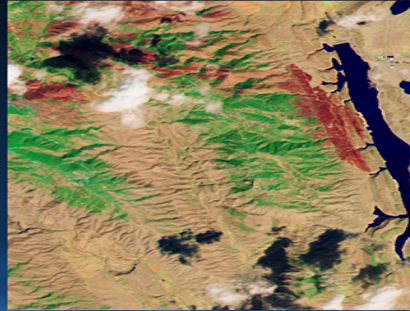
SMD utilizes ISS and sees science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure



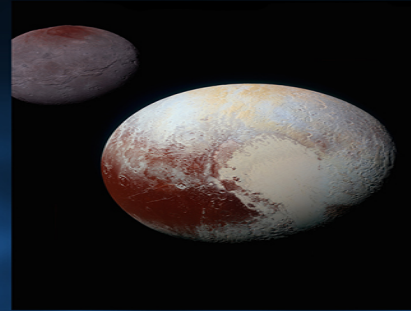
# NASA SCIENCE MISSION DIRECTORATE



HELIOPHYSICS



EARTH SCIENCE



PLANETARY SCIENCE



ASTROPHYSICS



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



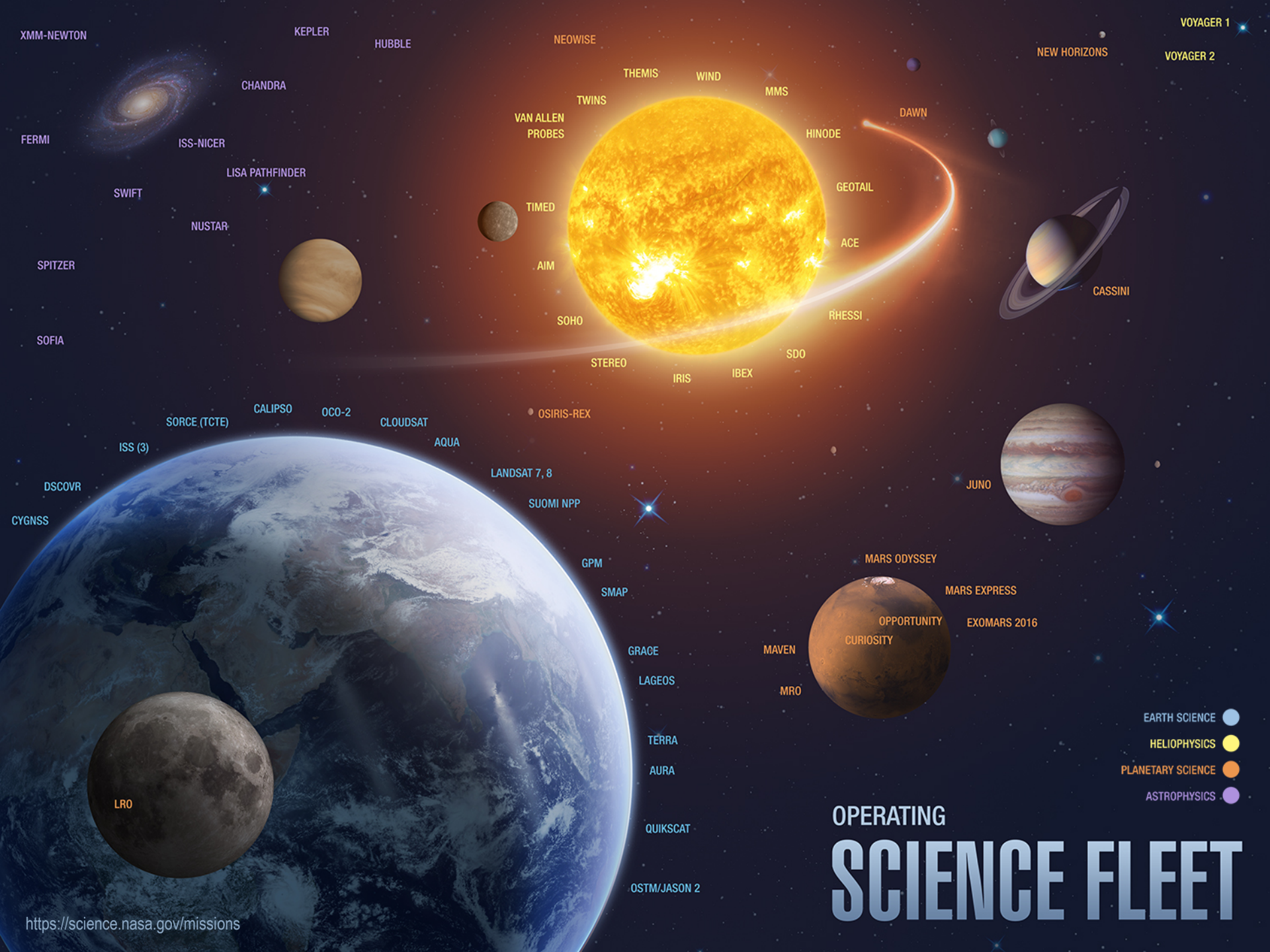
## Technology Development

~\$400M invested annually



## Research

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



XMM-NEWTON KEPLER HUBBLE NEOWISE VOYAGER 1

CHANDRA THEMIS WIND MMS NEW HORIZONS VOYAGER 2

FERMI ISS-NICER LISA PATHFINDER VAN ALLEN PROBES TWINS HINODE DAWN

SWIFT NUSTAR SOHO GEOTAIL ACE

SPITZER TIMED AIM RHESSI

SOFIA STEREO IRIS IBEX SDO

CALIPSO OCO-2 CLOUDSAT OSIRIS-REX

ISS (3) AQUA LANDSAT 7, 8

DSCOVR SUOMI NPP JUNO

CYGNSS GPM MARS ODYSSEY

SMAP MARS EXPRESS

GRACE OPPORTUNITY EXOMARS 2016

LAGEOS MAVEN MRO

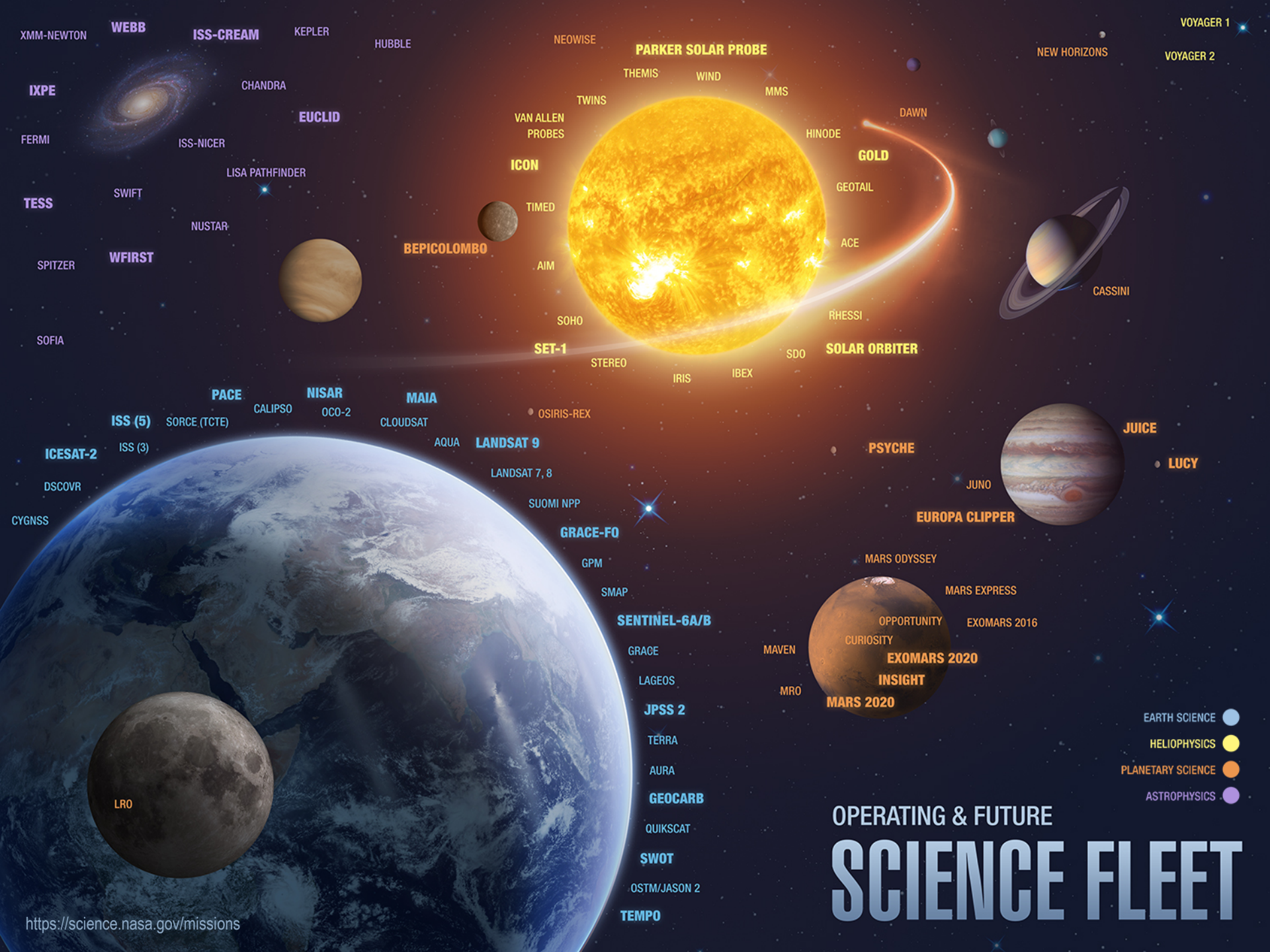
TERRA AURA

QUIKSCAT

OSTM/JASON 2

- EARTH SCIENCE ●
- HELIOPHYSICS ●
- PLANETARY SCIENCE ●
- ASTROPHYSICS ●

# OPERATING SCIENCE FLEET



**OPERATING & FUTURE SCIENCE FLEET**

**ASTROPHYSICS** (Purple)  
**PLANETARY SCIENCE** (Orange)  
**HELIOPHYSICS** (Yellow)  
**EARTH SCIENCE** (Blue)

**ASTROPHYSICS:** XMM-NEWTON, WEBB, CHANDRA, EUCLID, FERMI, LISA PATHFINDER, SWIFT, NUSTAR, SPITZER, WFIRST, SOFIA, PACE, CALIPSO, NISAR, OCO-2, MAIA, CLOUDSAT, ISS (5), ISS (3), DSCOV, CYGNSS, LRO, LISA PATHFINDER, LISA PATHFINDER.

