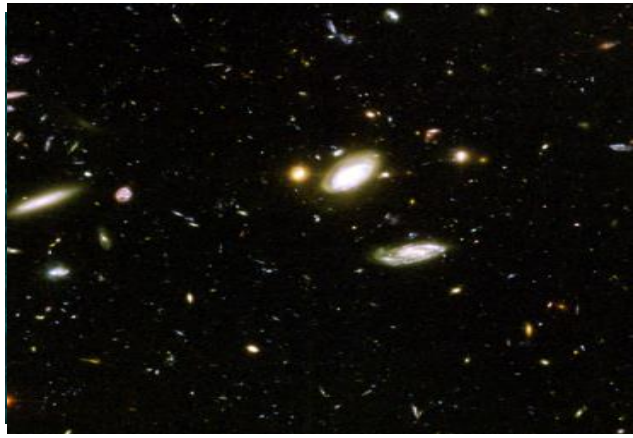
SCIENCE

National Aeronautics and Space Administration



ASTROPHYSICS DIVISION, SCIENCE MISSION DIRECTORATE

FY 2019 BUDGET ESTIMATES

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FY 2019 SMD Budget Highlights

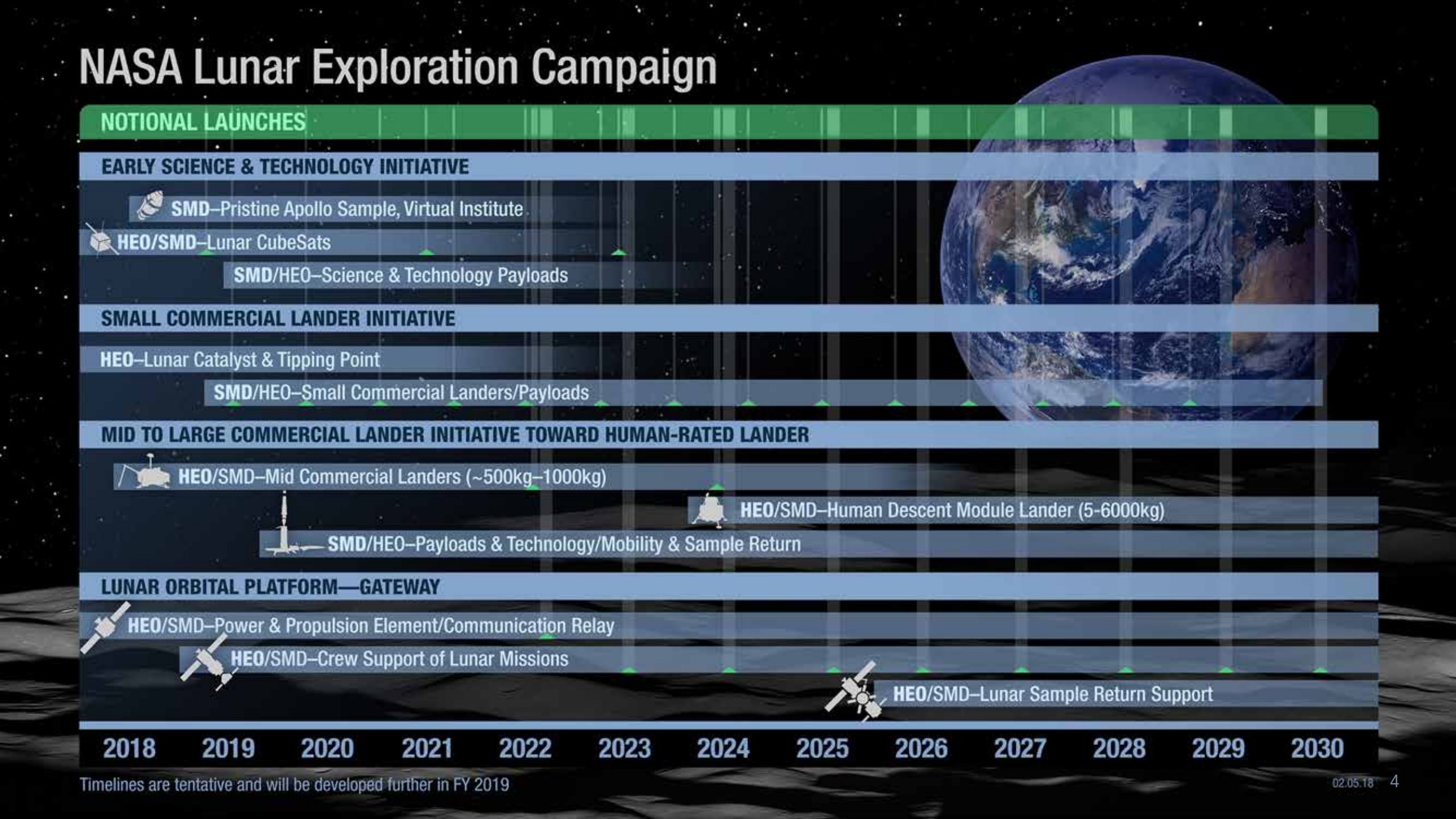
- Advance National Science and Exploration Goals
- Safeguard and Improve Life
- Execute a Balanced and Integrated Science Program

