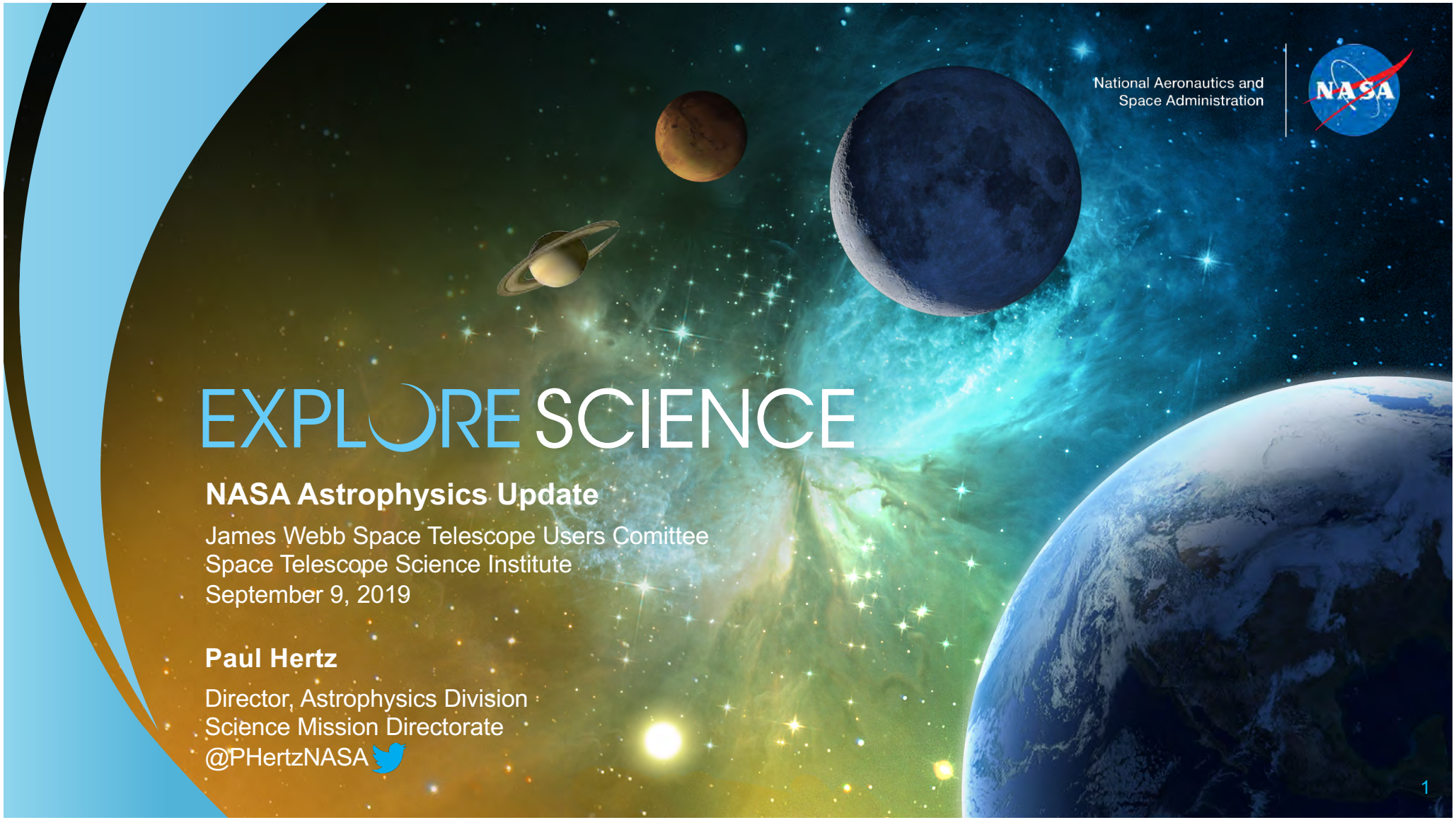


NASA Astrophysics Update

James Webb Space Telescope Users Comittee
Space Telescope Science Institute
September 9, 2019

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

National Aeronautics and Space Administration

NASA'S CHANDRA X-RAY OBSERVATORY

SCIENCE BY THE NUMBERS SO FAR

0.002 seconds
for a neutron star (47 Tuc W) observed with Chandra to spin around once

2.3 days
before Chandra started observing a neutron star merger and gravitational wave source after it was discovered

3 number of remnants observed with Chandra of thermonuclear supernova explosions seen with the unaided eye

300 million
Sun masses are swallowed by a black hole to create enormous cavities in hot gas in a galaxy cluster

100
factor of energy that particles obtain over the Large Hadron Collider after being accelerated in a supernova remnant

32 million miles
expansion speed per hour of blast wave in supernova remnant G1.9+0.3

20,000 light years
distance between the black hole in the "Death Star" galaxy and the target galaxy it is striking

10 years
for a supermassive black hole took to dine on the remains of a star it tore apart

3 quintillion
quantity of Sun masses in the El Gordo galaxy cluster

1 quadrillion
how many times stronger the magnetic field of a magnetar is than the magnetic field of Earth

4 inches
height of atmosphere of the neutron star in Cassiopeia A

0.01 number of electrons per cubic centimeter in hot gas in a galaxy cluster

100 million quadrillion
hydrogen bombs are needed to produce the energy a quasar releases every second

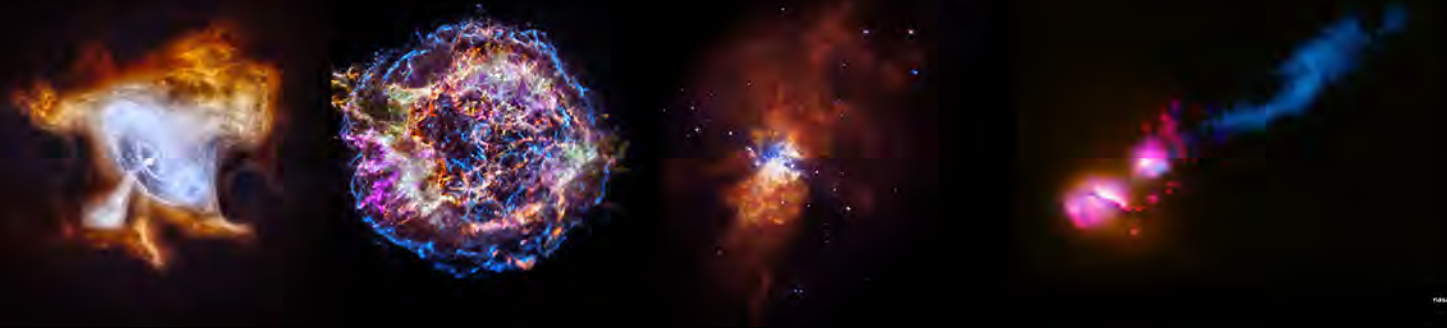
99.9 fraction of the speed of light that particles reach in a jet formed by a neutron star

110 years
age of the youngest supernova remnant, timed from Earth, in the Milky Way galaxy

1 billion tons
weight of a sugar cube-sized piece of neutron star

1 million
number of Earth masses worth of oxygen ejected into space in the Cassiopeia A supernova remnant

57 number of octaves below middle C of a note produced by a supermassive black hole observed by Chandra.

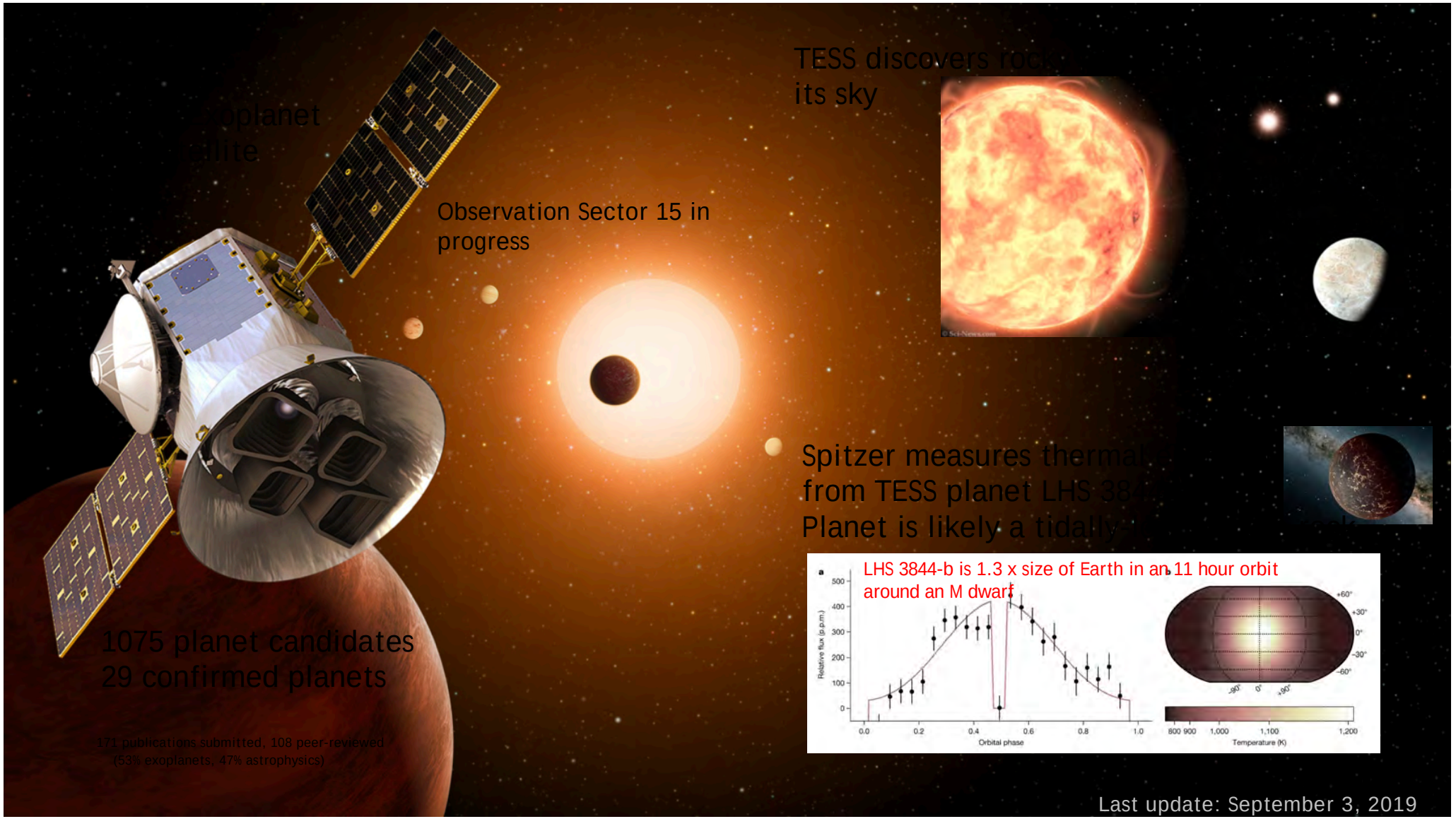


nasa.gov

NASA

20 YEARS

Chandra X-ray Observatory


Observation Sector 15 in progress
1075 planet candidates
29 confirmed planets
171 publications submitted, 108 peer-reviewed
(53% exoplanets, 47% astrophysics)
LHS 3844-b is 1.3 x size of Earth in an 11 hour orbit around an M dwarf
Relative flux (p.p.m.)
Orbital phase
Temperature (K)
Last update: September 3, 2019

Astrophysics Division Hiring

- Deputy Division Director
- Associate Division Director for Flight Projects
- Program Scientist(s)
- Program Executive(s)

All advertisements have closed

- NASA will be calling for IPA applications in the Fall

Building An Excellent Workforce

NASA achieves excellence by relying on diverse teams, both within and external to NASA, to most effectively perform NASA's work

"Assess the state of the profession. Identify areas of concern and importance [regarding] the future vitality and capability of the astronomy and astrophysics work force. Where possible, provide specific, actionable and practical recommendations to the agencies." – Astro2020 Statement of Task

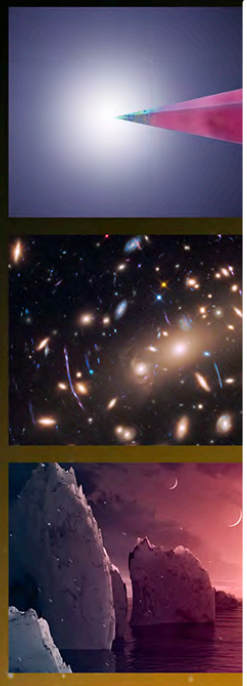
NASA Science Mission Directorate

- Developed a PI resources webpage at https://science.nasa.gov/researchers/new-pi-resources
- Introduced pre-reviews of mission peer review panels to ensure diversity
- Added a code of conduct requirement for SMD-funded conferences to ROSES 2019
- Included career development positions and associated evaluation criteria as part of Discovery and New Frontiers AOs
- Implemented a Code of Conduct and implicit bias training for all ROSES peer reviews
- Adopting dual anonymous reviews for all GO programs, and piloting them for other R&A programs, following successful demonstration by STScI for Hubble GO program
- Presented a national symposium by SMD AA Thomas Zurbuchen on lessons learned regarding mission proposal success
- Is developing award terms and conditions mandating reporting harassment, similar to NSF's
- Is presenting information sessions at major conferences to support people developing first proposal

NASA is looking forward to specific, actionable, and practical recommendations

Setting the Stage for the Decadal Survey

Why Astrophysics?



