Report to ESSC

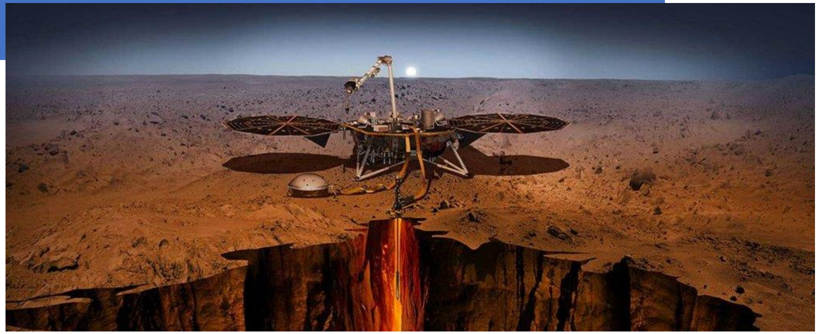
November, 2018

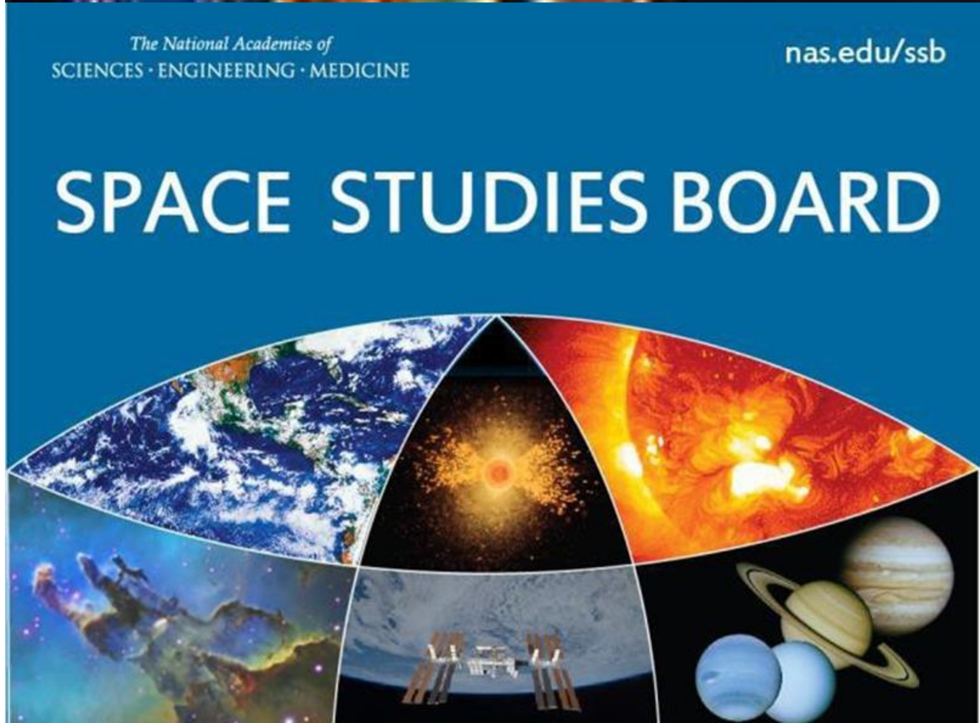
Colleen N. Hartman, PhD

Director, Space & Aeronautics

National Academies of Sciences

Congratulations Insight!

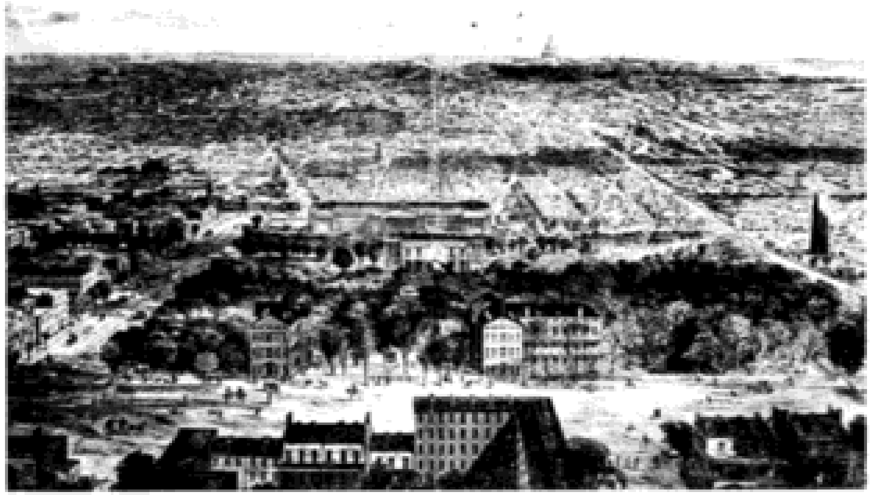




The National Academy of Sciences

"Amid the din of war, the heat of party, the deviltries of politics, and the poisons of hypocrisy, science will be inaudible, incapable, incoherent, and inanimate."

Benjamin Peirce,1863



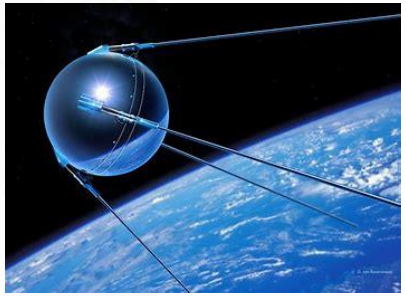
The city of Washington, 1869.
Photo courtesy the Library of Congress

Creation of the Space Studies Board
June 26, 1958

NATIONAL ACADEMY OF SCIENCES

NATIONAL RESEARCH COUNCIL

2101 CONSTITUTION AVENUE, WASHINGTON 25, D. C.



26 June 1958

Dear Dr. Berkner:

I am glad to express to you the great satisfaction taken by the officers of the Academy-Research Council in your acceptance of the responsibilities of the chairmanship of the new Space Science Board. We feel that the formation of this Board can have especial significance for science as we face the chal .nge and adventure of the new steps into space that are surely and swiftly on the way.

It is my hope that the Board will give the fullest possible attention to every aspect of space science, including both the physical and the life sciences. I believe that we have a unique opportunity to bring together scientists from many fields to survey in concert the problems, the opportunities, and the implications of man's advance into space, and to find ways to further a wise and vigorous national scientific program in this field.

We have talked of the main task of the Board in three parts -

2101 CONSTITUTION AVENUE, N. W. WASHINGTON 25, D. C. TELEPHONE EXECUTIVE 3-8100

FOR RELEASE SUNDAY, AUGUST 3rd

For further information call
Howard J. Lewis, Ext. 310

National Academy of Sciences Establishes Space Science Board

Washington, D.C., August 2nd -- Dr. Detlev W. Bronk, president of the National Academy of Sciences - National Research Council, announced today the formation of a 16-man Space Science Board, "to survey in concert the scientific problems, opportunities and implications of man's advance into space."

Dr. Lloyd V. Berkner, president of Associated Universities, Inc., president of the International Council of Scientific Unions and a member of the National Academy of Sciences, has been named chairman.

The Board, besides acting as the focal point for all Academy-Research Council activities connected with space-science research, will be called upon to coordinate its work with appropriate civilian and government agencies, particularly the National Aeronautics and Space Administration, the National Science Foundation, and the Advanced Research Projects Agency, and with foreign groups active in this field.

SSB Memorandum Report, Dec 1, 1958

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VI. INTERPLANETARY PROBES AND SPACE STATIONS

2. With vehicles of the Thor-Able it appears possible to get a payload of the order of 50 lbs. out to interplanetary distances in the fairly near future, while maintaining communication and control. As far as the Thor is concerned, it is recommended that it be used without a control retro rocket as part of the payload and that the additional weight thereby made available be used to increase the reliability of communications, and perhaps for a

3. It is recommended
Mars probe during
initiated.

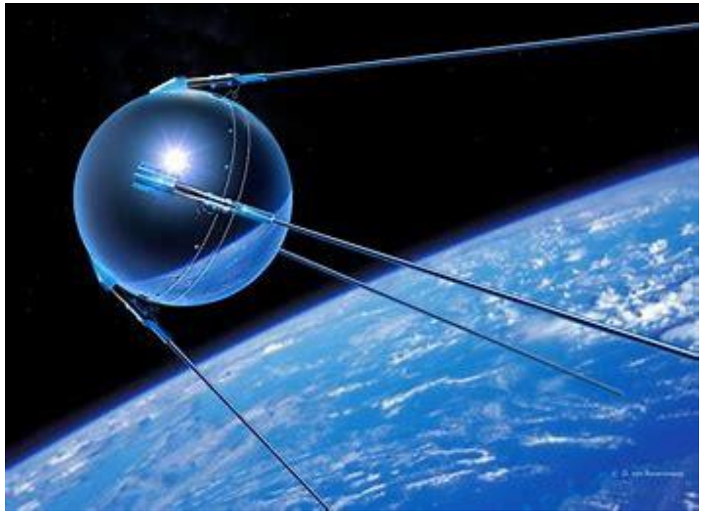
4. With a combinatio
second stage, a p
feasible. It is
steps be taken to
vehicle based on
second stage, tog
controls, in orde
carry out a more
iments on the planets Venus and Mars. In addition, because of the long lead time involved in such a program, development of vehicle telemetry and experimental equipment should be started soon.

5. A study of appropriate scientific packages for different classes of space probes is now in progress. Recommendations resulting from this study will be provided to the Government shortly after the first of the year.

6. With regard to manned space stations, the Board feels that further study is required before specific recommendations can be provided.

Supporting Document: Minutes of the Ad Hoc Committee on Interplanetary Probes and Space Stations, September 13, 1958.

With a combination such as Atlas and a high Performance second stage, a payload in excess of 1,000 lbs. seems feasible.