FY 2019 Budget Highlights

Advance National Science and Exploration Goals

- Execute a new **Lunar Discovery and Exploration** program to leverage commercial partnerships and innovative approaches to achieve human and science exploration goals
- Build on extensive past **Lunar** exploration and science experience
- Study concepts for a **Mars Sample Return** mission, a decadal survey priority, leveraging international and commercial partnerships

NASA Lunar Exploration Campaign



Timelines are tentative and will be developed further in FY 2019

FY 2019 Budget Highlights

Safeguard and Improve Life

- Execute **Planetary Defense** program for near-Earth object detection and mitigation, developing DART and studying a low-cost space-based near-Earth object detection mission
- Provide additional funding for **Space Weather research** to improve forecasting and prediction, and strengthen cross-agency collaboration on Research-to-Operations / Operations-to-Research
- Execute a robust **Earth Science** program consistent with the 2017 Decadal Survey
- Support **interagency partners** to achieve missions and leverage data obtained from partners (e.g., NOAA, USGS) to further science research

FY 2019 Budget Highlights

Execute a Balanced and Integrated Science Program

- Execute program informed by National Academy of Sciences **Decadal Surveys**
- Support for **Europa Clipper** mission, no funding for Europa Lander
- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, **WFIRST** terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Continue leveraging innovation and partnerships, including **SmallSats/CubeSats** and commercial efforts
- Invest in innovative early-stage research and technology to promote **economic growth**

FY 2019 Budget

Program Highlights

Planetary Science

- New Lunar Discovery and Exploration program supports commercial partnerships and innovative approaches to achieving human & science exploration goals
- New Planetary Defense program includes DART development
- Europa Clipper launch as early as FY25
- Study concepts and develop technology for a potential Mars Sample Return mission

Astrophysics

- Webb remains on track for 2019 launch
- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research

Heliophysics

- Space Weather increase will strengthen cross-agency collaboration on Research-to-Operations/Operations-to-Research
- Provides for a balanced Heliophysics portfolio, including enhanced emphasis on small missions, technology development and expanded opportunities for R&A

Earth Science

- Continues focused, balanced Earth science portfolio
- Maintains regular cadence of Venture Class missions and instruments solicitations
- Healthy research and applied science programs, and SmallSat/CubeSat investments

Science budget ~2% above the FY17 appropriated level

Science Budget Request Summary ($M)