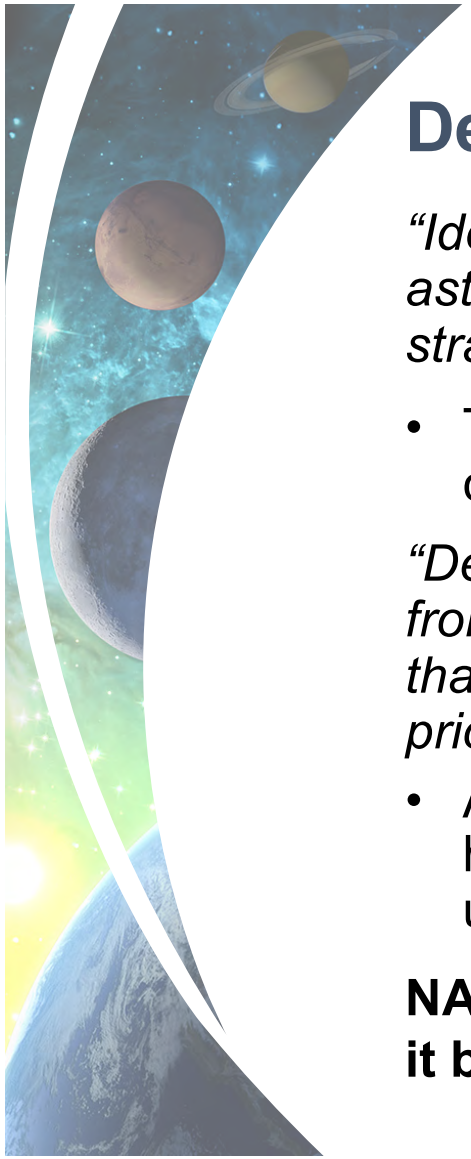
How did our universe

"Success criteria are progress in answering fundamental science questions, implementing the decadal survey priorities, and responding to direction from the Executive Branch and Congress."

NASA Strategic Plan (2018)

Enduring National Strategic Drivers

Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.



Decadal Survey Goal

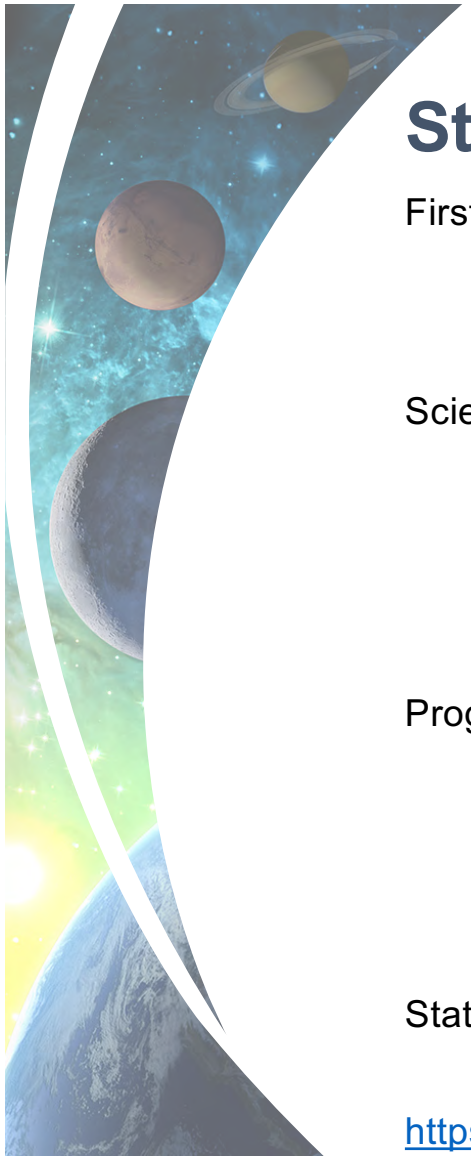
"Identify the most compelling science challenges and frontiers in astronomy and astrophysics, which shall motivate the committee's strategy for the future." – Astro2020 Statement of Task

- The important science questions require new and ambitious capabilities

"Develop a comprehensive research strategy to advance the frontiers of astronomy and astrophysics for the period 2022-2032 that will include identifying, recommending, and ranking the highest priority research activities." – Astro2020 Statement of Task

- Ambitious missions prioritized by previous Decadal Surveys have always led to paradigm shifting discoveries about the universe

NASA's highest aspiration for the 2020 Decadal Survey is that it be ambitious



Status of the Decadal Survey

First public meeting of Decadal Survey Steering Committee occurred on July 15-16

- Decadal survey is establishing Panels to review white papers and provide findings/recommendations to Steering Committee
- Second public meeting will be December 9-11

Science Panels

- Cosmology – Daniel Eisenstein (Aug 21-23)
- Galaxies – Daniela Calzetti (Aug 28-30)
- Interstellar Medium and Star and Planet Formation – Lee Hartmann (Aug 26-28)
- Stars, the Sun, and Stellar Populations – Sarbani Basu (Aug 21-23)
- Compact Objects and Energetic Phenomena – Deepto Chakrabarty (Sep 4-6)
- Exoplanets, Astrobiology, and the Solar System – Victoria Meadows (Sep 11-13)

Program Panels

- Electromagnetic Observations from Space 1
- Electromagnetic Observations from Space 2
- Optical and Infrared Observations from the Ground
- Radio, Millimeter, and Submillimeter Observations from the Ground
- Particle Astrophysics and Gravitation
- An Enabling Foundation for Research

