NASA Astrophysics Update

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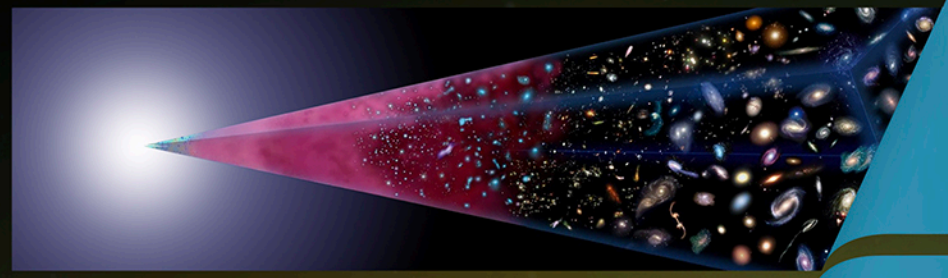
Astronomy and Astrophysics Advisory Committee
September 21, 2020

Why Astrophysics?



How did our universe begin and evolve?

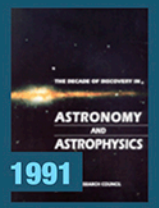
How did galaxies, stars, and planets come to be?

Are we alone?

Enduring National Strategic Drivers

1972

1982



1991

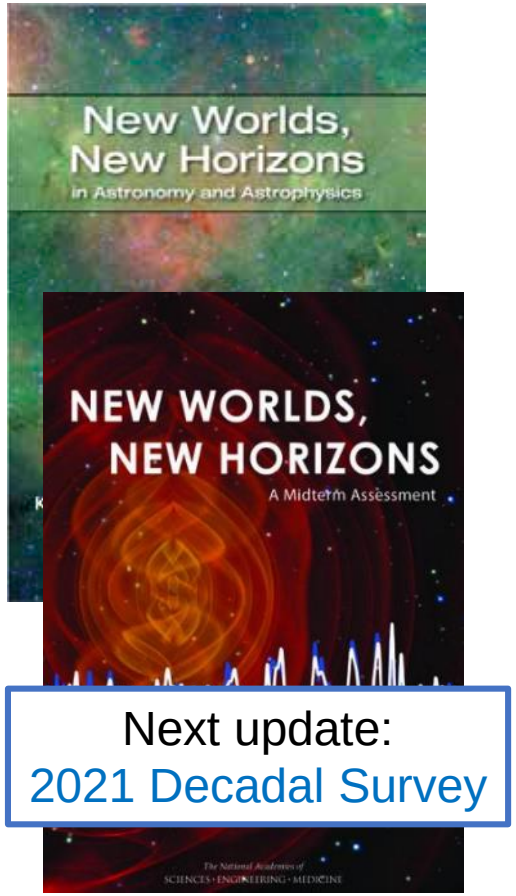
2001

2010

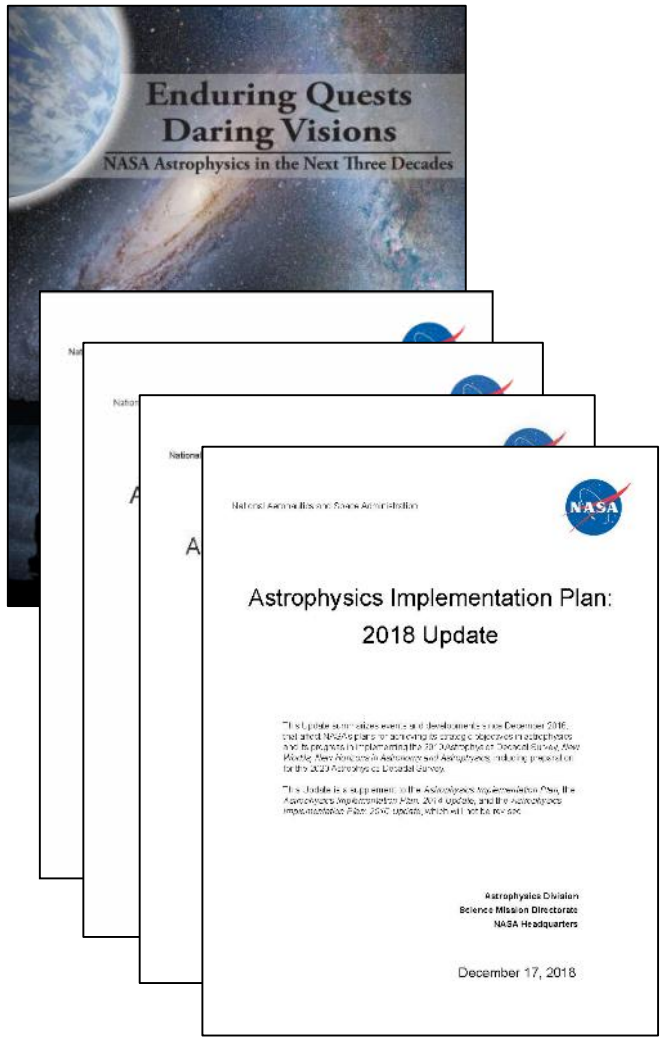
2021

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

Astrophysics Strategic Planning

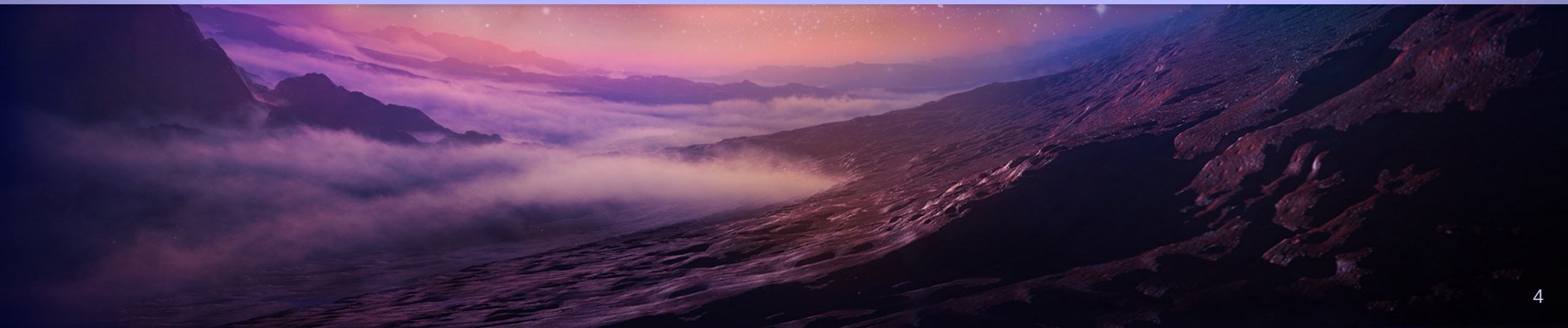


Next update:
2021 Decadal Survey



https://science.nasa.gov/astrophysics/documents

Context



NASA Newest Core Value

Inclusion *– NASA is committed to a culture of diversity, inclusion, and equity, where all employees feel welcome, respected, and engaged. To achieve the greatest mission success, NASA embraces hiring, developing, and growing a diverse and inclusive workforce in a positive and safe work environment where individuals can be authentic. This value will enable NASA to attract the best talent, grow the capabilities of the entire workforce, and empower everyone to fully contribute.*

Diversity, Equity, Inclusion, and Accessibility (DEIA) in Astrophysics and SMD

Enabling a community and stewarding the capabilities required to advance NASA's science objectives is one of NASA's roles