Summary of WESTEX, 1959

THEORETICAL POSSIBILITIES AND PRESENT EVIDENCE FOR PLANETARY LIFE

A detailed exposition of theoretical biology could warrantably lead to far flung speculations on the essential features that characterize living systems. Theoretical and experimental work of recent years has dispelled many of the obstacles to our understanding of the transition from inorganic to living matter.[13]

A priori, we believe it to be highly probable that life will evolve Spontaneously if concentrations of diverse organic materials are Maintained for intervals 10^9 years in temperate environments. The consequence might be life whose chemistry is not necessarily like our own.

design of experimental space flights. For the moment, and until such time as these investigations are rewarded or proven futile, we should confine our studies to living systems sharing two basic attributes with terrestrial life: the use of water as the primary solvent for biochemical interaction and the use of polymers based on carbon as structural and catalytic components. The atoms H, C, O, and N, from which water and other biochemicals are formed are so nearly universal in their distribution that the limiting parameter in a planetary environment will, as a rule, be its

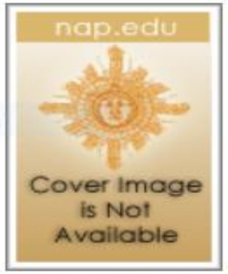
SSB Recent Reports

Thriving on Our Changing Planet A Decadal Strategy for Earth Observation from Space

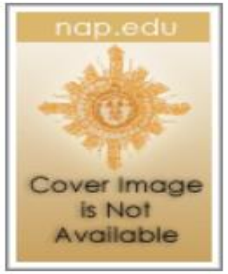
Review and Assessment of Planetary Protection Policy Development Processes

Visions into Voyages for Planetary Sciences in the Decade 2013-2022 A Midterm Review

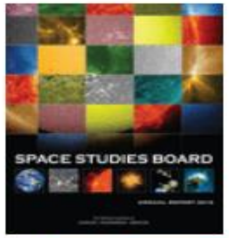
Searching for Life Across Space and Time: Proceedings of a Workshop



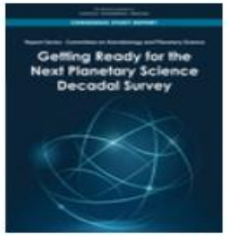
A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA



America's Future in Civil Space: Proceedings

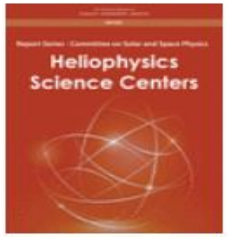


Space Studies Board Annual Report 2016



Report Series: Committee on Astrobiology and Planetary Science: Getting Ready for the Next Planetary Sciences Decadal Survey

The Goals, Rationales, and Definition of Planetary Protection: Interim Report



Report Series: Committee on Solar and pace Physics: Heliophysics Science Centers (2017)

Review of NASA's Planetary Science Division's Restructured Research and Analysis Programs

Report Series: Committee on Astronomy and Astrophysics: Small Explorer Missions

Update on Recently Released Studies

Congressionally Requested:

- An Astrobiology Strategy for the Search for Life in the Universe
- Exoplanet Science Strategy

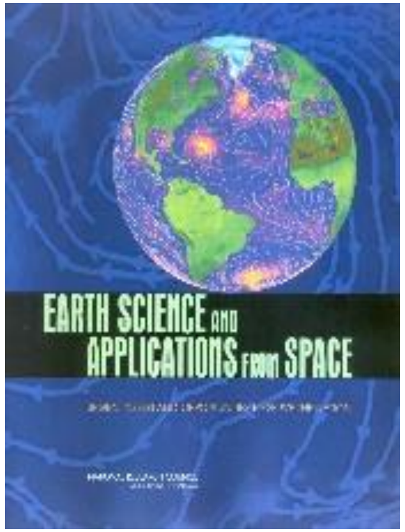
Other studies:

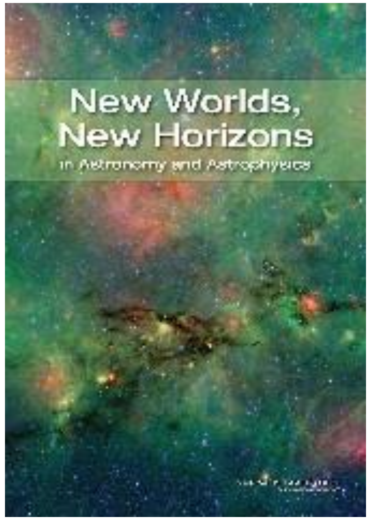
- Open Source Software Policy Options for NASA Earth and Space Sciences
- Review and Assessment of Planetary Protection Policy Development Processes
- Visions into Voyages for Planetary Sciences in the Decade 2013-2022: A Midterm Review

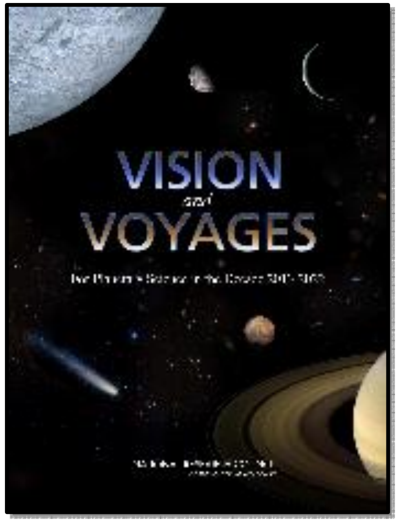
Current SSB Activities

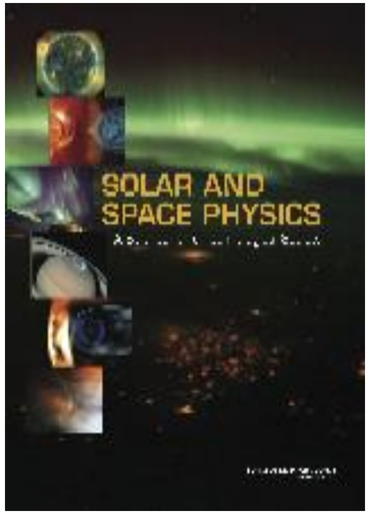
- Astro2020, SSB/BPA
- Continuous Improvement of NASA's Innovation Ecosystem - A Workshop and Meetings of Experts, SSB/ASEB
- Extraterrestrial Sample Analysis Facilities
- Near Earth Object Observations in the Infrared and Visible Wavelengths
- Planetary Protection Requirements for Sample-Return Missions from Martian Moons
- Review of Progress Toward Implementing the Decadal Survey - Solar and Space Physics: A Science for a Technological Society
- Science Enabled by Long-Duration Human Orbital Missions around the Moon: A Meeting of Experts

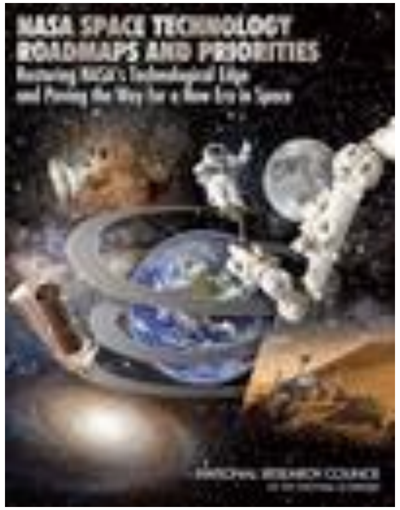
The Decadal Surveys in Space Science and other Major Reports











SPD-1

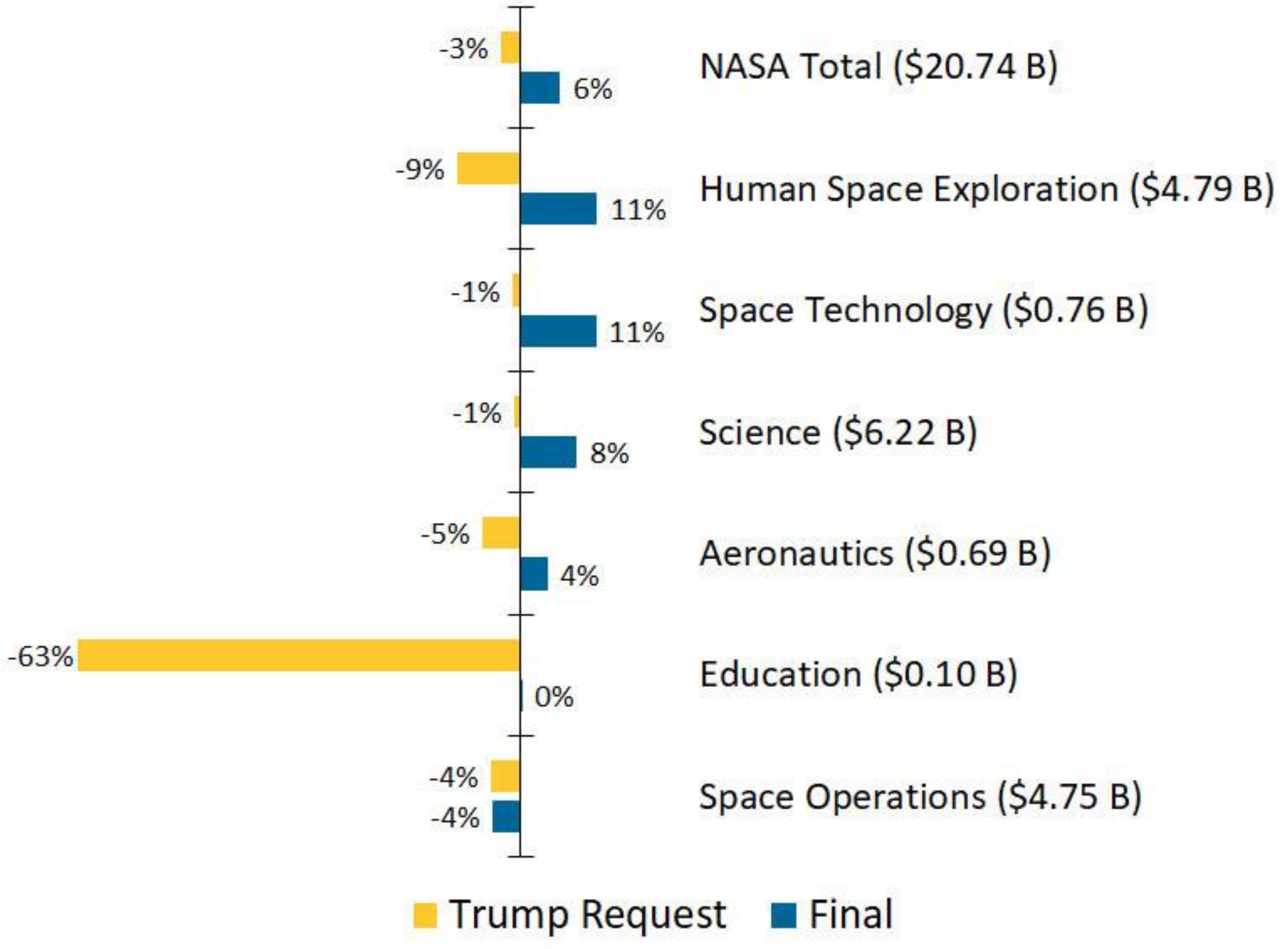
The United States shall

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.”