State of the Profession Panel

- State of the Profession and Societal Impacts

https://sites.nationalacademies.org/DEPS/astro2020/

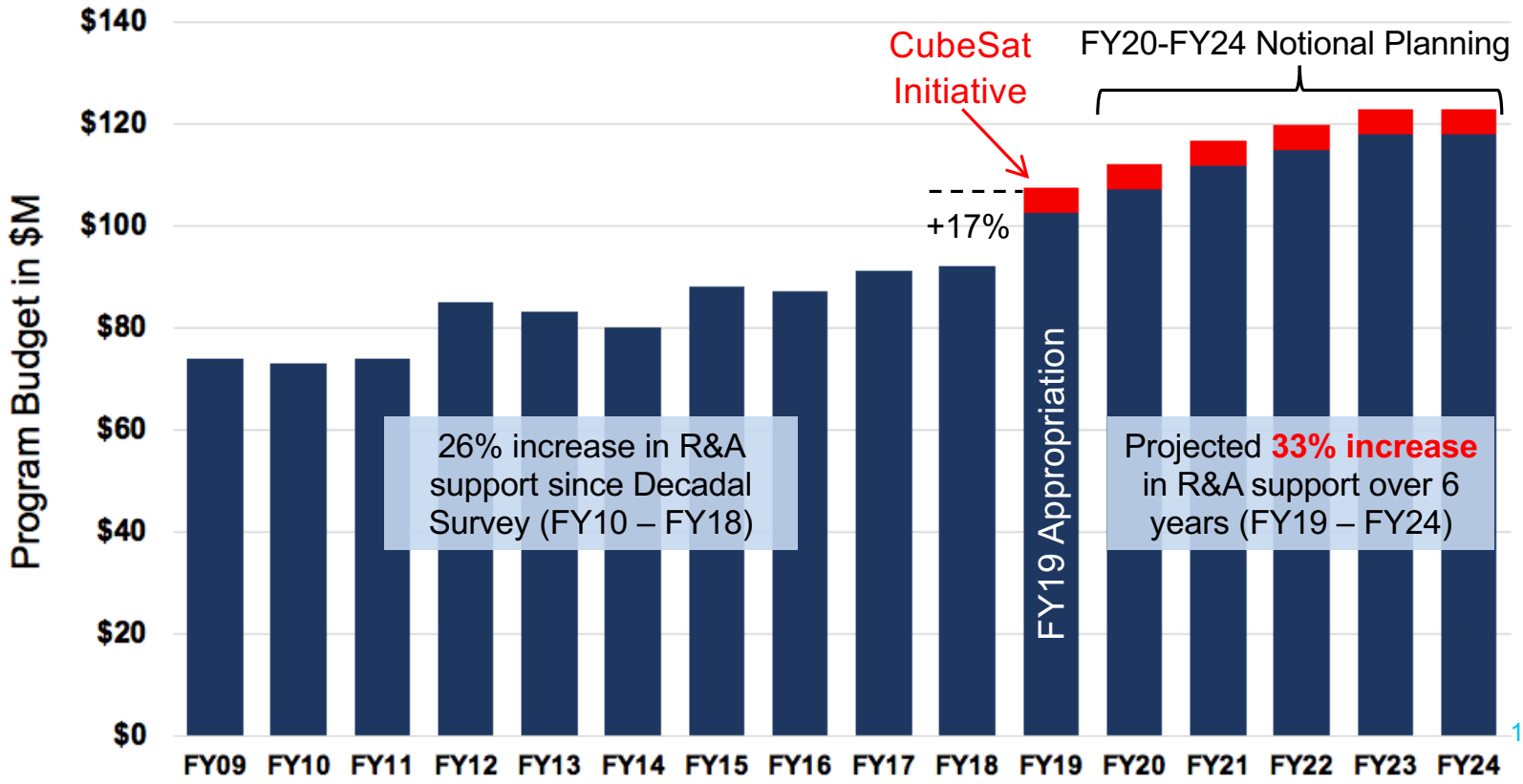
Program of Record

Program of Record

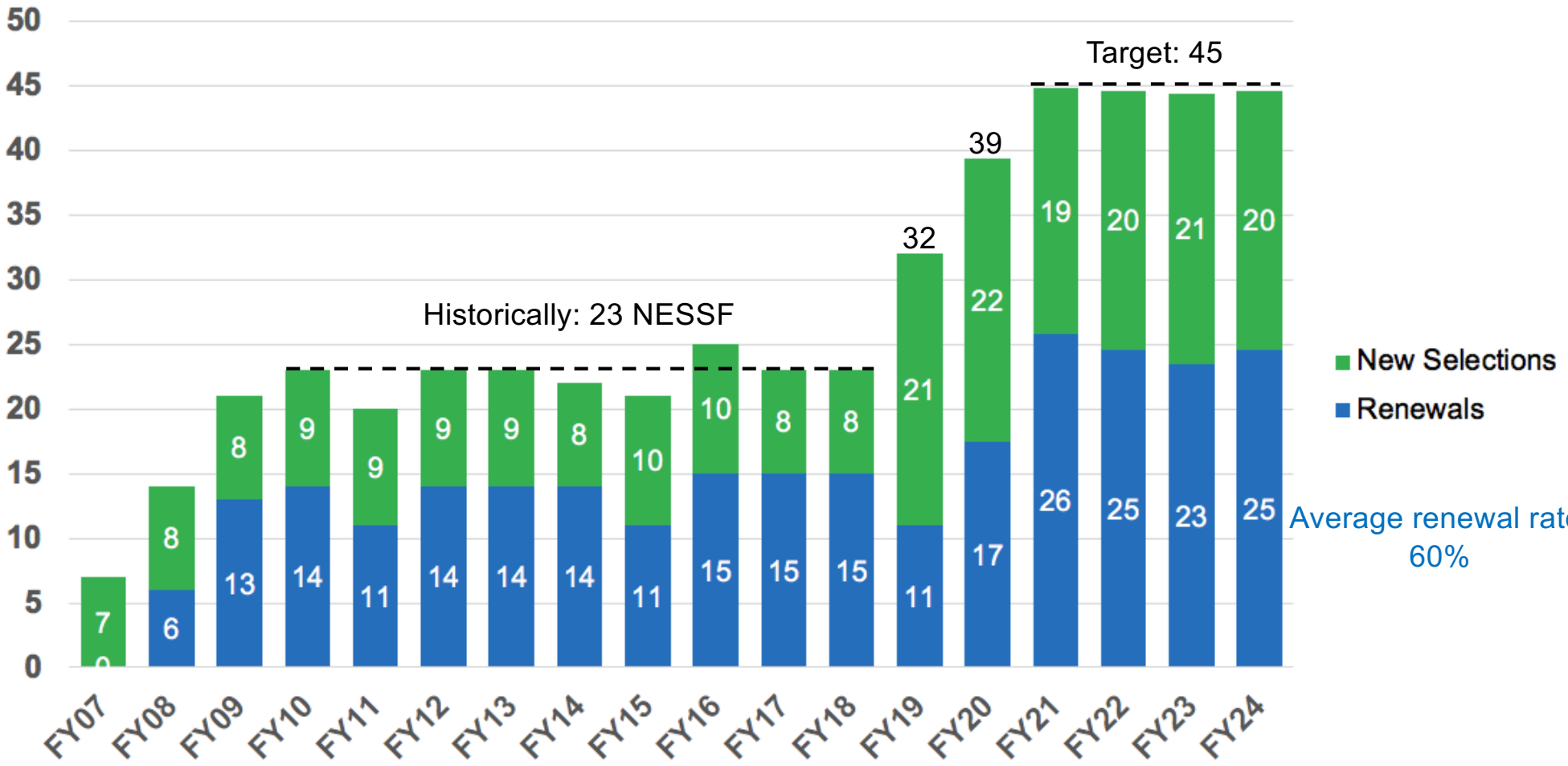
Supporting Research & Technology	**R&A**: ADAP, ATP, TCAN, XRP, Hubble Fellows, GO programs	**Technology**: APRA, SAT, Roman Fellows, Future flagship technologies	**Research support**: Keck, Balloon project, Astrophysics archives
Operating Missions	**Explorers**: Gehrels Swift, NuSTAR, NICER, TESS	**International Partnerships**: XMM-Newton	**Strategic Missions**: Hubble, Chandra, Spitzer, Fermi, SOFIA
Missions in Development or Under Study	**Explorers**: IXPE, GUSTO, SPHEREx, AO2019, AO2021, etc.	**International Partnerships**: Euclid, XRISM, Athena, LISA	**Strategic Missions**: Webb, WFIRST

Growth in R&A Funding ($M)

Program	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
R&A	$74	$73	$74	$85	$83	$80	$88	$87	$91	$92	$103	$107	$112	$115	$118	$118
CubeSat											$5	$5	$5	$5	$5	$5
Total	$74	$73	$74	$85	$83	$80	$88	$87	$91	$92	$108	$112	$117	$120	$123	$123



FINESST Renewals and New Selections



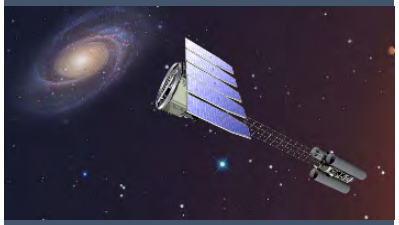
Average renewal rate: 60%

Missions in Development or Under Study

Webb 2021
NASA Strategic Mission

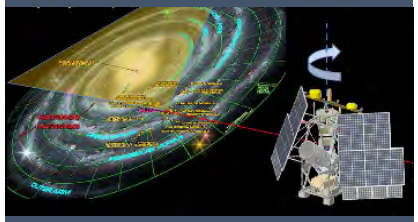
James Webb
Space Telescope

IXPE 2021
NASA Explorers Mission



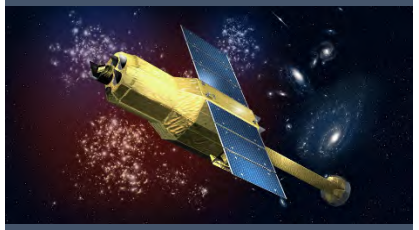
Imaging X-ray
Polarimetry Explorer

GUSTO 2021
NASA Explorers Mission



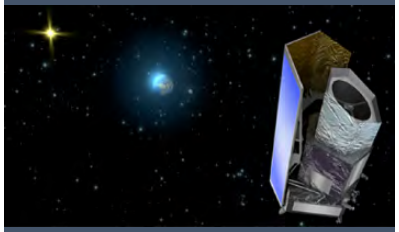
Galactic/ Extragalactic ULDB
Spectroscopic Terahertz Observatory

XRISM 2022
JAXA-led Mission



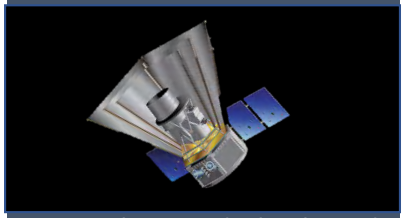
NASA is supplying the Resolve
detector and X-ray mirrors

Euclid 2022
ESA-led Mission



NASA is supplying the NISP
sensor chip system

SPHEREx 2023
NASA Explorers Mission



Spectro-Photometer for the History of
the Universe, Epoch of Reionization,
and Ices Explorer

WFIRST Mid 2020s
NASA Strategic Mission

Wide Field Infrared
Survey Telescope

Athena / LISA 2030s
ESA-led Missions

NASA is supplying instrument
and mission systems

Dates are the current planning launch dates, not the NASA commitment dates

The Webb observatory in the clean room in Redondo Beach, CA before observatory environmental testing and observatory deployment tests

Webb

The James Webb Space Telescope

- Science payload completed three months cryogenic testing at end of 2017
- Spacecraft and sunshield integration completed January 2018
- Spacecraft element including sunshield completed environmental testing May 2019
- Science payload and spacecraft integration completed August 2019, to be followed by test deployment of sunshield
- Testing of full observatory begins in 2019 and continues in 2020
- Webb overrun covered using offsets from Astrophysics Probes

Wide Field Infrared Survey Telescope

Work continues with FY19 funding

2016 – Completed Mission Concept review and began Phase A

2018 – Completed Mission Design review / System requirements Review and began Phase B

2019 – Completing Preliminary Design Reviews

2020 – Complete Confirmation Review and begin Phase C

2021 – Call for Core Surveys

Mid-2020s – Launch

WFIRST is 100 to 1500 times faster than Hubble for large surveys at equivalent area and depth

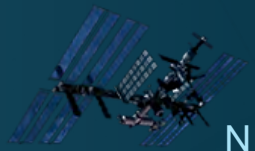
Science Program includes

- Dark energy and the fate of the universe through surveys measuring the expansion history of the universe and the growth of structure
- The full distribution of planets around stars through a microlensing survey
- Wide-field infrared surveys of the universe through General Observer and Archival Research programs
- Technology development for the characterization of exoplanets through a Coronagraph Technology Demonstration Instrument

Astrophysics Explorers Program


Gehrels Swift


NuSTAR


NICER

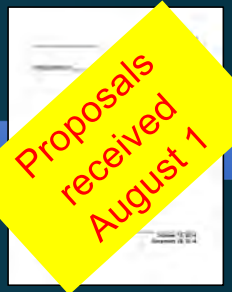

TESS

4 AOs per decade

MIDEX 2011

SMEX 2014

MIDEX 2016



SMEX 2019

MIDEX 2021

Small and Mid-Size Missions


TESS


IXPE

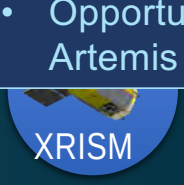

SPHEREx

Missions of Opportunity


NICER


GUSTO

MO TBD


XRISM

Explorers Mission of Opportunity AO includes new opportunities:

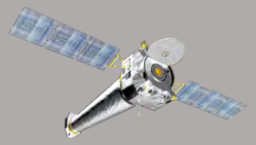
- NASA-provided RideShare
- SmallSat Secondary Payloads
- Opportunities enabled by the Artemis Program

Operating Missions

Hubble 4/90
NASA Strategic Mission

Hubble Space Telescope

Chandra 7/99
NASA Strategic Mission



Chandra X-ray Observatory

XMM-Newton 12/99
ESA-led Mission

X-ray Multi Mirror - Newton

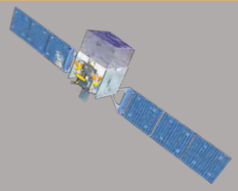
Spitzer 8/03
NASA Strategic Mission

Spitzer Space Telescope

Gehrels Swift 11/04
NASA MIDEX Mission

Neil Gehrels Swift Gamma-ray Burst Explorer

Fermi 6/08
NASA Strategic Mission

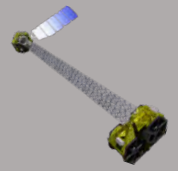


Fermi Gamma-ray Space Telescope

Kepler 3/09
NASA Discovery Mission

Mission Complete!

NuSTAR 6/12
NASA SMEX Mission



Nuclear Spectroscopic Telescope Array

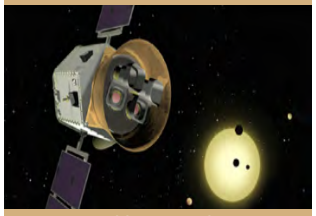
SOFIA 5/14
NASA Strategic Mission

Stratospheric Observatory for Infrared Astronomy

ISS-NICER 6/17
NASA Explorers Miss. of Oppty

Neutron Star Interior Composition Explorer

TESS 4/18
NASA MIDEX Mission

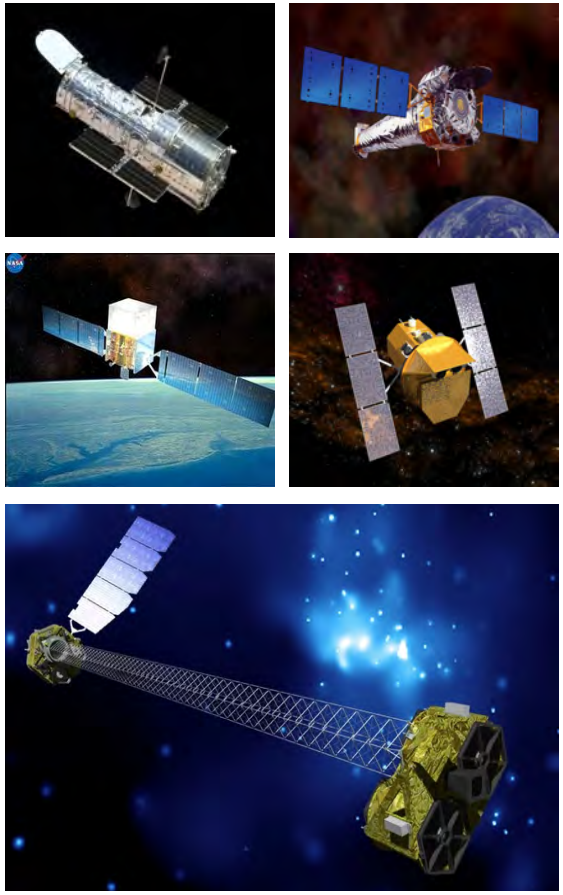


Transiting Exoplanet Survey Satellite

SOFIA

Stratospheric Observatory for Infrared Astronomy

- SOFIA's 5-year prime mission will be completed at the end of FY19
- Given that the program has finished 5 years of operations, NASA has conducted two reviews of the SOFIA project to make changes directed at increasing the science productivity of SOFIA in FY20 and beyond
  - Review of SOFIA's maintenance and operations paradigm
  - Review of SOFIA's science progress and science prospects
- Based on the reviews, NASA will be making some changes in the SOFIA project to improve SOFIA's science productivity and responsiveness to community science priorities
  - Complete transition of SOFIA from a development mode to a more productive science operations mode
  - SOFIA will fly more frequently to obtain more science hours
  - SOFIA will primarily fly shorter (~8 hour) flights to immediately get to higher altitudes
- HIRMES, the next SOFIA science instrument, continues development
  - Expected delivery date is Dec 2020