We must have compelling science priorities

- The important science questions require new and ambitious capabilities

We must be inclusive to attract the most capable researchers

- SMD has commissioned a NASEM study to identify the barriers to next generation mission Principal Investigators (https://www.nationalacademies.org/our-work/increasing-diversity-in-the-leadership-of-competed-space-missions)
- NASA and SMD are prioritizing diversity, equity, inclusion, and accessibility both internally and for NASA-selected and -funded projects and teams
- SMD has established internal groups: Anti-Racism Action Group and DEIA Working Group
- SMD has enacted process changes and evaluations: Dual Anonymous Peer Review, Equity Audits, Barrier Analysis
- SMD is incorporating DEIA requirements and evaluation into AOs and ROSES
- Additional

Diversity, Equity, Inclusion, and Accessibility (DEIA) in Astrophysics and SMD

Enabling a community and stewarding the capabilities required to advance NASA's science objectives is one of NASA's roles

A third day has been added to the October 19-21, 2020, meeting of the NASA Astrophysics Advisory Committee to discuss the State of the Profession, including inclusion and diversity in NASA's astrophysics program

- Additional channels allowing extensive community input during APAC meetings will be available at the October 2020 APAC meeting (https://science.nasa.gov/researchers/nac/science-advisory-committees/apac)