Final FY18 Funding: NASA

% change from FY17 enacted

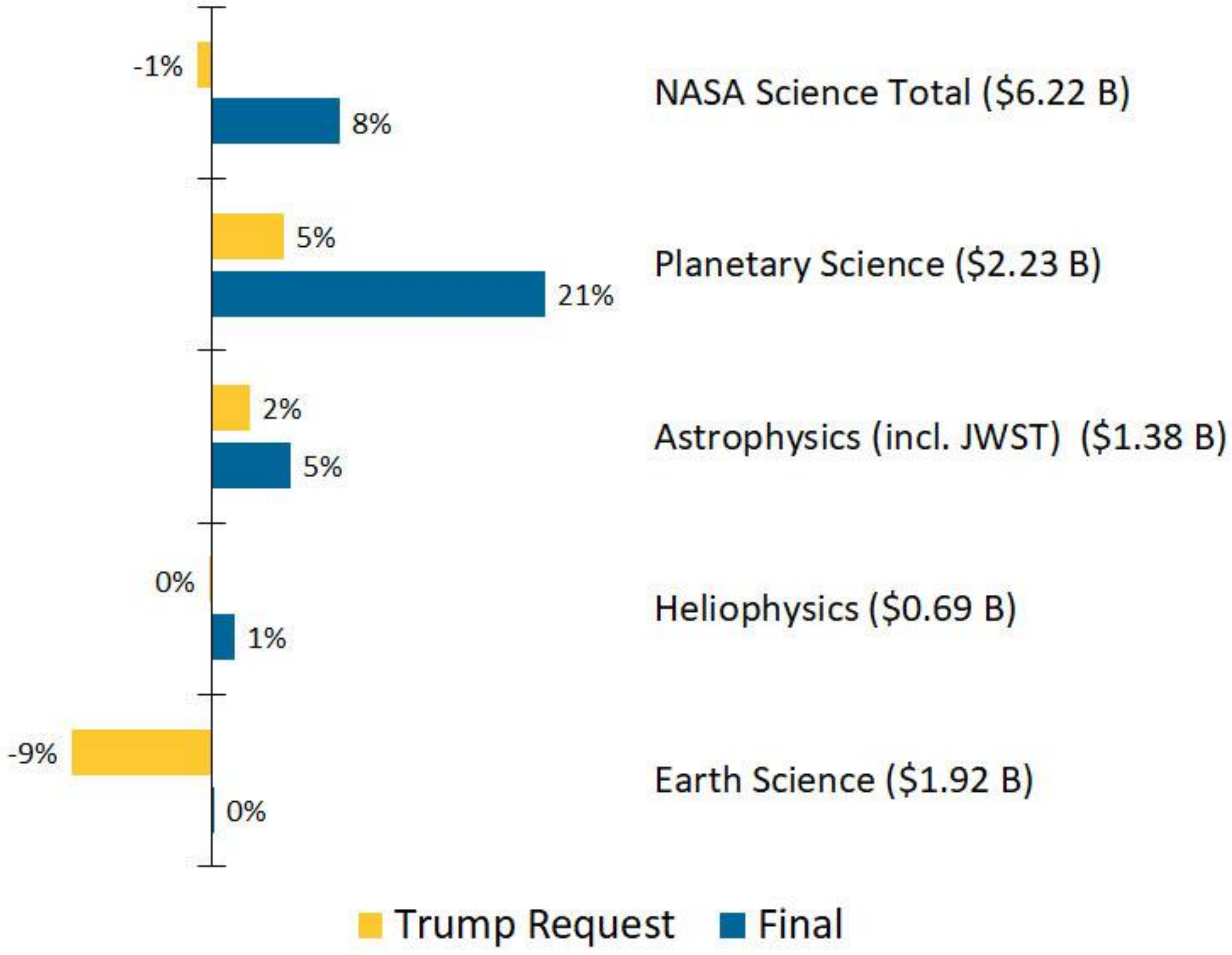
$ in () are the FY18 enacted amounts



Final FY18 Funding: NASA Science

% change from FY17 enacted

$ in () are the FY18 enacted amounts

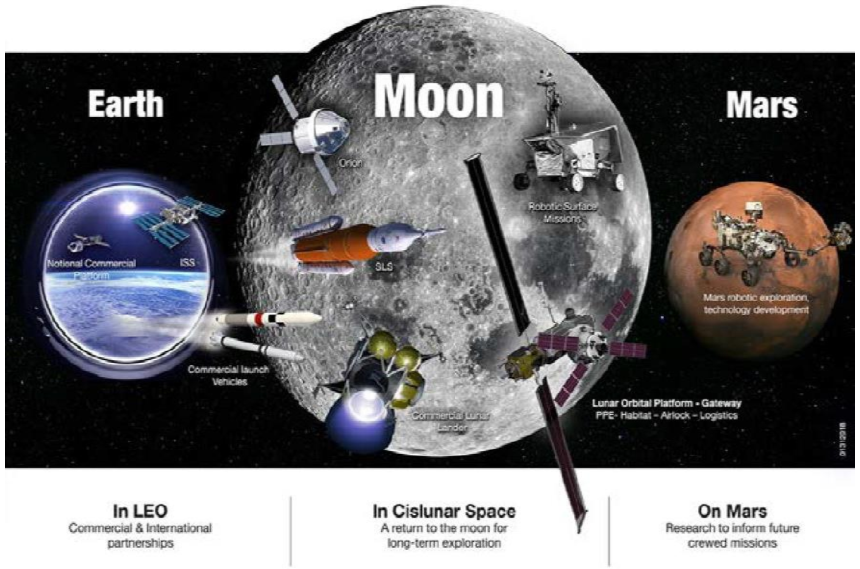


2019 Budget Highlights

- Provides $19.9B, including $10.5B to lead an innovative and sustainable campaign of exploration and lead the return of humans to the Moon for long-term exploration and utilization followed by human missions to Mars and other destinations.

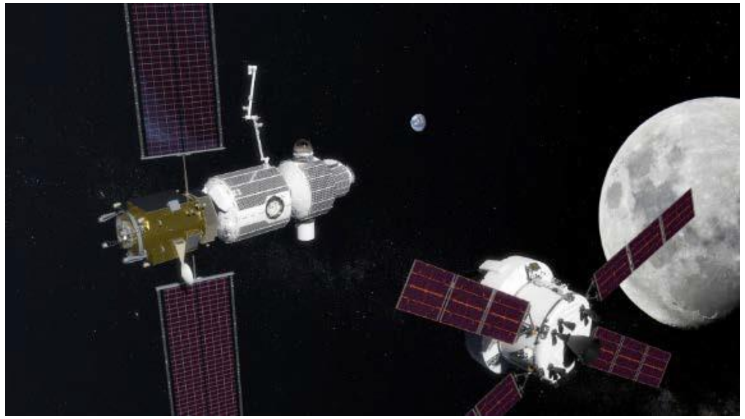
- Refocuses existing NASA activities towards exploration, by redirecting funding to innovative new programs and providing additional funding to support new public-private initiatives.

- Conducts uncrewed SLS/Orion first flight in 2020, leading to Americans around the Moon in 2023. This will be the first human mission to the moon since Apollo 17 in 1972, and will establish U.S. leadership in cislunar space.



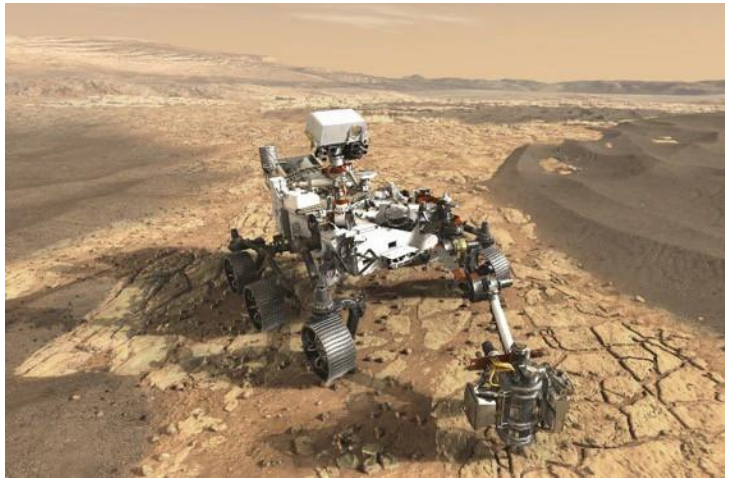
Highlights *(continued)*

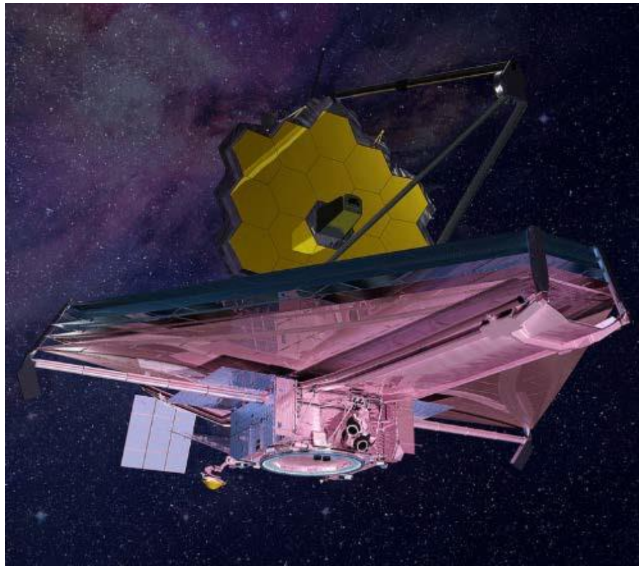
- Serves as a catalyst for growth of a vibrant American commercial space industry expanding commercial partnerships to strengthen U.S. leadership in space.
- Achieves early Human Exploration milestone by establishing a Lunar Orbital Platform-Gateway in cislunar space; launching a power and propulsion space tug in 2022.
- Develops a series of progressively more capable robotic lunar missions to the surface of the moon using innovative acquisition approaches while meeting national exploration and scientific objectives.
- Begins transition to commercialization of low Earth orbit and ends direct federal government support of the International Space Station in 2025.
- Begins a new $150M program to encourage development of new commercial Low Earth orbital platforms and capabilities for use by the private



Highlights *(continued)*

- Continues robotic exploration of the Solar System including funding for the next Mars rover launch in 2020, funding to explore possibilities of returning geological samples from Mars and a Europa Clipper mission to fly repeatedly by Jupiter's icy ocean moon Europa.
- Enables our wide-ranging science work on many fronts, which continues to lead the world in its size, scope, and scientific output.
- Supports a focused Earth science program; no funding for missions proposed for termination in FY18 budget (PACE, OCO-3, CLARREO Pathfinder, DSCOVR, and RBI).
- Continues exploring the universe with launch of James Webb Space Telescope.
- Cancels WFIRST due to its significant cost and higher priorities within NASA. Increases funding for competed astrophysics missions and research.