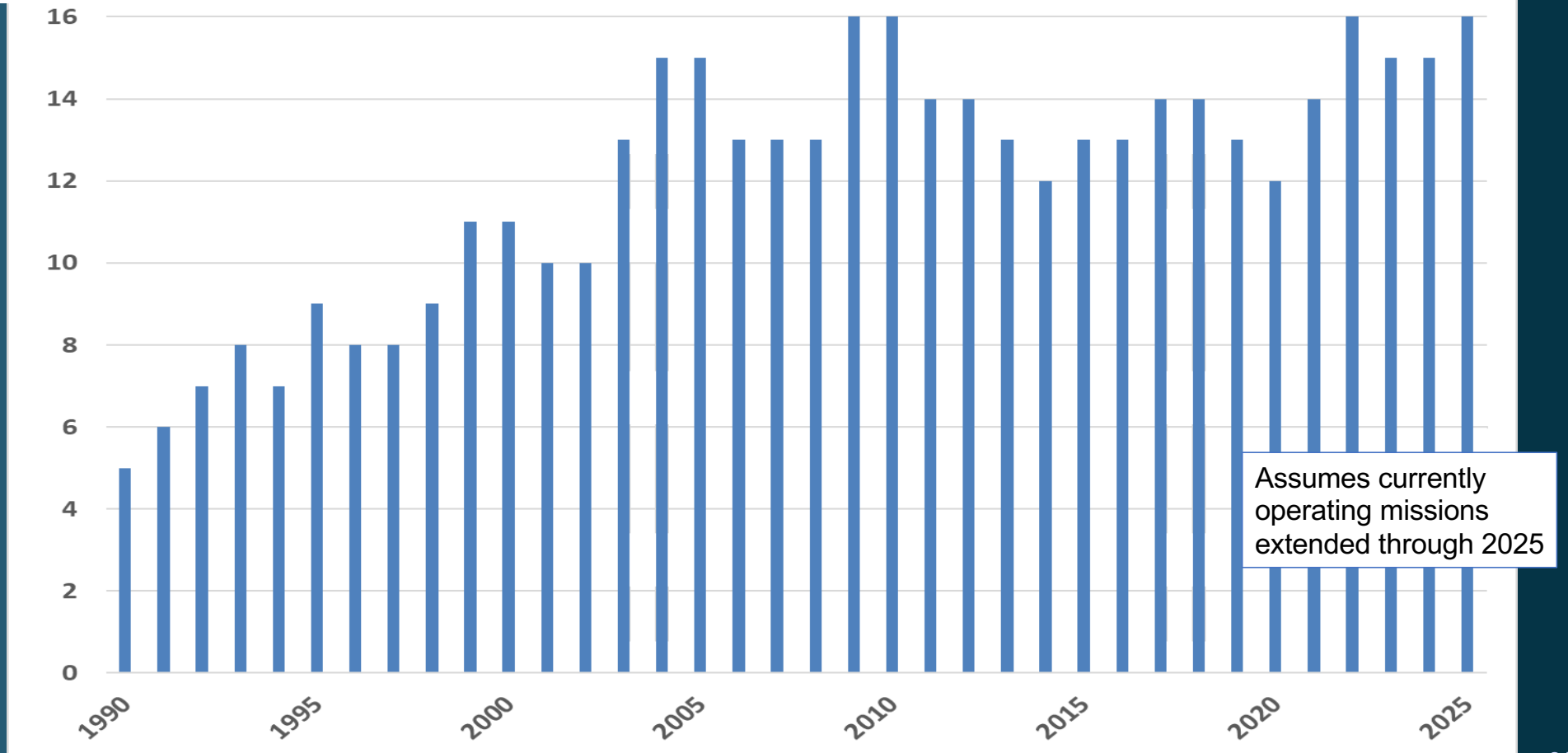
Senior Review 2019

• Hubble	No change to budget guideline
• Chandra	Selected overguides: Audit fees, labor & GO (inflation)
• TESS	Extended mission w/ full funding & continued GO program
• Swift	Selected overguides: New tools for Targets of Opportunity (TOO) and Ultraviolet-Optical Telescope (UVOT)
• Fermi	Ops w/out Department of Energy (DOE)
• NICER	Extended mission w/ reduced ops & new GO program
• NuSTAR	Phase out legacy science for GO science
• XMM-Newton	No change

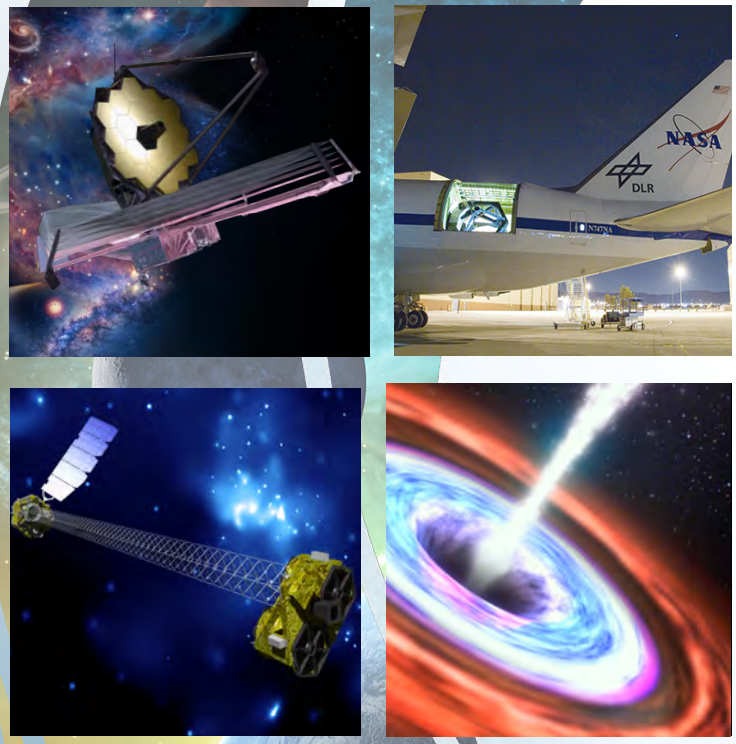
Not in Senior Review: Kepler, SOFIA, Spitzer

Astrophysics Mission Timeline

Missions operating each year



Budget



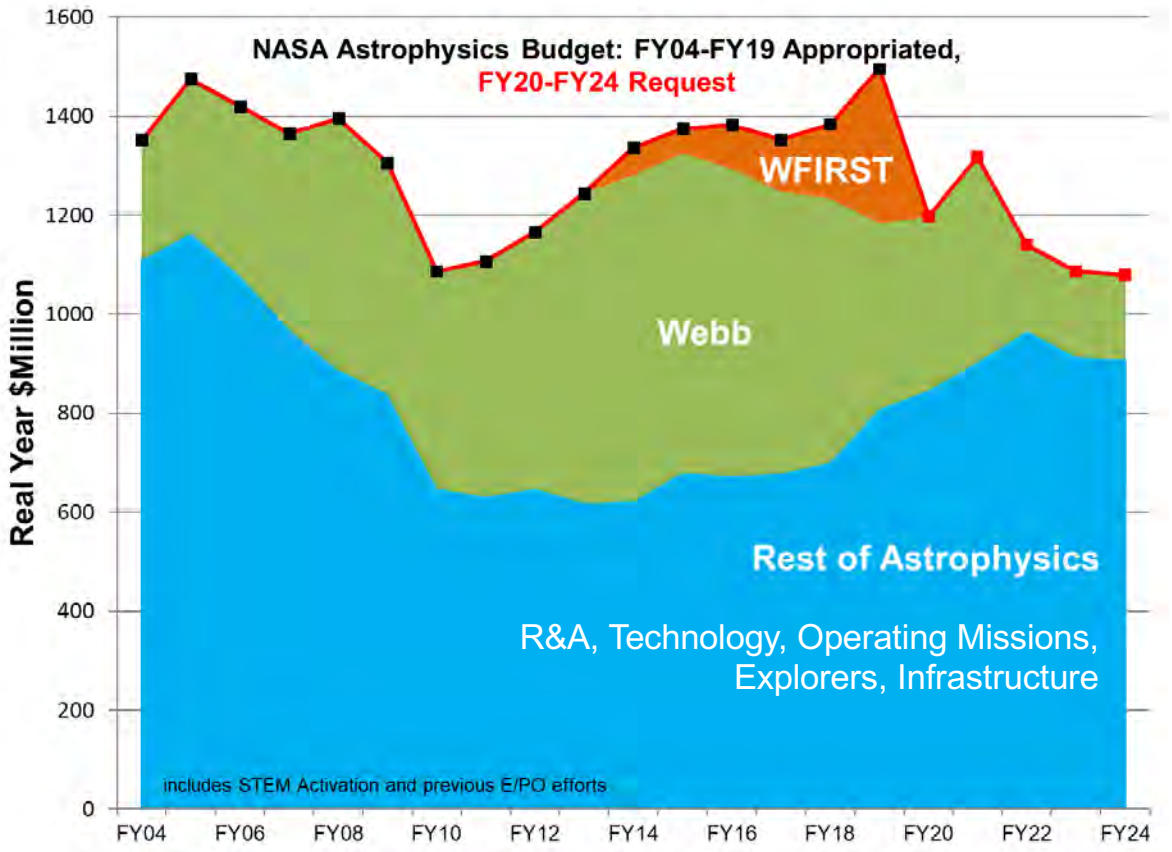
FY20 Budget Request

- Accommodates Webb replan to March 2021 LRD
- Given its significant cost within proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards completing Webb
- Supports formulation of a probe mission as early as 2022, conditional on Decadal Survey recommendations
- Maintains decadal cadence of four AOs per decade for Astrophysics Explorers and Missions of Opportunity
- Funds SOFIA for three years beyond end of prime mission in FY19 at reduced budget; two alternate reviews conducted in 2019 in lieu of inclusion in 2019 Senior Review
- Extends operating missions (other than Hubble and Chandra) at reduced budget beyond FY20 following 2019 Senior Review
- Supports mission concept studies and technology investments starting in 2022 to respond to Astrophysics Decadal Survey priorities

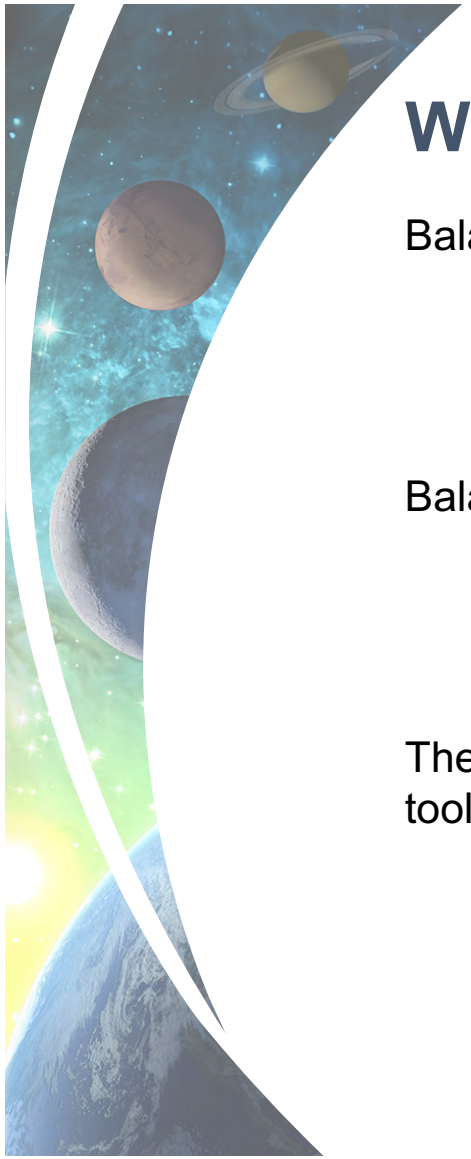
Congressional Markup of FY20 Budget

($M)	Request	House	Senate	Comment
Webb	352.6	352.6		Supports replan
WFIRST	0	510.7		Includes $65M for CGI
SOFIA	73.0	85.2		
Rest of Astrophysics	772.8	771.8		$1M (0.1%) reduction
Total	1,197.4	1,720.3		

NASA Astrophysics Budget



Program of the Future



What is a Balanced Program?