**PLANETARY SCIENCE:** NEOWISE, HUBBLE, PARKER SOLAR PROBE, THEMIS, WIND, MMS, TWINS, VAN ALLEN PROBES, ICON, BEPICOLOMBO, TIMED, AIM, SOHO, SET-1, STEREO, IRIS, IBEX, OSIRIS-REX, LANDSAT 9, LANDSAT 7, 8, SUOMI NPP, GRACE-FO, GPM, SMAP, SENTINEL-6A/B, GRACE, LAGEOS, JPSS 2, TERRA, AURA, GEOCARB, QUIKSCAT, SWOT, OSTM/JASON 2, TEMPO, VOYAGER 1, VOYAGER 2, NEW HORIZONS, DAWN, HINODE, GOLD, GEOTAIL, ACE, RHESI, SDO, SOLAR ORBITER, JUNO, JUICE, LUCY, PSYCHE, EUROPA CLIPPER, MARS ODYSSEY, MARS EXPRESS, OPPORTUNITY, EXOMARS 2016, INSIGHT, MARS 2020, MAVEN, MRO.

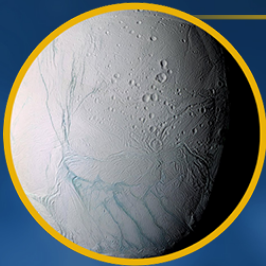
**HELIOPHYSICS:** PARKER SOLAR PROBE, THEMIS, WIND, MMS, TWINS, VAN ALLEN PROBES, ICON, BEPICOLOMBO, TIMED, AIM, SOHO, SET-1, STEREO, IRIS, IBEX, OSIRIS-REX, LANDSAT 9, LANDSAT 7, 8, SUOMI NPP, GRACE-FO, GPM, SMAP, SENTINEL-6A/B, GRACE, LAGEOS, JPSS 2, TERRA, AURA, GEOCARB, QUIKSCAT, SWOT, OSTM/JASON 2, TEMPO, VOYAGER 1, VOYAGER 2, NEW HORIZONS, DAWN, HINODE, GOLD, GEOTAIL, ACE, RHESI, SDO, SOLAR ORBITER, JUNO, JUICE, LUCY, PSYCHE, EUROPA CLIPPER, MARS ODYSSEY, MARS EXPRESS, OPPORTUNITY, EXOMARS 2016, INSIGHT, MARS 2020, MAVEN, MRO.

**EARTH SCIENCE:** XMM-NEWTON, WEBB, CHANDRA, EUCLID, FERMI, LISA PATHFINDER, SWIFT, NUSTAR, SPITZER, WFIRST, SOFIA, PACE, CALIPSO, NISAR, OCO-2, MAIA, CLOUDSAT, ISS (5), ISS (3), DSCOV, CYGNSS, LRO, LISA PATHFINDER, LISA PATHFINDER.

