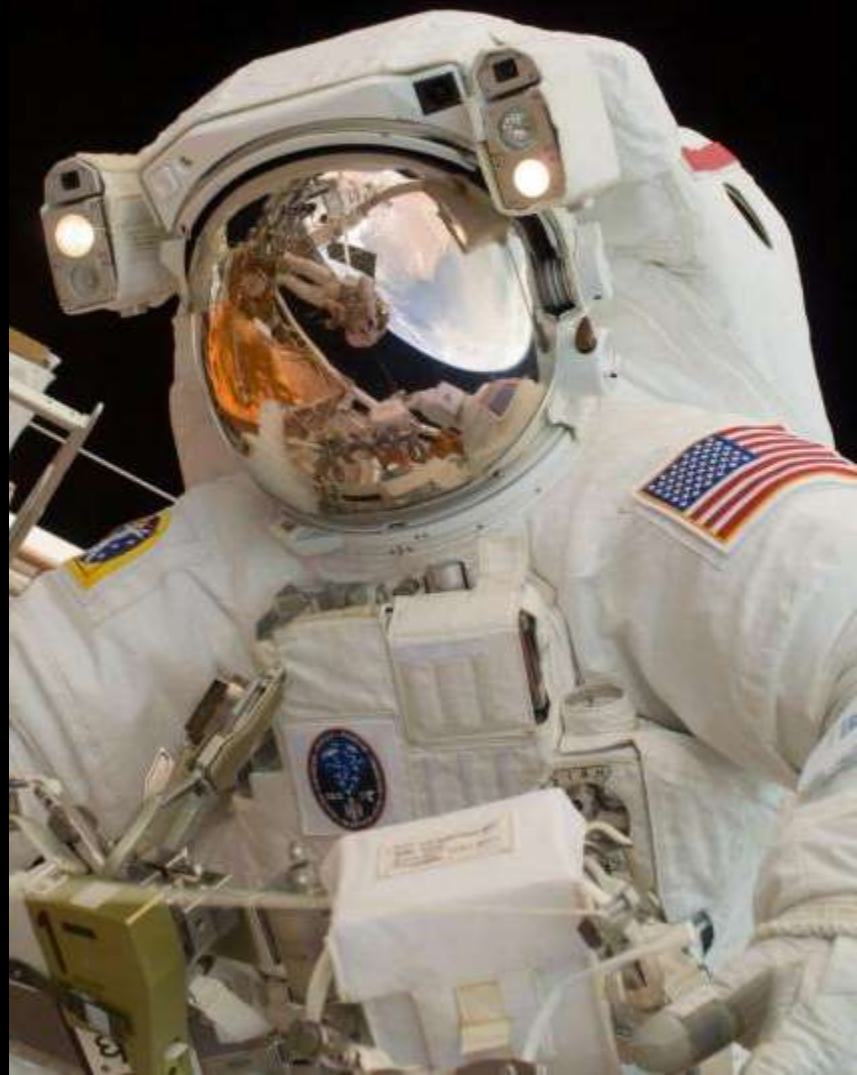
Science @ NASA

John M. Grunsfeld PhD
Associate Administrator, Science
National Aeronautics and Space Administration

Our Mission:

Innovate
Explore
Discover
Inspire

www.nasa.gov



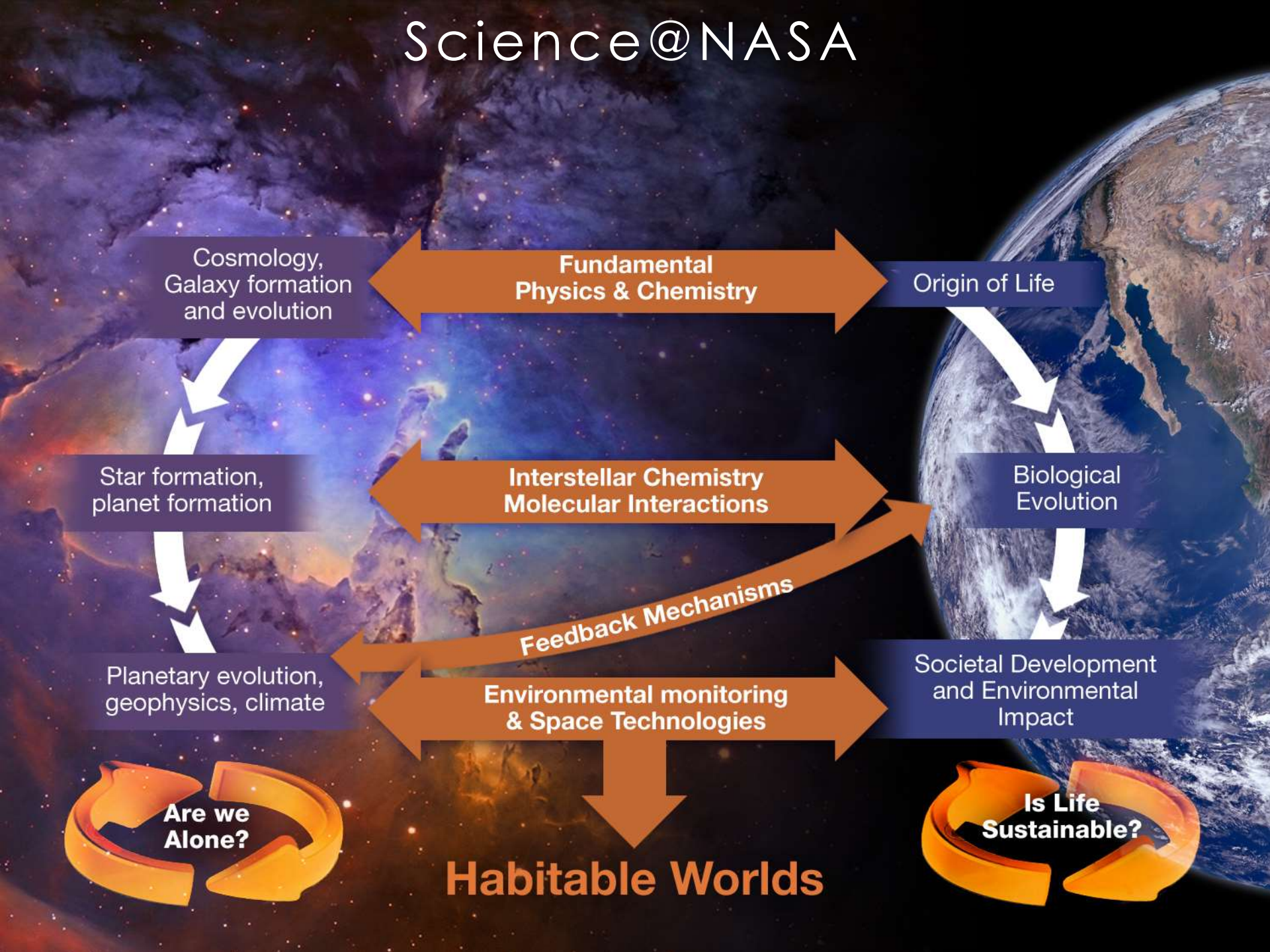
Big Scientific Questions:

Where did we come from?

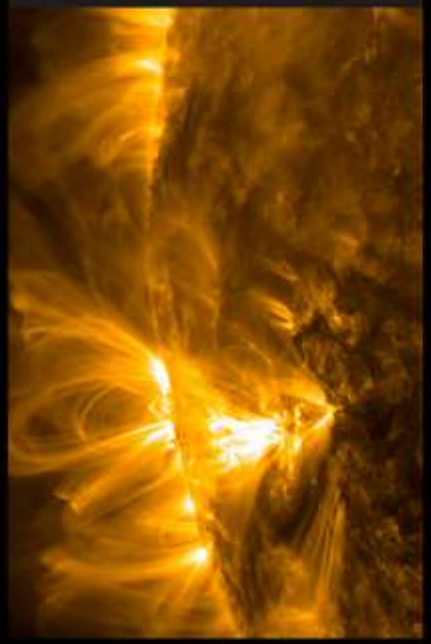
Where are we going?

Are we alone?