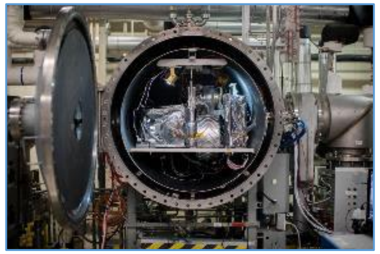




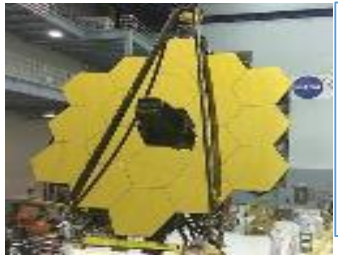
Highlights *(continued)*

- Focuses and integrates space technology investments to enable new robotic and human exploration capabilities and missions and contribute to economic development and growth by enabling innovative systems and services supporting the emerging space economy.
- Fully funds a supersonic X-plane and increases hypersonics research funding. Maintains robust investment in air traffic management improvements that will safely increase air traffic capacity, reduce flight delays, and enable safe, robust UAS integration.
- Redirects Office of Education funding to new initiatives supporting NASA's core mission of exploration.
- Strengthens cybersecurity capabilities, safeguarding critical systems and data, and continues to support improved overall management of IT.

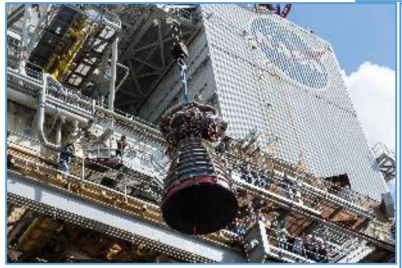
Anticipated Accomplishments in FY 2019



Advanced Exploration Systems
Power propulsion element requirements studies, acquisition planning, and partnership approaches. Ground testing of full size prototype cislunar habitats.



James Webb Space Telescope
Completes assembly and testing, ships to French Guiana, and launches between March and June of 2019.



Exploration Systems
Continues systems integration in preparation for Ascent Abort test in April 2019 and EM-1 launch.

Other Science
Use of emerging commercial lunar lander capabilities to deliver payloads to surface of the Moon. Selects next New Frontiers mission, Heliophysics Small Explorer, Astrophysics Medium Explorer and suite of Earth Venture Suborbital-3 investigations.

Commercial Crew
Completes developmental milestones and plans for post certification missions to begin in 2019.

Exploration R&T
Launches 3 payloads demonstrating laser comm, green propellant, and precision navigation. Delivers MOXIE, MEDA, MEDLI2, and TRN to Mars 2020 mission.

Supersonic X-Plane
Completes a critical design review for the Low Boom Flight Demonstrator

Science: Earth Science

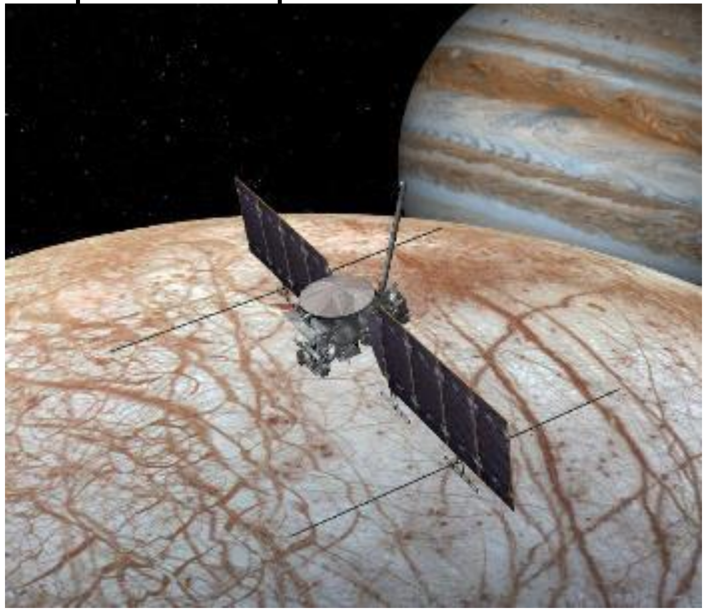
($M)	2019	2020	2021	2022	2023
Earth Science	**$1,784**	**$1,784**	**$1,784**	**$1,784**	**$1,784**

- Launches GRACE Follow-On, ICESat-2, ECOSTRESS, and GEDI.
- Supports formulation and development of Landsat-9, NISAR, SWOT, TEMPO, OMPS-L, Sentinel-6, and TSIS-2.
- Selects Earth Venture Suborbital-3 investigations from the AOs released in 2016 and 2017.
- Releases AOs for Earth Venture Mission (EVM)-3, and Earth Venture Instrument (EVI)-6.
- Operates 19 additional missions, and the Airborne Science project.
- Invests in CubeSats/SmallSats that can achieve entirely new science at lower cost.
- Plans to engage stakeholders in order to incorporate new Earth Science Decadal Survey recommendations into the Earth Science portfolio
- Proposes to terminate PACE, OCO-3, CLARREO Pathfinder, and DSCOVR. Following a detailed review in Jan. 2018, RBI has been cancelled and is not funded in this Budget.

Science: Planetary Science

($M)	2019	2020	2021	2022	2023
Planetary Science	$2,235	$2,200	$2,181	$2,162	$2,143

- Creates a robotic Lunar Discovery and Exploration program, that supports commercial partnerships and innovative approaches to achieving human and science exploration goals.
- Continues development of Mars 2020 and Europa Clipper.
- Establishes a Planetary Defense program, including the Double Asteroid Redirection Test (DART) and Near-Earth Object Observations.
- Studies a potential Mars Sample Return mission incorporating commercial partnerships.



- Formulates the Lucy and Psyche missions.
- Selects the next New Frontiers mission.
- Invests in CubeSats/SmallSats that can achieve entirely new science at lower cost.
- Operates 10 Planetary missions.
    - OSIRIS-REx will map asteroid Bennu.
    - New Horizons will fly by its Kuiper belt target.

Science: Astrophysics

($M)	2019	2020	2021	2022	2023
Astrophysics	**$1,185**	**$1,185**	**$1,185**	**$1,185**	**$1,185**

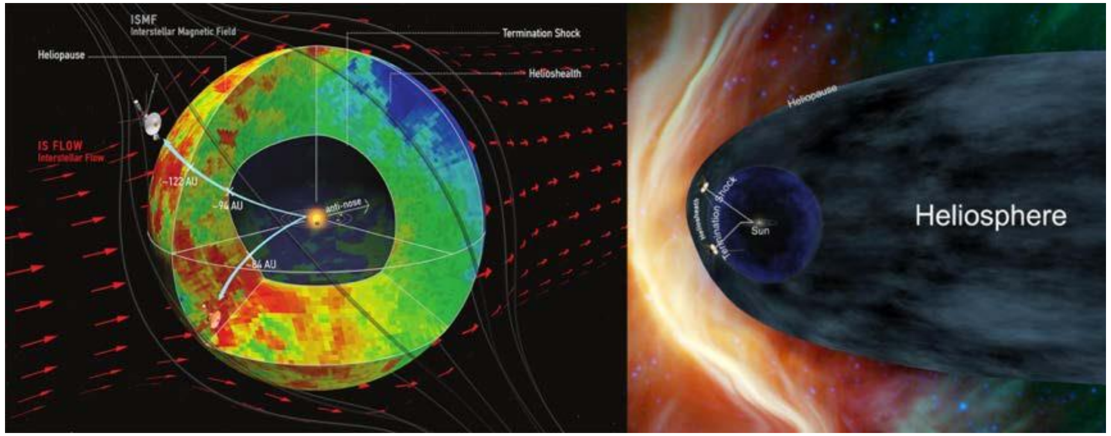
- Launches the James Webb Space Telescope.
- Moves Webb into the Cosmic Origins Program within the Astrophysics Account.
- Terminates WFIRST due to its significant cost and higher priorities elsewhere within NASA. Increases funding for future competed missions and research.

