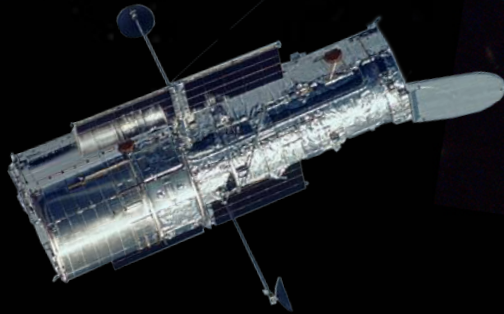


Science @ NASA



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

Our Mission:

Innovate

Explore

Discover

Inspire

www.nasa.gov



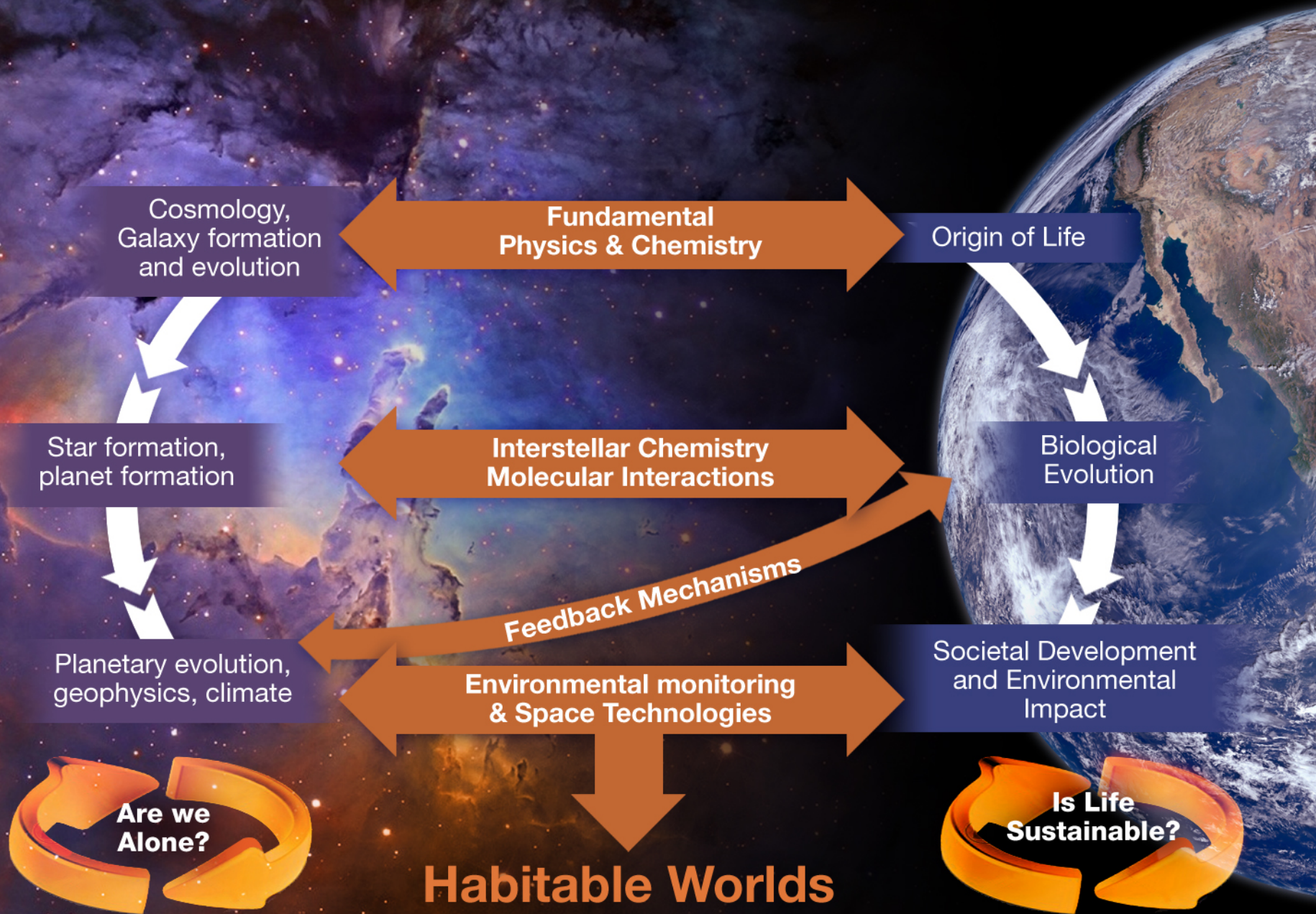
Big Scientific Questions:

Where did we come from?

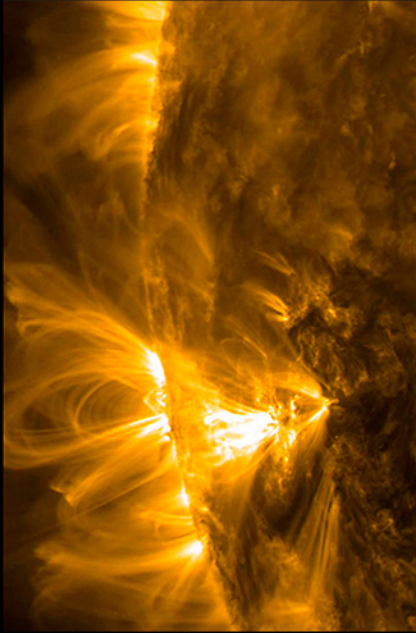
Where are we going?

Are we alone?

Science@NASA



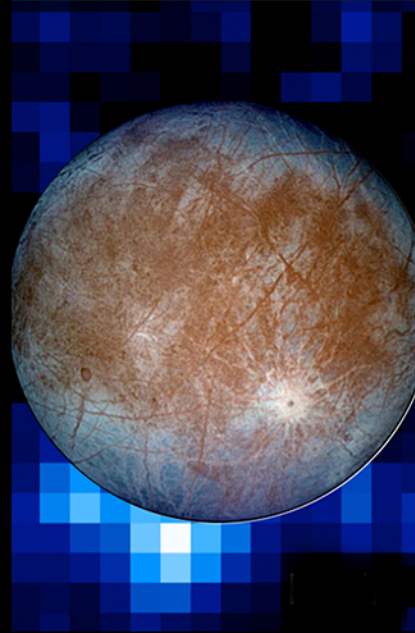
Science Mission Directorate



HELIOPHYSICS



EARTH SCIENCE



PLANETARY SCIENCE



ASTROPHYSICS



An Integrated Program of Science

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
<u>Earth Science</u>	<u>1,784.1</u>		<u>2,032.2</u>	<u>1,989.5</u>	<u>2,001.3</u>	<u>2,020.9</u>	<u>2,047.7</u>
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
<u>Planetary Science</u>	<u>1,446.7</u>		<u>1,518.7</u>	<u>1,439.7</u>	<u>1,520.1</u>	<u>1,575.5</u>	<u>1,625.7</u>
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
<u>Astrophysics</u>	<u>730.7</u>		<u>781.5</u>	<u>761.6</u>	<u>992.4</u>	<u>1,118.6</u>	<u>1,192.5</u>
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
<u>James Webb Space Telescope</u>	<u>645.4</u>	<u>620.0</u>	<u>569.4</u>	<u>533.7</u>	<u>304.6</u>	<u>197.2</u>	<u>149.8</u>
<u>Heliophysics</u>	<u>636.1</u>		<u>698.7</u>	<u>684.0</u>	<u>698.3</u>	<u>714.8</u>	<u>723.9</u>
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