	Actual	Enacted	Request	Notional			
	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22	FY 23
Science	5,762.2		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
Earth Science Research	462.0		451.4	457.4	483.8	507.7	537.8
Earth Systematic Missions	929.7		788.1	729.5	689.1	646.5	595.0
Earth System Science Pathfinder	208.8		235.0	273.7	268.2	274.3	287.7
Earth Science Multi-Mission Operations	204.9		196.9	208.7	225.0	231.6	237.1
Earth Science Technology	62.9		59.7	61.6	64.2	67.8	69.6
Applied Sciences	39.4		53.1	53.3	53.9	56.3	57.0
Planetary Science	1,827.5		2,234.7	2,199.6	2,180.8	2,162.1	2,143.3
Planetary Science Research	230.1		258.0	247.6	247.6	247.6	247.6
Planetary Defense	60.0		150.0	150.0	150.0	150.0	150.0
Lunar Discovery and Exploration	19.0		218.0	218.0	218.0	218.0	218.0
Discovery	194.6		381.2	476.6	375.0	355.6	348.5
New Frontiers	134.0		130.2	163.7	245.0	327.6	388.4
Mars Exploration	647.0		601.5	529.7	371.9	290.8	215.3
Outer Planets and Ocean Worlds	359.5		285.6	213.8	373.3	372.5	375.5
Technology	183.3		210.2	200.2	200.0	200.0	200.0
Astrophysics	1,352.3		1,185.4	1,185.4	1,185.4	1,185.4	1,185.4
Astrophysics Research	190.1		259.2	280.8	321.5	318.4	310.0
Cosmic Origins	779.4		491.4	354.5	311.9	312.7	312.7
Physics of the Cosmos	106.2		136.8	139.1	113.3	108.3	105.0
Exoplanet Exploration	152.6		52.4	44.5	44.6	44.4	44.9
Astrophysics Explorer	124.1		245.6	366.5	394.0	401.6	412.8
Heliophysics	674.7		690.7	690.7	690.7	690.7	690.7
Heliophysics Research	180.8		242.7	234.3	226.7	217.9	220.6
Living with a Star	368.4		247.8	103.4	83.5	93.2	127.8
Solar Terrestrial Probes	38.8		91.0	89.9	177.7	175.6	247.9
Heliophysics Explorer Program	86.7		109.2	263.1	202.9	204.1	94.4

Science Mission Directorate
Astrophysics

Astrophysics Overview

Strategic Objective

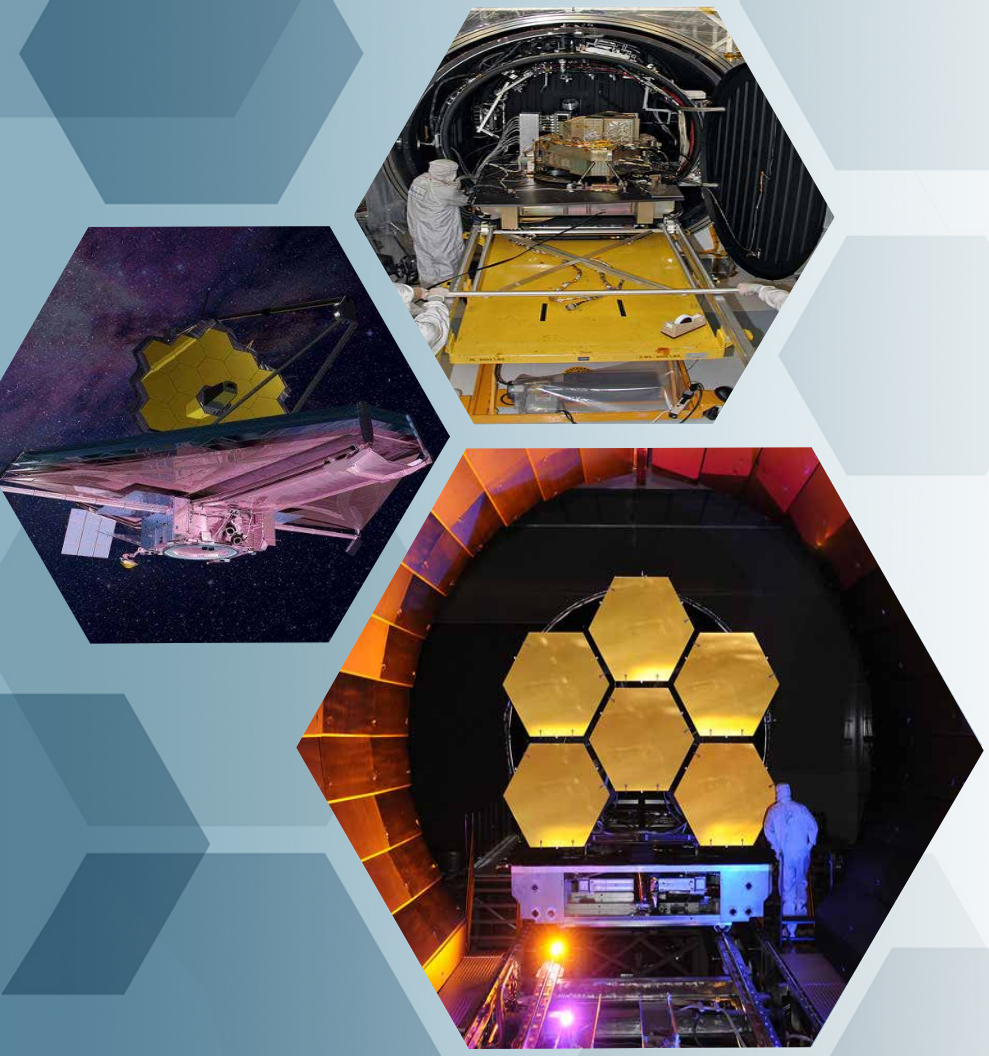
- Discover how the Universe works, explore how it began and evolved, and search for life on planets around other stars