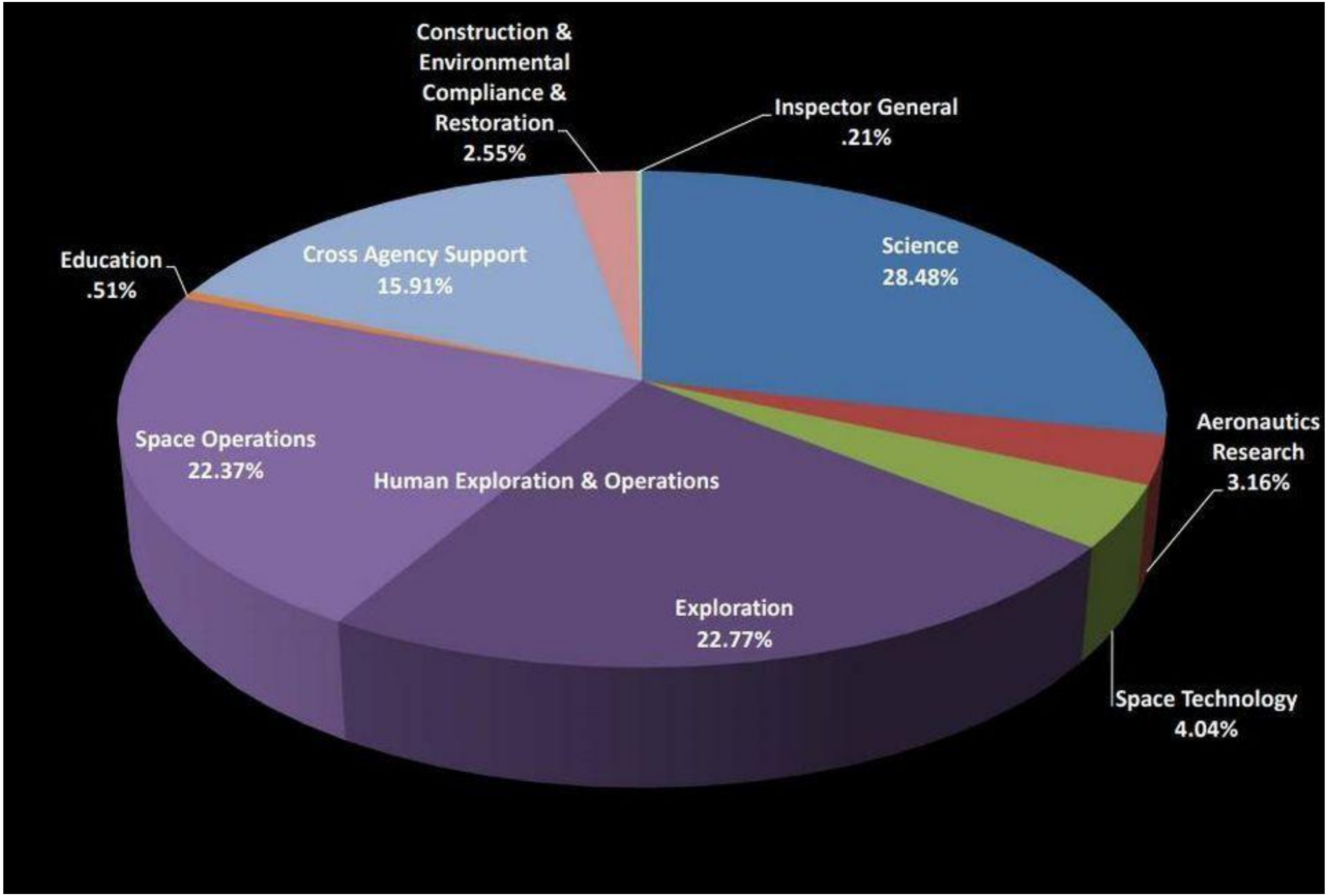
- Supports the TESS exoplanet mission following launch by June 2018.
- Formulates or develops, IXPE, GUSTO, XARM, Euclid, and a new MIDEX mission to be selected in FY 2019.
- Operates ten missions and the balloon project.
- Invests in CubeSats/SmallSats that can achieve entirely new science at lower cost.
- All Astrophysics missions beyond prime operations (including SOFIA) will be subject to senior review in 2019.

Science: Heliophysics

($M)	2019	2020	2021	2022	2023
Heliophysics	**$691**	**$691**	**$691**	**$691**	**$691**

- Continues support of Parker Solar Probe, Ionospheric Connection Explorer (ICON), readying for launch in FY 2018 and recently launched Global-scale Observations of the Limb and Disk (GOLD).
- Continues Solar Orbiter Collaboration (SOC) partnership with ESA.
- Includes a $3 million increase for collaborating with other agencies to improve space weather observation and forecasting capabilities.
- Invests in CubeSats/SmallSats that can achieve entirely new science at lower cost.
- Supports the Sounding Rockets and CubeSat projects.
- Operates 17 additional missions.





Construction & Environmental Compliance & Restoration 2.55%
Inspector General .21%
Science 28.48%
Cross Agency Support 15.91%
Education .51%
Space Operations 22.37%
Human Exploration & Operations
Exploration 22.77%
Aeronautics Research 3.16%
Space Technology 4.04%

FY 2019 Budget Request ($M)

Budget Authority ($ in millions)	Fiscal Year						
				Notional			
	2017	2018	2019	2020	2021	2022	2023
NASA TOTAL	$19,653.3	$19,519.8	$19,892.2	$19,592.2	$19,592.2	$19,592.2	$19,592.2
Deep Space Exploration Systems	$4,184.0	$4,222.6	$4,558.8	$4,859.1	$4,764.5	$4,752.5	$4,769.8
Exploration Systems Development	$3,929.0		$3,669.8	$3,790.5	$3,820.2	$3,707.5	$3,845.6
Advanced Exploration Systems	$97.8		$889.0	$1,068.6	$944.3	$1,045.0	$924.1
Exploration Research and Development	$157.2		$0.0	$0.0	$0.0	$0.0	$0.0
Exploration Research and Technology	$826.5	$820.8	$1,002.7	$912.7	$912.7	$912.7	$912.7
LEO and Spaceflight Operations	$4,942.5	$4,850.1	$4,624.6	$4,273.7	$4,393.3	$4,430.3	$4,438.0
International Space Station	$1,450.9		$1,462.2	$1,453.2	$1,471.2	$1,466.2	$1,451.2
Space Transportation	$2,589.0		$2,108.7	$1,829.1	$1,858.9	$1,829.2	$1,807.3
Space and Flight Support (SFS)	$902.6		$903.7	$841.4	$888.2	$934.9	$954.6
Commercial LEO Development	$0.0		$150.0	$150.0	$175.0	$200.0	$225.0
Science	$5,762.2	$5,725.8	$5,895.0	$5,859.9	$5,841.1	$5,822.4	$5,803.6
Earth Science	$1,907.7		$1,784.2	$1,784.2	$1,784.2	$1,784.2	$1,784.2
Planetary Science	$1,827.5		$2,234.7	$2,199.6	$2,180.8	$2,162.1	$2,143.3
Astrophysics	$1,352.3		$1,185.4	$1,185.4	$1,185.4	$1,185.4	$1,185.4
Heliophysics	$674.7		$690.7	$690.7	$690.7	$690.7	$690.7
Aeronautics	$656.0	$655.5	$633.9	$608.9	$608.9	$608.9	$608.9
Education	$100.0	$99.3	$0.0	$0.0	$0.0	$0.0	$0.0
Safety, Security, and Mission Services	$2,768.6	$2,749.8	$2,749.7	$2,744.8	$2,738.6	$2,732.3	$2,726.1
Center Management and Operations	$1,986.5		$1,949.6	$1,945.4	$1,939.8	$1,934.1	$1,928.5
Agency Management and Operations	$782.1		$800.1	$799.4	$798.8	$798.2	$797.6
Construction & Envrmtl Compl Restoration	$375.6	$358.3	$388.2	$293.8	$293.8	$293.8	$293.8
Construction of Facilities	$305.4		$305.3	$210.9	$210.9	$210.9	$210.9
Environmental Compliance and Restoration	$70.2		$82.9	$82.9	$82.9	$82.9	$82.9
Inspector General	$37.9	$37.6	$39.3	$39.3	$39.3	$39.3	$39.3
NASA TOTAL	$19,653.3	$19,519.8	$19,892.2	$19,592.2	$19,592.2	$19,592.2	$19,592.2

FY 2017 reflects funding amounts specified in Public Law 115-31, Consolidated Appropriations Act, 2017. Table does not reflect emergency supplemental funds also appropriated in FY 2017, totaling $184 million.

FY 2018 reflects Continuing Resolution funding as enacted under Public Law 115-56, as amended..

Lot’s happening in a tiny table……

- $19.892 billion requested by the President for NASA in FY2019.
  - FY 2019 request is $844 million less than NASA’s current funding level.
  - Budget Control Act of FY 2011 means NASA will return to $19.6B after FY 2019.
- NASA proposes to eliminate STMD to focus more attention on developing new technologies that are not mission-specific.
  - It merges whatever will remain into HEOMD.
- Return Humans to the Moon with no increase in budget. How?
  - ISS (2025) and WFIRST
- Commercial capital and companies open up new partnerships (SpaceX, Blue Origin, Moon Express, Astrobotic, etc…)

NASA Mission Launches (Fiscal Years 2018 – 2023)

- NASA Mission on US ELV
- Reimbursable Mission for NOAA
  - **** NASA does not directly manage/control
- Joint NASA-Int'l Partner Mission
- Int'l Mission with NASA contribution
- Joint NASA-USAF Mission
- Joint NASA-Public/Private Partnership
- Exploration Systems Development Mission
- Commercial Crew Mission
- Commercial Resupply Services Mission
- Future Commercial Resupply Mission
- Aeronautics Mission

New lunar missions in red text

✓ Mission successfully launched
X Mission unsuccessful

** Ground-based elements (includes suborbital) block of 5 missions
*** Instrument only
+ Future CRS Capabilities unknown, will be updated after award of CRS-2 when cargo delivery capabilities are known

FY2018
- ✓ JPSS-1
- GOES-S
- InSight
- ✓ GOLD***
- ICON
- PSP
- ✓ TSIS-1 MoO***
- GRACE FO
- ICESat-2
- TESS
- SpaceX-15 CRS
- SpaceX-14 CRS
- ✓ SpaceX-13 CRS
- Orbital ATK-9 CRS
- ✓ Orbital ATK-8 CRS
- CCtCap DM-1 - SpaceX flight test w/o crew
- CCtCap - Boeing orbital flight test
- TDM GPIM
- TDM DSAC