Science@NASA



Science Mission Directorate



HELIOPHYSICS

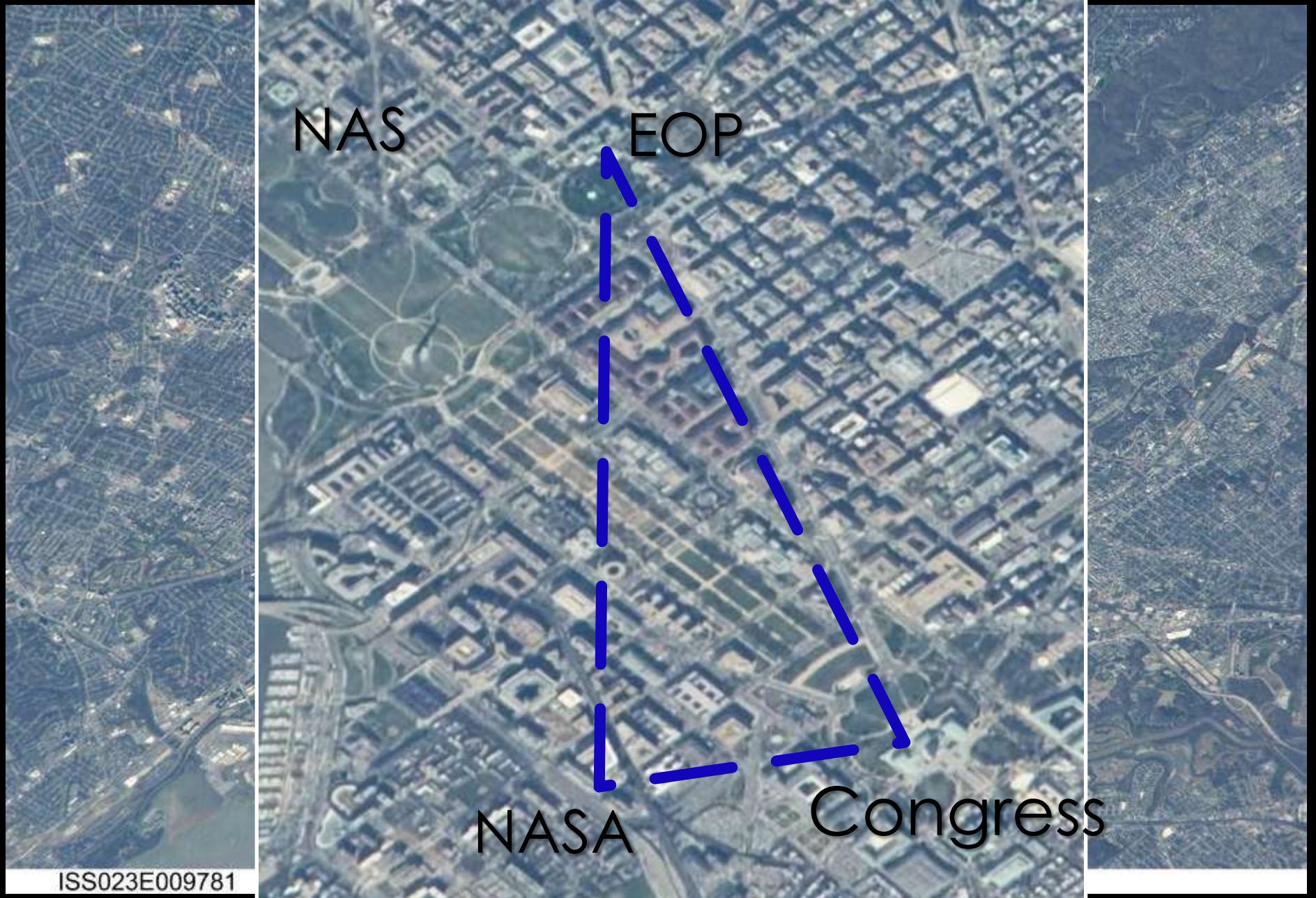
EARTH SCIENCE

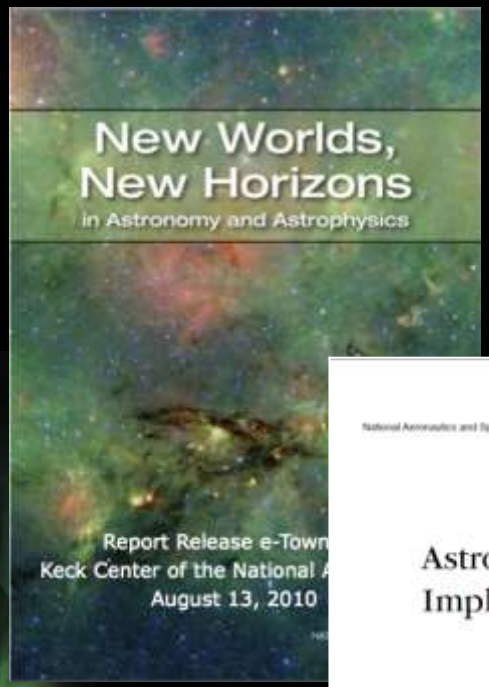
PLANETARY SCIENCE

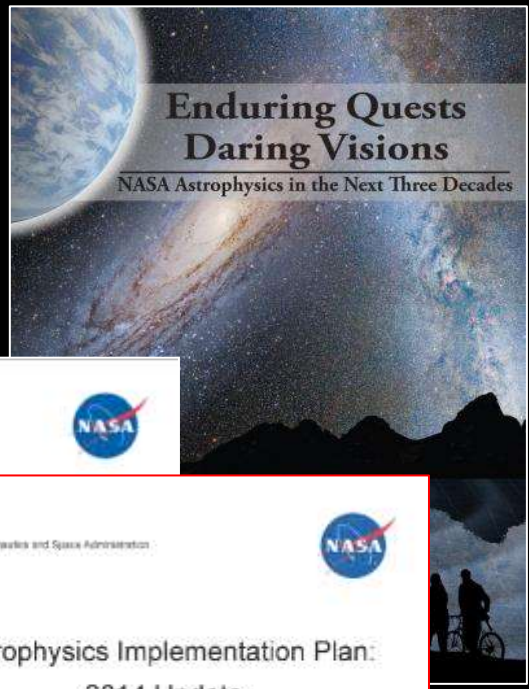
ASTROPHYSICS

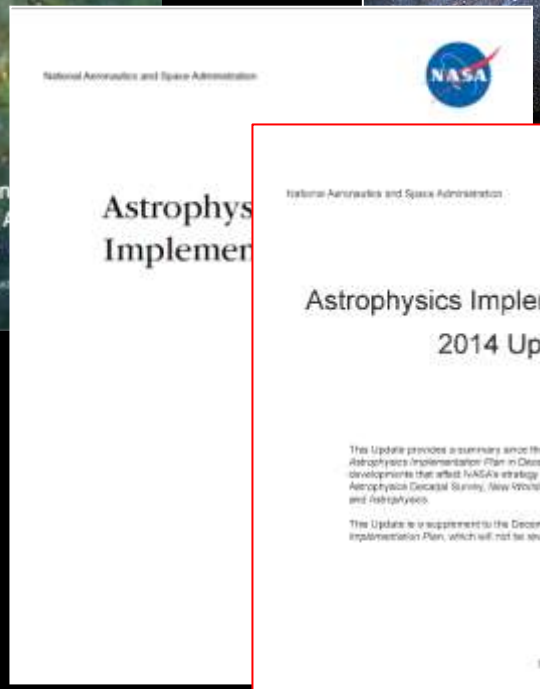
An Integrated Program of Science

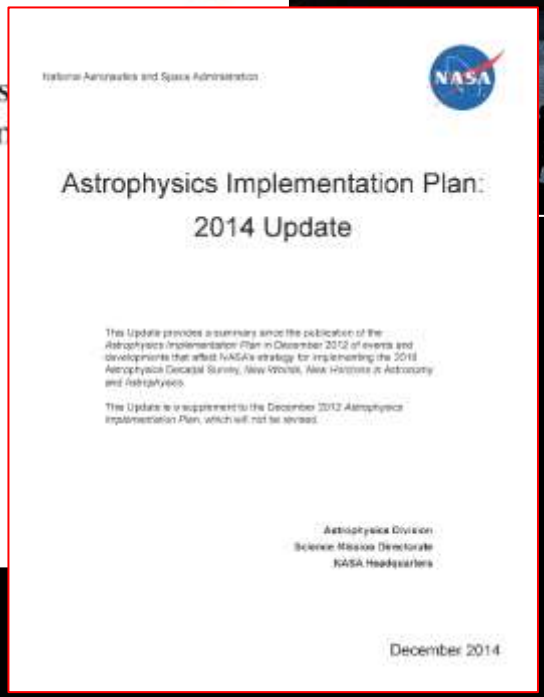
A Team Effort











http://science.nasa.gov

Science Budget Request Summary

	Actual	Enacted	Request	Notional			
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Science	**5,243.0**	**5,589.4**	**5,600.5**	**5,408.5**	**5,516.7**	**5,627.0**	**5,739.6**
Earth Science	**1,784.1**		**2,032.2**	**1,989.5**	**2,001.3**	**2,020.9**	**2,047.7**
Earth Science Research	453.2		501.7	472.9	461.3	475.9	484.2
Earth Systematic Missions	827.3		933.0	965.5	1,021.3	1,005.0	1,000.1
Earth System Science Pathfinder	223.8		296.0	248.6	216.7	227.8	245.1
Earth Science Multi-Mission Operations	179.7		191.8	194.3	193.6	197.9	202.6
Earth Science Technology	59.7		61.4	60.4	59.7	62.7	63.7
Applied Sciences	40.4		48.2	47.9	48.7	51.5	52.0
Planetary Science	**1,446.7**		**1,518.7**	**1,439.7**	**1,520.1**	**1,575.5**	**1,625.7**
Planetary Science Research	252.8		284.7	271.6	285.7	281.6	287.3
Discovery	259.7		202.5	277.3	337.4	345.0	405.3
New Frontiers	286.0		144.0	81.6	90.7	142.8	234.0
Mars Exploration	305.0		584.8	588.8	565.0	498.4	279.9
Outer Planets and Ocean Worlds	184.0		137.3	56.0	77.8	128.0	247.3
Technology	159.2		165.5	164.4	163.5	179.7	172.0
Astrophysics	**730.7**		**781.5**	**761.6**	**992.4**	**1,118.6**	**1,192.5**
Astrophysics Research	201.7		226.1	236.3	235.7	248.5	252.0
Cosmic Origins	201.0		198.5	198.4	197.3	195.5	209.5
Physics of the Cosmos	104.1		94.1	88.0	94.1	97.7	94.0
Exoplanet Exploration	100.6		133.8	148.0	309.3	373.3	450.8
Astrophysics Explorer	123.3		129.0	91.0	156.0	203.5	186.2
James Webb Space Telescope	**645.4**	**620.0**	**569.4**	**533.7**	**304.6**	**197.2**	**149.8**
Heliophysics	**636.1**		**698.7**	**684.0**	**698.3**	**714.8**	**723.9**
Heliophysics Research	192.0		180.1	192.0	210.0	215.9	214.2
Living with a Star	263.5		374.2	398.7	244.6	135.8	127.3
Solar Terrestrial Probes	70.6		39.8	38.8	127.3	179.4	198.4
Heliophysics Explorer Program	110.0		104.6	54.5	116.3	183.8	184.0

Astrophysics Earth Science
Heliophysics Planetary Science
Joint Agency Satellite Division (JASD)

Total Orbital Missions : 104

23 March 2016

Formulation 12

GSFC 5
WFIRST
GEDI [ISS]
TSIS-1 [ISS]
LandSat 9
JPSS-2

JPL 5
NISAR
OCO-3 [ISS]
SWOT
Europa
Mars 2020

LaRC 1
RBI [J2]

MSFC 1
JUICE

Implementation 31

GSFC 20
JWST
NICER [ISS]
TESS
CREAM [ISS]
*Hitomi**
ICESat-2
OMPS-L [J2]
GOLD [SES-14]
ICON
SET-1 [DSX]
SOC
SPP
GOES-R, -S, -T, -U
JPSS-1
MetOp-C
MOMA-MS [ExoMars18]
OSIRIS-REx

JPL 6
Euclid
ECOSTRESS [ISS]
GRACE FO (2)
Jason-3*
InSight
*ExoMars 16**

LaRC 3
CYGNSS (8)
SAGE III [ISS]
TEMPO [GEO]

MSFC 2
LIS [ISS]
Strofio [MPO]

Primary Ops 15

ARC 1
SOFIA

GSFC 6
CATS
DSCOVR~
GPM
LandSat 8~
TCTE
MMS (4)

JPL 7
LISA Pathfinder
OCO-2
SMAP
RapidScat
Dawn
Juno
Rosetta~

MSFC 1
New Horizons

Extended Ops 46

ARC 1
Kepler

JPL 14
NuSTAR
Spitzer
CloudSat
GRACE (2)
Jason-2~
QuikSCAT
Voyager (2)
Cassini
Mars Express~
Mars Odyssey
MRO
MSL
NEOWISE
MER-Oppy

MSFC 2
Chandra
Hinode~

GSFC 28
Fermi
HST
Swift
XMM-Newton~
Aqua
Aura
EO-1
LAGEOS (2)
LandSat 7~
S-NPP
SORCE
Terra
ACE
AIM
Geotail
IBEX
IRIS
RHESSI
SDO
SoHO
STEREO (2)
THEMIS (5)
TIMED
TWINS (2)
Van Allen (2)
Wind
LRO
MAVEN

LaRC 1
CALIPSO~

Div	Form	Imp	Pri Ops	Ext Ops	Total
Astro	1	6	2	8	**17**
Earth	7	8	8	13	**36**
Planet	3	5	4	9	**21**
Helio		5	1	16	**22**
JASD	1	7			**8**
Total	**12**	**31**	**15**	**46**	**104**

Italics = NASA instruments not managed under a separate NASA spacecraft project
*** = Launched** **~ = Operated by another agency in operations**

Updates: **ExoMars16 – formally Electra, launched**

NAME: LCC > $1B
NAME: $250M < LCC < $1B
NAME: **LCC < $250M**
} **for projects in formulation & implementation**

TARGET Launch Dates for SMD Missions

NASA Science Mission Directorate (SMD)

March 16 Updates: ECOSTRESS LRD to 6/18, LIS LRD to 7/16, OCO-3 LRD to 3/2018, GOES-S LRD to 2/1/18, CYGNSS LRD to 10/31/16

Assigned

- Foreign
- Minotaur
- Pegasus
- Atlas V
- Taurus
- Delta IV
- Delta II
- Falcon 9
- Falcon Heavy

Unassigned

- Medium
- Intermed/ Heavy
- TBD/ Hosted PL

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
GRAIL 9/10/11	MSL 11/26/11	IRIS 6/26/13	CATS 1/10/14	DSCOVR 2/11/15	Jason-3 1/16/16	CREAM 7/1/17	ECOSTRESS 6/1/18	GEDI 10/1/18	Euclid 3/1/20	JPSS-2 7/1/21	Europa 6/6/22	LandSat 9 1/1/23
Aquarius 6/10/11	NuSTAR 6/13/12	LandSat 8 2/11/13	GPM 2/27/14	MMS 3/12/15	LIS 7/1/16	CYGNSS 10/31/16	GOES-S 2/1/18	GOES-T 4/1/19	Mars 2020 8/4/20	OMPS-L 7/1/21	JUICE 1/1/22	
Juno 8/5/11	S-NPP 10/25/11	LADEE 9/7/13	MAVEN 11/18/13	SMAP 1/29/15	OSIRIS-REx 9/8/16	GOES-R 10/14/16	ICESat-2 10/31/17	JWST 10/31/18		RBI 7/1/21		
Glory* 3/4/11	Van Allen 8/30/12		OCO-2 7/2/14		SAGE III 6/10/16	GOLD 9/30/17	InSight 5/5/18	MetOp-C 10/1/18		SWOT 10/9/20		
			RapidScat 9/21/14		SET-1 9/1/16	GRACE FO 8/5/17	OCO-3 3/1/18	SOC 10/19/18		NISAR 12/1/20		
			TCTE 11/19/13		Hitomi 2/12/16	ICON 6/15/17	SPP 7/31/18	TEMPO 9/20/19				
					LISA Pathfinder 12/2/15	JPSS-1 1/20/17	TSIS-1 6/1/18					
					ExoMars16 3/14/16	NICER 3/1/17	MOMA-MS 5/1/18					
						Strofio 1/1/17						
						TESS 8/1/17						