We must not let the current pandemic massively derail the careers of our future leaders

- SMD is prioritizing funded extensions to support graduate students, post docs, and early career researchers
- SMD is temporarily expanding the NASA Postdoctoral Program

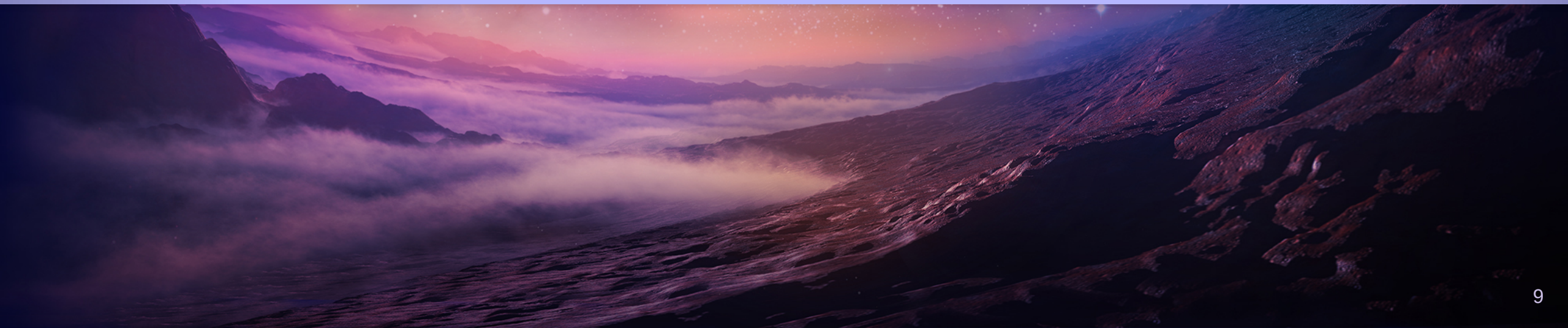
NASA welcomes actionable and practical recommendations to advance diversity, equity, inclusion, and accessibility within astronomy and astrophysics

REFERENCE

Diversity, Equity, Inclusion, and Accessibility (DEIA) in Astrophysics and SMD

APAC Recommendations		Snapshot September 21, 2020
1	The APAC fully endorses, and the community welcomes, a clear statement that the NASA Astrophysics Division values the well-being and lives of Black, Indigenous, People of Color (BIPOC) and recognizes their contributions to advancing the Astrophysics Division's strategic scientific, education, and technical enterprise.	Thomas Zurbuchen and Paul Hertz have made such clear statements at community meetings.
2	The APAC advises the Astrophysics Division to conduct a professionally led equity-audit of institutional racism within the Division.	The Astrophysics Division has initiated an equity audit of institutional racism within the division, conducted by an external organization.
3	The APAC strongly recommends ensuring BIPOC representation in future APAC membership.	BIPOC voices are, and will continue to be, among the diverse set of voices on the APAC. .
4	The APAC recommends that NASA immediately consider including an evaluation criterion on "promoting diversity, equity, and inclusion in the field" in the review for all Astrophysics Division proposals and directed work.	New requirements and a new evaluation criterion are being added to the Standard AO. Addressing it for ROSES and directed work will be considered by SMD as next steps.
5	The APAC recommends that the Astrophysics Division critically assess current programs and initiatives within the Division portfolio directed toward diversity, equity, and inclusion. The Division should examine why these mechanisms and means have not fully worked and assess what fundamental changes are required to break exclusive and, specifically, racist structures within these.	An internal Astrophysics Division team has been established, coordinating with parallel groups in other Divisions, includes support from DEIA expert contractor.
6	The APAC recommends that Astrophysics Division Projects and Programs explicitly authorize use of funds for Investigation, Project, and Program leads or their designees to participate in and engage at conferences organized to support BIPOC and other minority scientists, with a reporting requirement.	The Director of Astrophysics has issued guidance to astrophysics leadership at NASA Centers allowing such authorization (authority for use lies with Centers).
7	The APAC recommends establishing additional channels for more extensive community input in APAC discussions.	The Astrophysics Division has arranged for additional channels allowing extensive community input during APAC meetings, beginning at the October 2020 meeting.

Program Update



NASA's Mars 2020 Perseverance rover launched on the Atlas V-541 rocket from Launch Complex 41 at Cape Canaveral Air Force Station, Florida on July 30, 2020, at 7:50 a.m.