Best Hits of 2026

Or how what we're doing now is setting up
the great science for the next decade

- Formulation
- Implementation
- Primary Ops
- Extended Ops

Spitzer
8/25/2003

Kepler
3/7/2009

LISA Pathfinder (ESA)
12/3/2015

JWST
2018

TESS
2017

XMM-Newton (ESA)
12/10/1999

NuSTAR
6/13/2012

Hubble
4/24/1990

Fermi
6/11/2008

CREAM (on ISS)
2017

NICER (on ISS)
2017

SOFIA
Full Ops 2014

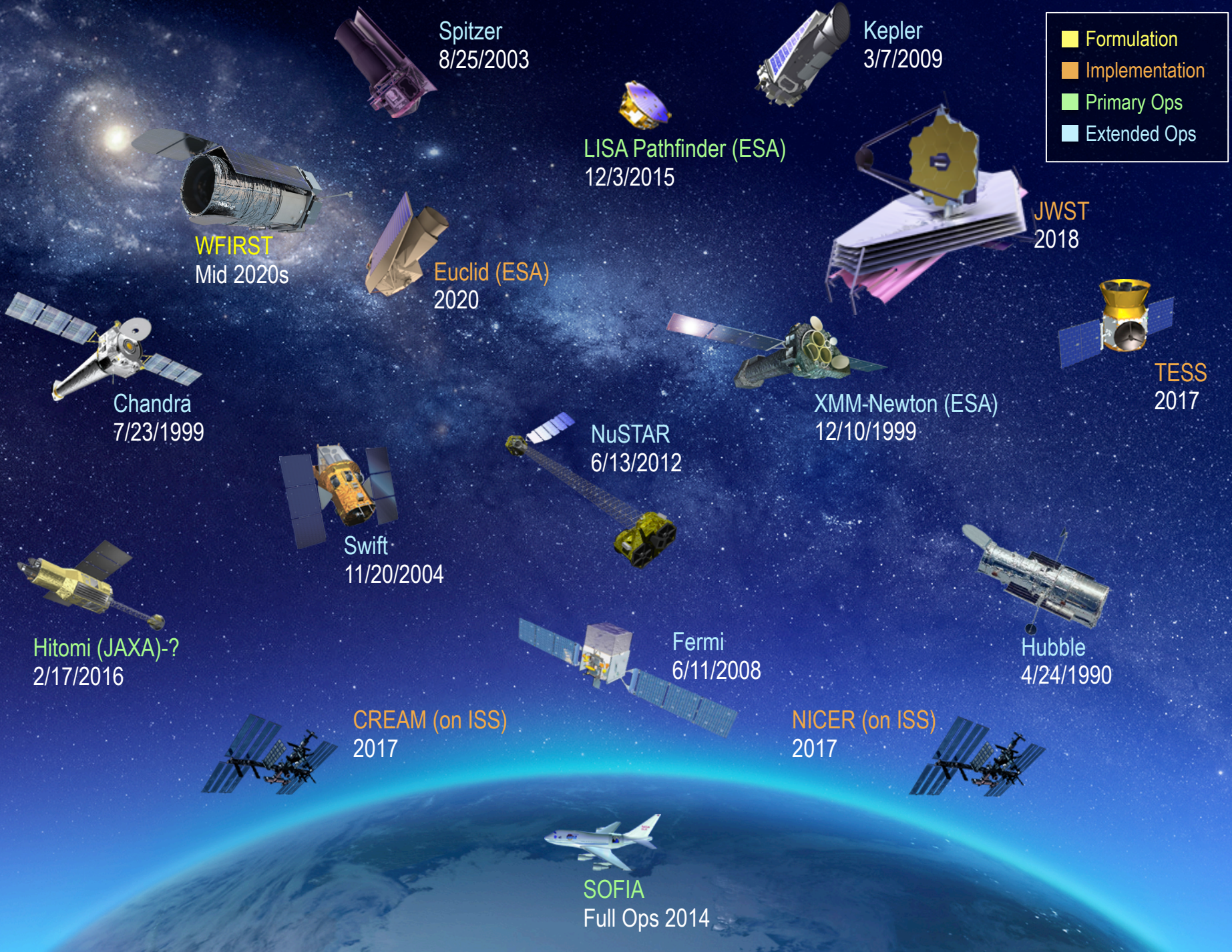
WFIRST
Mid 2020s

Euclid (ESA)
2020

Swift
11/20/2004

Hitomi (JAXA)-?
2/17/2016

Chandra
7/23/1999



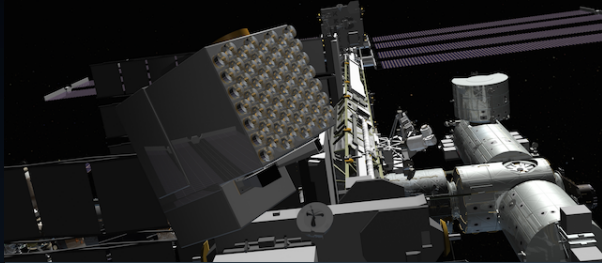
Astrophysics Missions in Development



NICER

NASA Mission

3/2017

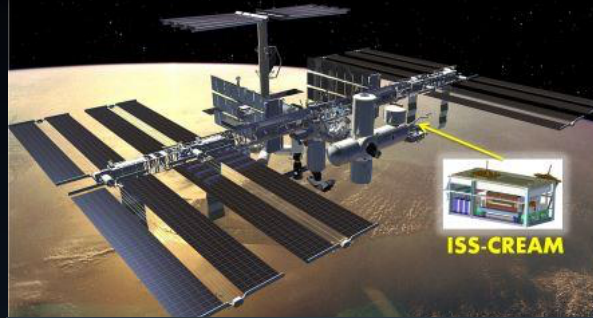


Neutron Star Interior
Composition Explorer

CREAM

NASA Mission

7/2017

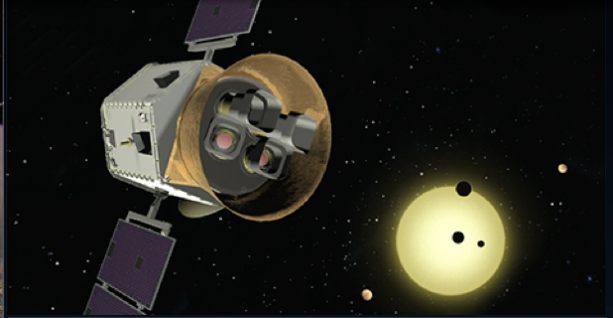


Cosmic Ray Energetics
And Mass

TESS

NASA Mission

8/2017

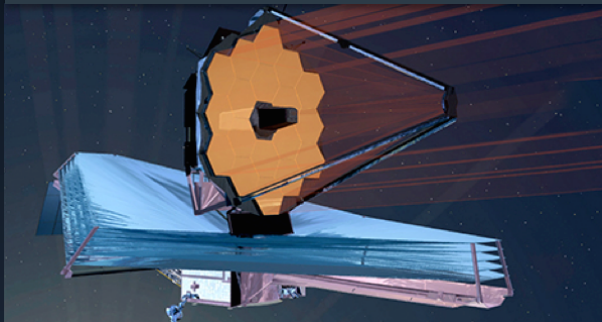


Transiting Exoplanet
Survey Satellite

JWST

NASA Mission

10/2018

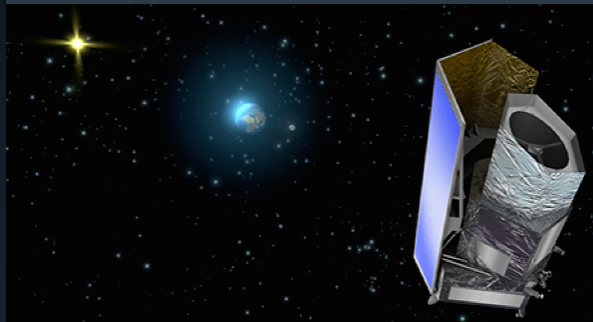


James Webb
Space Telescope

Euclid

ESA-led Mission

2020



NASA is supplying the NISP
Sensor Chip System (SCS)

WFIRST

NASA Mission

Mid 2020s



Wide-Field Infrared
Survey Telescope

James Webb Space Telescope



...going where no Hubble has gone
before

JWST Mirror Fully Assembled

Congrats JWST
Team on successful
completion of
primary mirror
assembly!





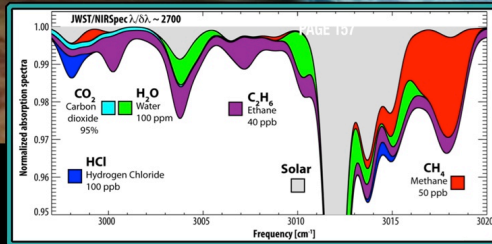
JWST 3/27/2016

World Science

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

Water, Water Everywhere!