Fiscal Years

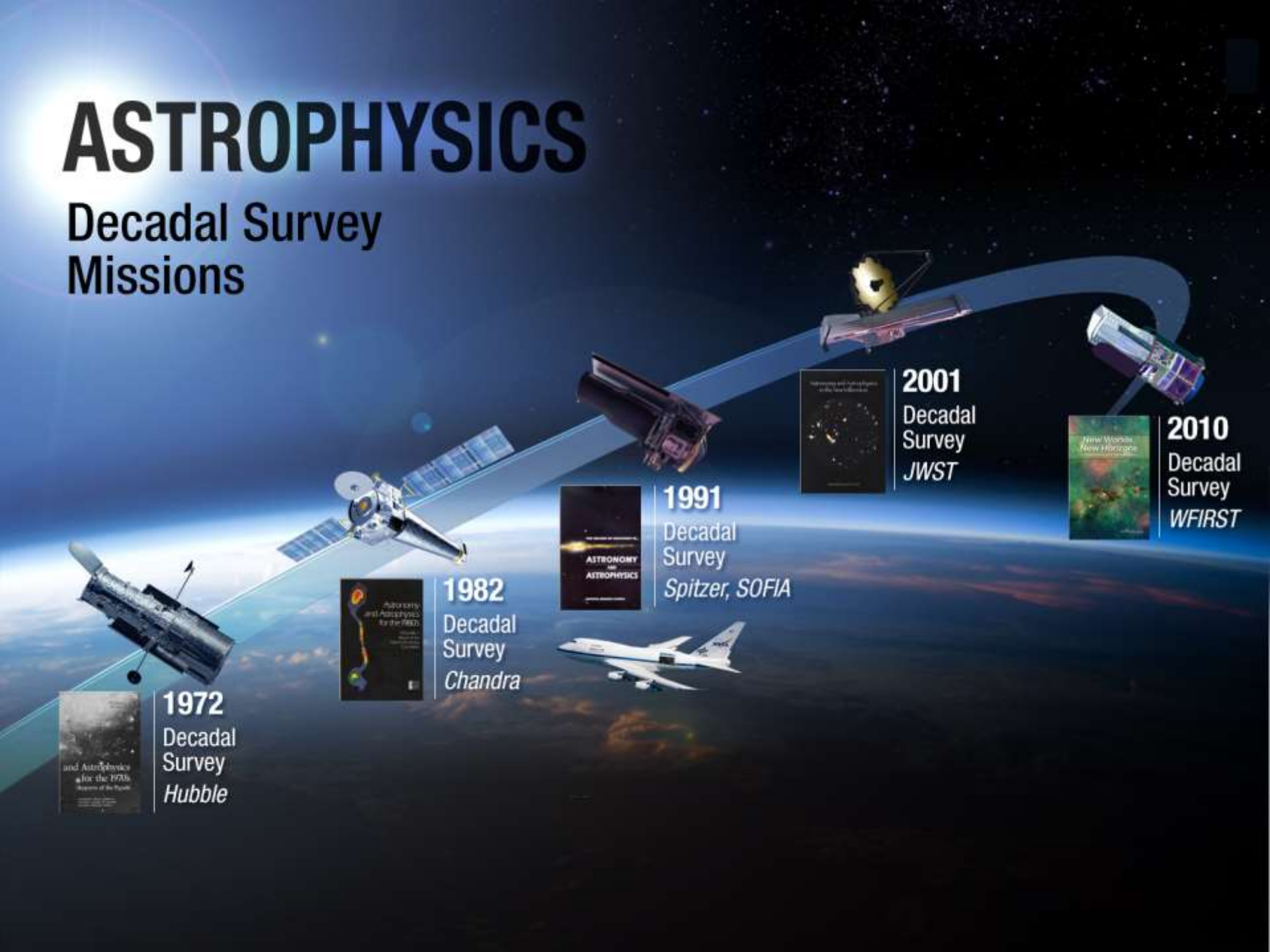
*Launch Failure

National Academies of Sciences Space Studies Board Status

Study Title	Status / Outlook	Chair
Achieving Science Goals with CubeSats	The Committee's report entered review Feb 18; Prepublication release in late April/early May	T. Zurbuchen
Review of Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics	The Committee' final report went into review in mid April	J. Hewitt
NASA Science Mission Extensions	3rd meeting April 18-20. Report to be completed summer 2016	V. Hamilton H. Tanabaum
Decadal survey for Earth Sciences and Applications from Space ESAS2017	Steering committee met in January; Staff working on panel nominations. 2nd Meeting June 2-5 (Jamboree)	A. Busalacchi W. Abdalatti
Review of PSD's restructured R&A Program	Staff working on committee nominations Funding received. 1st meeting likely mid May	TBD
Searching for Life Across Space and Time (workshop)	Staff working on committee nominations Funding received.	TBD
Large Strategic Science Missions	Staff working on committee nominations Funding received.	TBD
Planetary Protection Policy Dev.	Academies due to send proposal in May.	TBD

ASTROPHYSICS

Decadal Survey Missions




Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
LISA Pathfinder (ESA)
12/3/2015
JWST
2018
WFIRST
Mid 2020s
Euclid (ESA)
2020
TESS
2017
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
NuSTAR
6/13/2012
Swift
11/20/2004
Hitomi (JAXA)-?
2/17/2016
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 2014

Astrophysics Missions in Development

NICER
3/2017

NASA Mission

Neutron Star Interior Composition Explorer

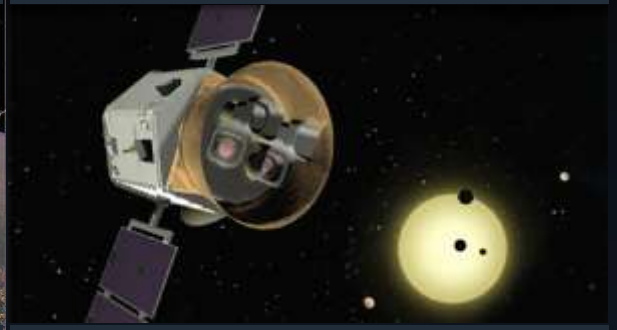
CREAM
7/2017

NASA Mission

Cosmic Ray Energetics And Mass

TESS
8/2017

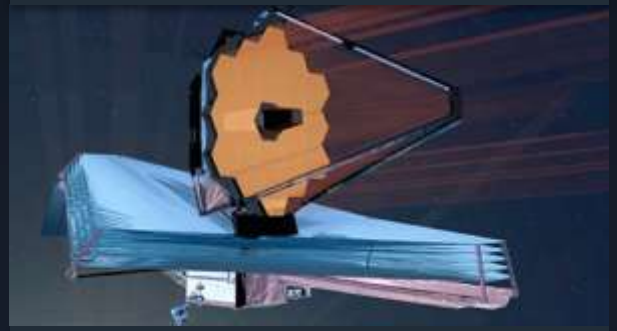
NASA Mission



Transiting Exoplanet Survey Satellite

JWST
10/2018

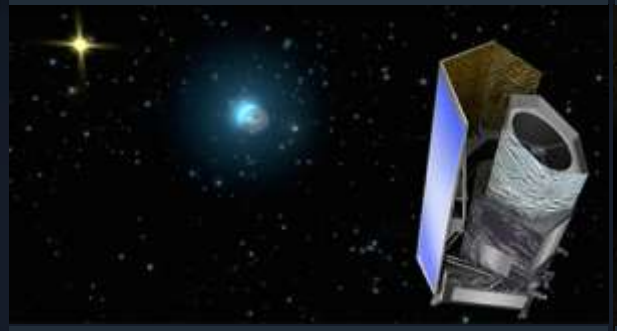
NASA Mission



James Webb Space Telescope

Euclid
2020

ESA-led Mission



NASA is supplying the NISP Sensor Chip System (SCS)