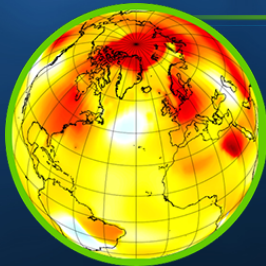
# KEY SCIENCE THEMES



**Discovering the  
Secrets of the Universe**



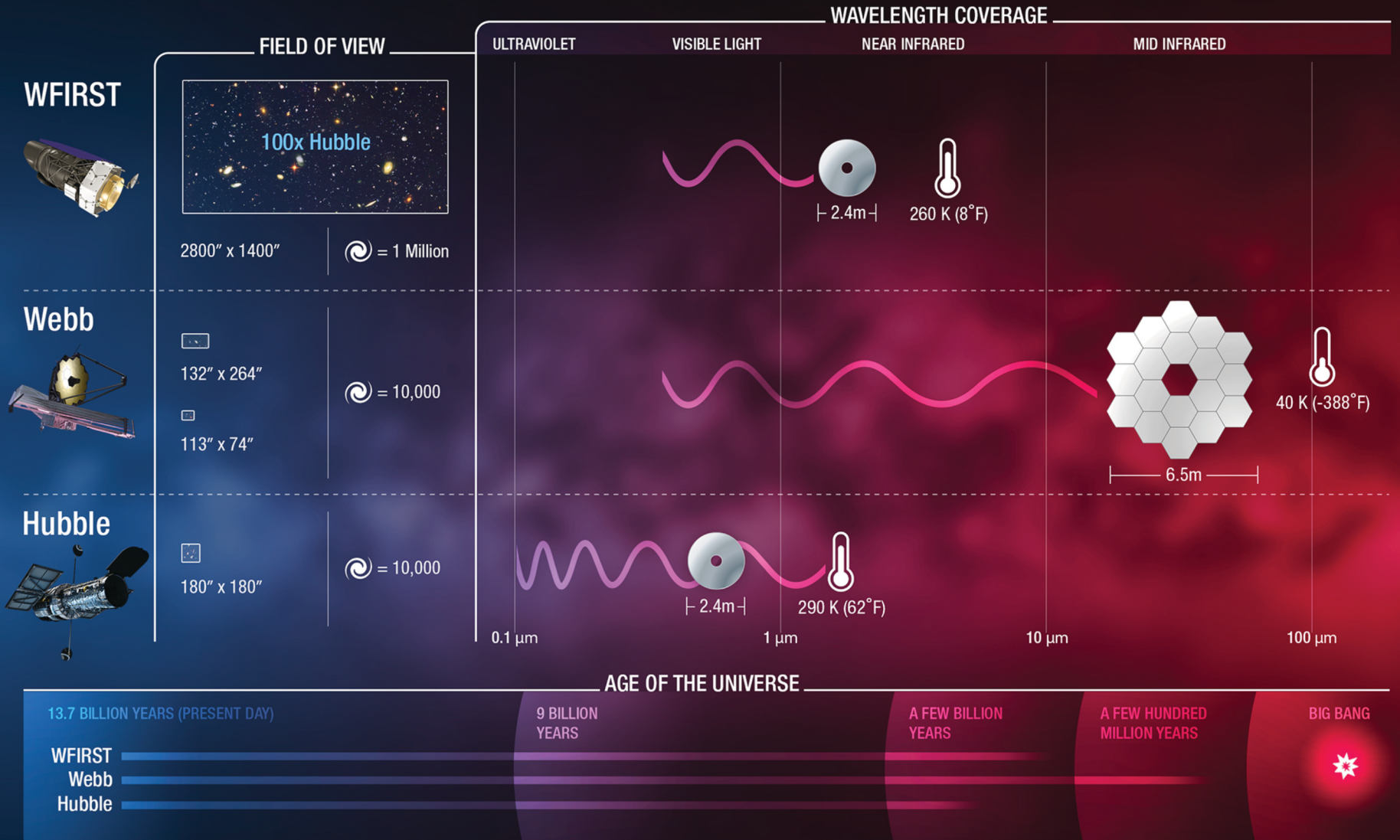
**Searching for  
Life Elsewhere**



**Safeguarding and  
Improving Life on Earth**



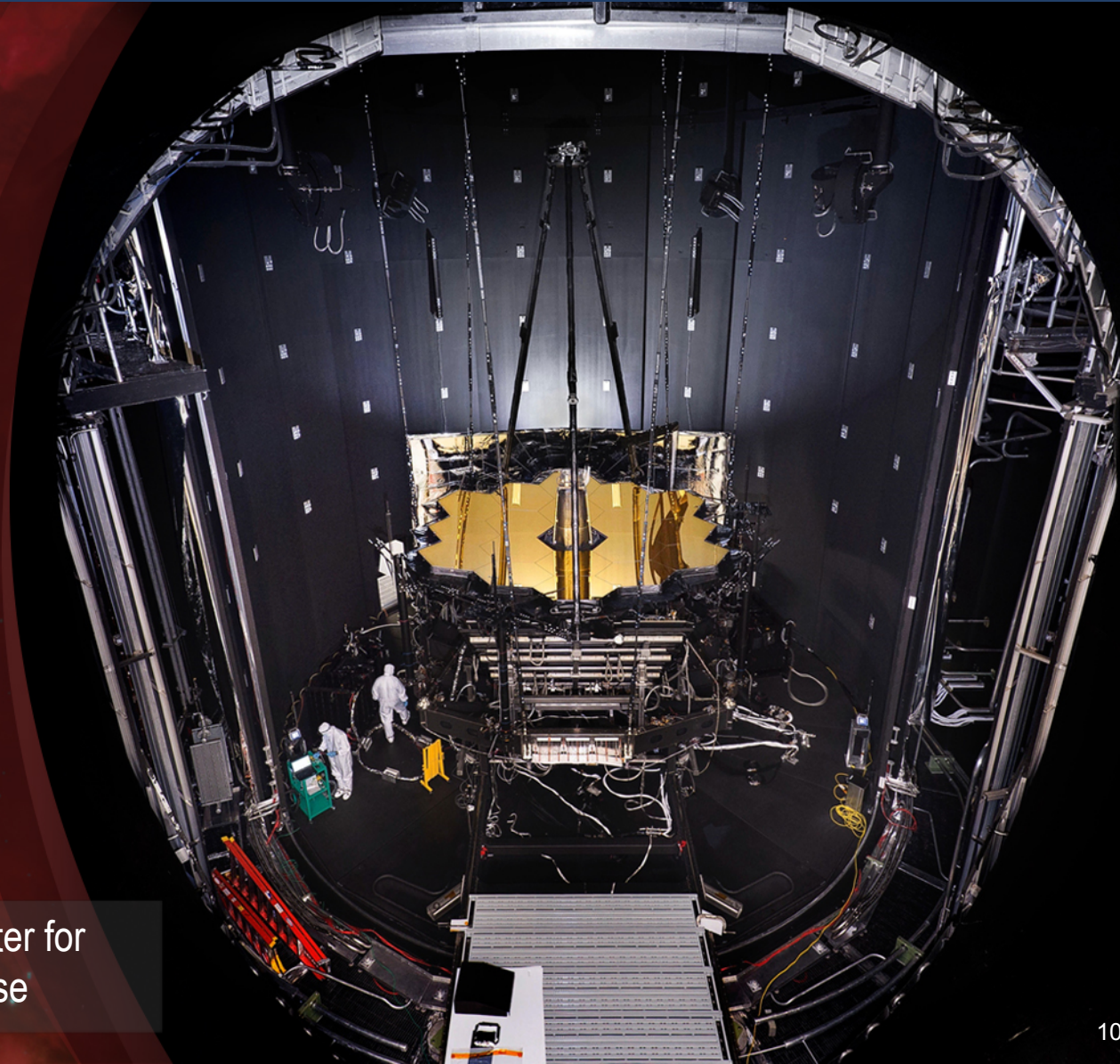
# GREAT OBSERVATORIES



# DISCOVERING THE SECRETS OF THE UNIVERSE

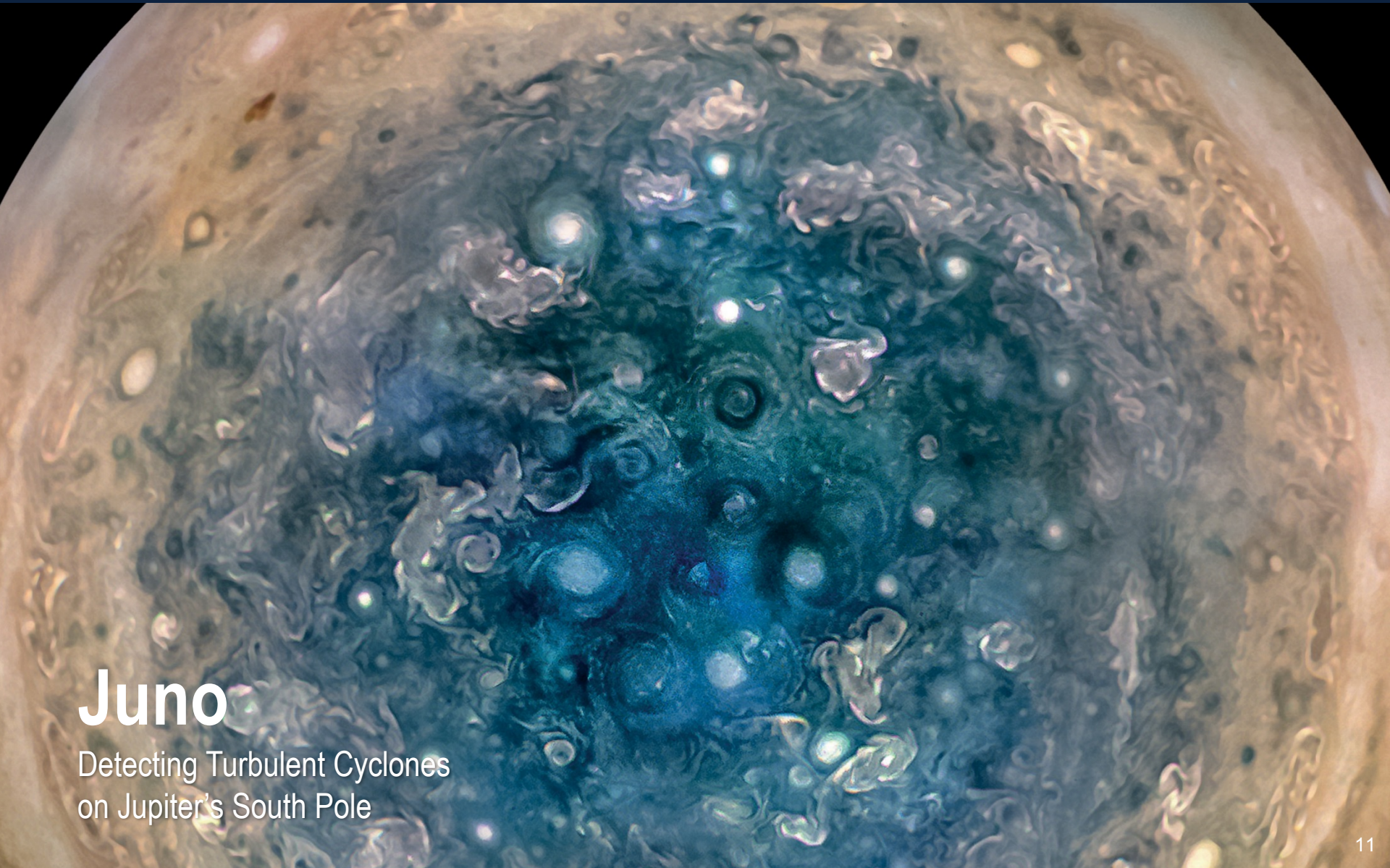
# Webb

The James Webb  
Space Telescope



WEBB at Johnson Space Center for  
cryogenic-vacuum testing phase

# DISCOVERING THE SECRETS OF THE UNIVERSE



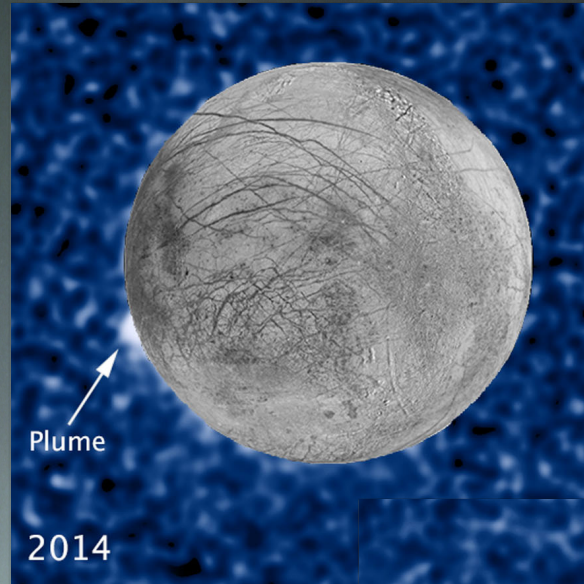
## Juno

Detecting Turbulent Cyclones  