Major Activities

- Building, launching, and operating strategic and competed space observatories, many with international partners
- Developing technologies to enable future observatories, both large and small
  - Basic R&D as well as focused technology development
- Conducting and sponsoring cutting-edge research, mission enabling studies, technology demonstrations, and workforce development
  - Suborbital-class projects using scientific balloons, sounding rockets, SmallSats/CubeSats, International Space Station, and other platforms
  - Analysis of data from NASA and partner space observatories
  - Theoretical and computational investigations
  - Laboratory experiments in support of astrophysical understanding

Major Recent Accomplishments FY17-18

- IXPE downselected January 2017 as next Astrophysics Small Explorer (SMEX) mission
- Seven Earth-sized planets, three in habitable zone, discovered orbiting red dwarf star TRAPPIST-1 by Spitzer February 2017
- Two missions launched to ISS
  - Neutron Star Interior Composition Explorer (NICER) June 2017
  - Cosmic Ray Energetics and Mass (CREAM) August 2017
- Final Kepler prime-mission catalog, containing 4,000+ exoplanet candidates, released June 2017
- Three Medium-class Explorer (MIDEX) and three Mission of Opportunity proposals selected August 2017 for competitive Phase A concept studies
- Gravitational waves and light detected from a kilonova caused by two merging neutron stars August 2017
- WFIRST Independent External Technical/Management/Cost Review (WIETR) completed November 2017
- Webb payload completed cryotesting and Webb sunshield integrated with spacecraft December 2017, on track for 2019 launch
- XARM passed KDP-C January 2018 and began implementation
- TESS completed testing, on track for April 2018 launch



James Webb Space Telescope

- Civilization-scale mission to observe first galaxies formed after Big Bang
- Science payload completed three months cryogenic testing at end of 2017
- Spacecraft and sunshield integration complete January 2018
- Science payload and spacecraft integration planned Summer 2018
- Launch scheduled for 2019