WFIRST
Mid 2020s

NASA Mission

Wide-Field Infrared Survey Telescope

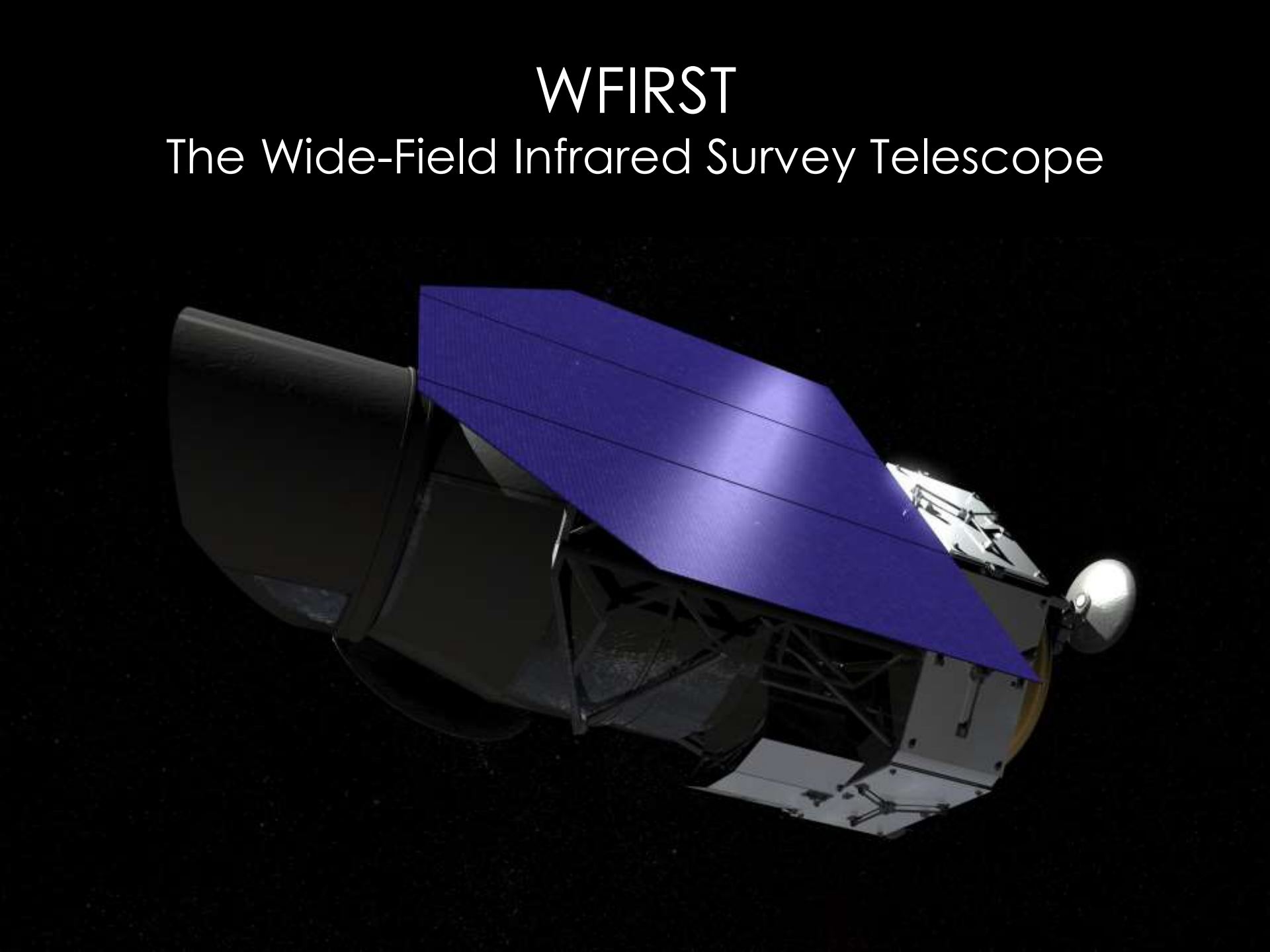
James Webb Space Telescope

…going where no Hubble has gone before

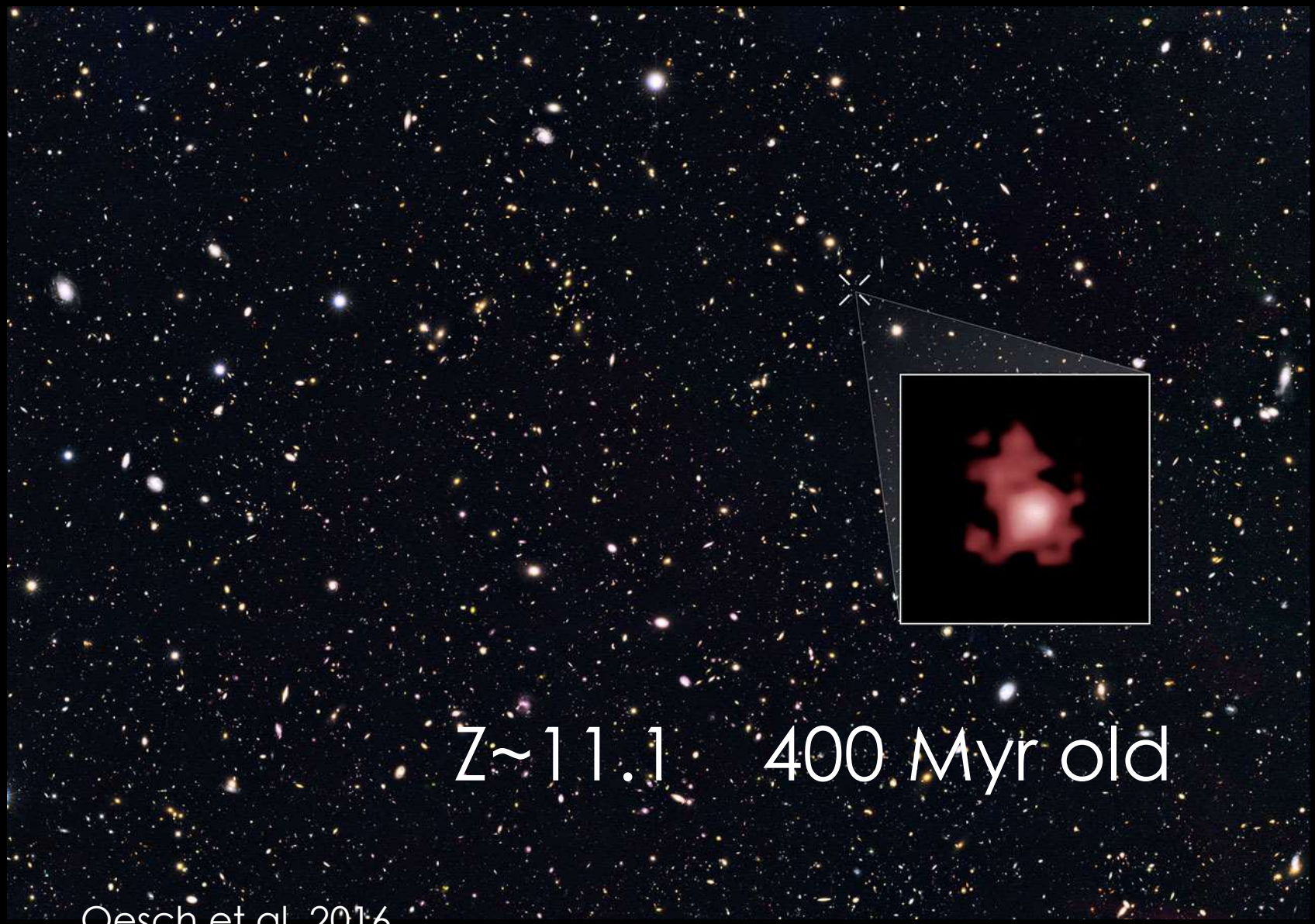
JWST Mirror Fully Assembled

WFIRST

The Wide-Field Infrared Survey Telescope

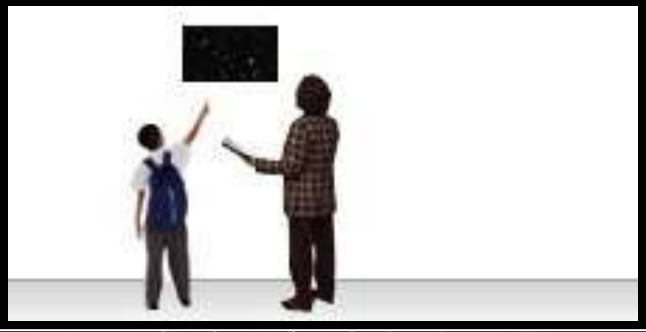


Hubble breaks cosmic distance record



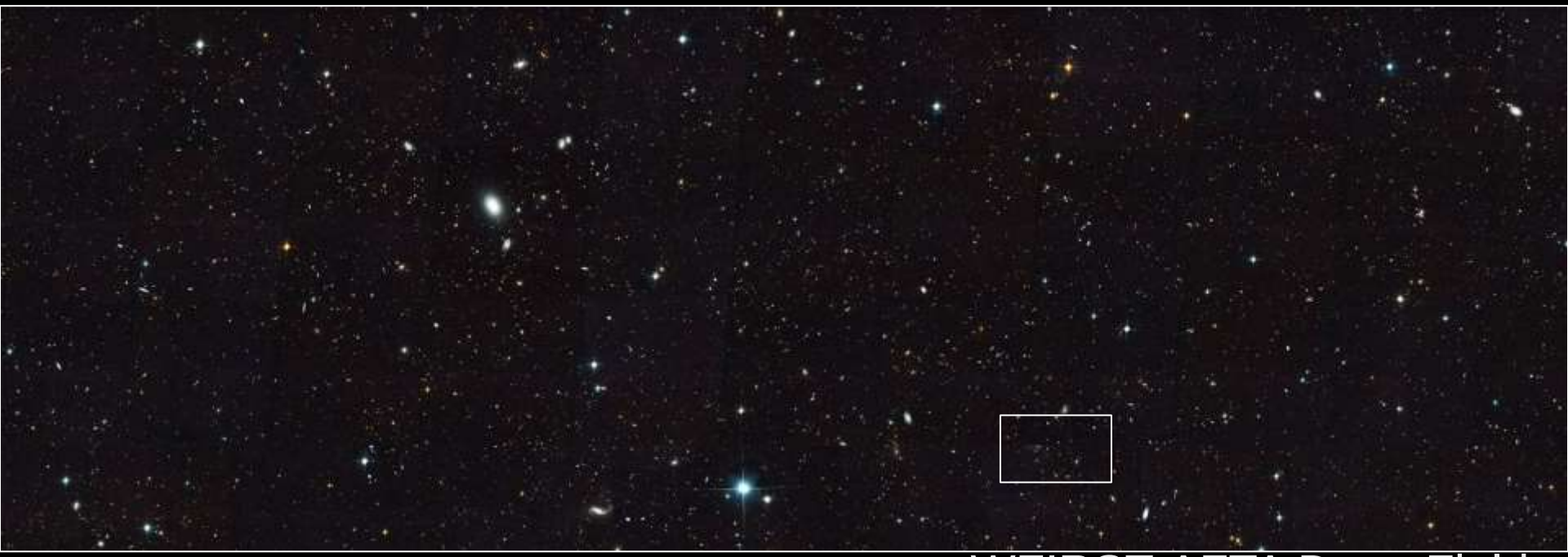
Oesch et al. 2016

WFIRST-AFTA vs Hubble



Hubble Ultra Deep Field - IR
~5,000 galaxies in one image
(60 orbits, 4 days)

PI: Illingworth



70,000 galaxies in each field
of AFTA survey

WFIRST-AFTA Deep Field
>1,000,000 galaxies in each image

2015 Wanaka New Zealand Balloon Campaign

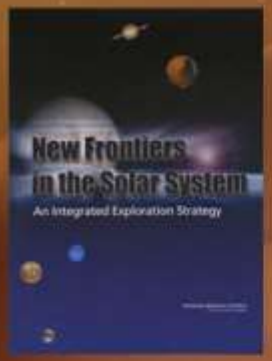
Wanaka, New Zealand SPB Launch March 26, 2015

SPB flight path
Balloon brought down April 27th

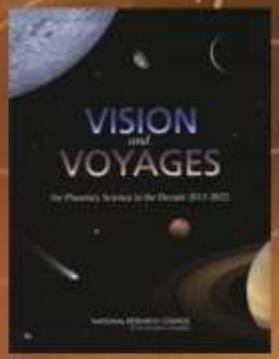
- Superpressure balloon (SPB) total flight time was 32 days, 5 hours.
  - The test flight exceeded the minimum success criteria.
  - The test flight validated both the SPB's design and the viability of New Zealand as a future mid-latitude SPB launch location.
  - Science community expressing interest in future SPB flights from New Zealand.

Planetary Science

Decadal Survey Missions



2003 Decadal Survey



2013 Decadal Survey

Europa

Mars Rover 2020

2018 InSight

2016 OSIRIS-REx

2013 MAVEN

2011 MSL

2011 Juno

2006 New Horizons

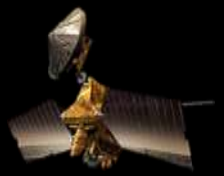
1997 Cassini

Current & Future Mars Missions

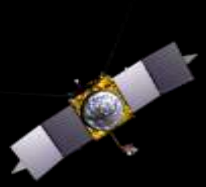
Operational 2001 - 2014

Mars Odyssey

ESA Mars Express
(NASA: MARSIS)



Mars Reconnaissance Orbiter

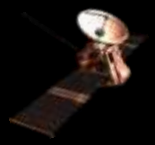


MAVEN

Opportunity – Mars Exploration Rover

Curiosity – Mars Science Laboratory

2016



ESA
Trace Gas Orbiter
(NASA: Electra)

2018

InSight

ESA
ExoMars Rover
(NASA: MOMA)