Balanced among multiple goals and priorities

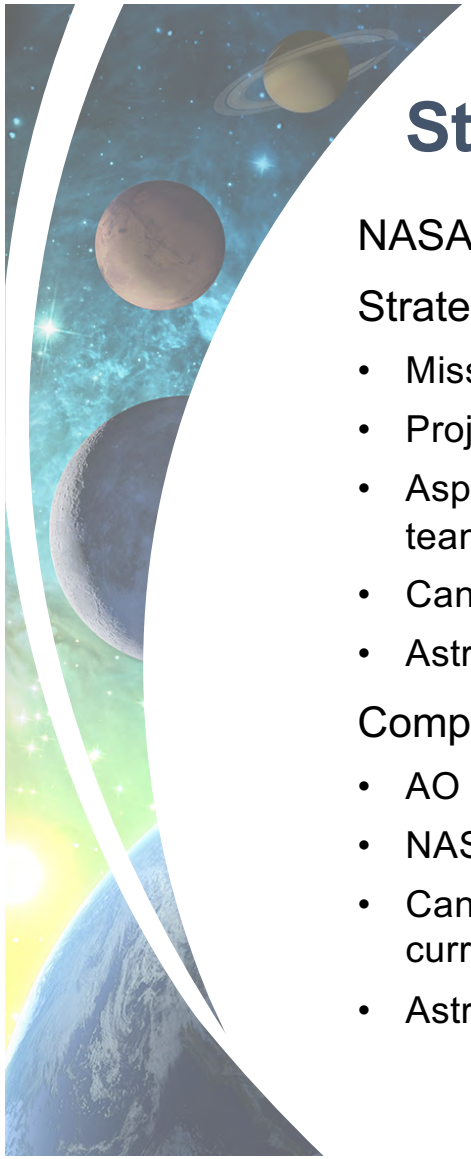
- Addresses science (Decadal Survey) goals and priorities
- Addresses National goals and priorities
- Addresses NASA goals and priorities

Balanced through time

- Yields science discoveries today
- Enables science discoveries tomorrow
- Is sustainable: maintains necessary National capabilities

The needs for different mission sizes and/or wavelength diversity are necessary tools for success

- A balanced astrophysics portfolio reduces overall risk with different mission sizes that have different risk/reward postures
- A balanced astrophysics portfolio is capable of addressing multiple science goals and priorities and increases overall productivity with wavelength diversity



Strategic Missions and Competed Missions

NASA science missions are generally initiated in two different ways

Strategic missions are initiated to respond to specific science objectives

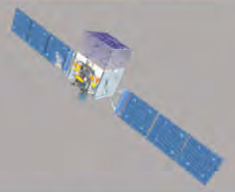
- Mission architecture and acquisition strategy is tailored to the science objectives
- Project management is generally directed to a NASA Center
- Aspects of the mission may be competed through an AO (instruments), ROSES (science team, key science projects), or an RFP (spacecraft, integration and test)
- Can be any mission size: Flagship, Medium/Probe, International Contribution, or Small
- Astro2020 should recommend strategic missions

Competed missions are initiated through an AO

- AO solicits both the science objectives and the implementation plan (architecture, team)
- NASA selection of PI-led proposal is generally “take it or leave it”
- Can be any size except flagship, though only small (MIDEX, SMEX, MOs) are in the current astrophysics program
- Astro2020 should recommend competed programs, but not specific competed missions

Medium Mission Concepts (Probes)

Probes are strategic missions that have had a strong impact on astrophysics, either through a focused investigation or as a broadly-capable observatory

COBE 11/89 NASA Strategic Explorer	EUVE 06/92 NASA Strategic Explorer	Rossi XTE 12/95 NASA Strategic Explorer	GP-B 04/04 NASA Strategic Mission	Fermi 6/08 NASA Strategic Mission	Kepler 3/09 NASA Discovery Mission
					
Cosmic Background Explorer	Extreme Ultraviolet Explorer	Rossi X-ray Timing Explorer	Gravity Probe B The Relativity Mission	Fermi Gamma-ray Space Telescope	Kepler Space Telescope

NASA funded probe studies are available at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning

Options for 2020 Decadal Survey

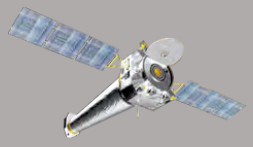
- Do not recommend a medium mission in Astro2020
- Recommend specific probe(s) as medium-size strategic missions
- Recommend several specific science concepts for an AO (New Frontiers)
- Recommend an unconstrained AO (Super-Explorer)

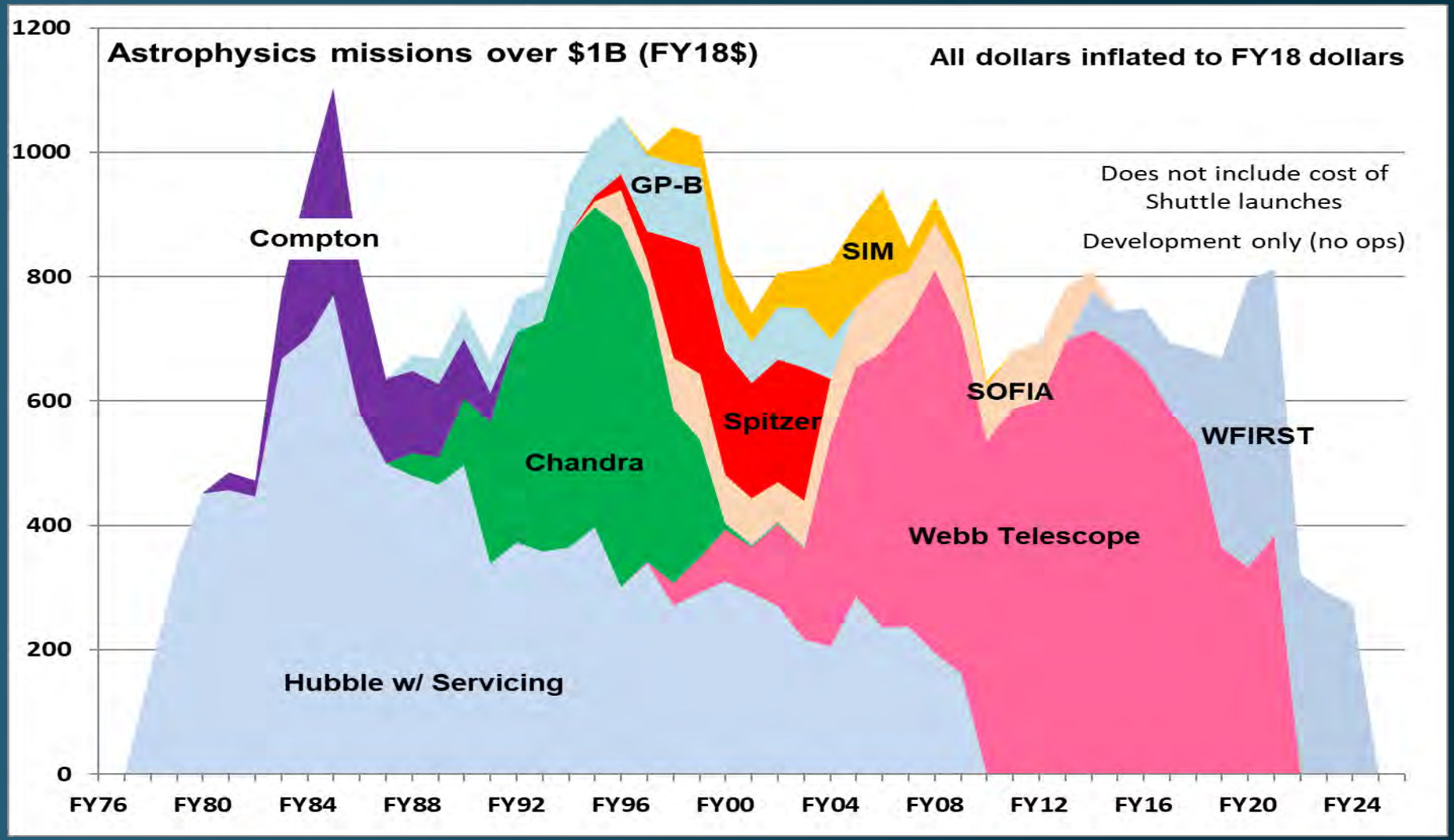
Why Flagships

Flagships drive science

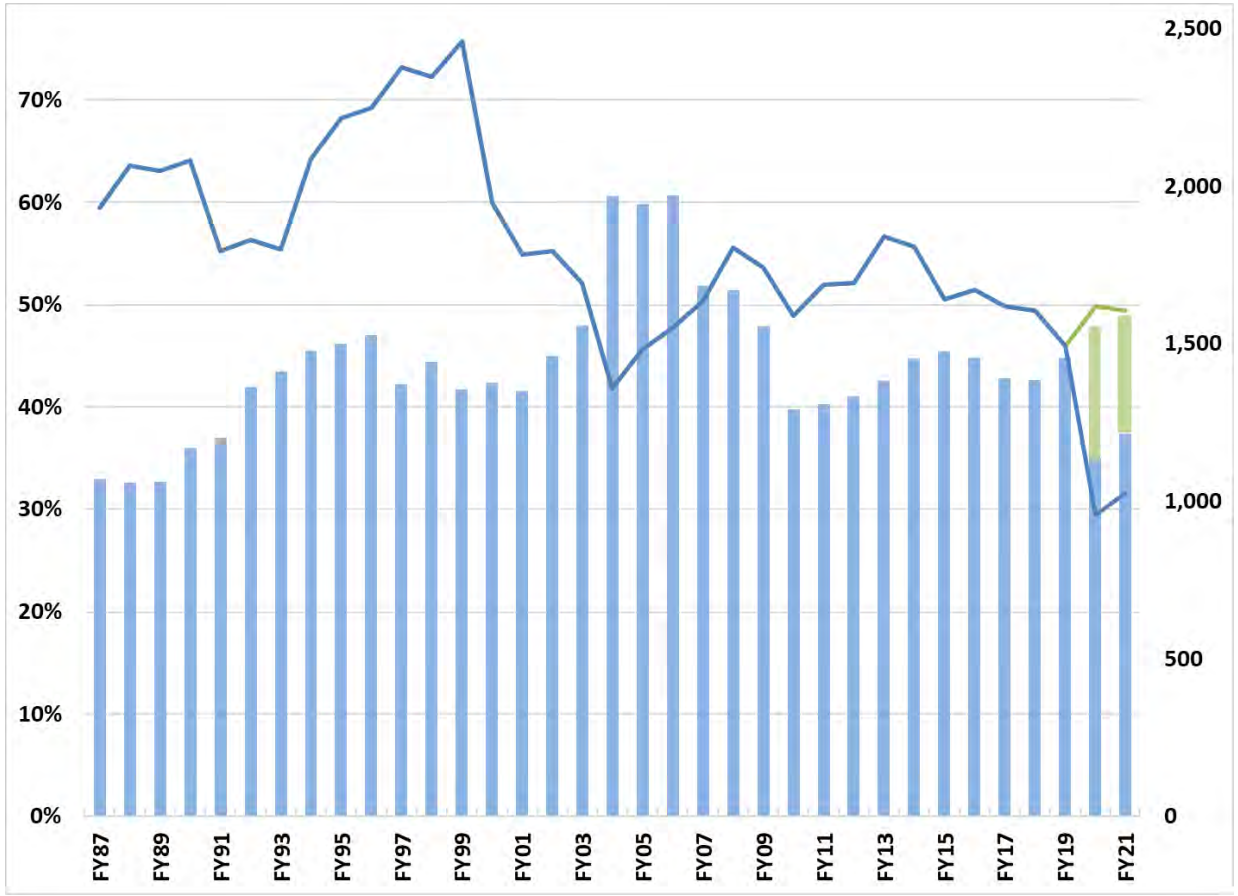
Flagships drive US capabilities and contribute to US leadership

Flagships drive NASA budget and create stakeholder support

Hubble 04/90	Compton 05/91	Chandra 09/99	Spitzer 8/03	Webb 2021	WFIRST Mid 2020s
NASA Great Observatory	NASA Great Observatory	NASA Great Observatory	NASA Great Observatory	NASA Mission	NASA Mission
					
Hubble Space Telescope	Compton Gamma Ray Observatory	Chandra X-ray Observatory	Spitzer Space Telescope	James Webb Space Telescope	Wide Field Infrared Survey Telescope


Astrophysics missions over $1B (FY18$)
All dollars inflated to FY18 dollars
Does not include cost of Shuttle launches
Development only (no ops)
Compton
GP-B
SIM
SOFIA
Spitzer
Chandra
WFIRST
Webb Telescope
Hubble w/ Servicing
1200
1000
800
600
400
200
0
FY76
FY80
FY84
FY88
FY92
FY96
FY00
FY04
FY08
FY12
FY16
FY20
FY24

Flagship Fraction of Astrophysics Budget

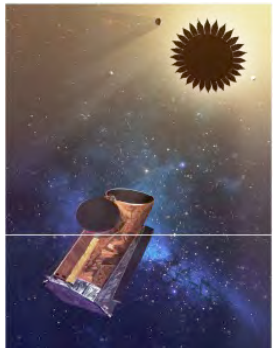


All dollars inflated to FY18$.
Development only, no ops.