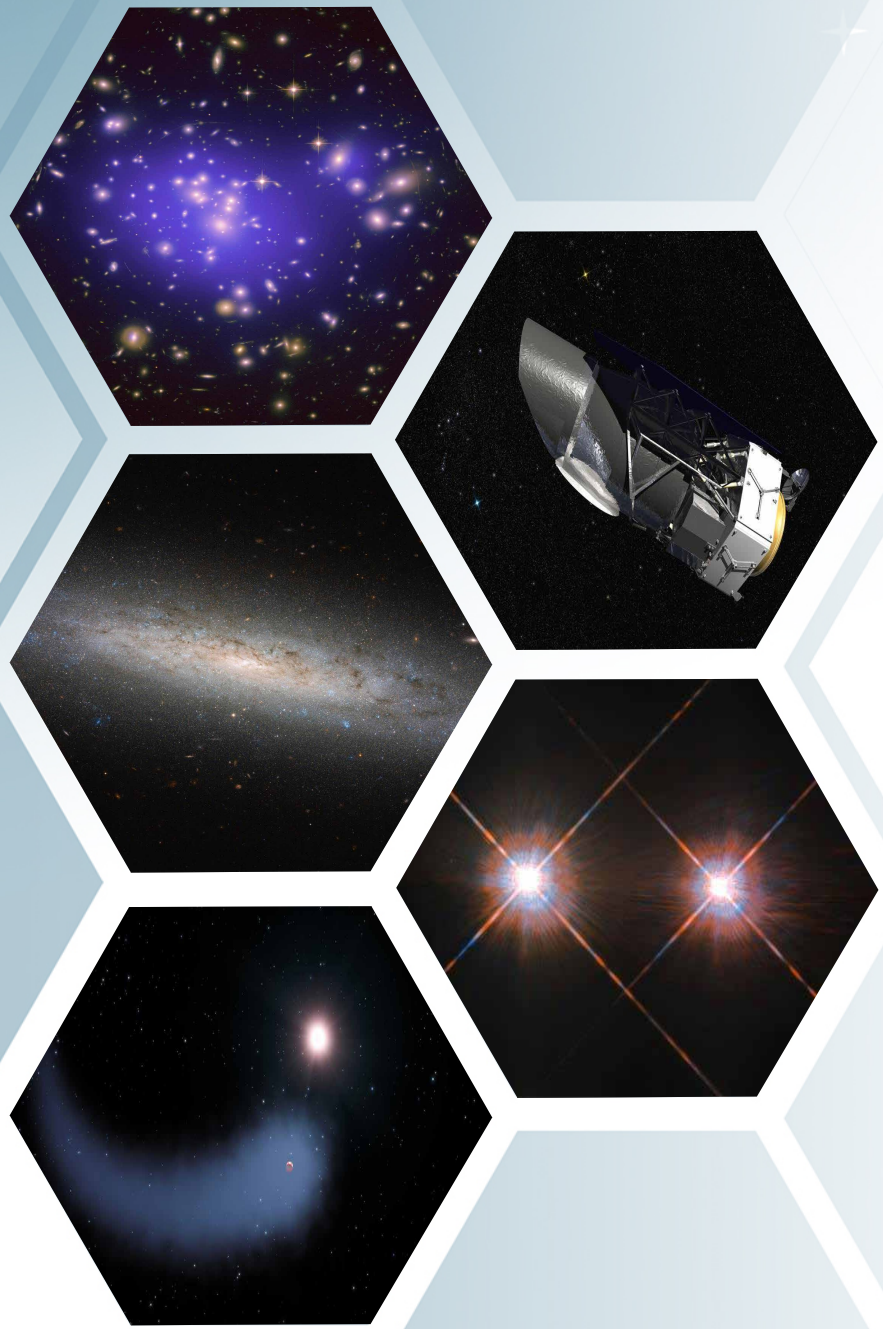
Astrophysics Budget Features

What's Changed

- Webb included as project within Astrophysics budget, remains on track and within budget for 2019 launch
- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Euclid budget increased to recover from failed sensor electronics design
- XARM begun within Explorers program
- Spitzer ops extended until Webb is operational, consistent with 2016 Senior Review

What's the Same

- TESS, IXPE, and GUSTO remain on track and within budget
- All 11 operating missions continue; next Senior Review in 2019
- CubeSat initiative and four balloon campaigns within healthy research program



WFIRST

- Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
- Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
- If Congress adopts the Administration's request to terminate WFIRST, the funds made available would enable a competed probe-class mission AO in FY19