FY2019
- Metop-C***
- Lunar Exploration MoO-1
- BepiColombo***
- GEDI MoO***
- ECOSTRESS MoO***
- EVS-2**
- Webb
- SpaceX-18 CRS
- SpaceX-17 CRS
- SpaceX-16 CRS
- Orbital ATK-11 CRS
- Orbital ATK-10 CRS
- CCtCap - Boeing PCM-2
- CCtCap - SpaceX PCM-2
- CCtCap - Boeing PCM-1
- CCtCap - SpaceX PCM-1
- CCtCap DM-2 - SpaceX flight test w/ crew
- CCtCap - Boeing crewed flight test
- Ascent Abort-2
- TDM LCRD

FY2020
- GOES-T
- Mars-2020
- ExoMars Rover***
- Solar Orb***
- SNC-1 CRS2
- SpaceX-21 CRS2
- SpaceX-20 CRS
- SpaceX-19 CRS
- Orbital ATK-13 CRS2
- Orbital ATK-12 CRS2
- Future Comm Crew
- Future Comm Crew
- EM-1
- TDM TRN***
- TDM MOXIE***

FY2021
- LBFD
- Lunar Exploration MoO-2
- DART
- Helio Expl MoO-1***
- MAIA MoO***
- TROPICS MoO***
- EVS-3**
- GUSTO***
- IXPE
- Euclid***
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Cargo+
- SpaceX-22 CRS2
- Future Comm Crew
- Future Comm Crew
- TDM LOFTID

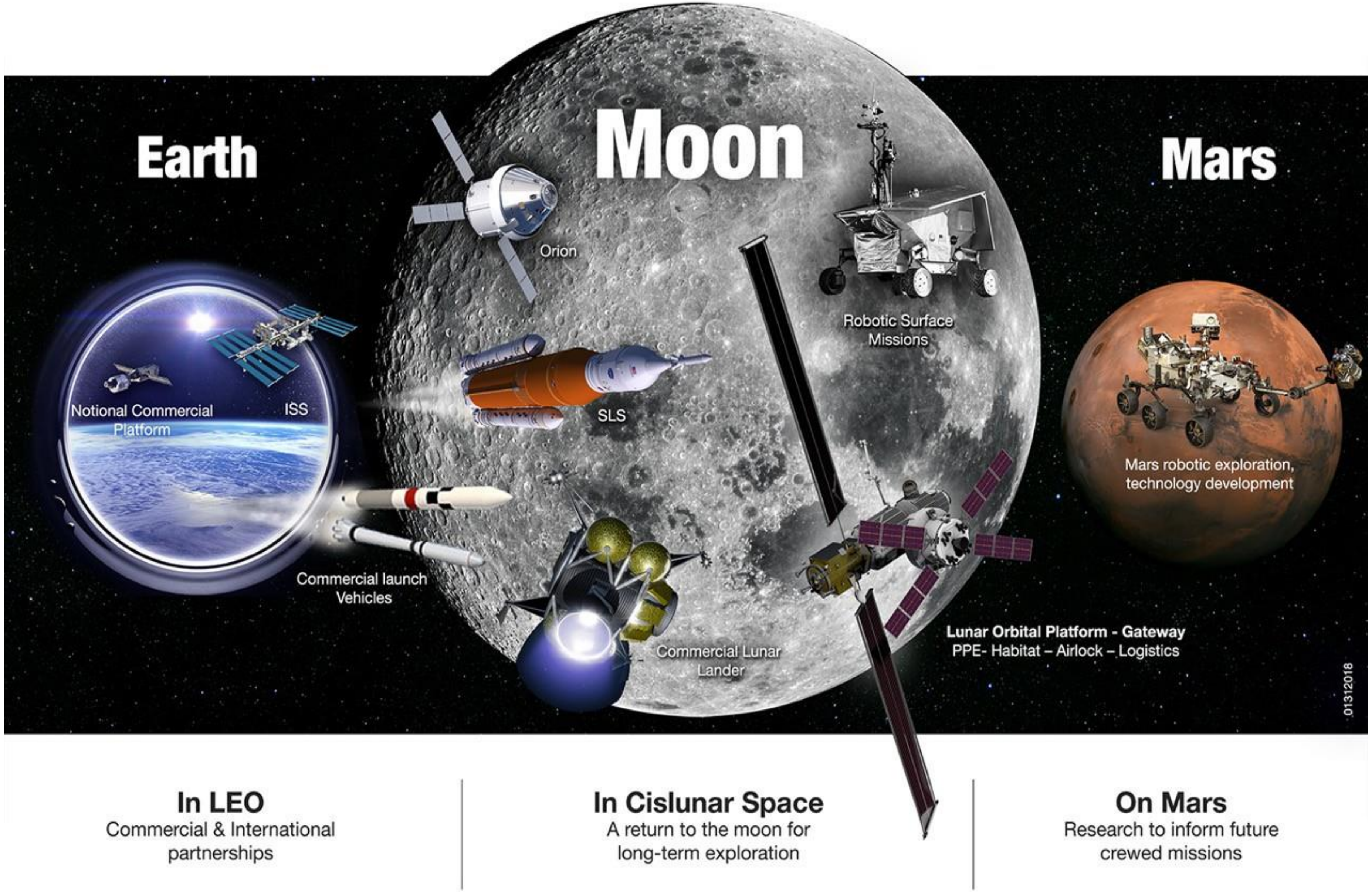
FY2022
- JPSS-2
- JUICE***
- Psyche
- Lucy
- LWS-MoO-4***
- STP MoO-3***
- Helio SMEX-1
- Helio Expl MoO-2***
- TEMPO MoO***
- OMPS-L***
- NISAR
- Sentinel-6a
- SWOT
- Landsat-9
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Comm Crew
- Future Comm Crew
- Robotic Lunar Lander 1
- LOP-G PPE
- TDM SEP***
- TDM DSOC***

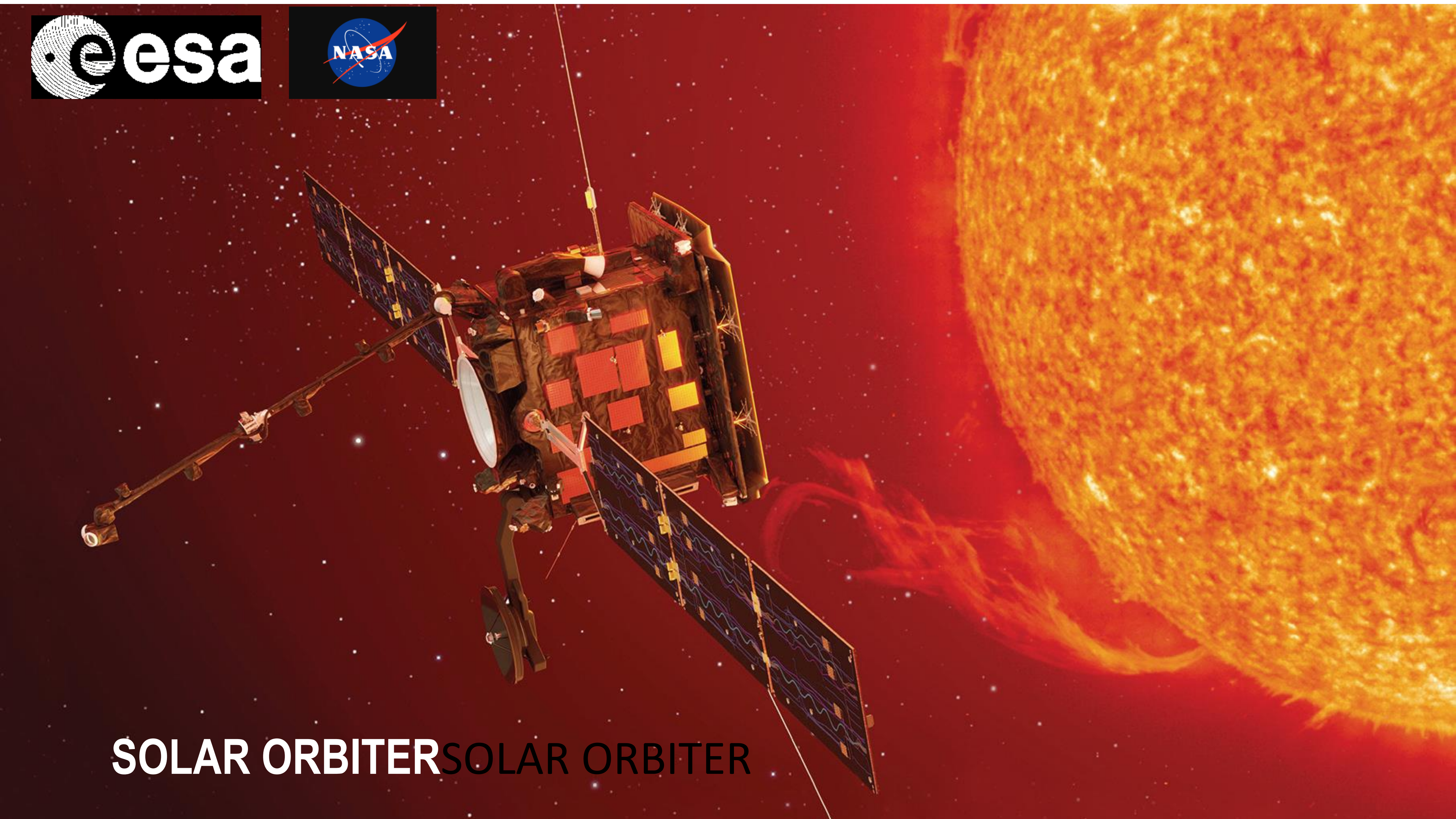
FY2023
- JPSS-3 Contingency
- Lunar Exploration MoO-3
- Helio Expl MoO-5***
- EVI-4 MoO***
- TSIS-2 MoO***
- GeoCarb
- XARM***
- Astro MIDEX-2
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Cargo+
- Future Comm Crew
- Future Comm Crew
- EM-2 Crew (EUS, LOP-G Hab)
- TDM CFM
- TDM IRMA

Notional

Dates reflect Agency Baseline Commitments or updated Agency schedules and may include schedule margin beyond any manifested launch dates