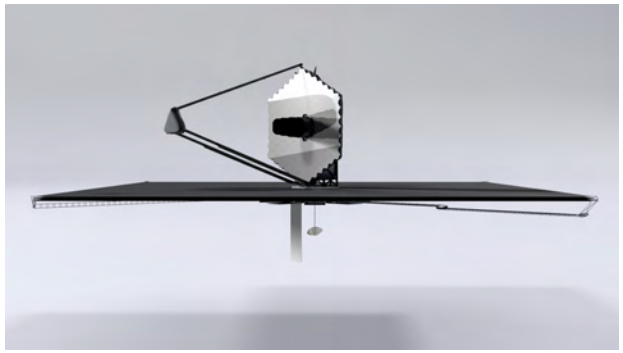
- Large mission fraction (left scale)
- Inflation adjusted Astrophysics budget (right scale)
- Current planning budget (without WFIRST beyond FY19)
- What if WFIRST is funded as needed on top of FY20 President's Budget Request?

Large Mission Concepts

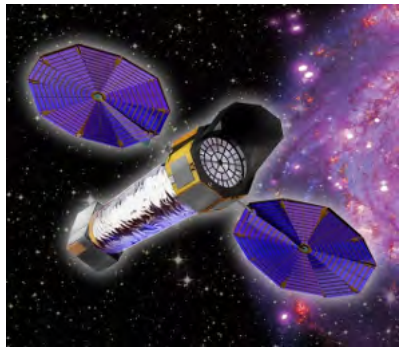
"NASA should ensure that robust mission studies that allow for trade-offs (including science, risk, cost, performance, and schedule) on potential large strategic missions are conducted prior to the start of a decadal survey. These trade-offs should inform, but not limit, what the decadal surveys can address." – Powering Science: NASA's Large Strategic Science Missions (NAS, 2017)



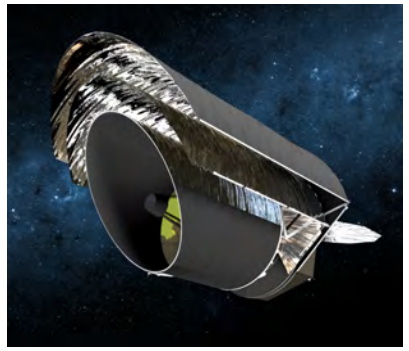
HabEx



LUVOIR

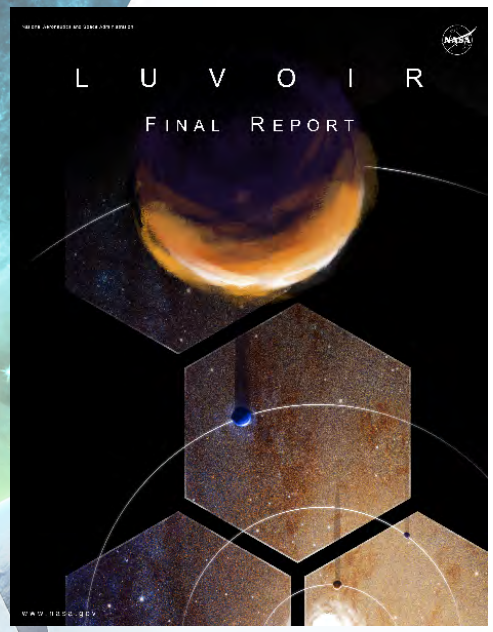


Lynx

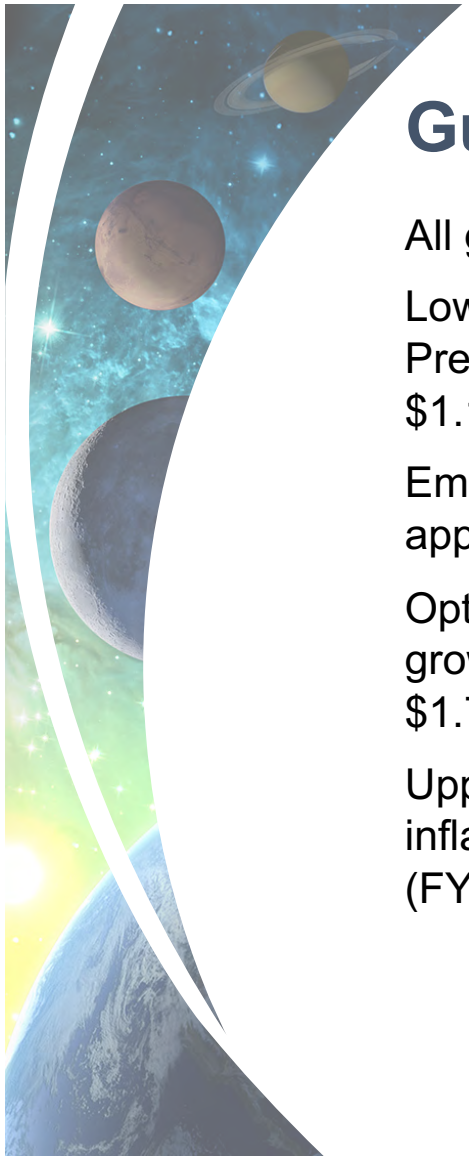


Origins

Large Mission Studies



Links to the concept study reports are posted at
https://science.nasa.gov/astrophysics/2020-decadal-survey-planning
and at
https://www.greatobservatories.org/



Guidance on Future Budgets

All guidance is for Astrophysics including Webb Telescope

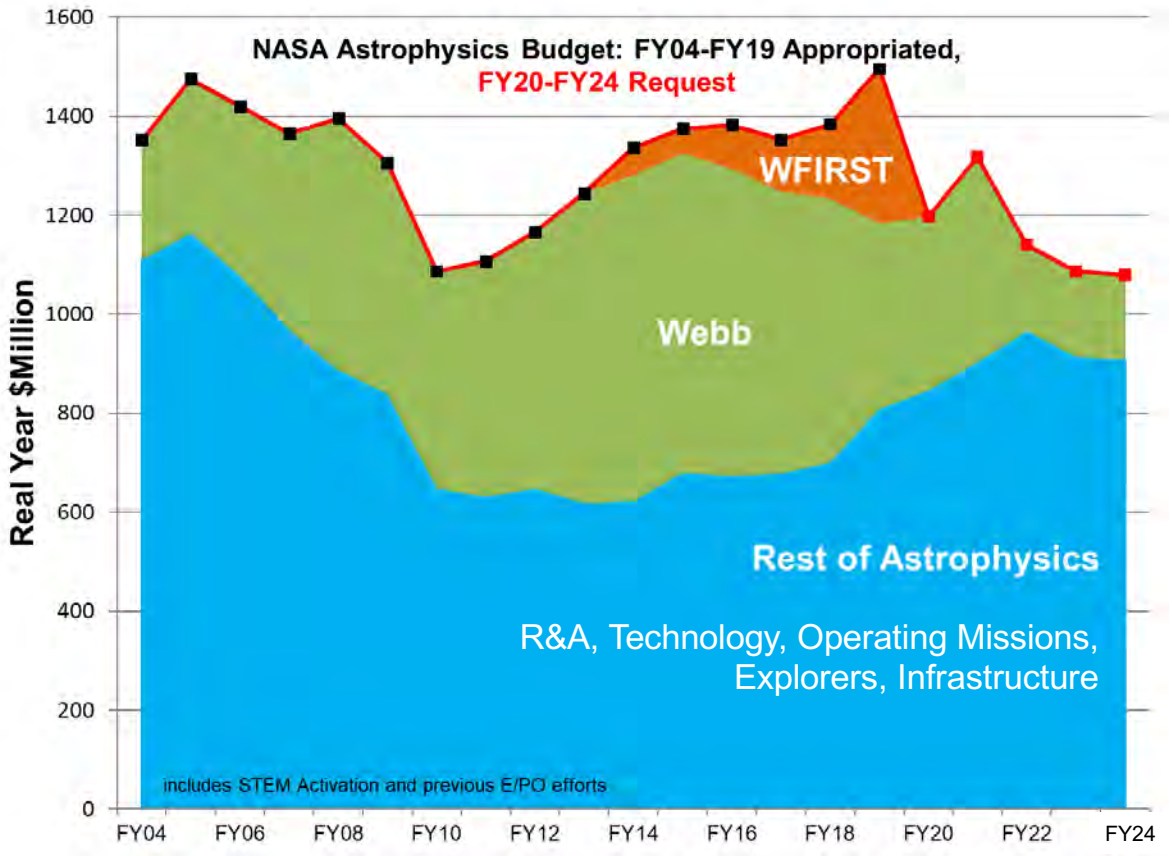
Lower bound budget projection – Extrapolation of out year planning numbers for President's FY20 budget request. Average of FY22-FY24 planning numbers is $1.1B/yr

Empirical budget projection – Extrapolation of recent NASA Astrophysics appropriations. Average of FY17-FY19 appropriations is $1.4B/yr

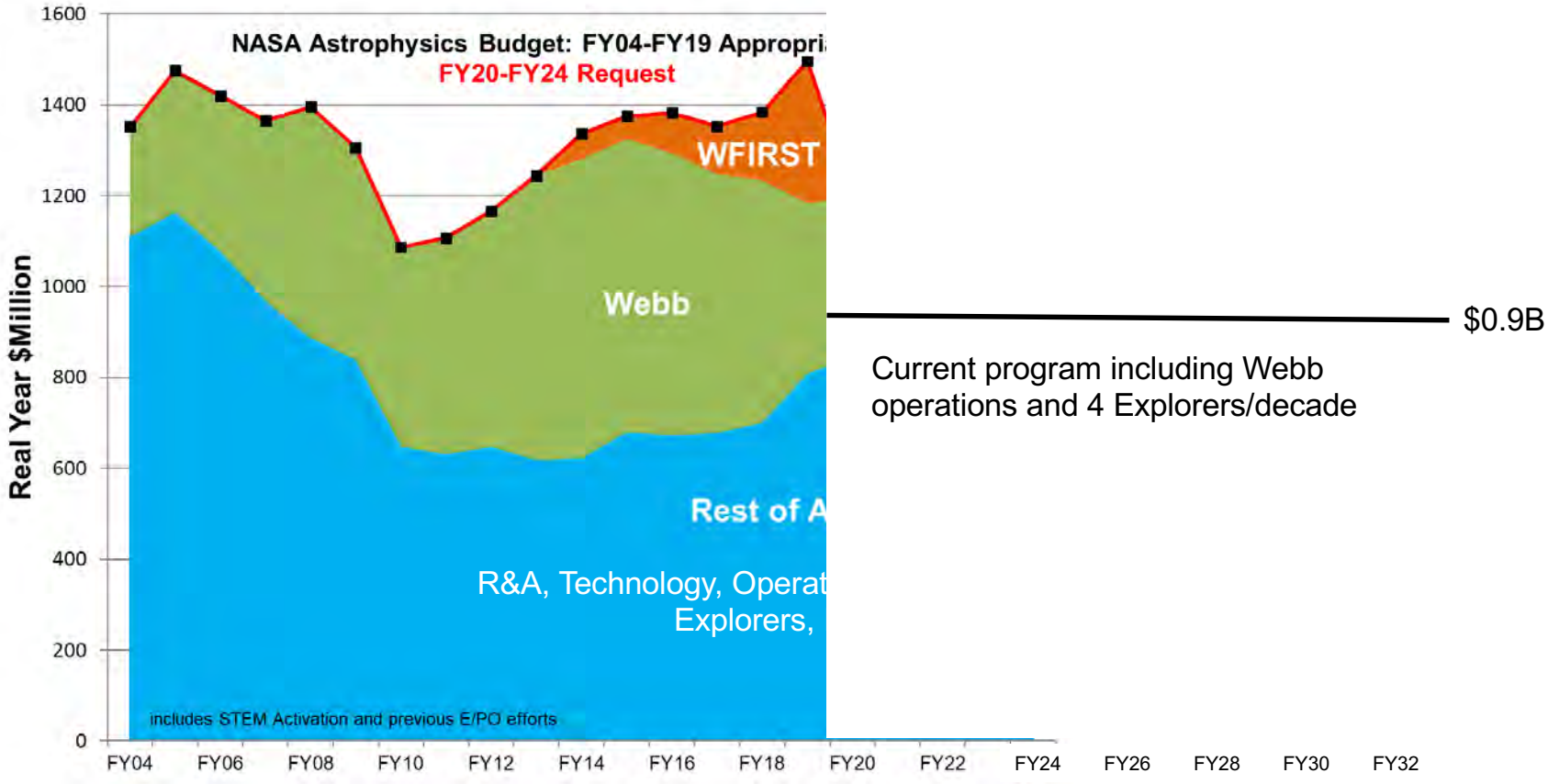
Optimistic budget projection – Empirical budget projection plus 1% inflationary growth in the out years. Budget grows from $1.5B (FY19) to $1.6B (FY25) to $1.7B (FY30)