on Jupiter's South Pole

# SEARCHING FOR LIFE ELSEWHERE

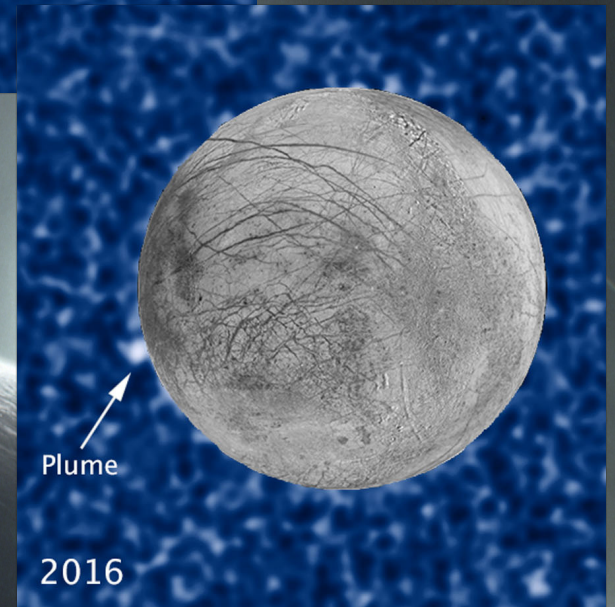
## Cassini

Diving through plumes  
from Saturn's Moon  
Enceladus



## Hubble

Plumes on Jupiter's  
Moon Europa



# SEARCHING FOR LIFE ELSEWHERE



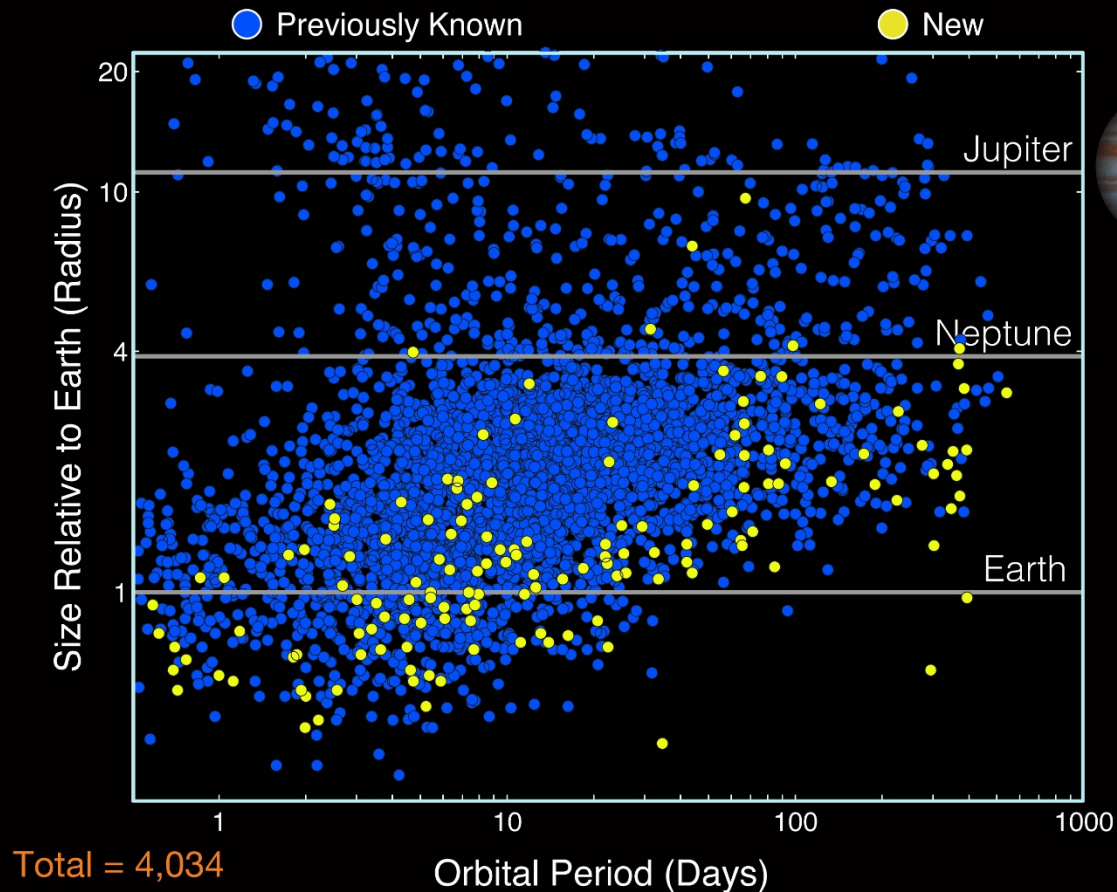
**Mars 2020**

*Artistic Rendering*

# SEARCHING FOR LIFE ELSEWHERE

## New Kepler Planet Candidates

As of June 2017

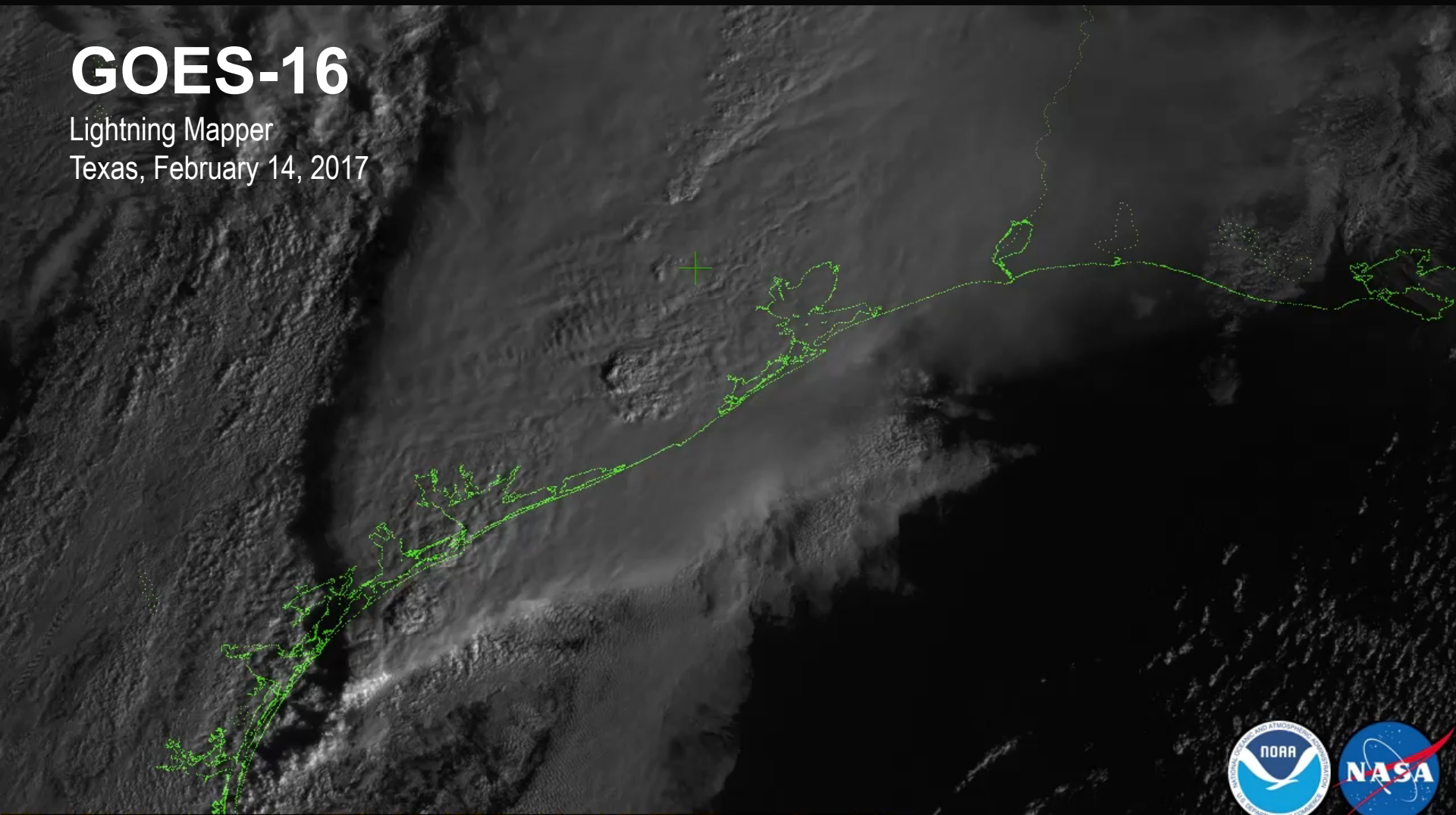


# SAFEGUARDING AND IMPROVING LIFE ON EARTH

## GOES-16

Lightning Mapper

Texas, February 14, 2017



GOES-16 GLM lightning events + ABI Band 2 2017-02-14 14:43:01.790 UTC 1.0x real time