WFIRST Terminated

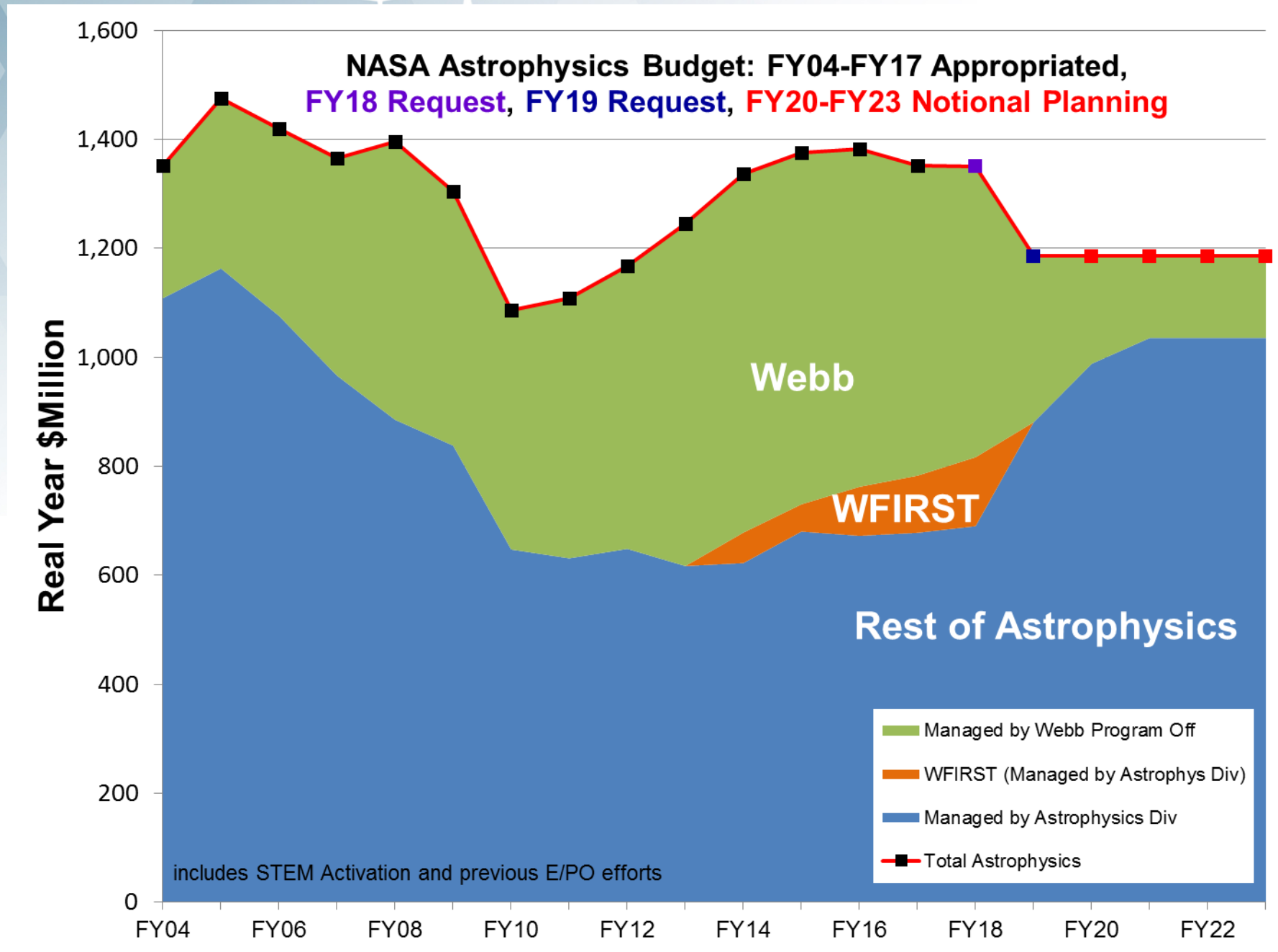
- “Given competing priorities at NASA, and budget constraints, developing another large space telescope immediately after completing the $8.8 billion James Webb Space Telescope is not a priority for the Administration.”
  - White House FY19 Budget Request document (https://www.whitehouse.gov/wp-content/uploads/2018/02/msar-fy2019.pdf)