Upper bound budget projection – Empirical budget projection plus 2% inflationary growth in the out years. Budget grows from $1.5B (FY19) to $1.7B (FY25) to $1.9B (FY30)

NASA Astrophysics Budget



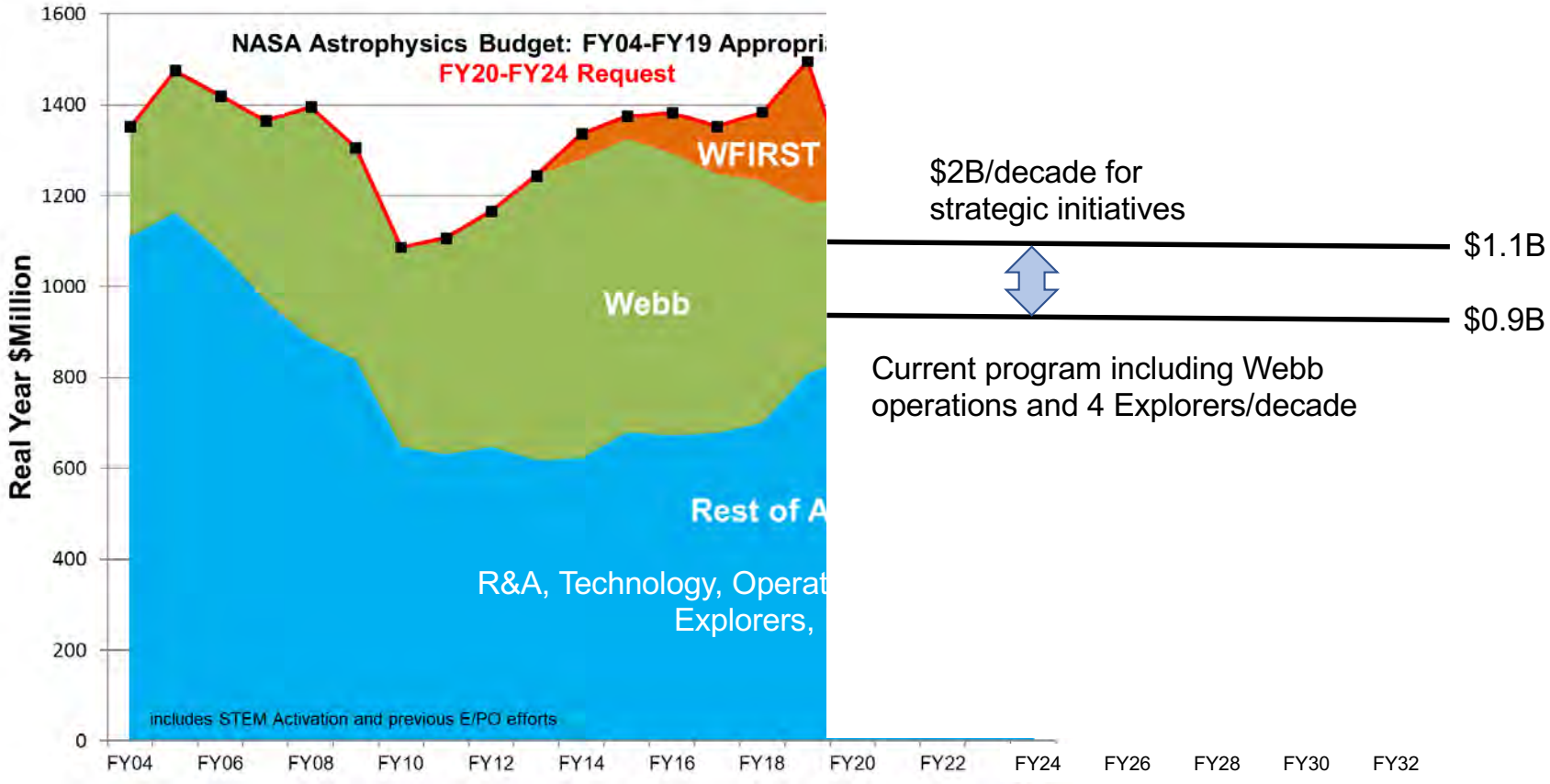
NASA Astrophysics Budget



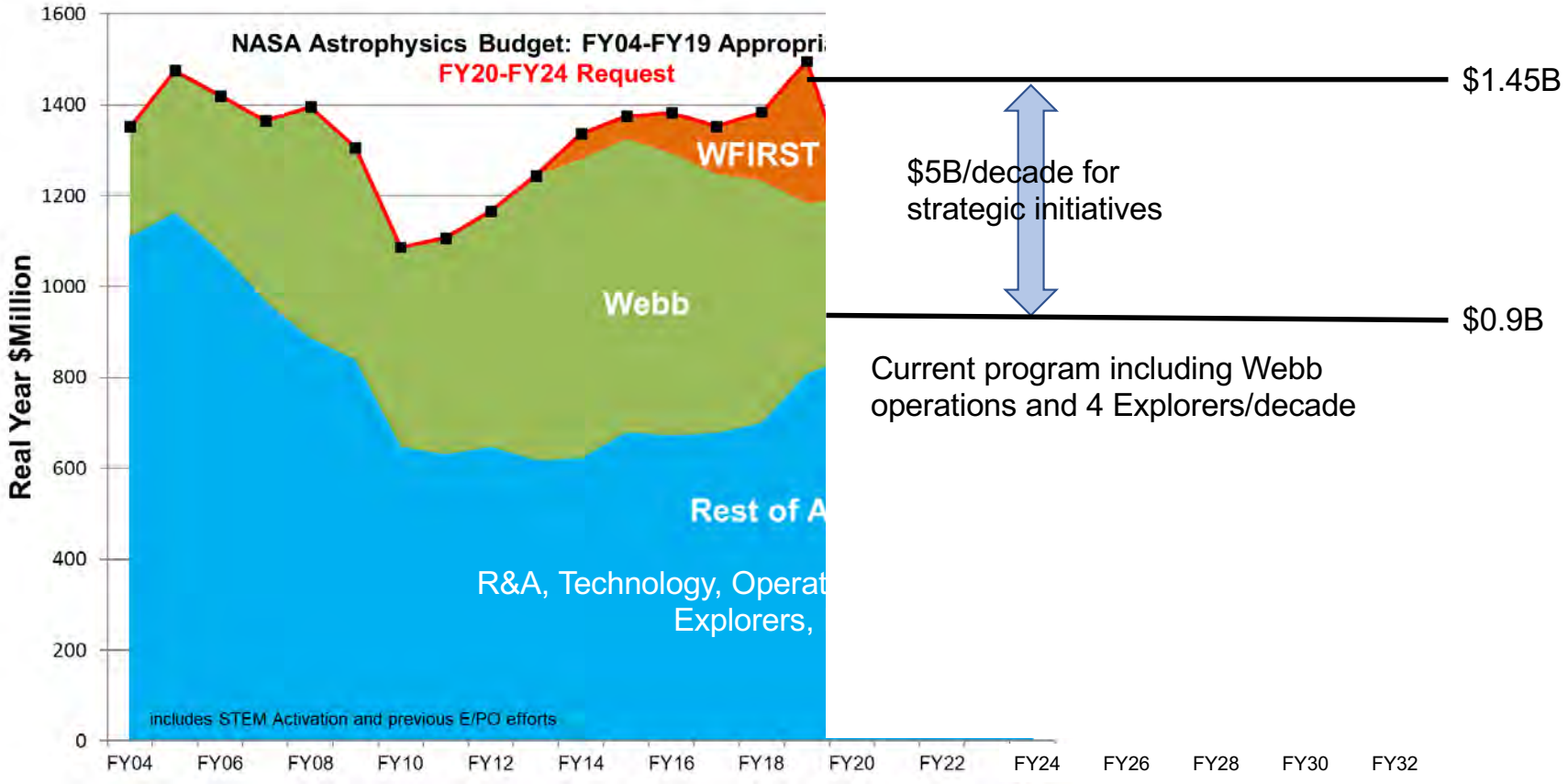
$0.9B

Current program including Webb operations and 4 Explorers/decade

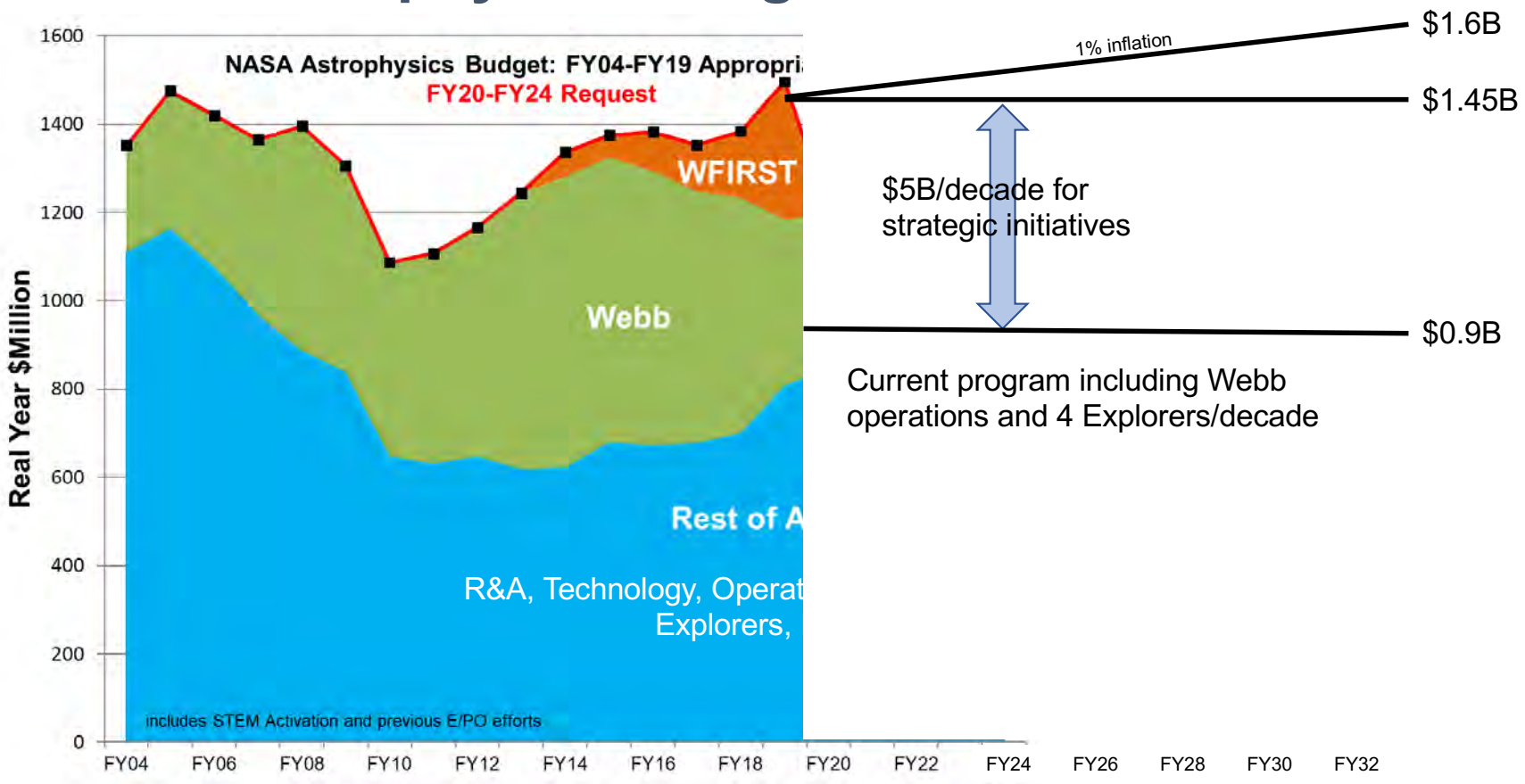
NASA Astrophysics Budget



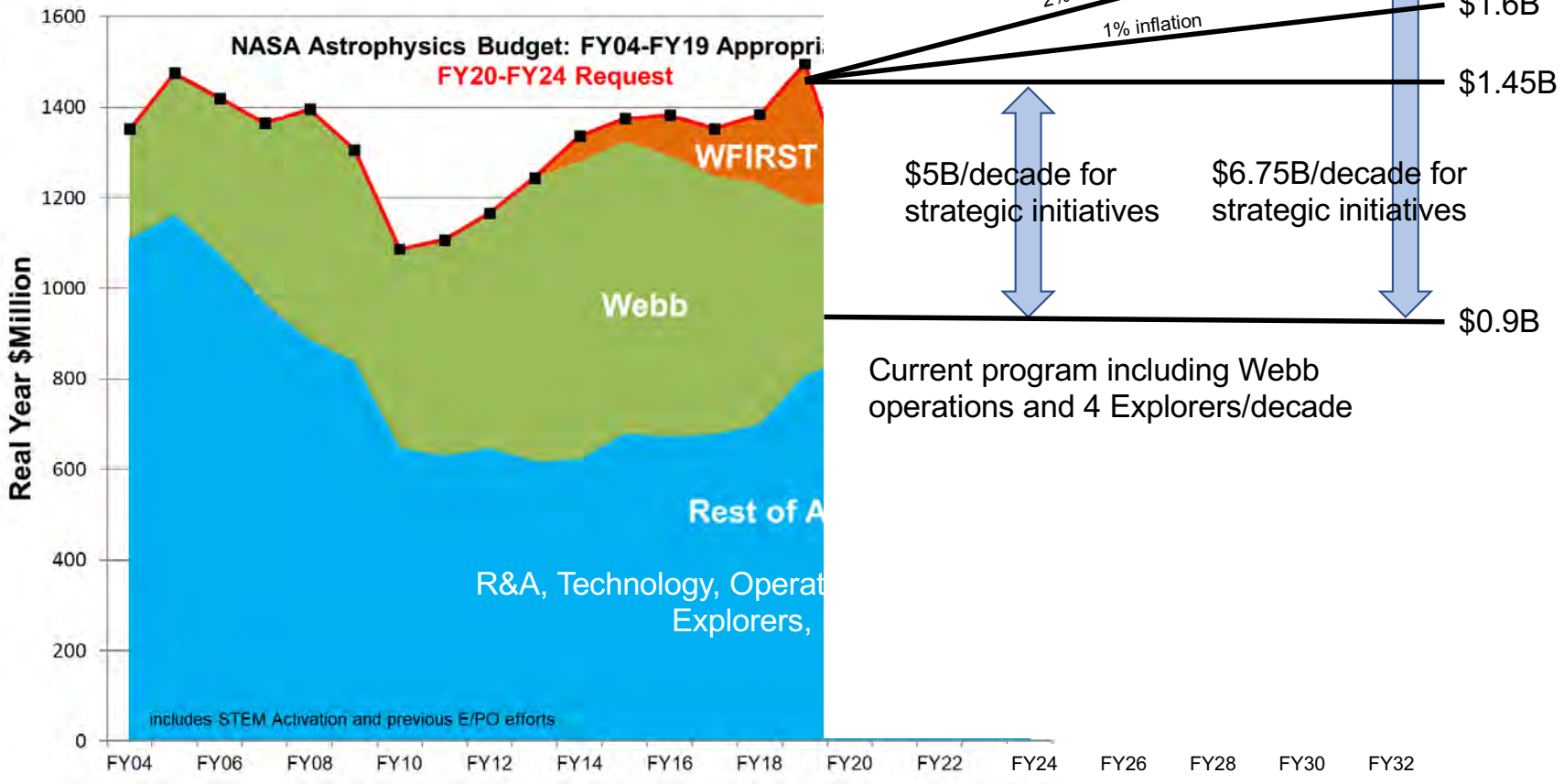
NASA Astrophysics Budget

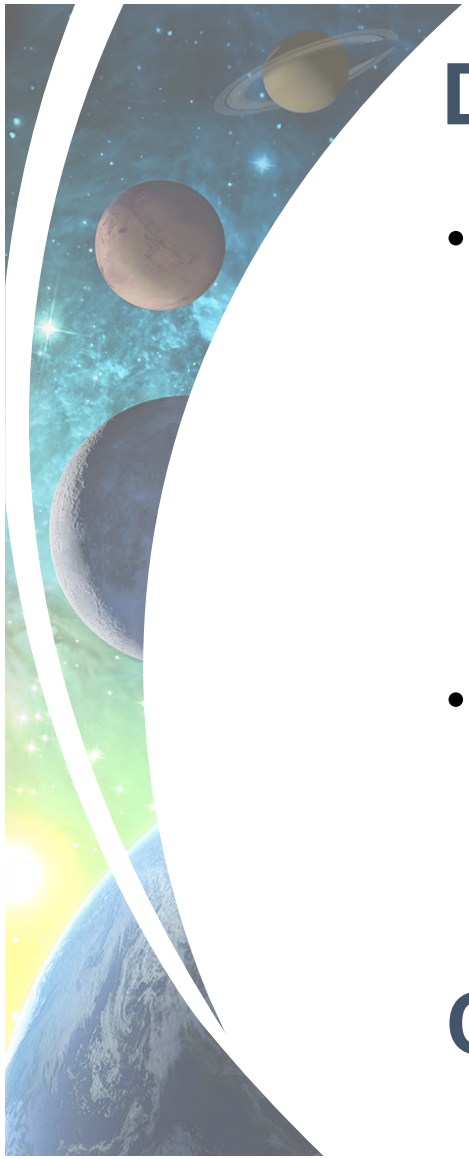


NASA Astrophysics Budget



NASA Astrophysics Budget

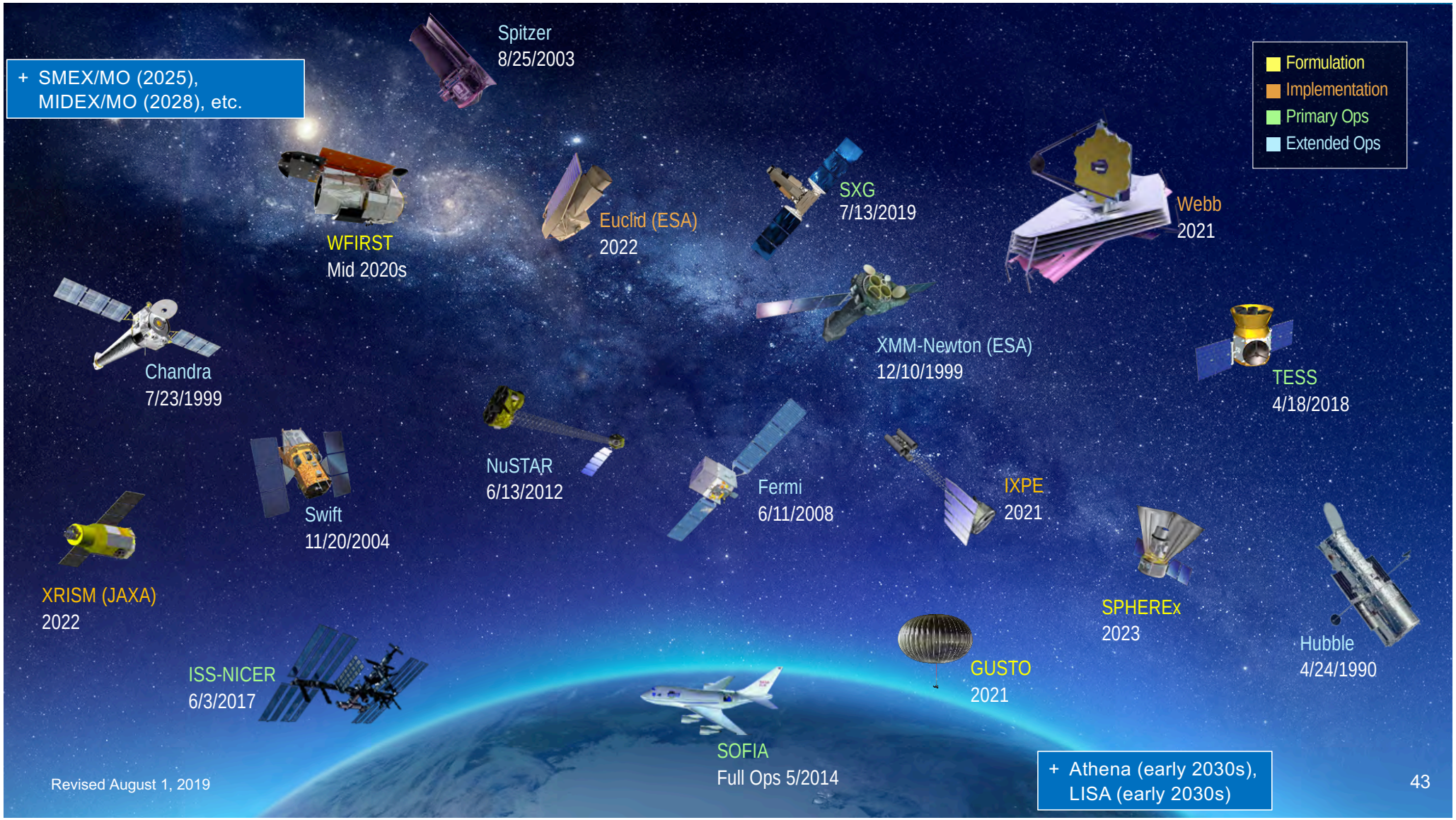




Decadal Survey Goal

- NASA's highest aspiration for the 2020 Decadal Survey is that it be ambitious
  - The important science questions require new and ambitious capabilities
  - Ambitious missions prioritized by previous Decadal Surveys have always led to paradigm shifting discoveries about the universe
- If you plan to a diminishing budget, you get a diminishing program.
  - Great visions inspire great budgets.

Carpe Posterum


+ SMEX/MO (2025), MIDEX/MO (2028), etc.
Spitzer 8/25/2003
Formulation
Implementation
Primary Ops
Extended Ops
WFIRST Mid 2020s
Euclid (ESA) 2022
SXG 7/13/2019
Webb 2021
Chandra 7/23/1999
XMM-Newton (ESA) 12/10/1999
TESS 4/18/2018
NuSTAR 6/13/2012
Swift 11/20/2004
Fermi 6/11/2008
IXPE 2021
XRISM (JAXA) 2022
SPHEREx 2023
Hubble 4/24/1990
ISS-NICER 6/3/2017
GUSTO 2021
SOFIA Full Ops 5/2014
+ Athena (early 2030s), LISA (early 2030s)