JWST proves
that we're not so different
after all



NATURE.COM/NATURE

20 February 2016 \$10

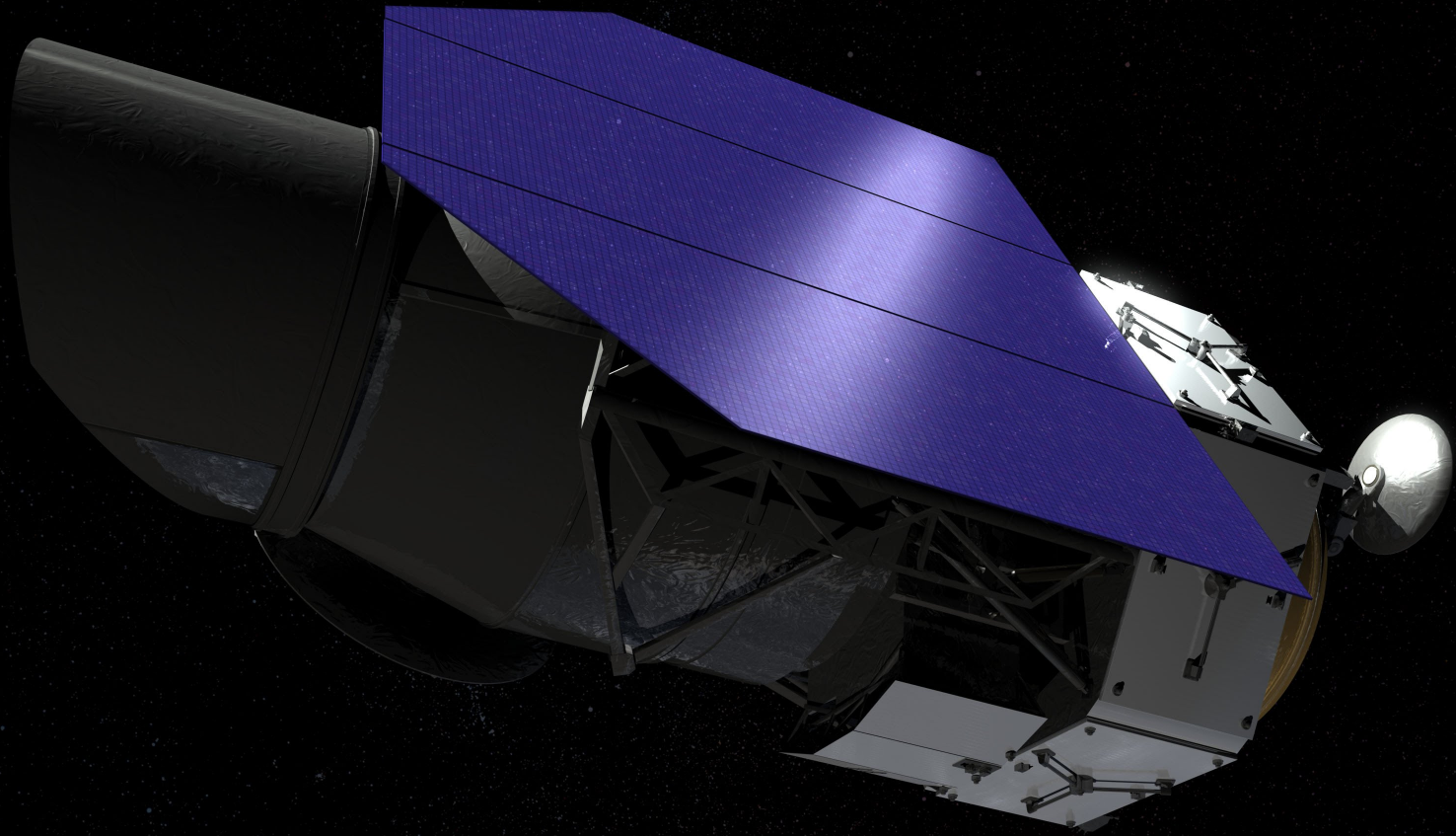
Vol. 507, No. 7891



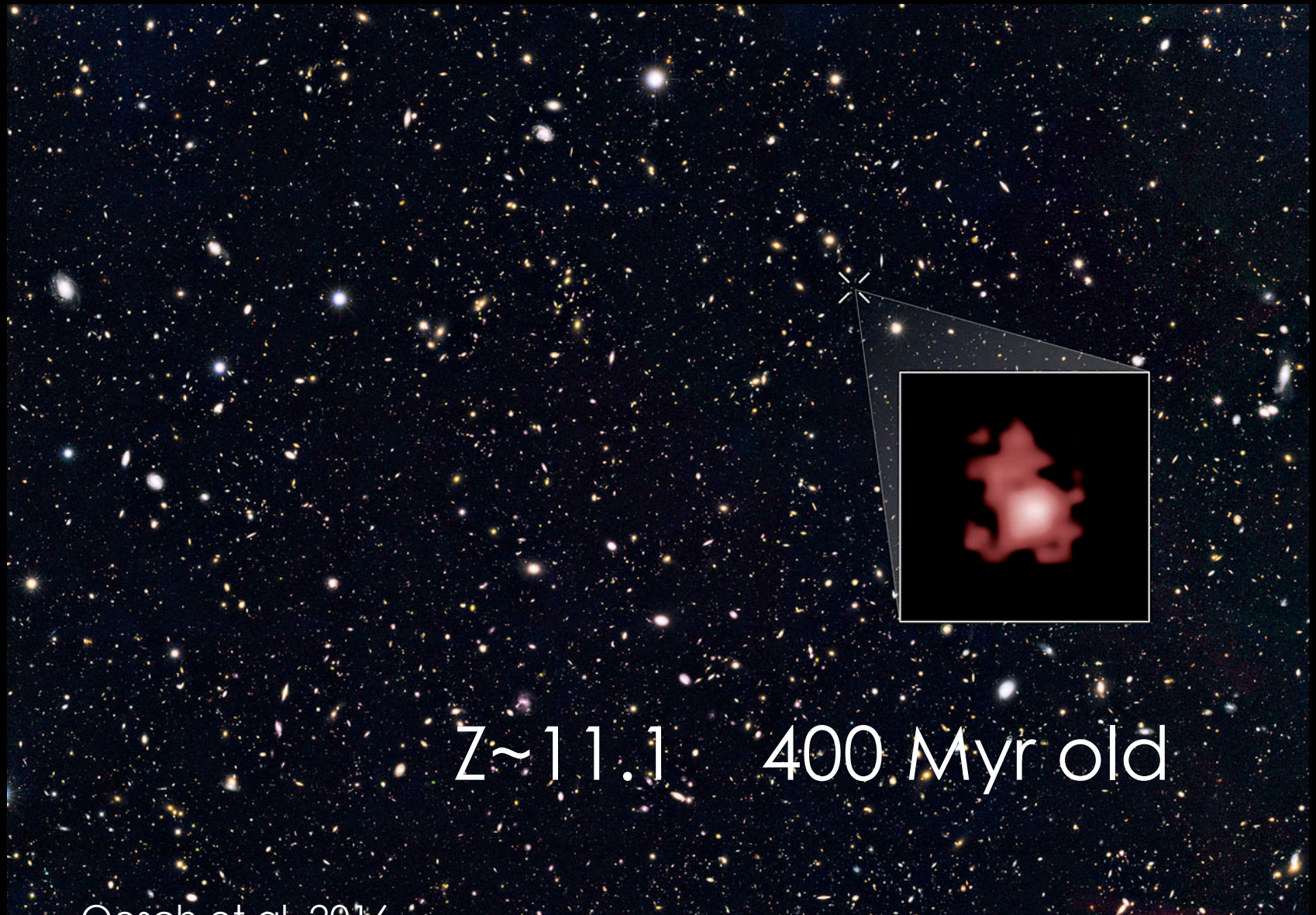
- Atmospheres of exoplanets Analyzed!
- Population III Stars Discovered!
- Assembly of Galaxies Explained!
- Birth of New Solar Systems Witnessed!
- Segmented Space Telescopes Proven

WFIRST

The Wide-Field Infrared Survey Telescope



Hubble breaks cosmic distance record



$z \sim 11.1$ 400 Myr old

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

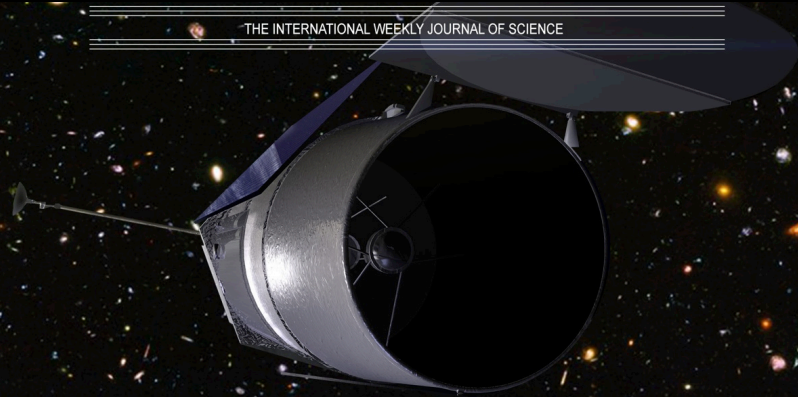


70,000 galaxies in each field
of AFTA survey

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

World Science

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE



DARK ENERGY NOT SO DARK AFTER ALL

PAGE 157

*WFIRST sheds light
on the darkest force
in the universe*

PAGE 223

NATURE.COM/NATURE

20 February 2016 \$10

Vol. 507, No. 7891



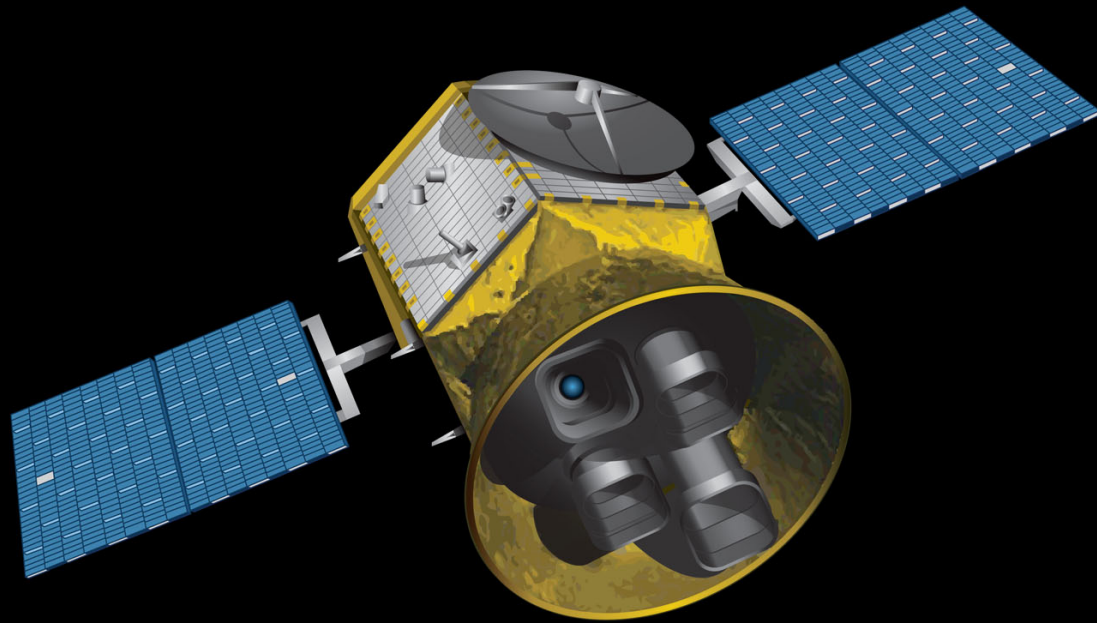
Millions and Millions of
Galaxies Imaged!