2020

Science Rover

2022

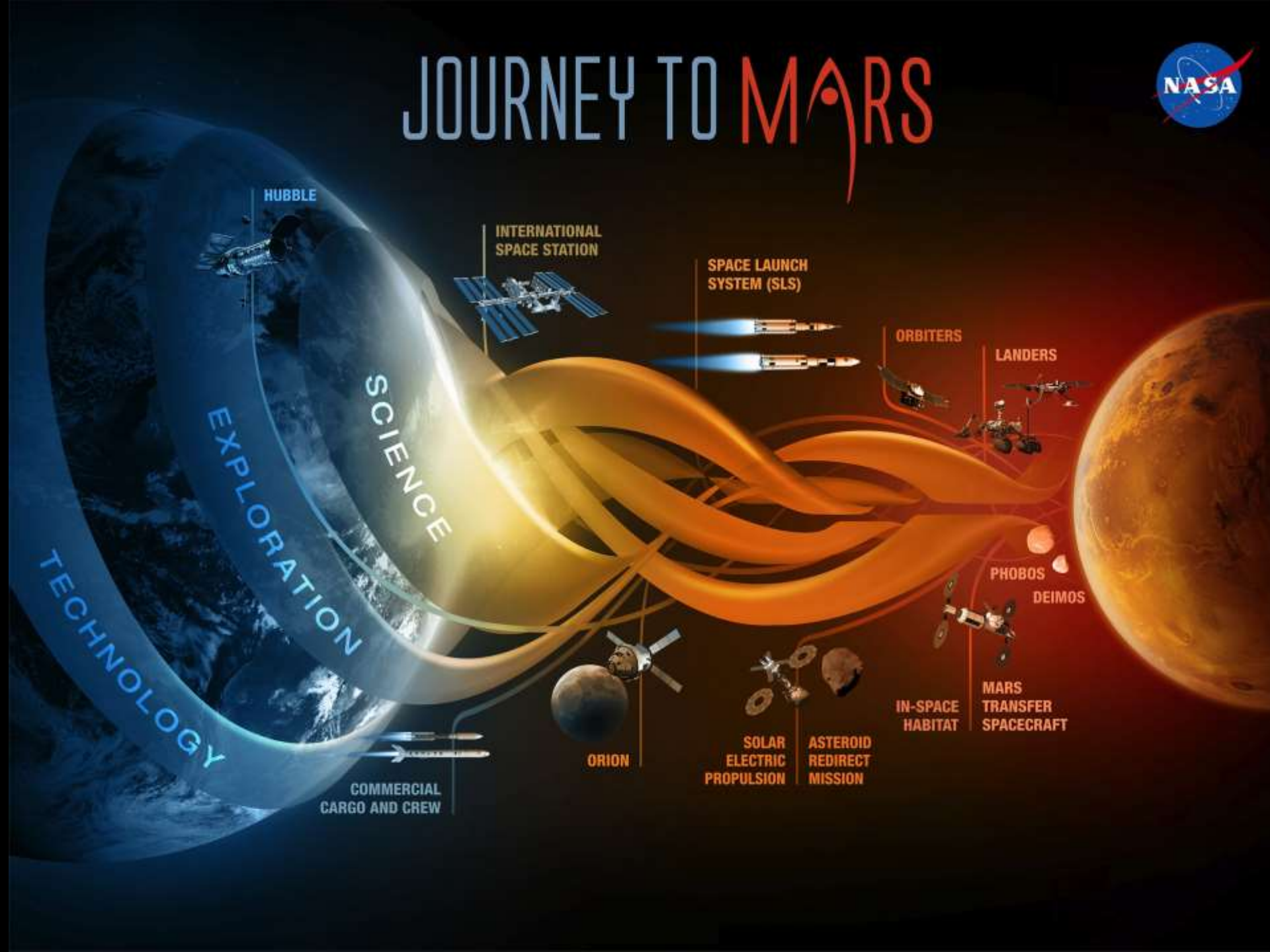
Follow the Water

Explore Habitability

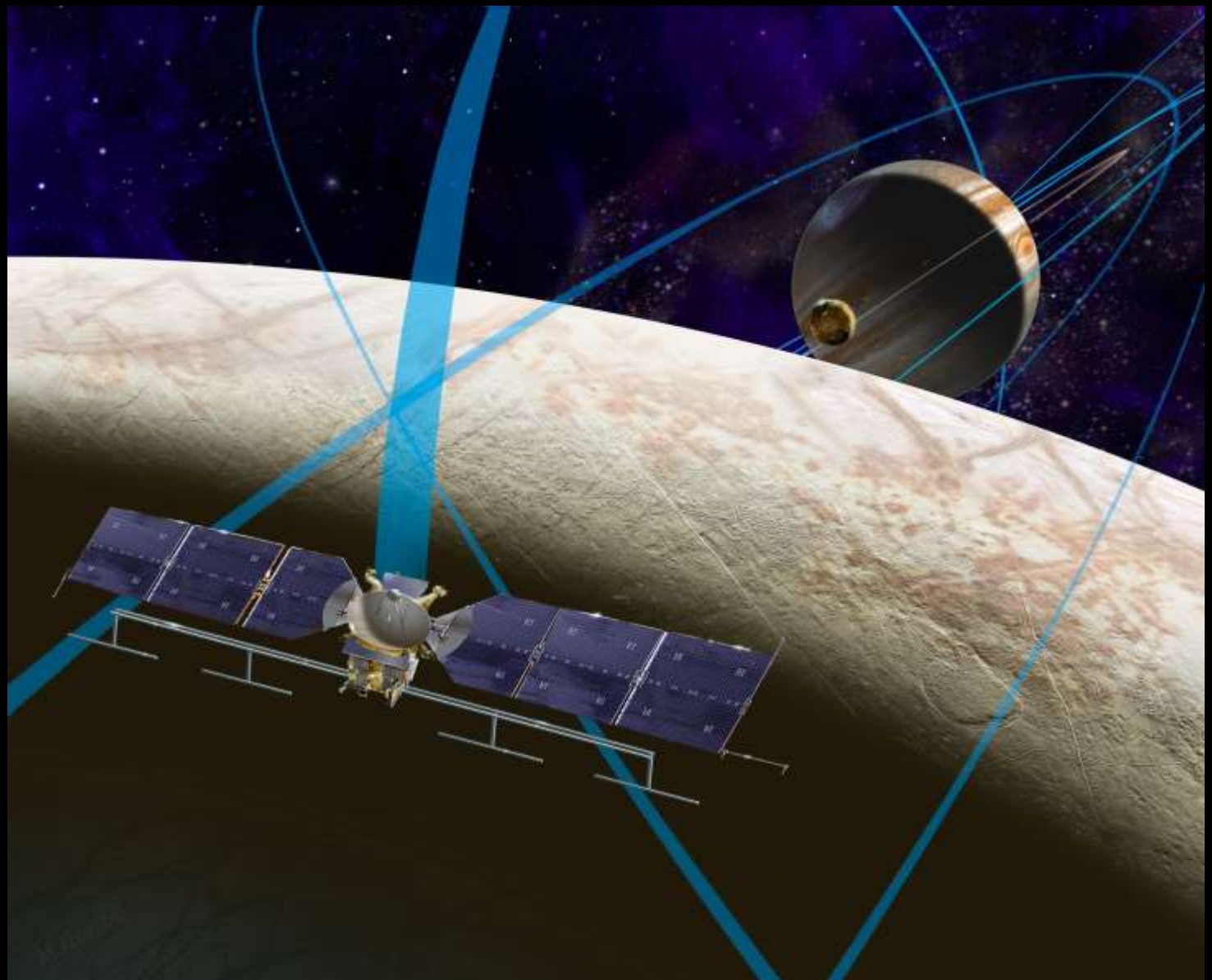
Seek Signs of Life

Prepare for Future Human Explorers

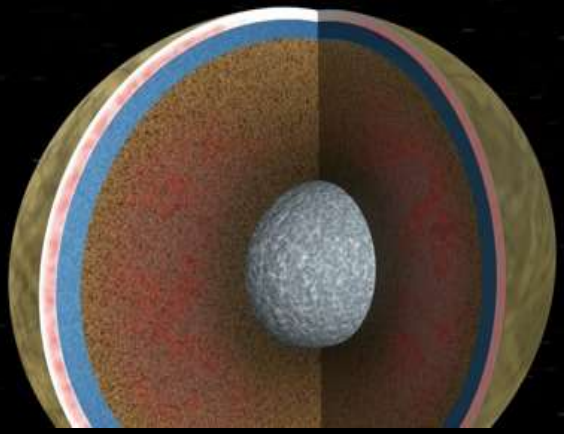
EVOLVING MARS SCIENCE THEMES


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
COMMERCIAL CARGO AND CREW

Europa Mission



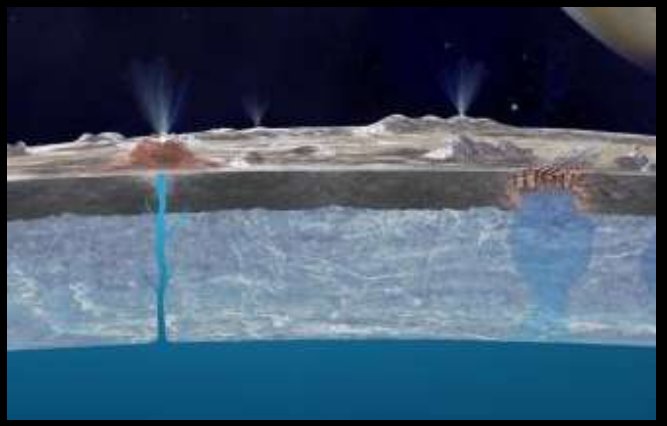
The Big Question: Is Europa Habitable?

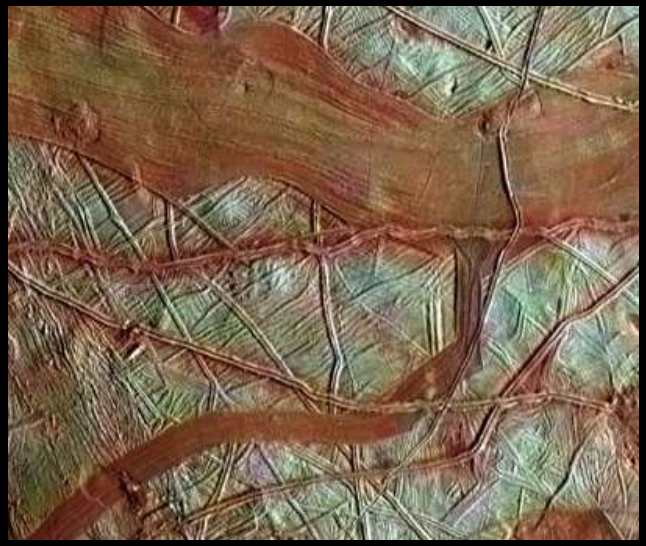


Credit: NASA/JPL

What's in the plumes?
Mass Spectrometer
(Cassini)

How deep and salty is the ocean?
Gravity, Magnetometer
(GRAIL, GRACE)





Credit: NASA/JPL-Caltech/SETI Institute

How active is the ice shell?
Camera, Thermal Imager
(MRO, ICESat)

How thick is the ice shell?
Radar, Gravity
(MRO, Cassini)