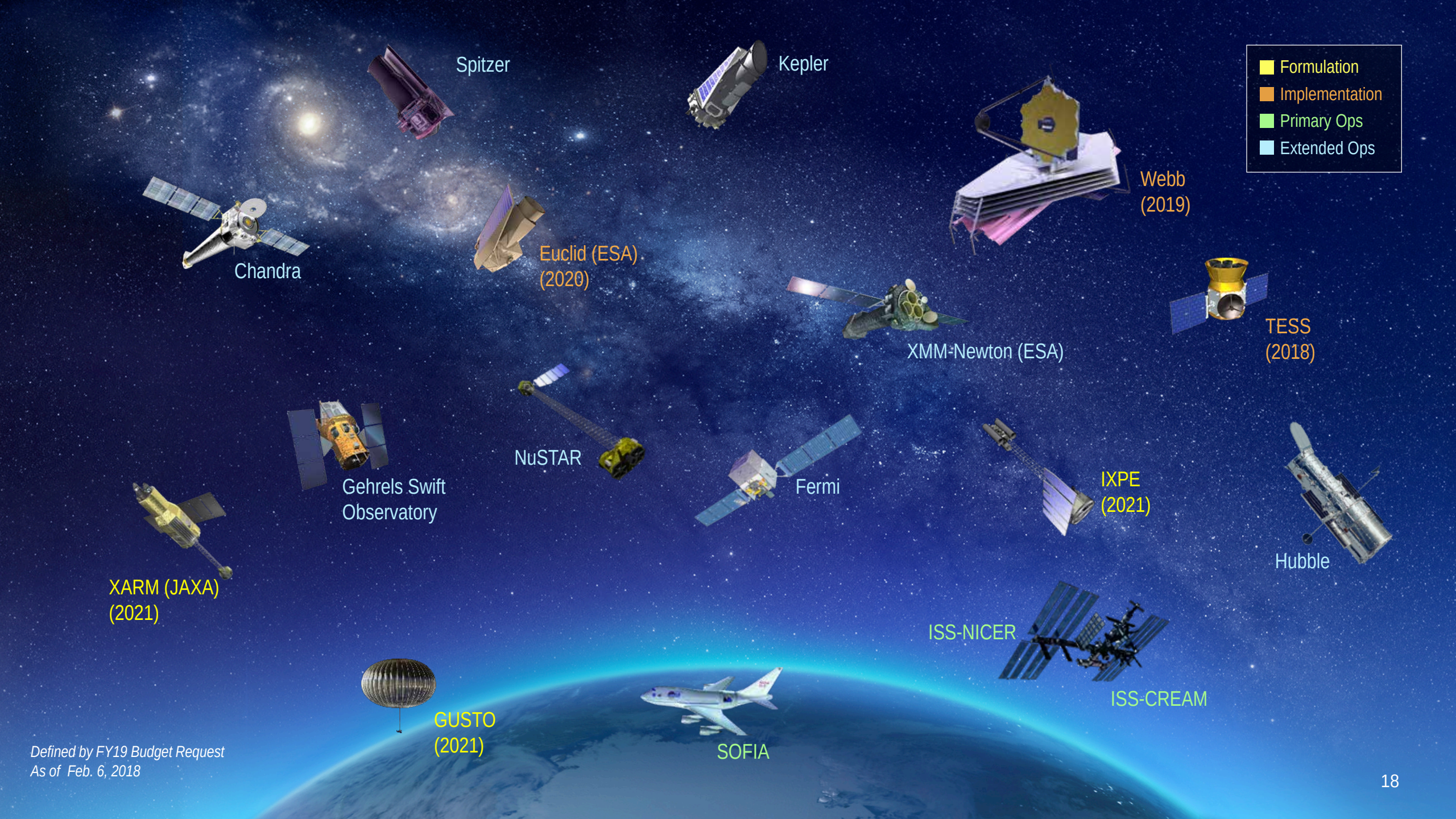
- “We did have to make some hard decisions in science. This budget proposes cancelling our WFIRST mission and taking those resources and redirecting them to other agency priorities.”
  - Robert Lightfoot, Acting Administrator, “State of NASA” address, February 12, 2018

- “Given its significant cost and higher priorities within NASA, the budget proposes termination of the WFIRST mission. Remaining WFIRST funding is redirected towards other priorities of the astrophysics community, including competed astrophysics missions and research.”
  - NASA FY19 Budget Estimates (https://www.nasa.gov/sites/default/files/atoms/files/fy19_nasa_budget_estimates.pdf)

Planned Accomplishments FY18-19

- TESS will launch April 2018
- Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
- IXPE will complete preliminary design review and enter Phase C Fall 2018
- Next MIDEX and Mission of Opportunity missions will be downselected by January 2019
- Decadal Survey will begin January 2019
- Webb will complete observatory integration and will launch in 2019
- Senior Review will be conducted Spring 2019
- If Congress approves the Administration's request to terminate WFIRST, the funds made available would enable a competed probe-class mission AO in FY19


NASA Astrophysics Budget: FY04-FY17 Appropriated,
FY18 Request, FY19 Request, FY20-FY23 Notional Planning
Real Year $Million
1,600
1,400
1,200
1,000
800
600
400
200
0
FY04
FY06
FY08
FY10
FY12
FY14
FY16
FY18
FY20
FY22
Webb
WFIRST
Rest of Astrophysics
includes STEM Activation and previous E/PO efforts
Managed by Webb Program Off
WFIRST (Managed by Astrophys Div)
Managed by Astrophysics Div
Total Astrophysics


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
Kepler
Webb
(2019)
Chandra
Euclid (ESA)
(2020)
XMM-Newton (ESA)
TESS
(2018)
NuSTAR
Gehrels Swift
Observatory
Fermi
IXPE
(2021)
Hubble
XARM (JAXA)
(2021)
ISS-NICER
ISS-CREAM
GUSTO
(2021)
SOFIA
Defined by FY19 Budget Request
As of Feb. 6, 2018