Universal Cosmic
Acceleration
Confirmed!

Dark Energy Not So Dark
Anymore!

Exoplanets Explored!

We're surrounded by rocky planets
in their habitable zones!

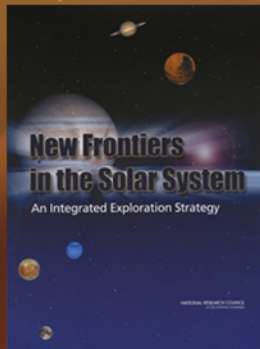


TRANSITING EXOPLANET SURVEY SATELLITE

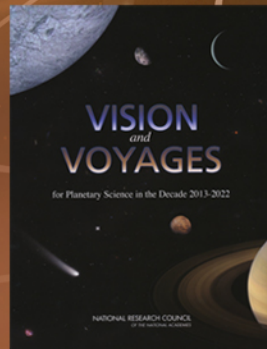
*DISCOVERING NEW EARTHS AND SUPER-EARTHS
IN THE SOLAR NEIGHBORHOOD*

Planetary Science

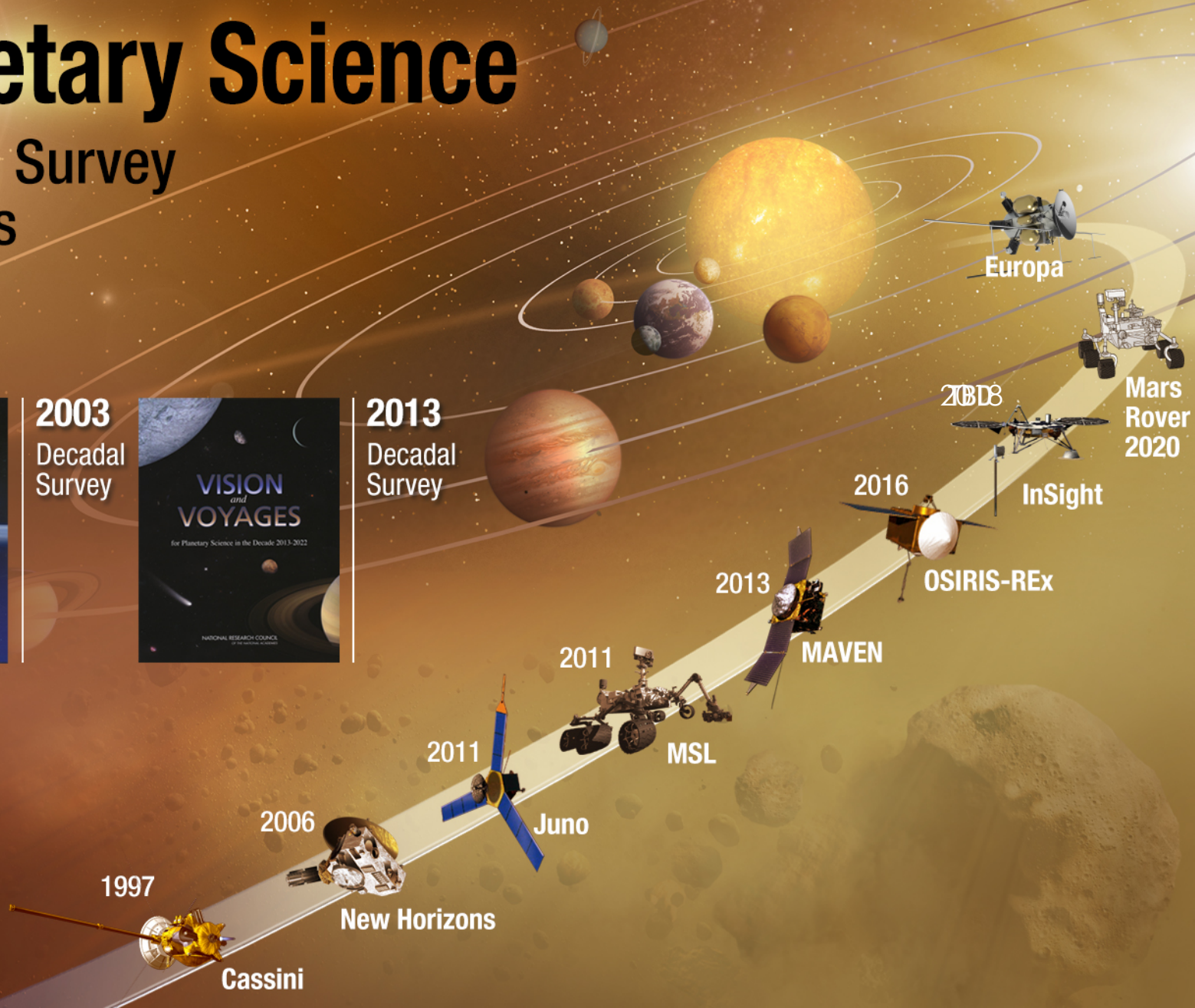
Decadal Survey Missions



2003
Decadal Survey



2013
Decadal Survey



Europa

2018

Mars Rover
2020

InSight

2016

OSIRIS-REx

2013

MAVEN

2011

MSL

2011

Juno

2006

New Horizons

1997

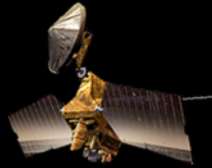
Cassini

Current & Future Mars Missions

**Operational
2001 - 2014**



Mars Odyssey



**Mars
Reconnaissance
Orbiter**

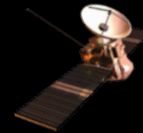


MAVEN



**ESA Mars Express
(NASA: MARSIS)**

2016



**ESA
Trace Gas Orbiter
(NASA: Electra)**

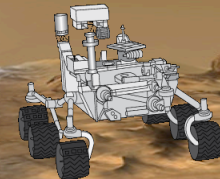
2018



InSight

**ESA
ExoMars Rover
(NASA: MOMA)**

2020



**Science
Rover**

2022

**Opportunity –
Mars Exploration
Rover**

**Curiosity –
Mars Science
Laboratory**

Follow the Water

Explore Habitability

Seek Signs of Life

Prepare for Future Human Explorers

EVOLVING MARS SCIENCE THEMES

World Science

Mars 2020 Retrospective

Five Spectacular Years on Mars

New Clues of Life!

Next Steps on the
Journey to Mars



Mars 2020 Rover Landed in
Habitable Environment!

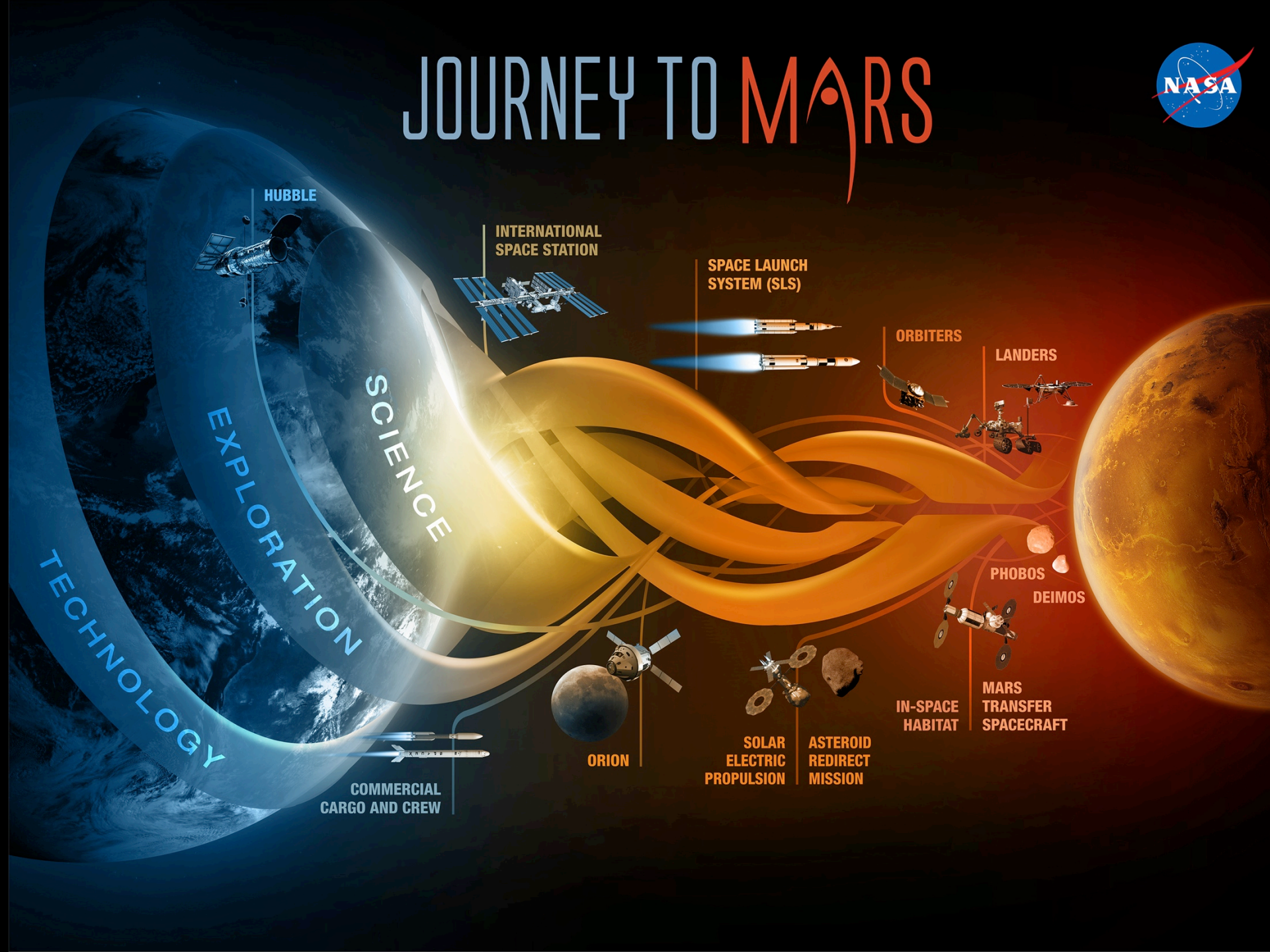
Possible Biosignatures
Found!