# SAFEGUARDING AND IMPROVING LIFE ON EARTH



Space weather effects  
on infrastructure

*Credit: Astronaut Scott Kelly from ISS*

*Credit: San Diego Gas & Electric*



# SAFEGUARDING AND IMPROVING LIFE ON EARTH



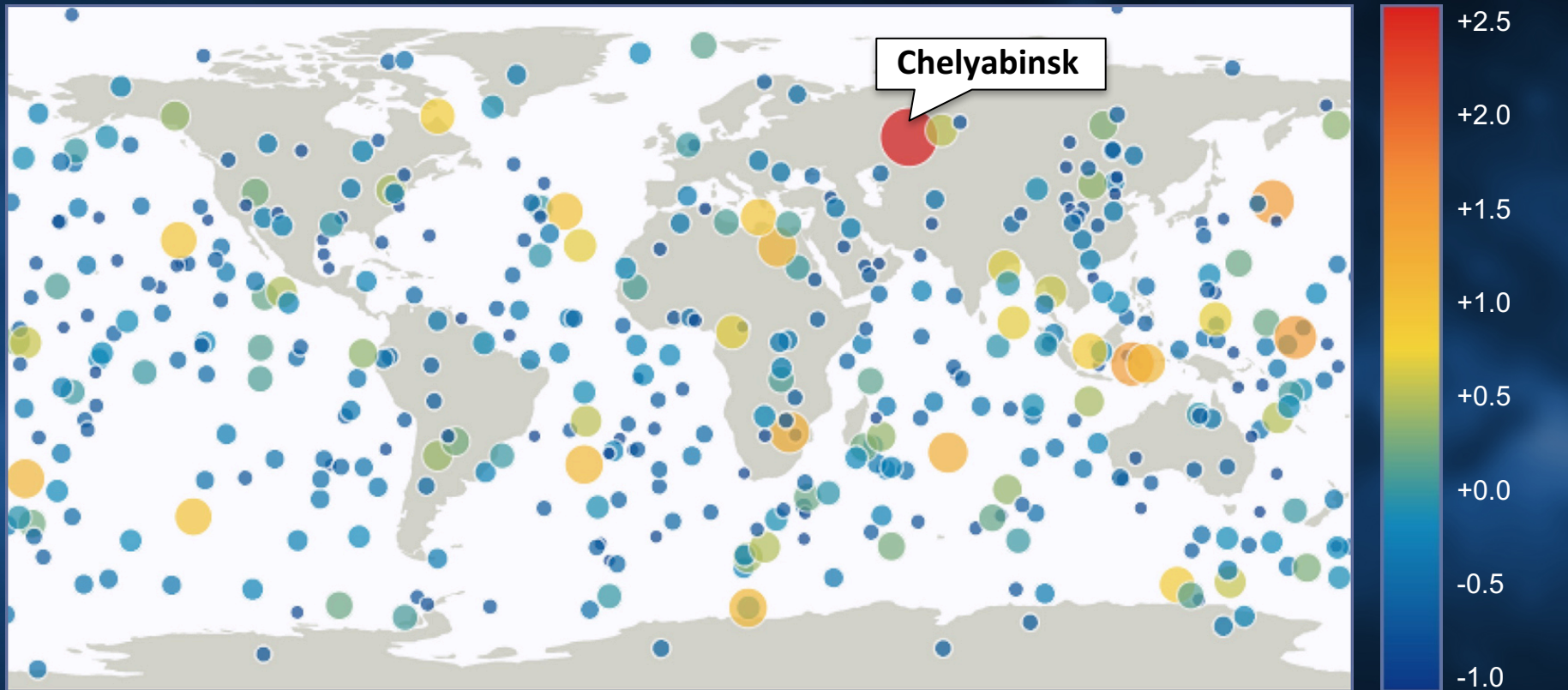
Chelyabinsk, Russia  
February 15, 2013

*Credit: Константин Кудинов*

*Credit: Nikita Plekhanov*

# SAFEGUARDING AND IMPROVING LIFE ON EARTH

## Fireball Events: 1988–2016



Alan B. Chamberlin (JPL/Caltech)

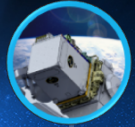
# LOOKING AHEAD



CREAM



TESS



NICER



Parker Solar Probe



Landsat 9



JPSS-2



Psyche



JPSS-1



ICESat-2



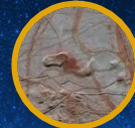
SOC



Mars2020



Lucy



Europa Clipper

Calendar Year

2017

2018

2019

2020

2021

2022

2023

2024



GOLD



Webb



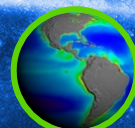
GOES-T



IXPE



NISAR



PACE



WFIRST



ICON






InSight



GRACE-FO



GOES-S

-  Discovering the Secrets of the Universe
-  Searching for Life Elsewhere
-  Safeguarding and Improving Life on Earth

# SCIENCE MISSION DIRECTORATE

## SMD INTEGRATED PORTFOLIO

Overview of SMD's high impact, integrated and multi-faceted portfolio

## ROLE OF INNOVATION

Innovation drives SMD activities, leading to scientific and technological breakthroughs

## SCIENCE AND HUMAN EXPLORATION NEXUS

SMD utilizes ISS and sees science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure



# SMD AND TECHNOLOGICAL INNOVATION

- Technology and continued technological progress are critical for the future of SMD and future missions
- SMD making a new commitment to foster innovation and technology for scientific research
- SMD is focused on technology investment and pathways to flight as strategic elements of SMD's programs
- SMD is actively developing flight opportunities for new technologies as part of AOs
  - Continually adjust based on experience, performance metrics and feedback

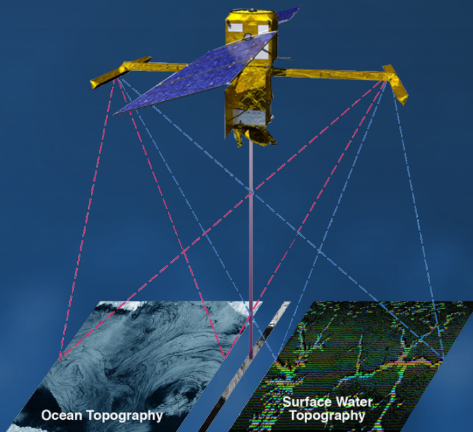
# ROLE OF TECHNOLOGICAL INNOVATION



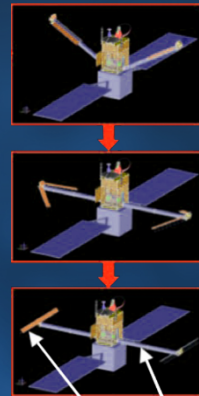
# BREAKTHROUGH INNOVATION

## Surface Water and Ocean Topography (SWOT) Mission

### CONCEPT

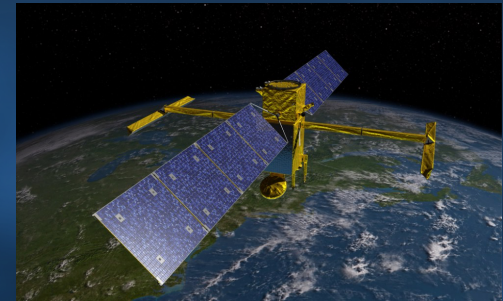


### TECHNOLOGY



Antenna  
Reflectarray  
Mast

### IMPLEMENTATION



### Enabling Technology

*Investments in Ka-band interferometer and precision antenna mast*

### Result

*Unprecedented swath measurements of terrestrial water heights and sea surface heights (SWOT to launch in 2020)*

# GAME CHANGING INNOVATION

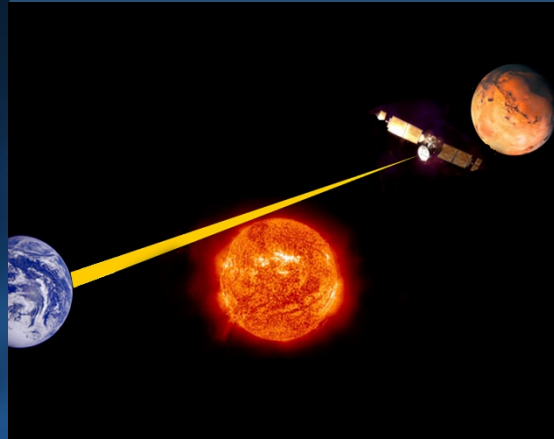
## Deep Space Optical Communications (DSOC)

### CONCEPT



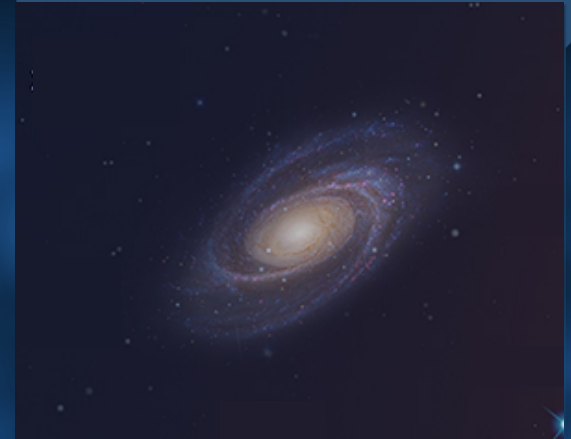
Psyche Mission

### TECHNOLOGY



Deep Space Optical Communications

### IMPLEMENTATION



Next Generation Deep Space Missions

### Enabling Technology

*Technology demonstration of DSOC near Psyche*

### Result

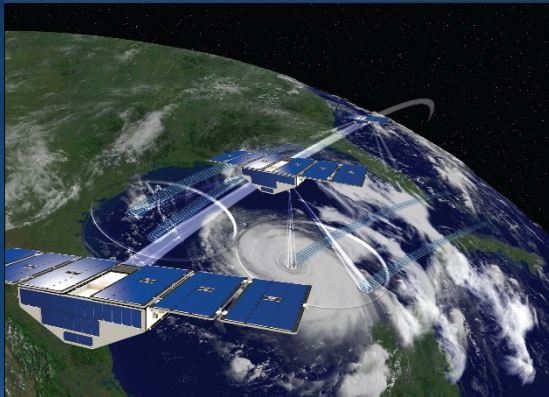
*Greatly increasing communications bandwidth to enable more rapid data and information streaming*



# POTENTIALLY DISRUPTIVE INNOVATION

## Cyclone Global Navigation Satellite System (CYGNSS)

### CONCEPT

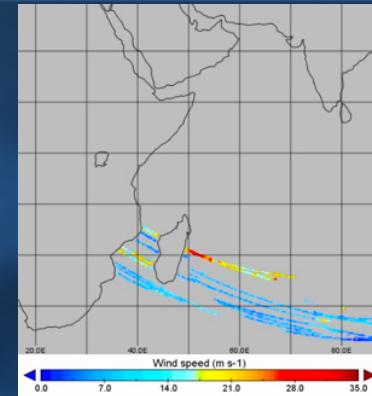


### TECHNOLOGY



Delay Mapping Receiver (DMR)

### IMPLEMENTATION



Tropical Cyclone Enawo overpass on 2017-03-06 prior to landfall

**Enabling Technology** *Existing technology (delay mapping receiver) deployed in a unique constellation of 8 LEO spacecraft*