Astrophysics Program Content

	Actual	Request	Notional			
	FY 17	FY 19	FY 20	FY 21	FY 22	FY 23
Astrophysics	**1,352.3**	**1,185.4**	**1,185.4**	**1,185.4**	**1,185.4**	**1,185.4**
Astrophysics Research	190.1	259.2	280.8	321.5	318.4	310.0
Science Activation	37.0	44.6	44.6	44.6	44.6	44.6
Astrophysics Research and Analysis	73.5	83.4	86.6	90.2	92.2	94.2
Balloon Project	34.0	39.2	41.7	40.4	40.5	40.6
Other Missions and Data Analysis	45.6	92.0	108.0	146.4	141.1	130.7
Astrophysics Data Curation and Archival	15.4	21.2	20.5	21.5	21.5	21.5
Astrophysics Data Program	17.6	19.1	20.4	21.6	22.6	23.6
Astrophysics Senior Review				31.5	33.0	33.0
Contract Administration, Audit & QA Svcs	12.6	12.7	12.7	12.7	12.7	12.7
Astrophysics Directed R&T		39.0	54.4	59.1	51.3	39.9
Cosmic Origins	779.4	491.4	354.5	311.9	312.7	312.7
Hubble Space Telescope	97.3	78.3	88.3	93.3	98.3	98.3
SOFIA	85.2	74.6	39.8	16.6		
James Webb Space Telescope	569.4	304.6	197.2	149.8	150.0	150.0
Other Missions and Data Analysis	27.5	33.9	29.1	52.2	64.4	64.4
Cosmic Origins Future Missions	0.0	2.7	2.2	28.7	43.8	43.8
Spitzer	11.0	11.0	8.0	3.0		
Herschel	1.0					
Cosmic Origins SR&T	12.8	17.6	16.8	18.4	18.4	18.4
Cosmic Origins Program Management	2.7	2.7	2.2	2.2	2.2	2.2

Astrophysics Program Content (cont'd)

	Actual	Request	Notional			
	FY 17	FY 19	FY 20	FY 21	FY 22	FY 23
Physics of the Cosmos	106.2	136.8	139.1	113.3	108.3	105.0
Euclid	12.9	20.2	16.4	9.4	9.5	8.9
Physics of the Cosmos Future Missions	0.1	2.3	3.4	3.7	4.0	4.4
Chandra X-Ray Observatory	50.7	58.9	58.4	58.4	58.4	58.4
Fermi Gamma-ray Space Telescope	12.5	15.5	14.0			
XMM	3.5	3.5	3.5			
Planck	0.6					
Physics of the Cosmos SR&T	23.3	33.5	41.1	39.4	34.1	30.9
Physics of the Cosmos Program Mgmt	2.6	2.9	2.4	2.4	2.4	2.4
Exoplanet Exploration	152.6	52.4	44.5	44.6	44.4	44.9
WFIRST	105.0					
Exoplanet Exploration Future Missions	0.9	1.5	1.6	1.4	1.2	1.0
Kepler	11.0	7.9	1.3			
Keck Operations	6.1	6.5	6.7	6.9	7.0	7.2
Large Binocular Telescope Interferometer	2.6					
Exoplanet Exploration SR&T	21.2	28.5	27.2	28.4	28.3	28.3
Exoplanet Exploration Program Mgmt	5.9	8.0	7.8	8.0	7.9	8.3

Astrophysics Program Content (cont'd)

	Actual	Request	Notional			
	FY 17	FY 19	FY 20	FY 21	FY 22	FY 23
Astrophysics Explorer	124.1	245.6	366.5	394.0	401.6	412.8
Transiting Exoplanet Survey Satellite	74.0	27.5	3.8	0.0		
Imaging X-Ray Polarimetry Explorer	11.3	65.9	67.3	40.7	5.0	4.2
Other Missions and Data Analysis	38.8	152.2	295.5	353.3	396.6	408.6
GUSTO	2.4	13.2	11.6	7.5	3.5	
Astrophysics Explorer Future Missions	15.2	112.1	262.9	334.1	385.2	398.5
Nuclear Spectroscopic Telescope Array	5.0	8.3	7.0			
Swift	5.5	5.4	5.5			
NICER	4.6	2.4				
Astrophysics Explorer Program Mgmt	6.1	10.9	8.5	11.8	7.9	10.1