Core Samples Cached!

In-Situ Resource Utilization
Demonstrated!

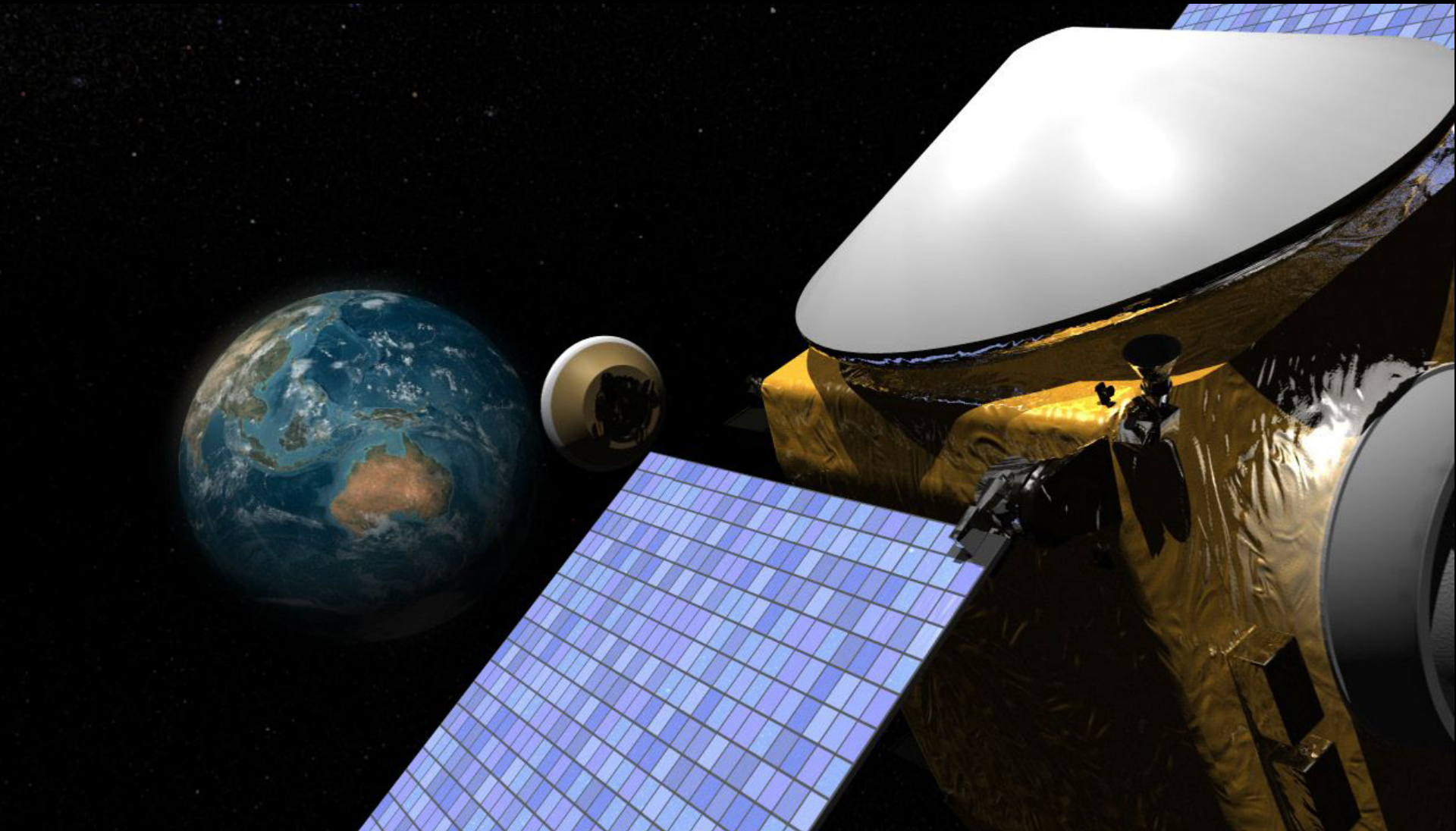
Sample Return Mission on
the Way to Mars

JOURNEY TO MARS



OSIRIS-REx

Origins Spectral Interpretation Resource Identification Security - Regolith Explorer







World Science

OSIRIS-ReX

The kiss that launched
a thousand papers

The Scientific
treasure trove
of Bennu

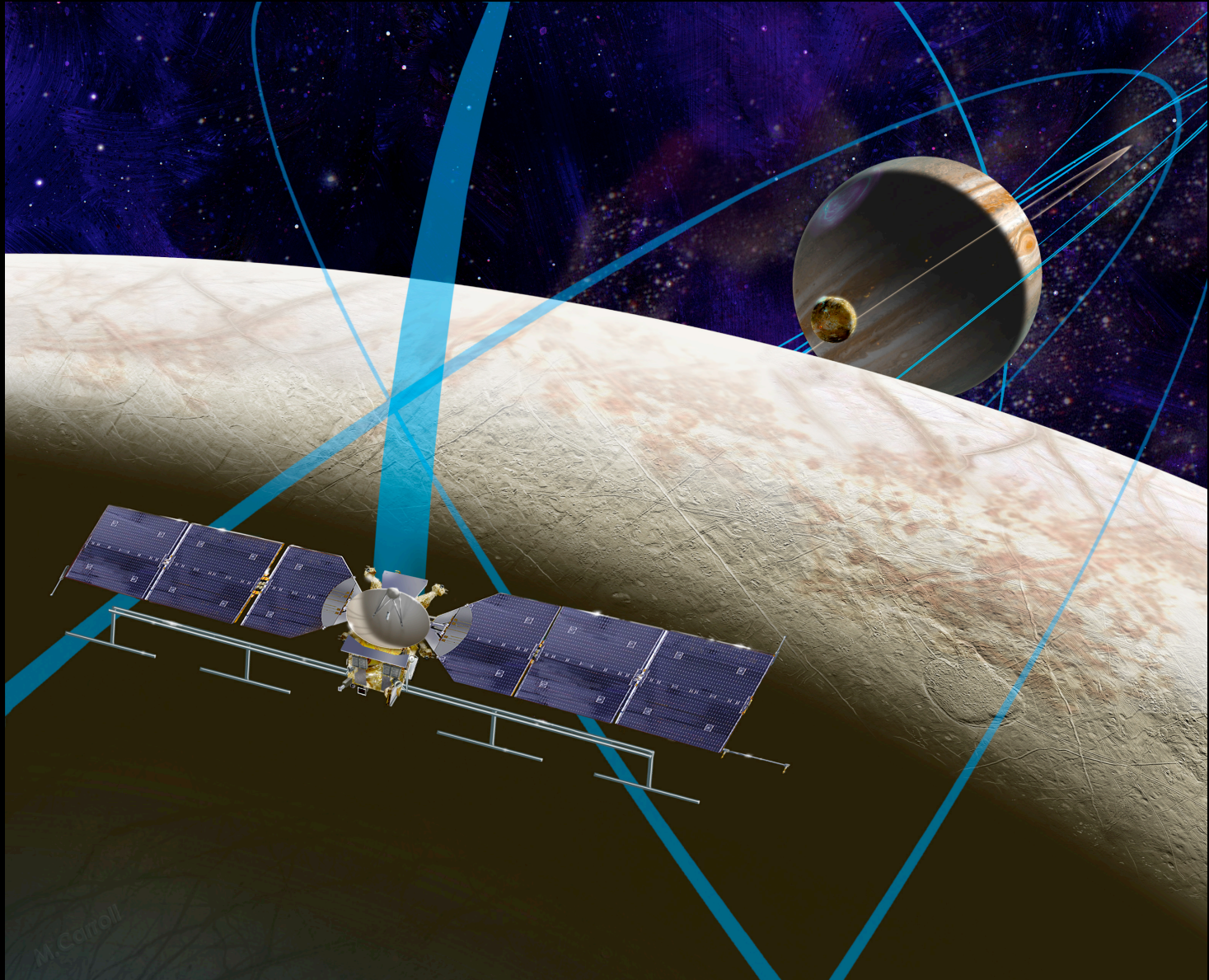
Asteroid Bennu
Mapped to mm
scale!