**Result** *Frequent and accurate measurement of ocean surface winds will improve tropical cyclone forecasting*

# ENHANCED TECH INFUSION

TRL 3-5

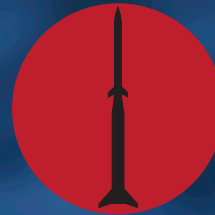
SMD Technology Programs



Coordination with STMD Game-Changing Development (GCD) Program

TRL 5-8

Ground, Suborbital & In-Space Validation



Coordination with STMD Technology Demonstration Mission (TDM) Program

TRL 6-9

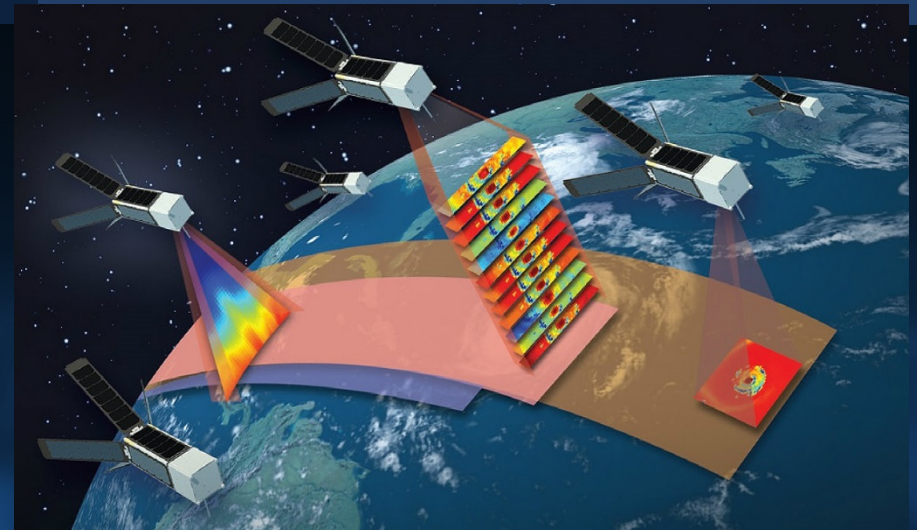
Announcements of Opportunity



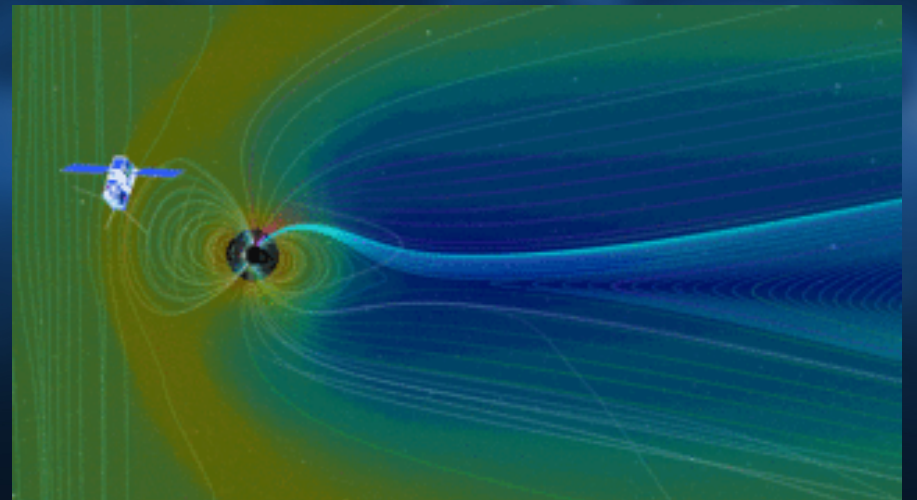
+ Enhanced technology demonstrations  
+ Increased technology infusions  
+ Expanded rideshare opportunities

# CUBESATS/SMALLSAS

- The FY 2018 budget includes SMD-wide initiative to use small satellites to advance selected high-priority science objectives in a cost-effective manner
- Implementing recommendations from the National Academy of Sciences' conclusion that small satellites are suitable to address science goals
- All four science divisions will focus technology development on CubeSats/SmallSats and targeted science missions to exploit this value
- Multi-disciplinary approach will leverage, and partner with, a growing commercial sector to collaboratively drive instrument and sensor innovation



*The TROPICS constellation of SmallSats will provide rapid-refresh temperature, humidity, and precipitation data over the tropics.*



*The CubeSat to study Solar Particles, or CuSP, will launch from the inaugural flight of NASA's Space Launch System.*

# CUBESATS/SMALLSATS: TRAINING OPPORTUNITY



# SCIENCE MISSION DIRECTORATE

## **SMD INTEGRATED PORTFOLIO**

Overview of SMD's high impact, integrated and multi-faceted portfolio

## **ROLE OF INNOVATION**

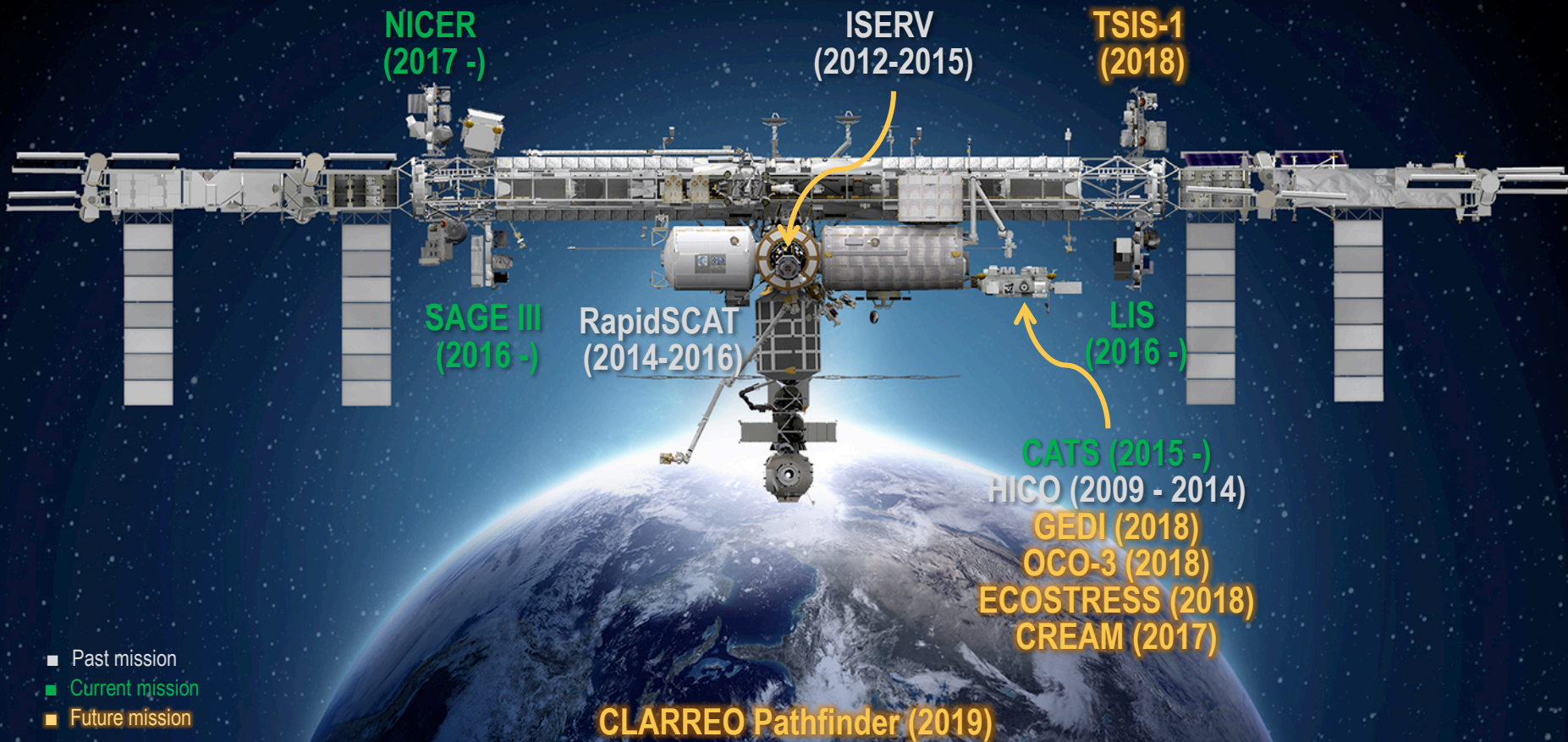
Innovation drives SMD activities, leading to scientific and technological breakthroughs