Hubble Helps Uncover the Mystery of the Dimming of Betelgeuse

Released: August 13, 2020

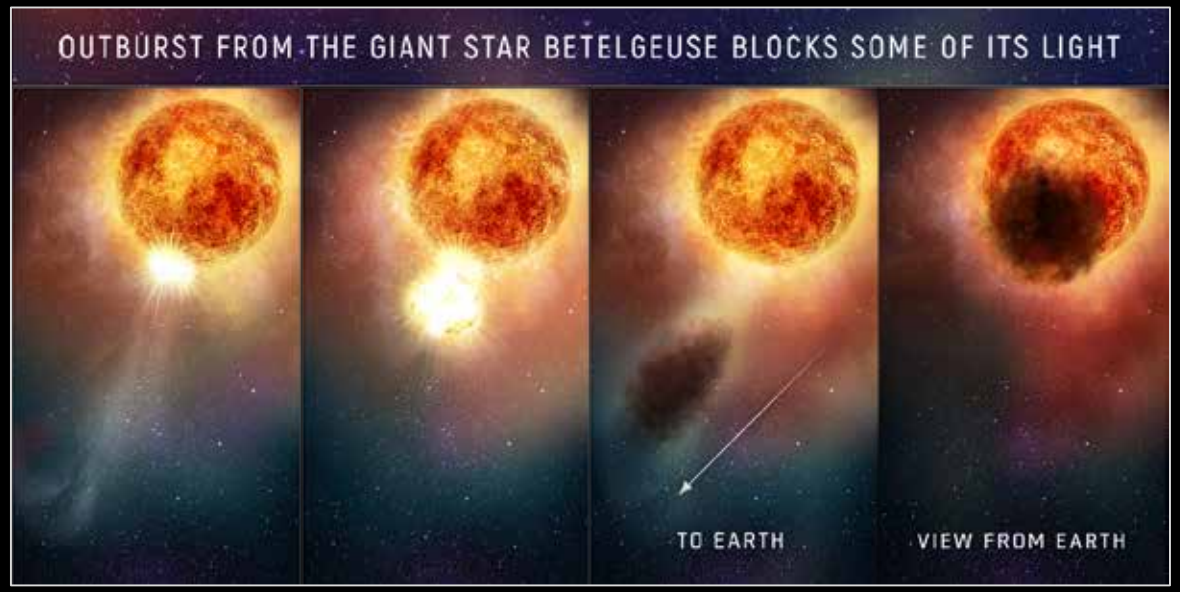


Image Credit: NASA, ESA, and E. Wheatley (STScI)
Caption: Illustration of outburst from Betelgeuse

A. Dupree et al., https://doi.org/10.3847/1538-4357/aba516

https://www.nasa.gov/feature/goddard/2020/hubble-finds-that-betelgeuses-mysterious-dimming-is-due-to-a-traumatic-outburst

SCIENCE HIGHLIGHT

- The aging, bright-red supergiant star Betelgeuse has captivated sky watchers since antiquity. It is one of the brightest stars in the night sky and appears even more luminous because it is so close to Earth, only 725 light-years away.
- The star periodically changes in brightness as the star expands and contracts, brightening and dimming, on a 420-day cycle.
- In October 2019, the star dimmed dramatically and continued to become even fainter. By mid-February 2020, the star had lost more than two-thirds of its brilliance.
- This sudden dimming mystified astronomers, who scrambled to develop theories for the abrupt change.
- Ultraviolet observations by the Hubble Space Telescope suggest that the unexpected dimming was probably caused by an immense amount of superhot material ejected into space.
- The material cooled and formed a dust cloud that blocked the starlight coming from about a quarter of Betelgeuse's surface.
- Hubble captured signs of dense, heated material moving through the star's atmosphere in September, October, and November 2019. In December, several ground-based telescopes observed the star decreasing in brightness in its southern hemisphere.
- The giant star is destined to end its life in a supernova blast. Some astronomers think the sudden dimming may be a pre-supernova event.
- Betelgeuse resides in Orion, one of the most recognizable constellations in the sky.

Missions Spy First Possible ‘Survivor’ Planet Hugging White Dwarf Star

Released: September 16, 2020

Artist Concept: NASA's Goddard Space Flight Center.

Caption: In this illustration, WD 1856 b, a potential Jupiter-size planet, orbits its much smaller host star, a dim white dwarf.