Pristine Sample of
Early Solar System
Returned!

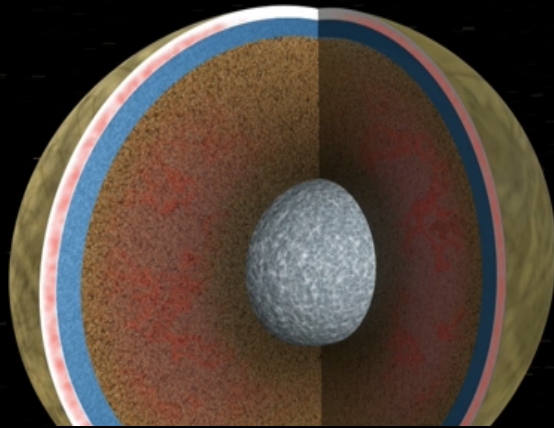
Asteroid Organics
Analyzed!

Scientific Community
Astounded!

Europa Clipper Arrives!



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)*

How active is the ice shell?

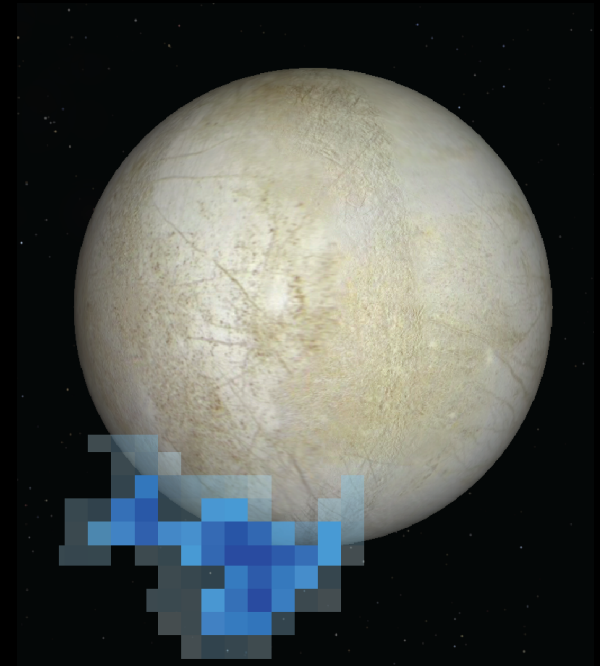
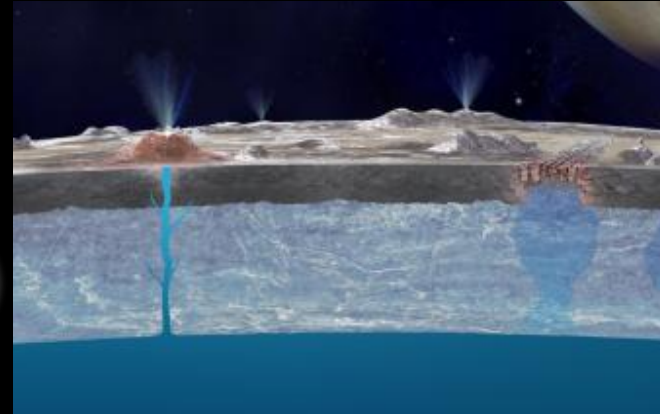
*Camera, Thermal Imager
(MRO, ICESat)*

How thick is the ice shell?

*Radar, Gravity
(MRO, Cassini)*

What's the brown stuff?

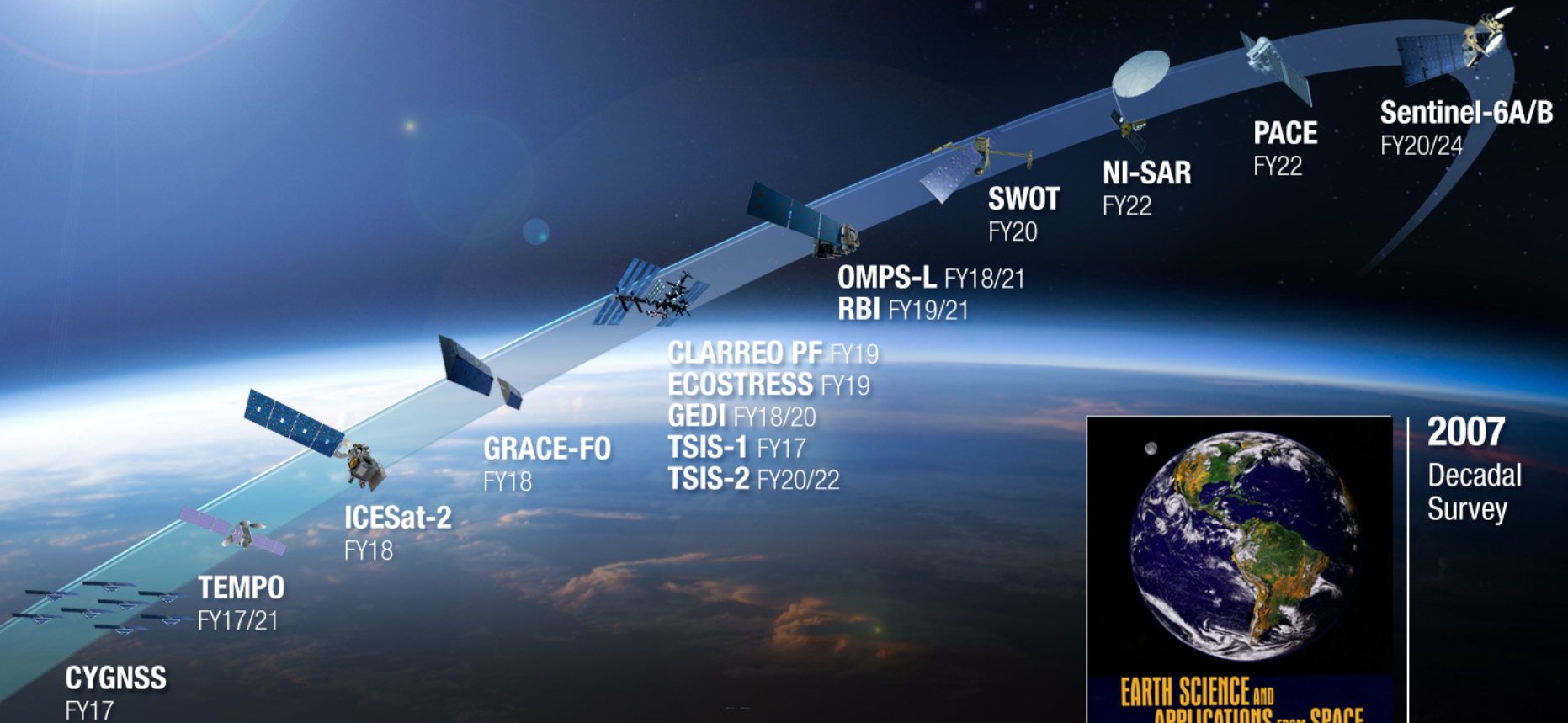
*IR & Mass Spectrometers
(Landsat, MRO)*