The Lunar Exploration Campaign



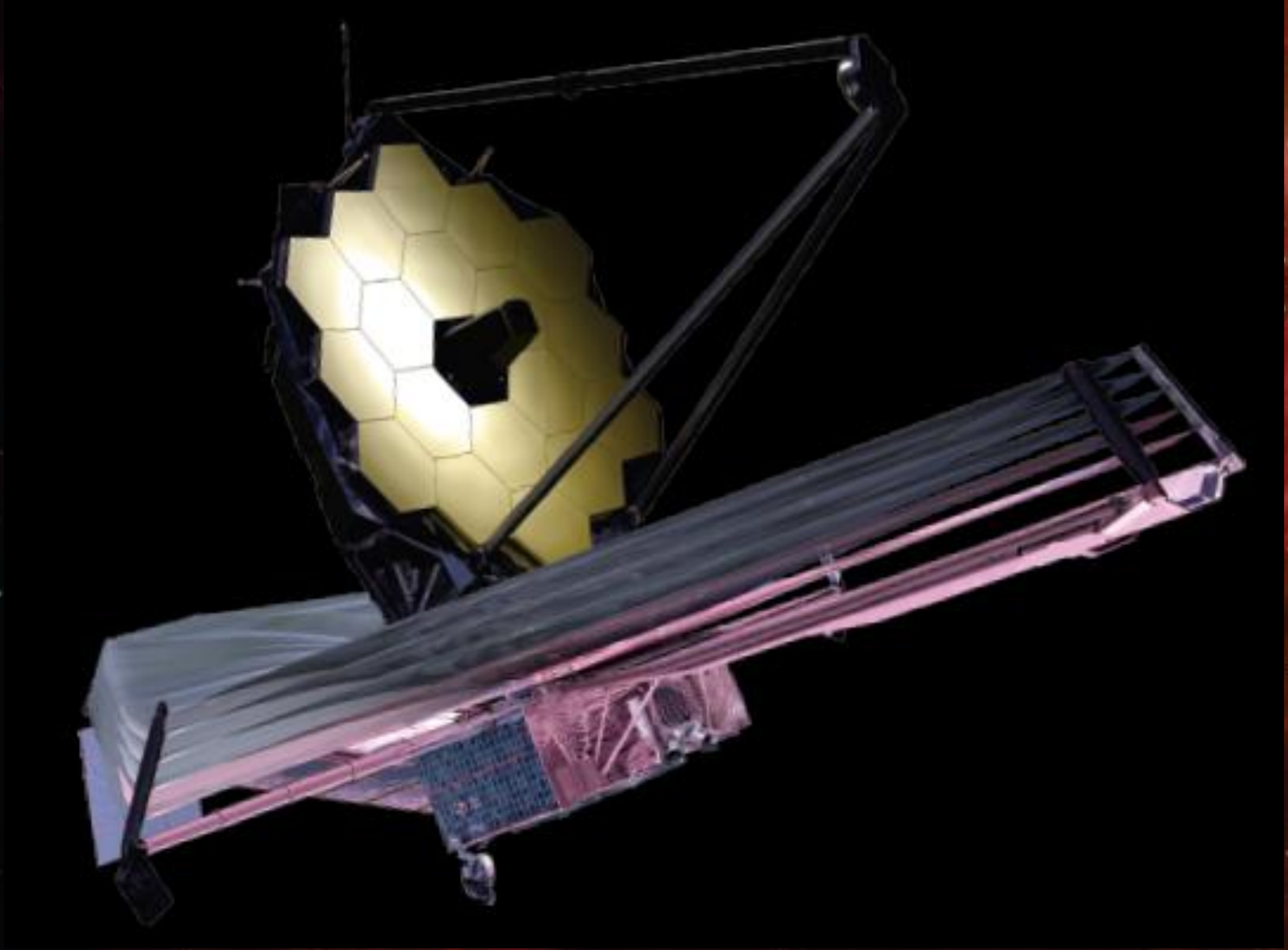


SOLAR ORBITERSOLAR ORBITER

BepiColombo

Studying Mercury from unique vantage points

The James Webb
Space Telescope



Sept. 24, 2018 - Technicians ready sunshield/spacecraft element for assembly at Northrop Grumman, Redondo Beach, California

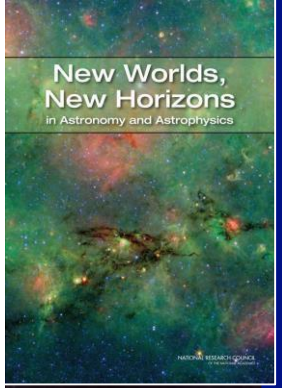
Why a Decadal Survey?

The National Academies of SCIENCES ENGINEERING MEDICINE

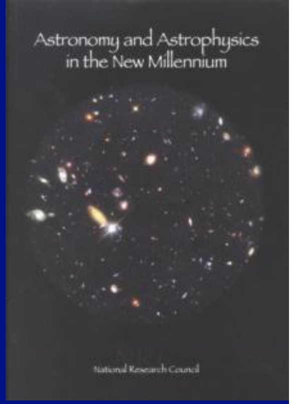
Decadal Survey Background

Over the past 50 years, Decadal Surveys have been conducted for: 6 astronomy, 2 each for planetary science and for solar and space physics and Earth sciences, and 1 for life and physical sciences research in space.

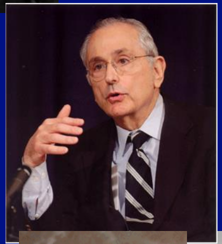
- The NASA Authorization Acts of 2005 and 2008 provided a formal legislative mandate for decadal surveys in each NASA science area.
- The 2005 act also mandated National Research Council (NRC) reviews of NASA's performance in each discipline at 5-year intervals (Public Law 109-155).
- The 2008 act called for "independent estimates of the life cycle costs and technical readiness of missions assessed in the decadal surveys whenever possible" (Public Law 110-422) and for identifying conditions or events that might trigger a reexamination of the survey's priorities.



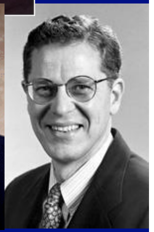
Recall Decadal Survey History




- 1964: Ground-based Astronomy: A Ten Year Program (Whitford)
  - Recommended building more large optical telescopes including one in Chile
  - QSOs had just been discovered
- 1972: Astronomy and Astrophysics for the 1970s (Greenstein)
  - Recommended building the VLA, HST
  - Astronomy satellites used to discover X-ray emission from stars

- 1982: Astronomy and Astrophysics for the 1980s (Field)
  - Recommended building the Chandra X-ray satellite
  - Many galaxies observed to produce large amounts of IR emission
- 1991: The Decade of Discovery in Astronomy and Astrophysics (Bahcall)
  - Recommended building Spitzer and the Gemini telescopes
  - Existence of dark matter demonstrated

- 2001: Astronomy and Astrophysics in the New Millennium (McKee-Taylor)
  - Recommended building JWST, ALMA
  - First exo-planets discovered, first evidence of dark energy seen

- 2010: New Worlds, New Horizons in Astronomy and Astrophysics (Blandford)
  - Recommended WFIRST, LSST

Who Charters and Uses the Survey?

- Congress and federal agencies that fund astronomy (eg., NASA Astrophysics, NSF Division of Astronomical Sciences, DOE High Energy Physics, DOC/NOAA, DOI/USGS) are groups that rely on Decadal Surveys for science guidance
- For Astro2020, three agencies fund the Survey and negotiate the Statement of Task and report due date with the National Academies

ASTRO 2020 Consultation Group

- Neta Bahcall, NAS Section 12 Chair
- Alan Dressler, Survey of Surveys Chair, NAS
- Debra Elmegreen, OIR System Study Chair
- Wendy Freedman, BPA member, NAS
- Sarah Gibson, CSSP Co-Chair and SSB XCOM member
- Fiona Harrison, SSB Chair, NAS
- Chryssa Kouveliotou, SSB XCOM member, NAS
- Avi Loeb, BPA Vice-Chair
- Marcia Rieke, CAA Co-Chair, NAS
- Steve Ritz, CAA Co-Chair, BPA member
- David Van Wie, ASEB member, NAE

NAS=National Academy of Sciences
BPA=Board on Physics and Astronomy
CSSP=Committee on Solar and Space Physics
CAA=Committee on Astronomy and Astrophysics
SSB=Space Studies Board
ASEB=Aeronautics and Space Engineering Board

Decadal Survey Preparatory Activities

- Issued a call for Science White Papers, timed so they will be available to the Survey Committee at the start of the process.
- Early-career colleague engagement event on Oct 8-9, 2018 in DC.
  http://sites.nationalacademies.org/SSB/SSB_185166
- Congress mandated two studies- exoplanets and astrobiology – that are now complete
  - These studies are input to the astronomy decadal and the planetary sciences decadal
  - They look at science strategies, not mission choice

The Statement of TASK can be found at the Astro2020 Website:

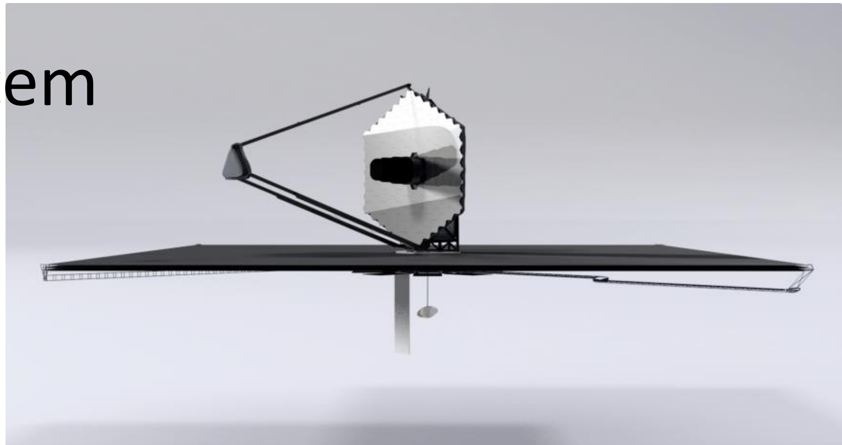
- http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_185159
- The Leadership will be announced before December 2018!

Lead-up to Astro2020
4 Large Strategic Science Mission)
+ 10 Probe Class Studies

Large Ultraviolet Optical Infrared Surveyor (LUVOIR):highly capable, multi-wavelength space observatory with ambitious science goals.