## **SCIENCE AND HUMAN EXPLORATION NEXUS**

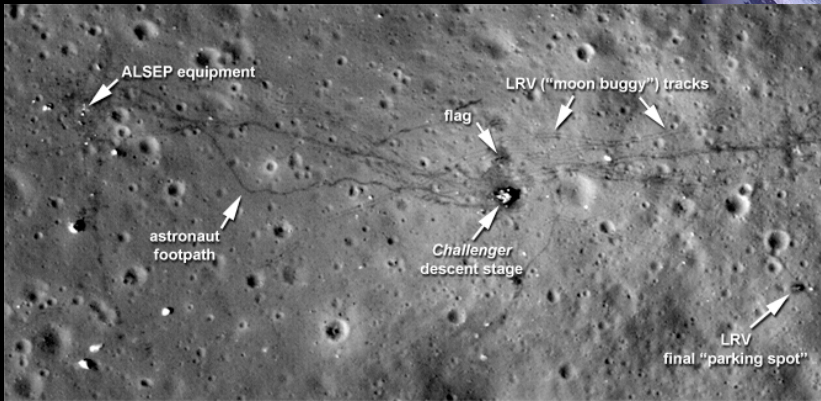
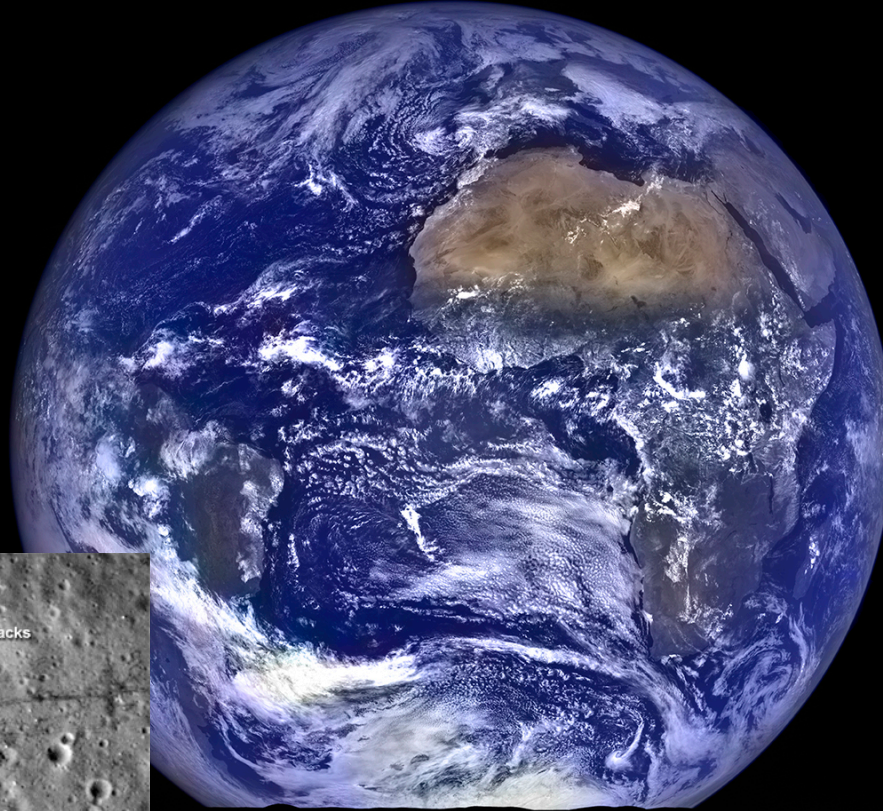
SMD utilizes ISS and sees science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure