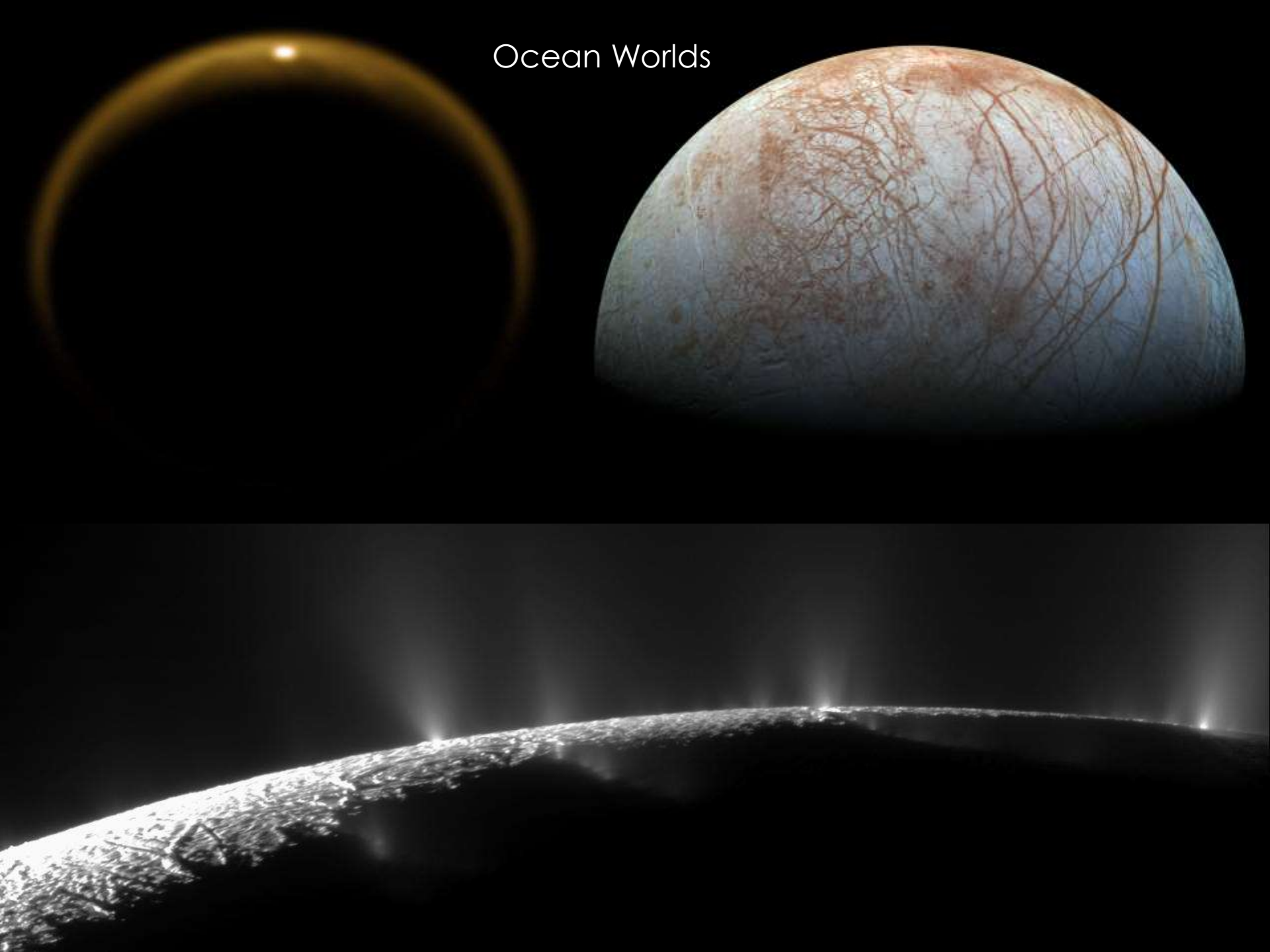
What's the brown stuff?
IR & Mass Spectrometers
(Landsat, MRO)

Credit: NASA/ESA/L. Roth/SWRI/University of Cologne

Potential Europa Lander

- NASA's FY 16 Appropriation included "orbiter with a lander to meet the science goals for the Jupiter Europa mission…use the SLS as the LV…plan for a launch NLT 2022…and include in the FY17 budget the five year funding profile necessary to achieve these goals."
- Working on Pre-Phase A studies including 2 launch scenario, early results due June 2016
- Science Definition Team
  - Received 80 expressions of interest
  - Kevin Hand, Jim Garvin and a TBD astrobiologist will serve as co-chairs
- Early Instrument development
  - Community announcement expected soon regarding opportunity to compete for risk reduction support for science instruments and sample acquisition systems for a surface mission.

Ocean Worlds



Earth Science

CYGNSS
FY17

TEMPO
FY17/21

ICESat-2
FY18

GRACE-FO
FY18

CLARREO PF FY19
ECOSTRESS FY19
GEDI FY18/20
TSIS-1 FY17
TSIS-2 FY20/22

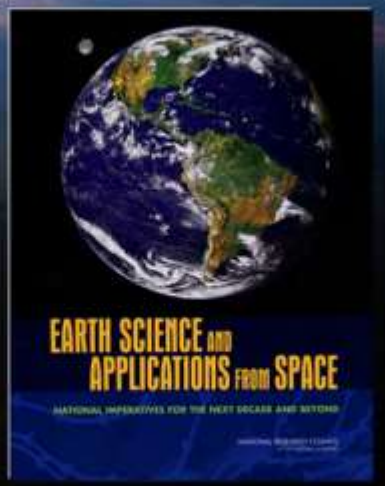
OMPS-L FY18/21
RBI FY19/21

SWOT
FY20

NI-SAR
FY22

PACE
FY22

Sentinel-6A/B
FY20/24



2007
Decadal
Survey

New NASA Earth Science Missions Expand View of Our Home Planet

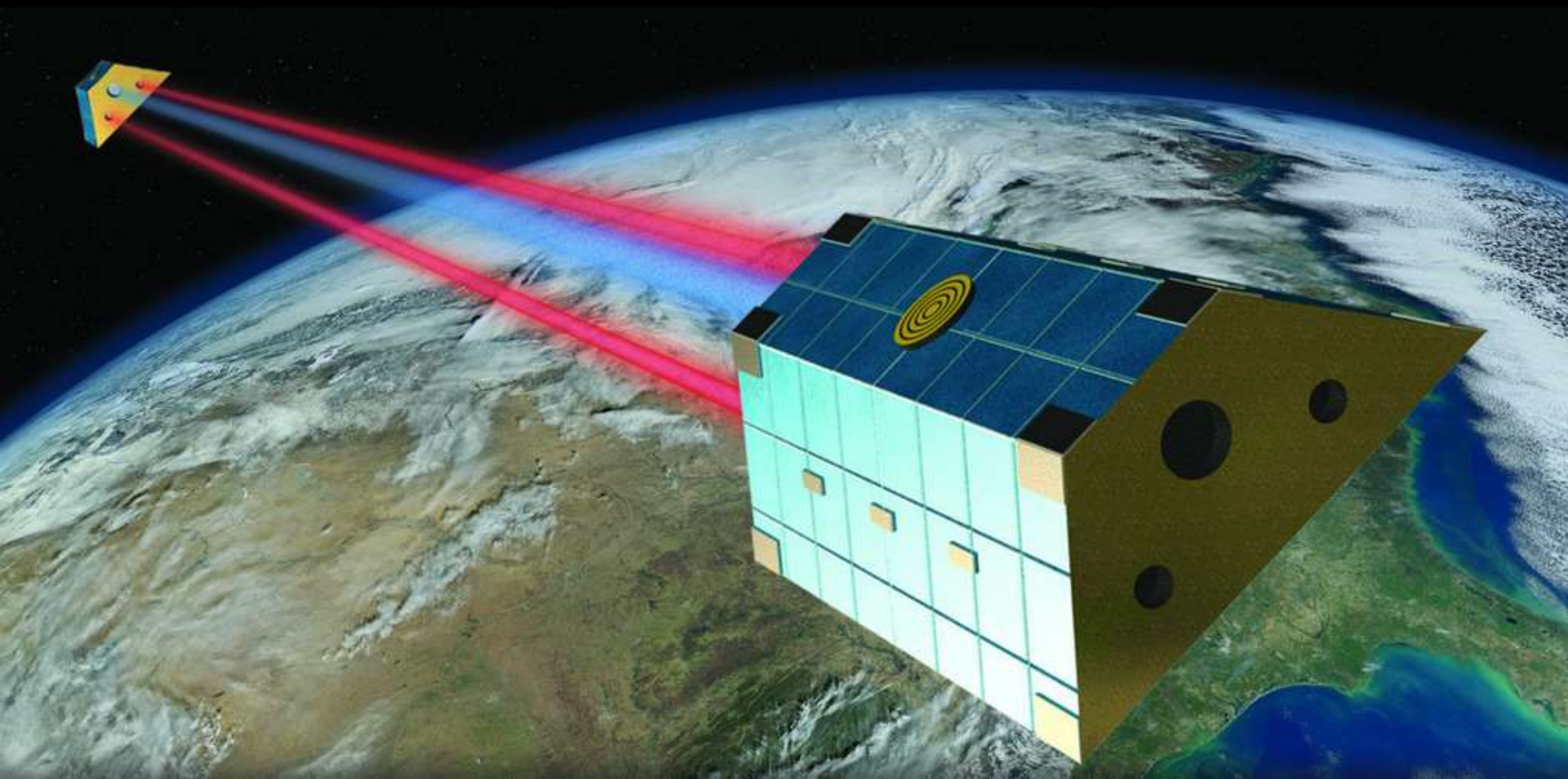
Credit: NASA

PACE

Pre-Aerosol Clouds and Ocean Ecosystem

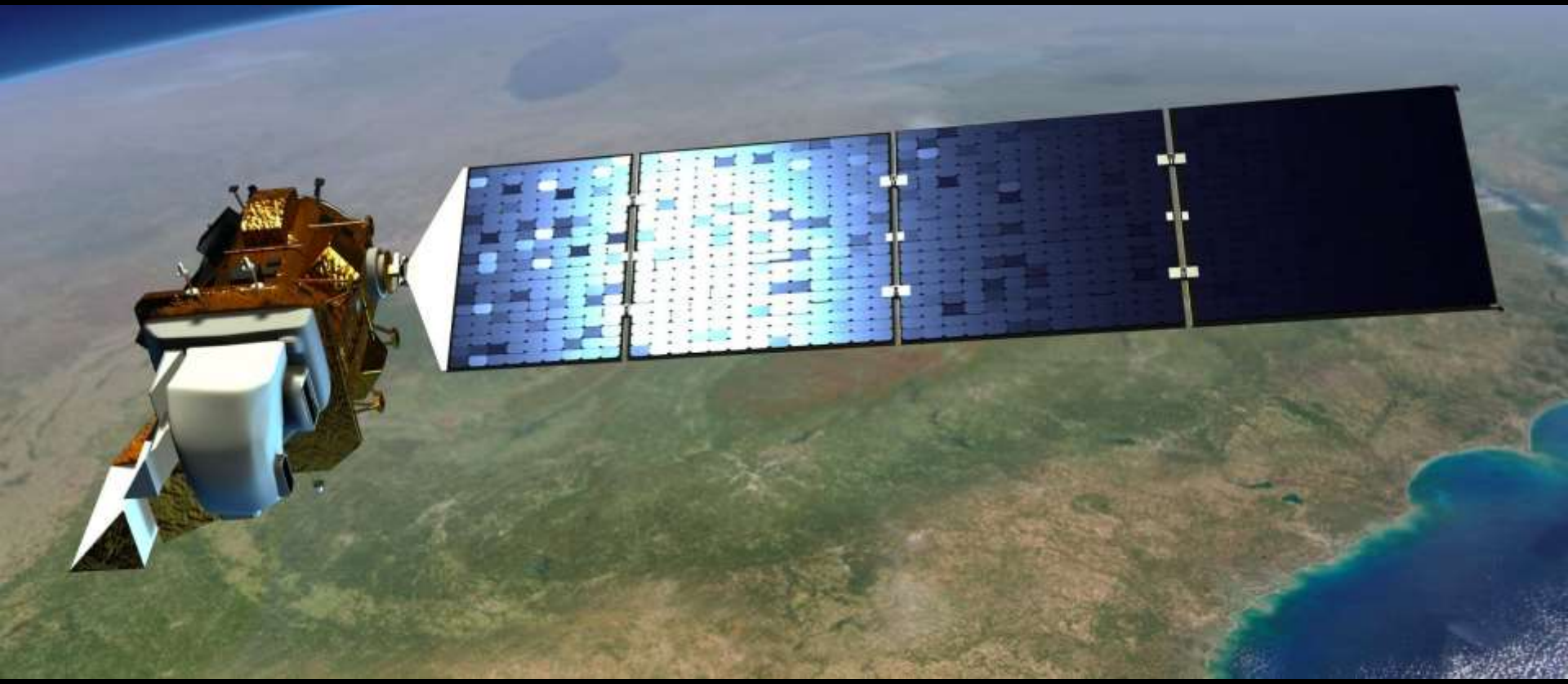
ICESat-2

GRACE Follow-On



Jason-3 and Sentinel-6

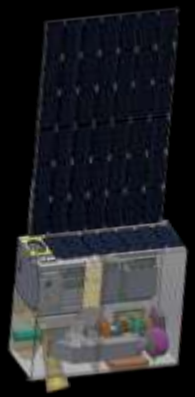
LandSat-9/Sustainable Land Imaging



InVEST 2015 Program

U-Class satellites advancing TRLs for Earth science measurements - ***all 6U***;
selected Sept. 17, 2015