Credit: NASA/JPL-Caltech/SETI Institute

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

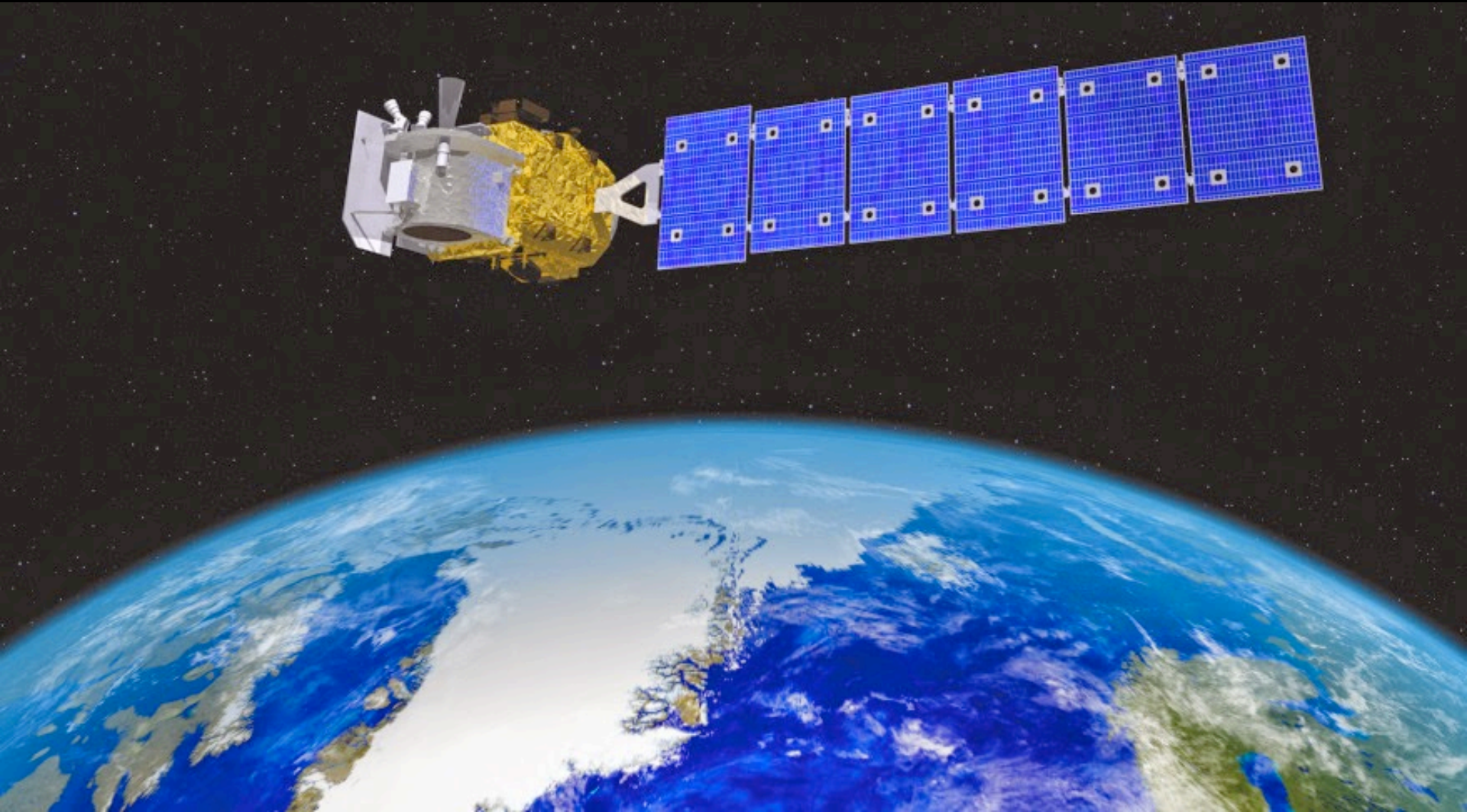
Earth Science



2007
Decadal
Survey

PACE

Pre-Aerosol Clouds and Ocean Ecosystem



PHYSICS

NEUROSCIENCE

SPACE EXPLORATION

SCIENTIFIC AMERICA

February 2016

ScientificAmerican.com



The Power of Color

NASA's PACE mission checks
the health of our oceans

The colors of climate change



Global Ocean Color:
Mapped!

Phytoplankton Health
Assessed!

Global Carbon Cycle
Better Understood!

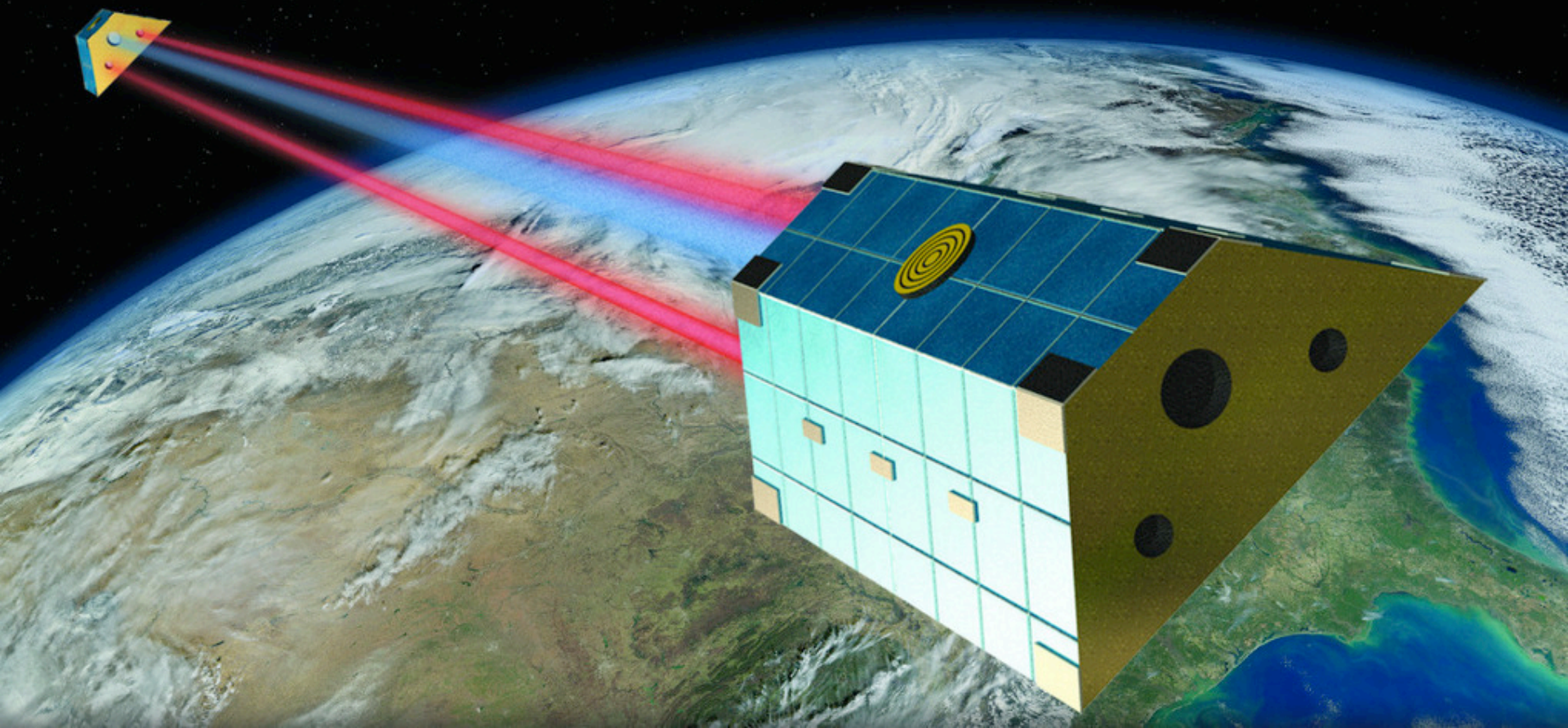
Harmful Algal Blooms
Deteteted Worldwide

News: Not Good!