- Highly capable, multi-wavelength space observatory with ambitious science goals
  - broad range of science, from the epoch of reionization, through galaxy formation and evolution, star and planet formation, to solar system remote sensing.
  - major goal of characterizing wide range of exoplanets.

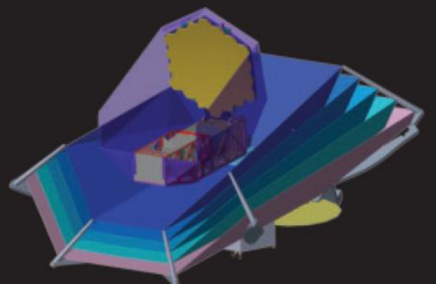
Start of mission	
Launch date	2035 (proposed)
Orbital parameters	
Reference system	Lagrange 2
Main	
Diameter	8 -18 m
Wavelengths	UV, vis, IR



Origins Space Telescope (OST)

OST Mission Concept 1*

Observatory



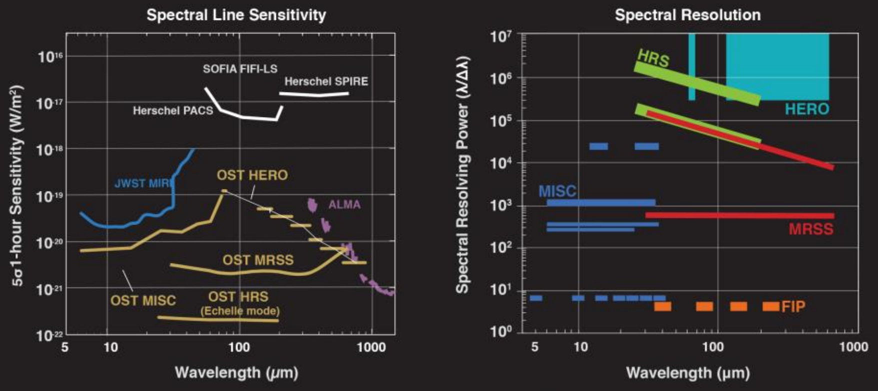
- 9.1 m off-axis primary mirror
- Cold (4K) telescope
- Wavelengths 5 – 660 µm
- 5 science instruments
- Launch 2030s
- Mission operations at Sun-Earth L2
- Data rate: 348 Mb/s
- 5 year lifetime, 10 year goal

* OST is an evolving concept for the Far-IR Surveyor mission in NASA's visionary astrophysics roadmap. Stay tuned for Concept 2, coming in the fall of 2018.

Instruments

Instrument	Wavelength (µm)	Observing Modes
MISC Mid-Infrared Imager, Spectrometer, Coronagraph	5-38	• Imaging, spectroscopy • Coronagraphy (10^{-6} contrast) • Transit Spectrometer < 10 ppm stability)
MRSS Medium Resolution Survey Spectrometer - IFU	30-660	• Multi-band Spectroscopy
FIP Far-Infrared Imager and Polarimeter	40, 80, 120, 240	• Broadband imaging • Field of view: 2.5'x5', 7.5'x15' • Differential polarimeteric imaging
HERO Heterodyne Receiver for OST	63-66 , 111-610	• Multi-beam spectroscopy
HRS High Resolution Spectrometer	25-200	• Spectroscopy

Performance



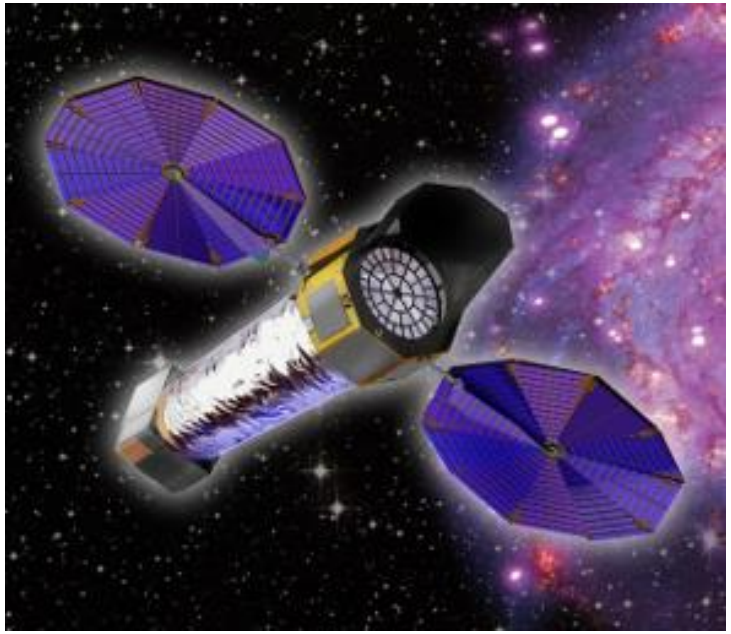
Leveraging improvements in detector technology and a large, cold primary mirror, OST will offer two to four order of magnitude improvement in sensitivity over Herschel. OST will bring arc-second imaging and unprecedented spectroscopic capabilities to the infrared universe.

-astrometry and astrophysics in the mid- to far-infrared using filled aperture telescope, effective diameter between 8 - 15 m.
-requires cryocooler systems to actively cool detectors at ~50 mK, telescope optics at ~4 K.
-sensitivities 100–1000 times greater than previous far-IR telescopes.

Lynx X-ray Surveyor (Lynx)

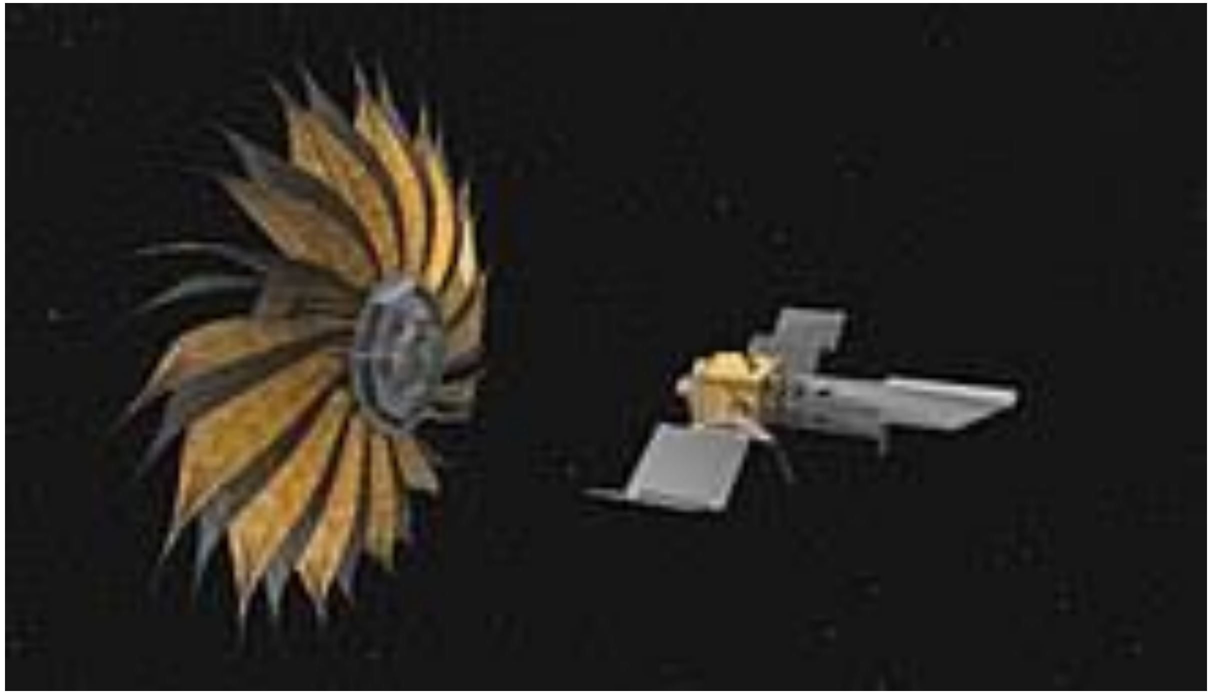
- Unprecedented X-ray vision to directly observe the dawn of supermassive black holes, reveal the drivers of galaxy formation, trace stellar activity including effects on planet habitability, and transform our knowledge of endpoints of stellar evolution.
- Excellent angular resolution, high throughput, large field of view, and high spectral resolution for both point-like and extended sources.

Diameter	3-6 m
Focal length	10 -20 m
Wavelengths	X-ray
Resolution	0.5 arcsec



Habitable Exoplanet Imaging Mission (HabEx)

Directly image planetary systems around Sun-like stars in the ultraviolet, optical, and near-infrared photons.



Why does NASA care about the decadal surveys?

The answer is that they are both swords and shields.

They are swords because a high decadal ranking provides a program manager with an argument supporting a new activity.

They are shields because they protect highly ranked programs from attack. The first decadal survey in any discipline is always difficult.

The changing environment over a decade is always an inherently difficult process to map, but Decision Rules have allowed for more relevant advise with changing budgets, mission costs.

European Space Science Committee and the SSB

ESSC established by the European Science Foundation in 1975

ESSC and SSB established a close relationship almost immediately

SSB and ESSC representatives regularly attend each others meetings

ESSC representatives served as liaison members of SSB discipline committees at one time (e.g., on COMPLEX and COEL)

Joint studies

Examples : Review of the MEPAG Report on Mars Special Regions (2015) Planetary Protection Classification of Sample-Return Missions, Phobos-Deimos Planetary Protection 2017-2018; Exo Oceans Study 2017 – 2018.

But we could do more together!

- Space Science Week has become an international engagement activity with regular participation by agency/academy representatives from Europe, Japan, China and Russia.
- Ad Hoc activities associated with a discipline committee.
  - Non-Academy activities in which participation of US scientists is facilitated by a discipline committee.
  - Two are currently active:
    - European Union's Planetary Protection for Outer Solar System
    - ESSC-EMB-ISSI ExoOceans study
- But we could do more. Possibilities:
  - Stronger collaboration during Space Science Week with Space Generation Advisory Council (SGAC)
  - Diversity & Inclusion Studies?
  - Re-institute a standing Committee on International Programs?
  - Conversations about additional interactions welcome.

Thank You!