# SCIENCE INSTRUMENTS ABOARD ISS



# LUNAR RECONNAISSANCE ORBITER



*LRO's look at the Apollo 17 Landing Site*

## LRO

In orbit around  
the moon

# MARS EXPLORATION PROGRAM

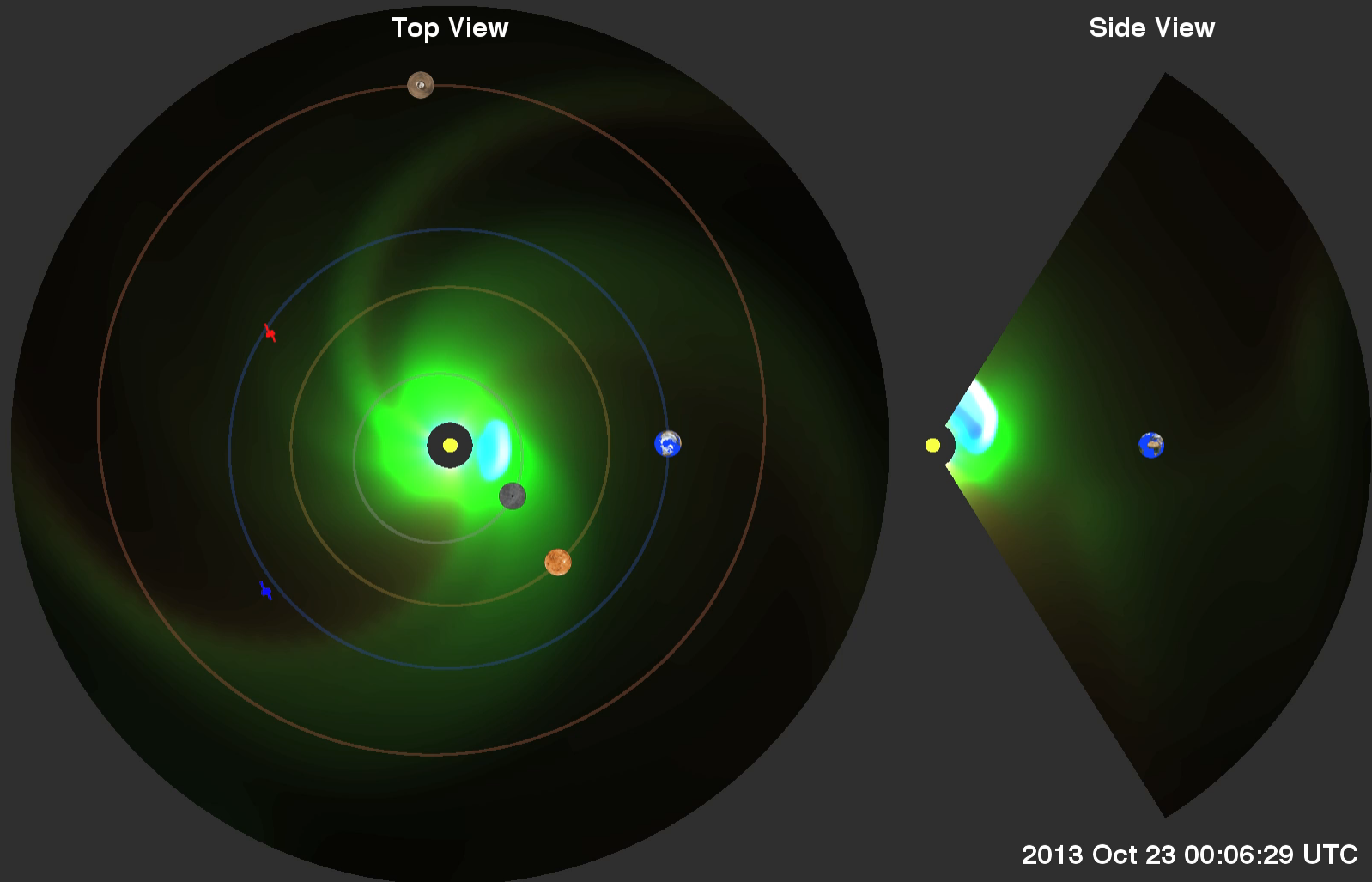


**Mars 2020**

*Artistic Rendering*



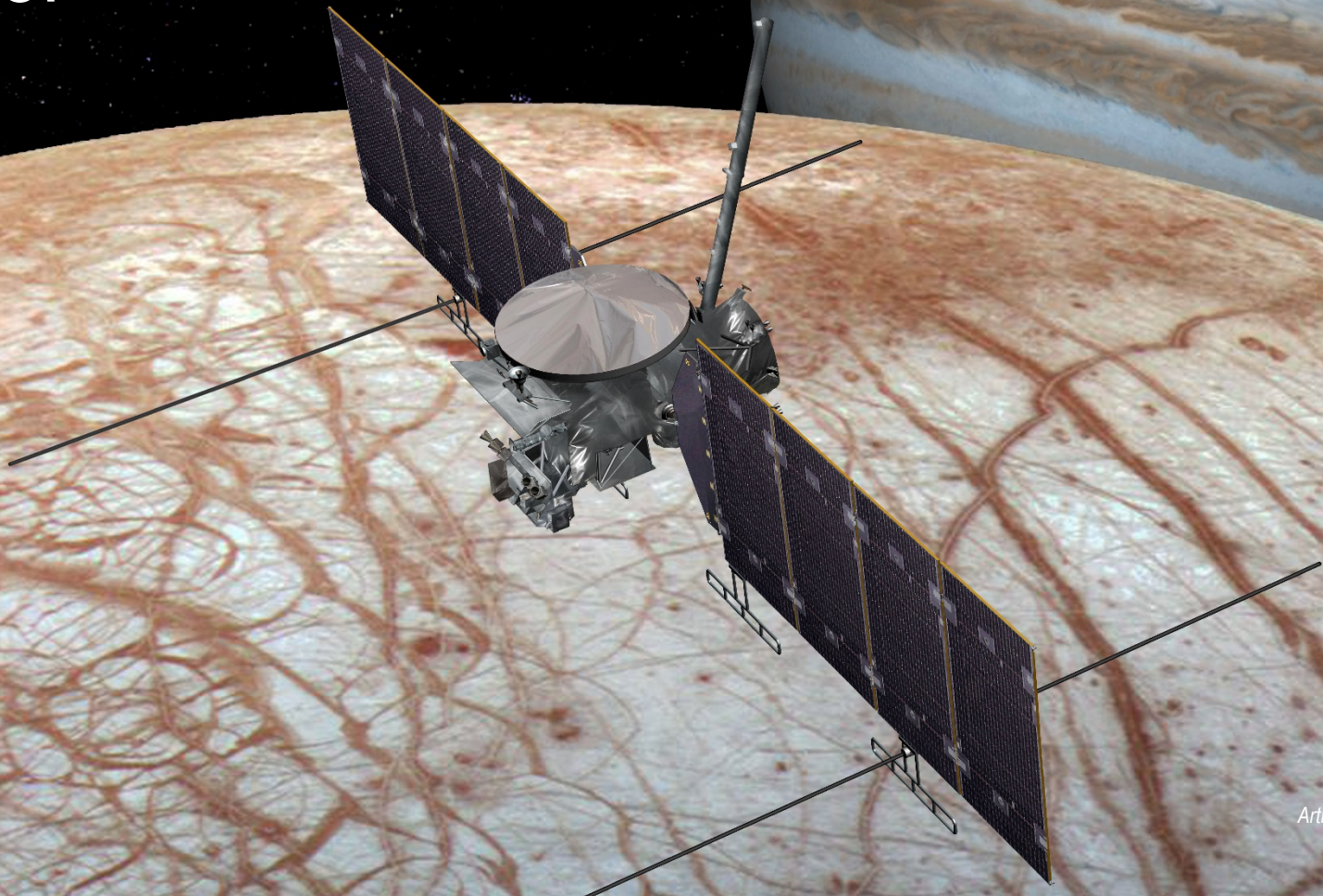
# STUDYING SPACE WEATHER EFFECTS



*CCMC model of multiple coronal mass ejections (CMEs)*

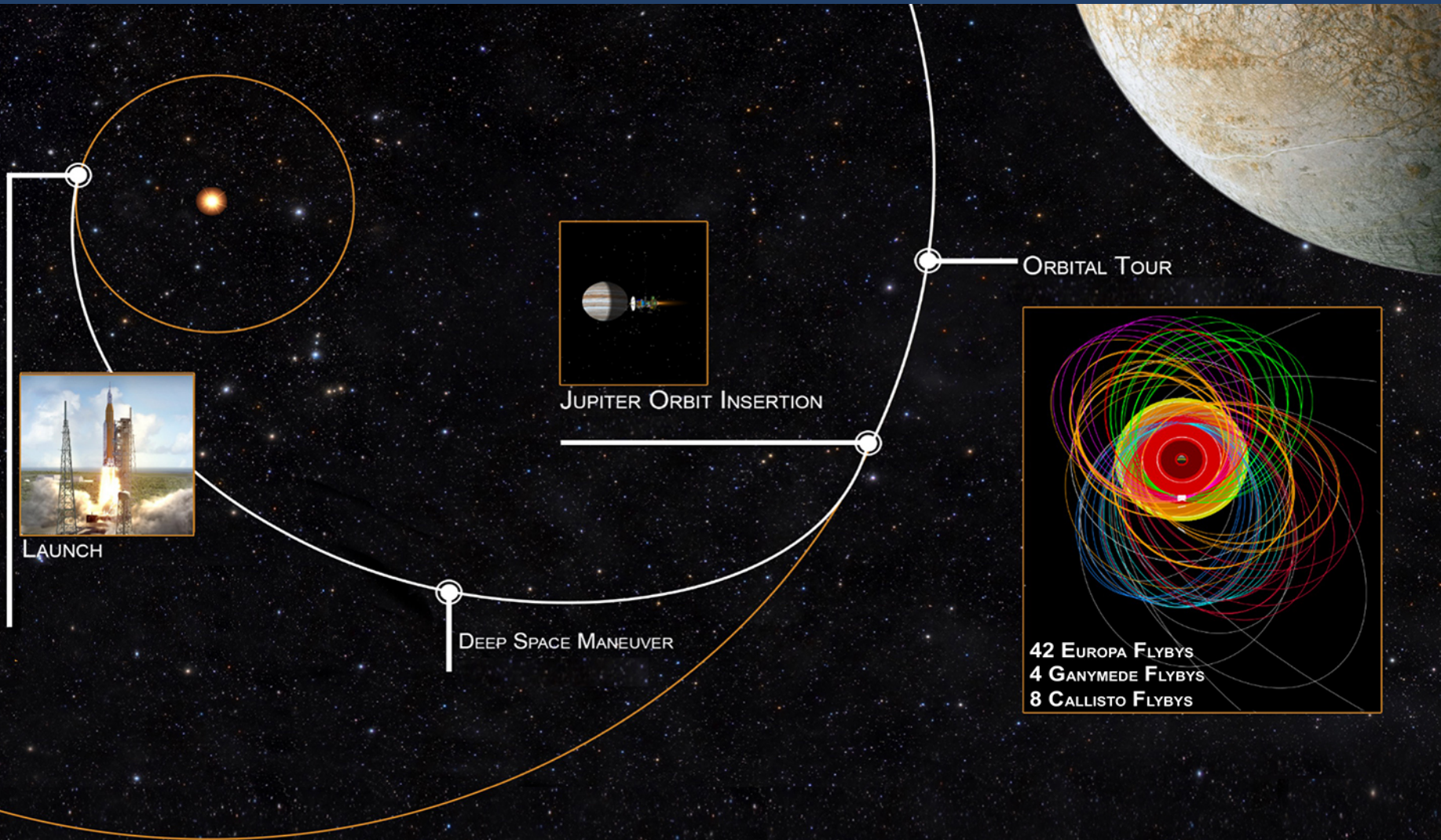
# FUTURE EXPLORATION OF OCEAN WORLDS

## Europa Clipper

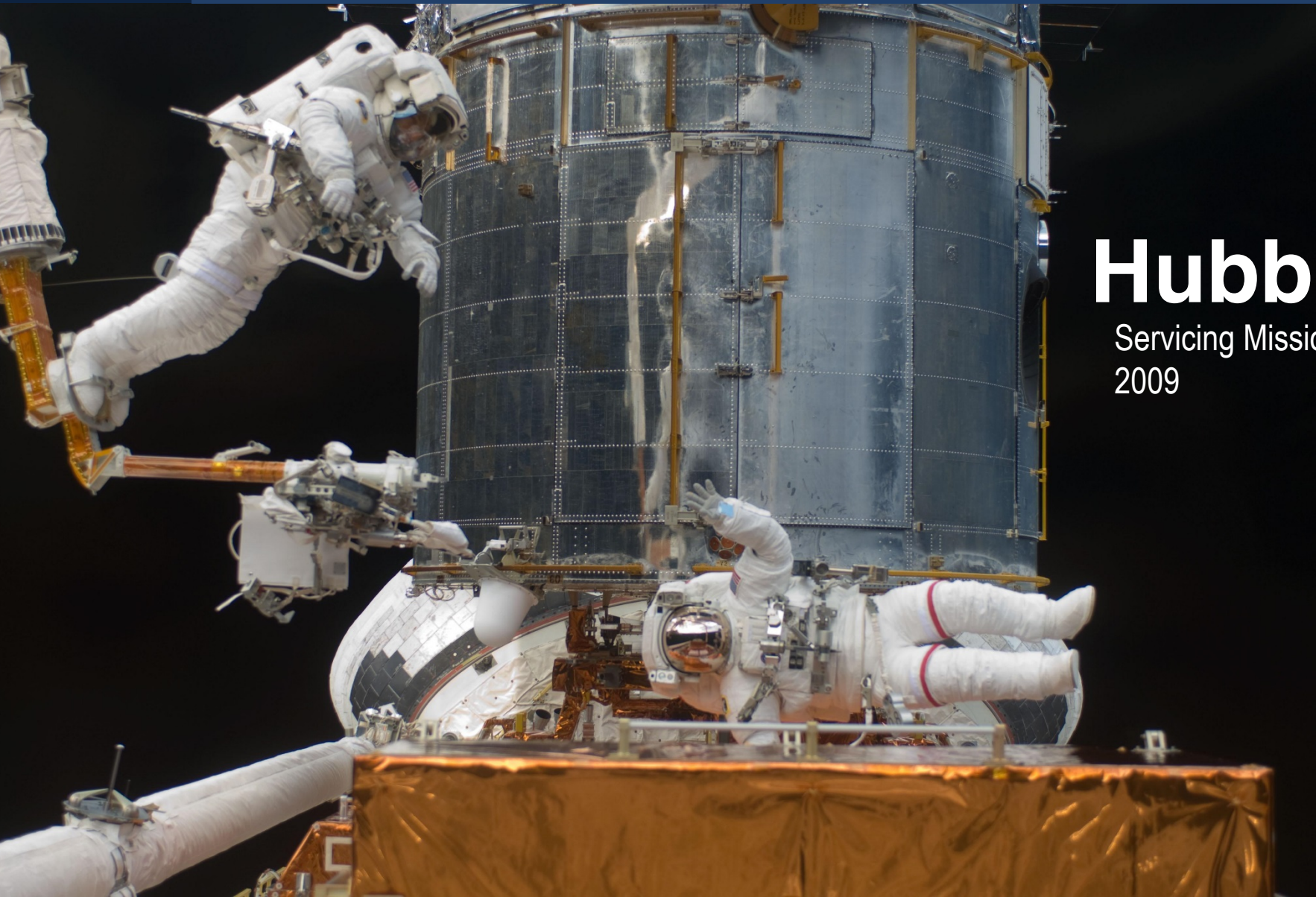


*Artistic Rendering*

# SLS: DIRECT INTERPLANETARY TRAJECTORY EXAMPLE



# HUMAN SERVICING OF LARGE TELESCOPES



## Hubble

Servicing Mission 4  
2009

# SCIENCE & HUMAN EXPLORATION

## **SMD INTEGRATED PORTFOLIO**

Overview of SMD's high impact, integrated and multi-faceted portfolio

## **ROLE OF INNOVATION**

Innovation drives SMD activities, leading to scientific and technological breakthroughs

## **SCIENCE AND HUMAN EXPLORATION NEXUS**

SMD utilizes ISS and sees science opportunities within HEOMD's developing architecture, i.e., Gateway infrastructure