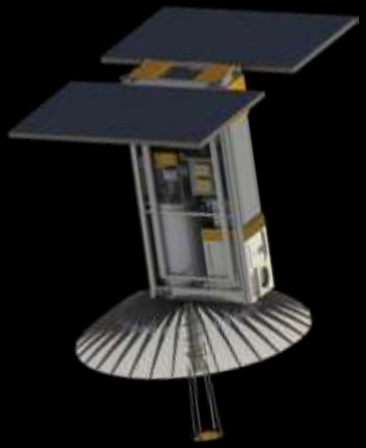
CIRAS
JPL



Infrared Atmospheric Sounder

Demonstrate ability to measure spectrum of upwelling infrared radiation in 4-5 micron spectral region

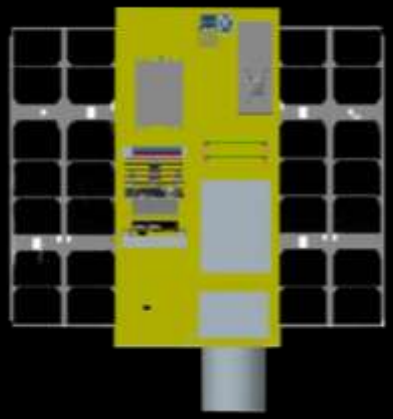
RainCube
JPL



Precipitation Profiling Radar

Validate Ka-band (35.75 GHz) radar payload using new deployable antenna and processing technologies

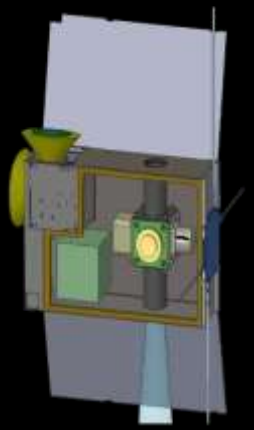
CubeRRT
The Ohio State University



Radiometer Radio Frequency Interference

Demonstrate wideband RFI mitigation technologies vital for future space-based microwave radiometers

CIRIS
Ball Aerospace



Infrared Radiometer

Validation of an uncooled imaging infrared (7.5-13 um) radiometer for high radiometric performance in LEO