ICESat-2



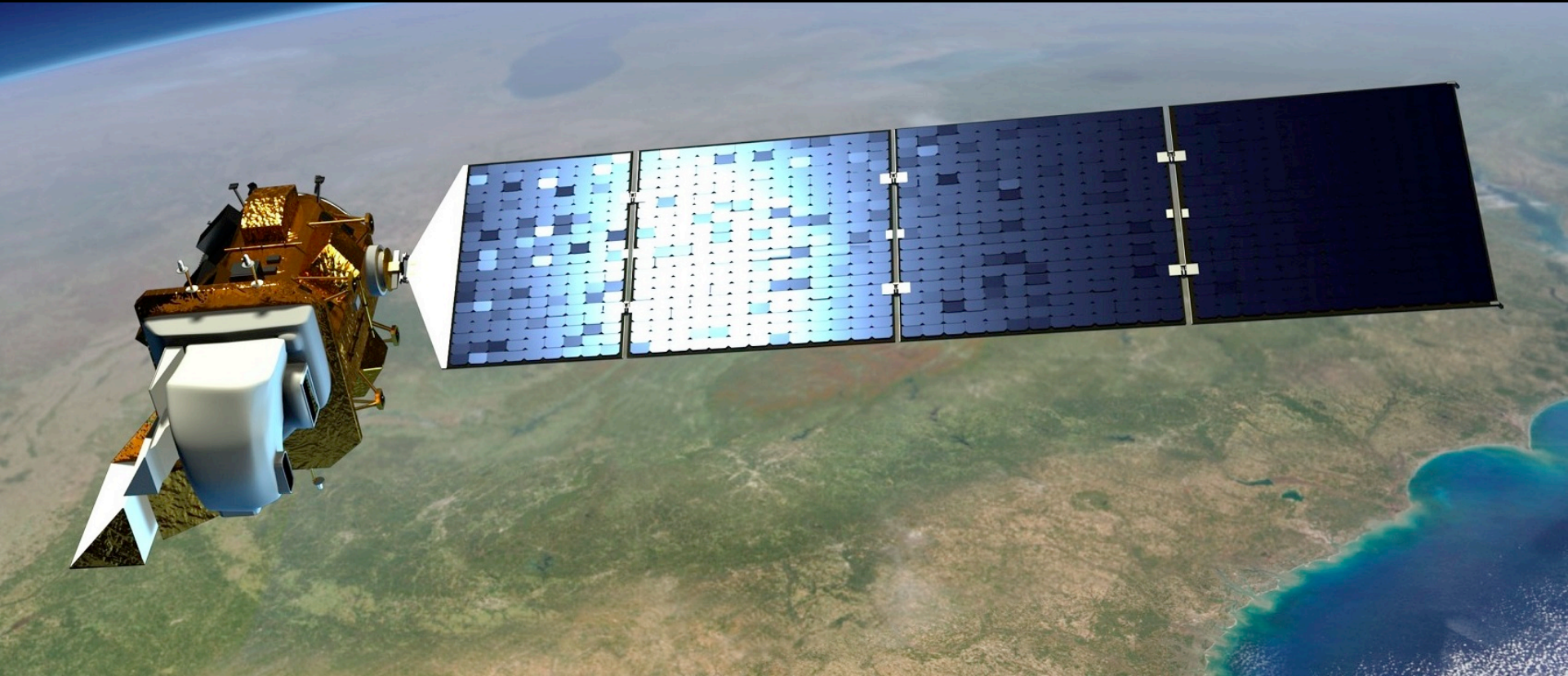
GRACE Follow-On



Jason-3 and Sentinel-6

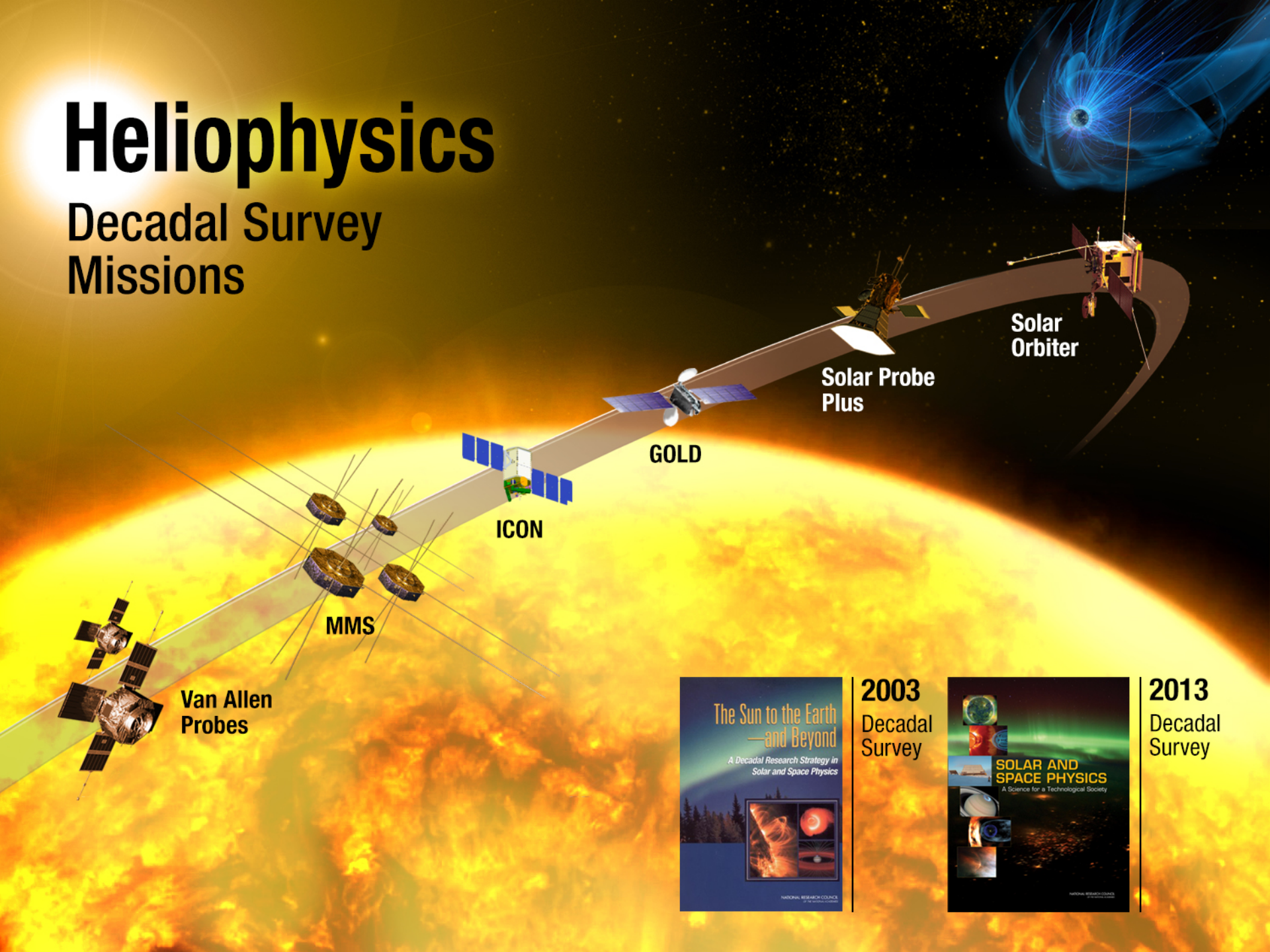


LandSat-9



Heliophysics

Decadal Survey Missions



Van Allen
Probes

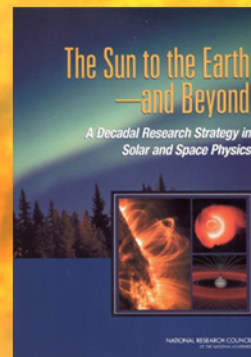
MMS

ICON

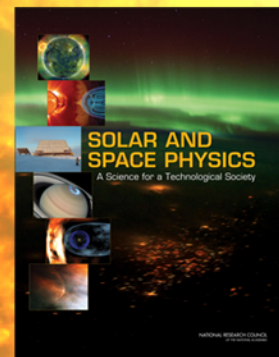
GOLD

Solar Probe
Plus

Solar
Orbiter

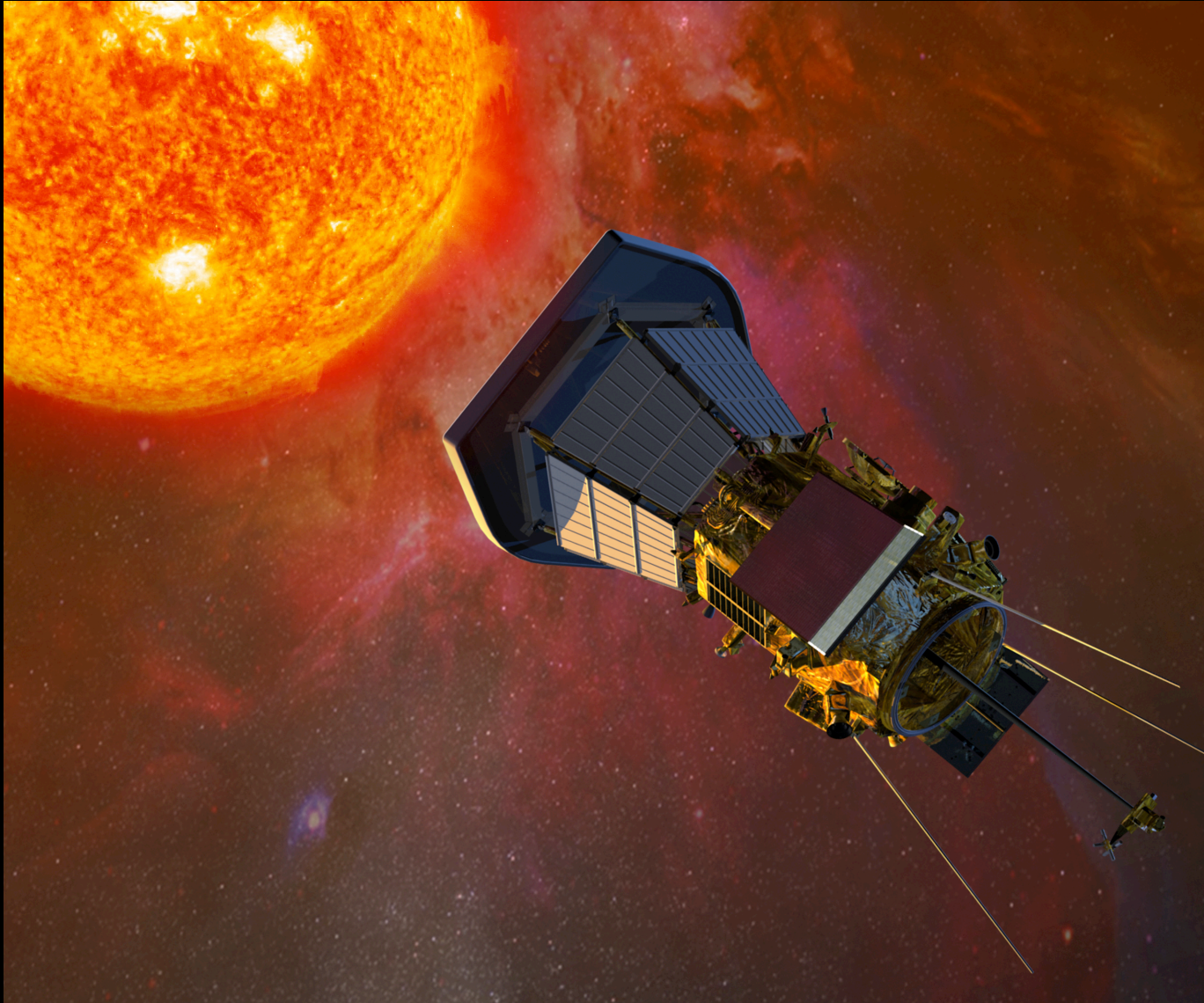


2003
Decadal
Survey



2013
Decadal
Survey

Solar Probe Plus Solve Mystery of the Solar Corona



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)

Superstars of Science



Steve Clark



Paul Hertz



Michael Freilich



Jim Green

Our future science looks pretty incredible

A word cloud featuring various names of future space science missions. The words are arranged in a dense, overlapping manner, with some oriented horizontally and others vertically. The colors of the text range from light yellow to dark brown. The missions included are: VLT, Euclid, LSST, PNH, M2020, Europa, SWOT, OSIRIS-REx, Chandra, ALMA, Avenir, JWST, DKIST, SMAP, TESS, GPM, Juno, PACE, SPP, WEIR, and THST.

VLT Euclid LSST PNH
M2020 SWOT
Europa
OSIRIS-REx
Chandra
ALMA Avenir JWST
DKIST SMAP TESS GPM
Juno PACE
SPP
WEIR THST