Rocket Labs

Virgin Galactic

Firefly

Heliophysics

Decadal Survey Missions

Solar Orbiter

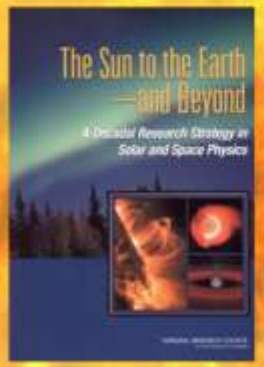
Solar Probe Plus

GOLD

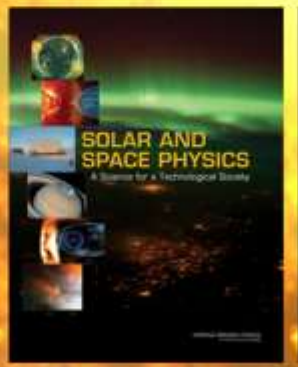
ICON

MMS

Van Allen Probes

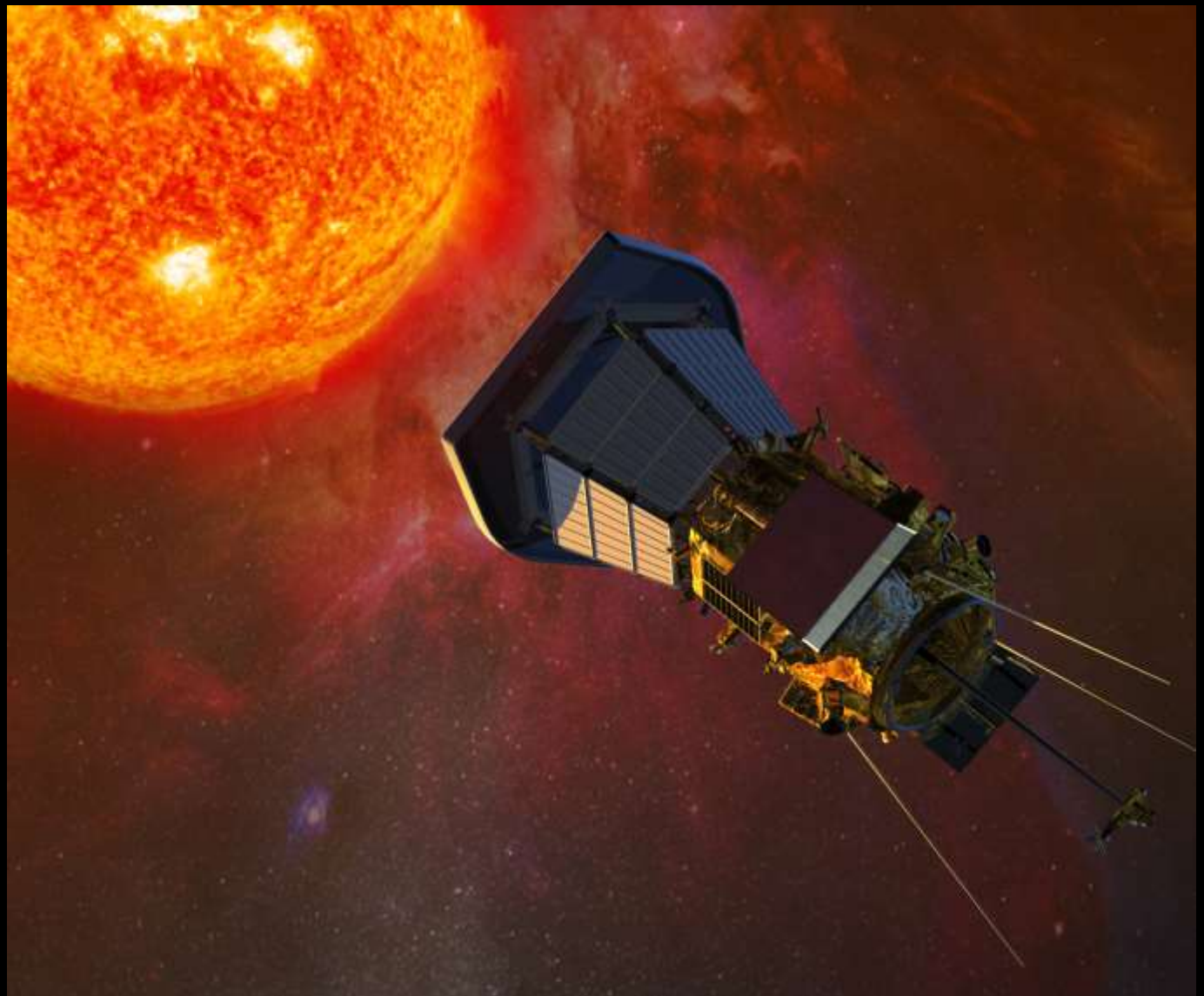


2003 Decadal Survey



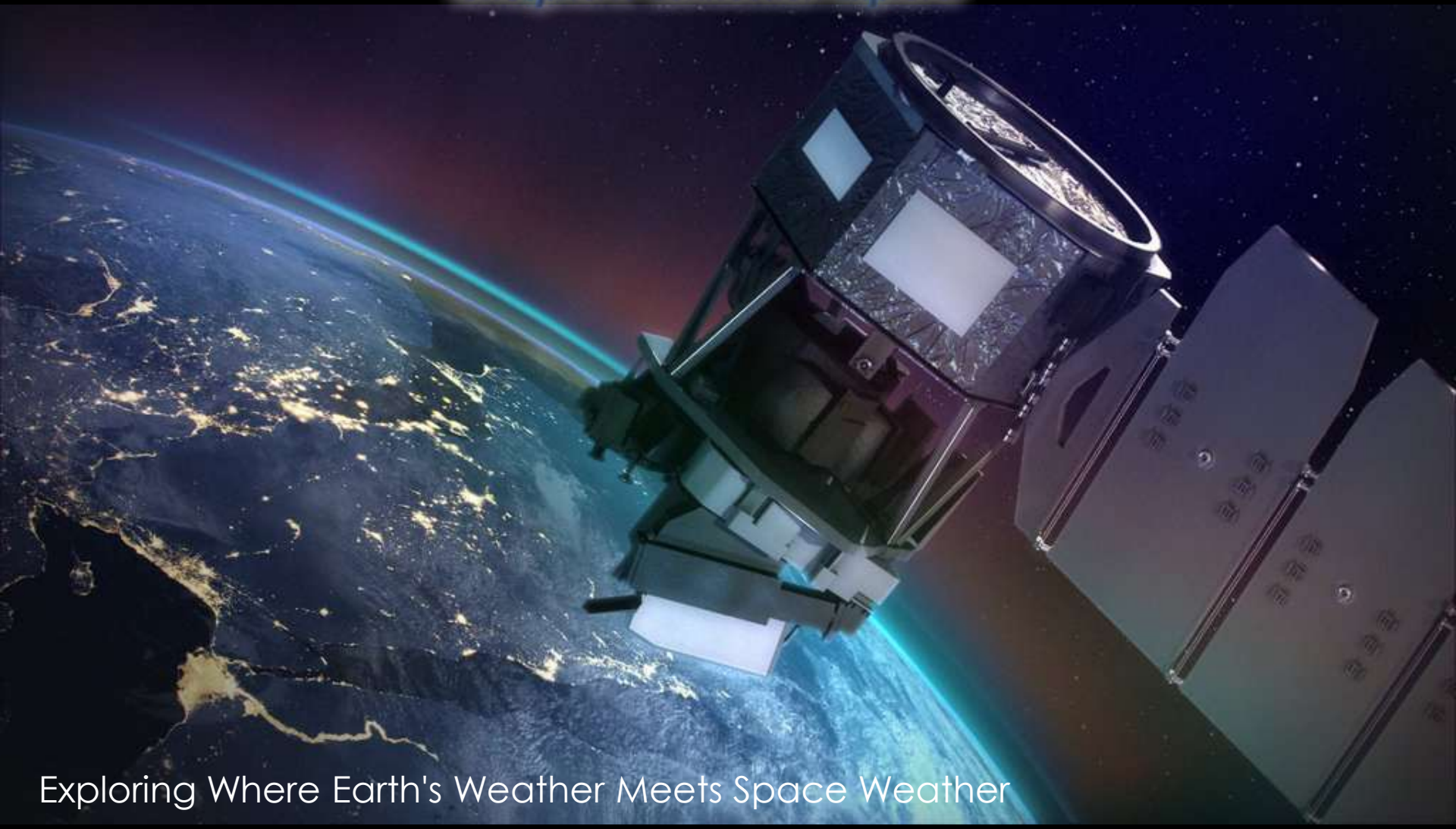
2013 Decadal Survey

Solar Probe Plus



ICON

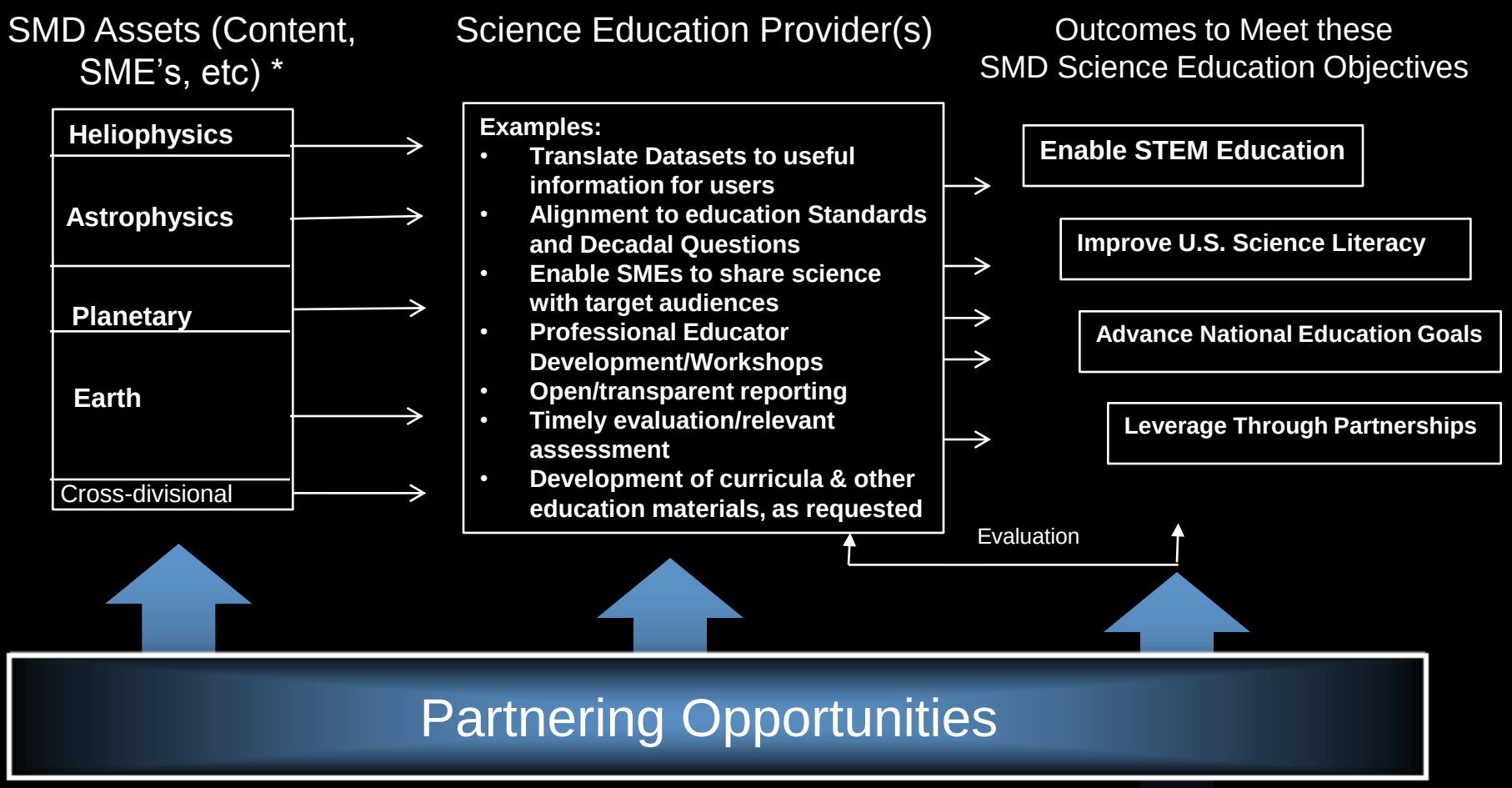
Ionospheric Connection Explorer



Exploring Where Earth's Weather Meets Space Weather

NASA Sounding Rocket Program

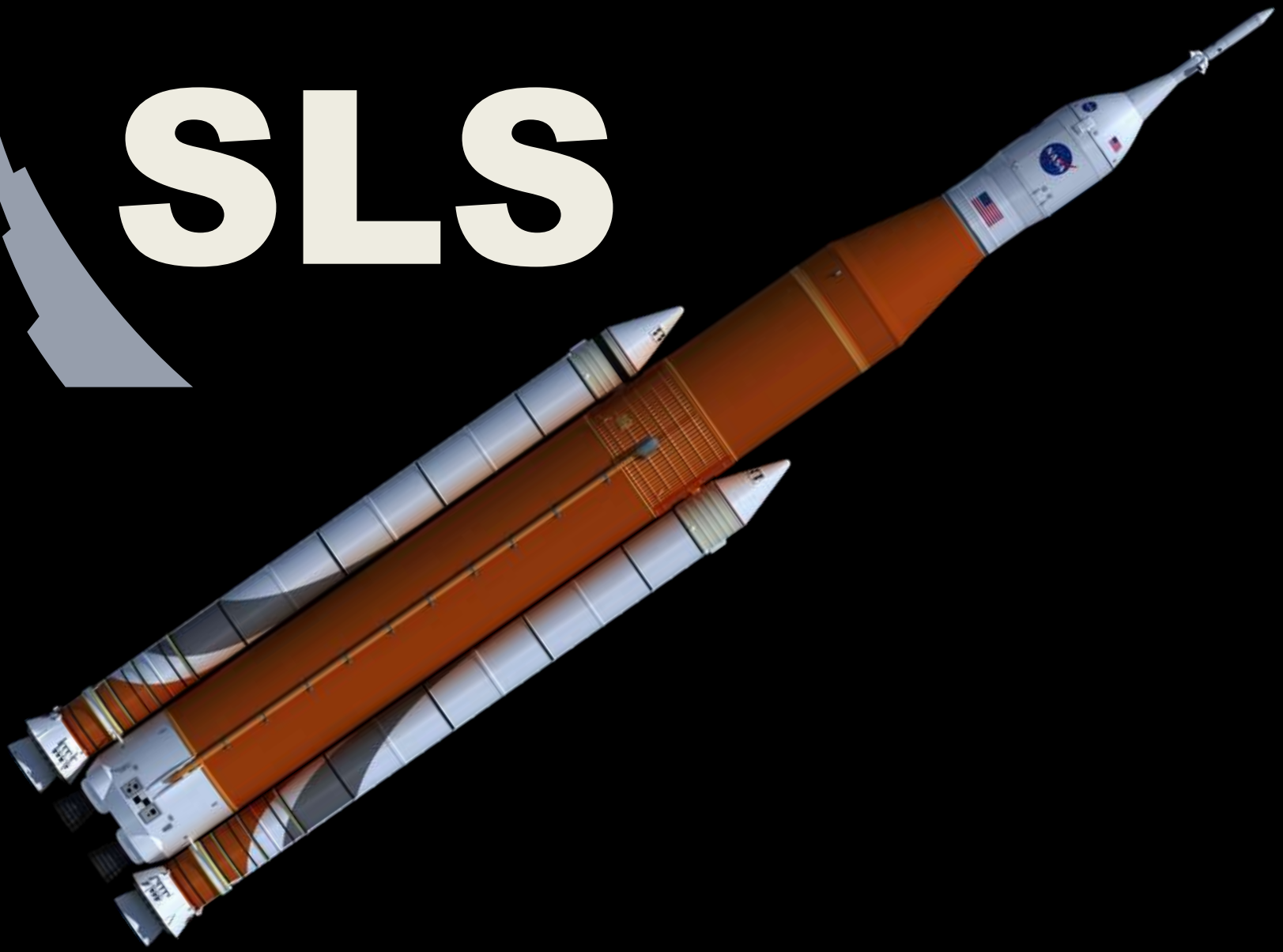
SMD Science Education Model



* Divisions responsible for science content datasets, Infrastructure/Tools (e.g. Eyes, GSFC Visualizations), SME selection, and enabling flight opportunities

IS THERE LIFE BEYOND EARTH?

SLS



The Versatile Space Launch System

Science Missions Such as Europa

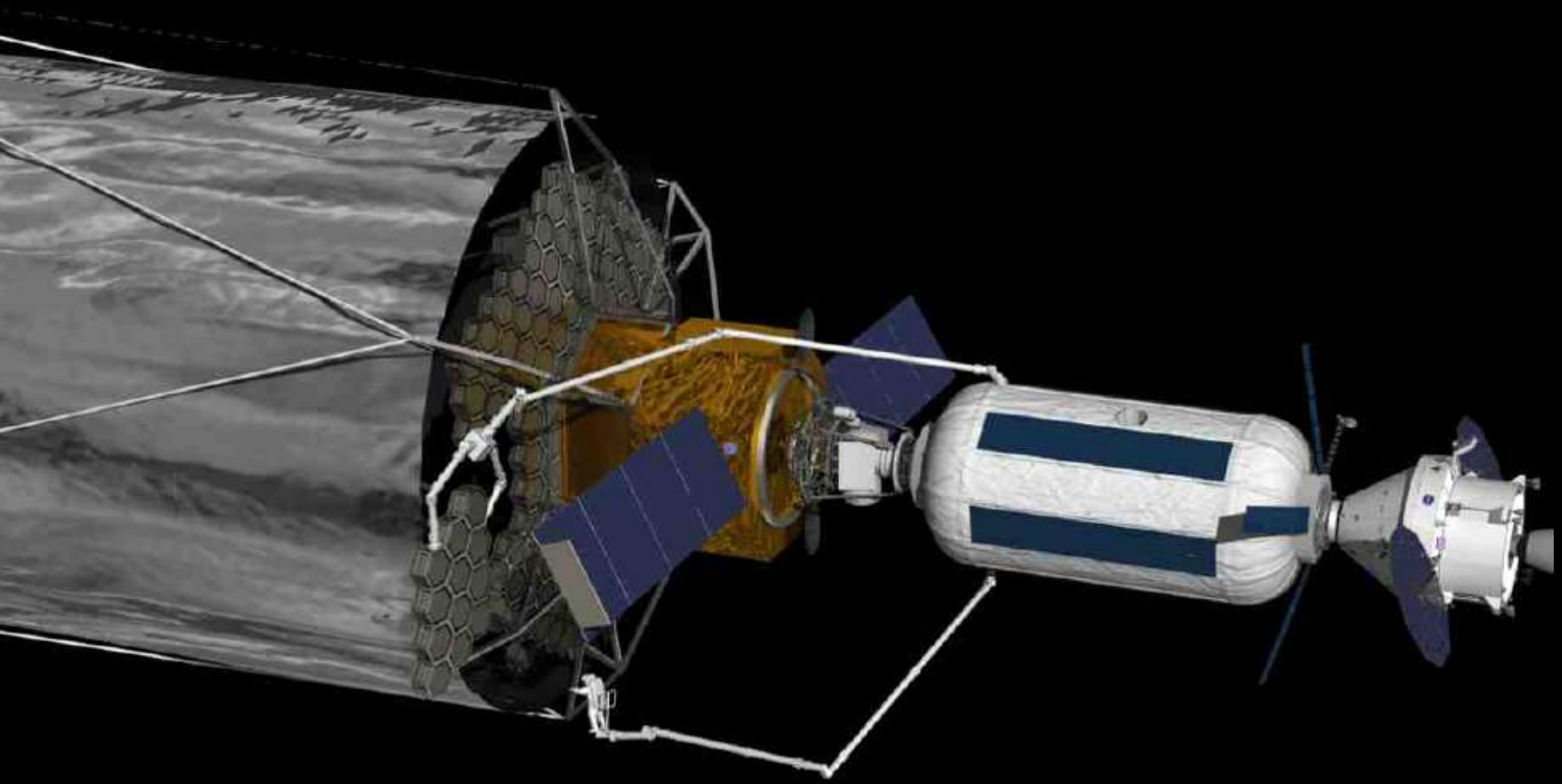
Orion

5m fairing w/robotic lunar lander & short-duration hab module

8m fairing with large aperture telescope

10m fairing w/notional Mars payload

Human Space Flight and Assembly of a Future Large-Aperture Telescope



imagine the moment...

What Are the Challenges to this Bright Future ?

- Bold and Consistent Leadership
- Cost and Schedule Performance
- High Quality Workmanship
- Teamwork
- Scientists, Engineers, Technicians, Dreamers

  (STEM education)

April 5, 2016

RELEASE: 16-042

John Grunsfeld Announces Retirement from NASA

John Grunsfeld will retire from NASA April 30, capping nearly four decades of science and exploration with NASA. His tenure included serving as Chief Scientist, astronaut, and head of NASA's Earth and space science activities.

"After exploring strange new worlds and seeking out new life in the Universe, I can now boldly go where I've rarely gone before – home," said Grunsfeld.

Thank You!