SCIENCE HIGHLIGHT

- An international team of astronomers using NASA’s Transiting Exoplanet Survey Satellite (TESS) and retired Spitzer Space Telescope has reported what may be the first intact planet found closely orbiting a white dwarf, the dense leftover of a Sun-like star.
- When a Sun-like star runs out of fuel, it swells up to hundreds to thousands of times its original size, forming a cooler red giant star. Eventually, it ejects its outer layers of gas, losing up to 80% of its mass. The remaining hot core becomes a white dwarf. Any nearby objects are typically engulfed and incinerated during this process.
- The white dwarf studied is named WD 1856+534, is roughly 11,000 miles (18,000 kilometers) across, may be up to 10 billion years old, and is a distant member of a triple star system.
- The Jupiter-size object that TESS and Spitzer found is called WD 1856 b. It is about seven times larger than the white dwarf. It circles this stellar cinder every 34 hours, more than 60 times faster than Mercury orbits our Sun. WD 1856 b is about 80 light-years away in the northern constellation Draco.
- The team suggests several scenarios that could have nudged WD 1856 b onto an elliptical path around the white dwarf. This trajectory would have become more circular over time as the star’s gravity stretched the object, creating enormous tides that dissipated its orbital energy.

A. Vanderburg et al., https://doi.org/10.1038/s41586-020-2713-y

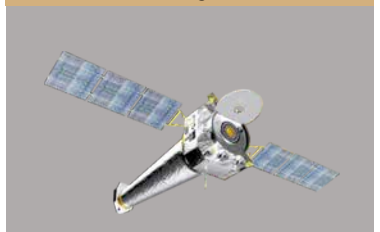
https://www.nasa.gov/press-release/nasa-missions-spy-first-possible-survivor-planet-hugging-white-dwarf-star

Astrophysics Missions in Operations

Hubble 4/90
NASA Strategic Mission

Operations Nominal

Chandra 7/99
NASA Strategic Mission



Science Ops Resumed

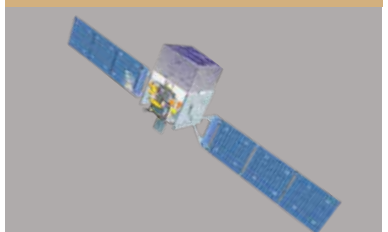
XMM-Newton 12/99
ESA-led Mission

Operations Nominal (ESA)

Gehrels Swift 11/04
NASA MIDEX Mission

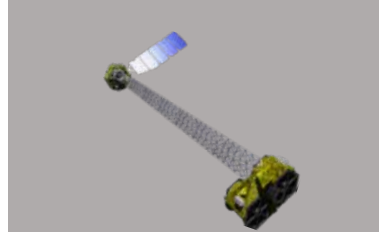
Operations Nominal

Fermi 6/08
NASA Strategic Mission



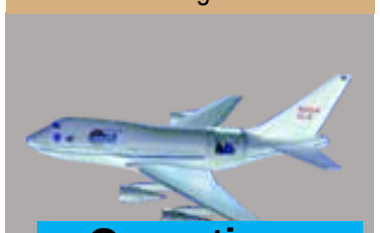
Operations Nominal

NuSTAR 6/12
NASA SMEX Mission



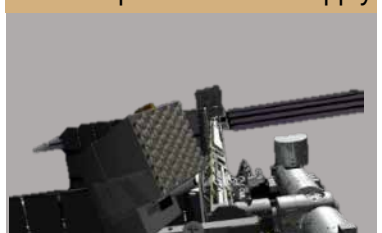
Operations Nominal

SOFIA 5/14
NASA Strategic Mission



Operations Restarted Aug 17

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



Operations Nominal

TESS 4/18
NASA MIDEX Mission

Operations Nominal

Balloon Program
Four Campaigns per Year

Operations Suspended

Sounding Rockets
Worldwide Campaigns

Operations Resumed Sep 8

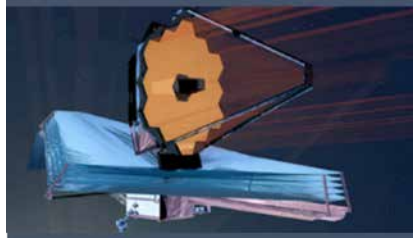
Data Archives
HEASARC, IPAC, MAST, etc.

Operations Nominal

https://www.nasa.gov/mission_pages/chandra/news/update-on-chandra-x-ray-observatory-anomaly.html

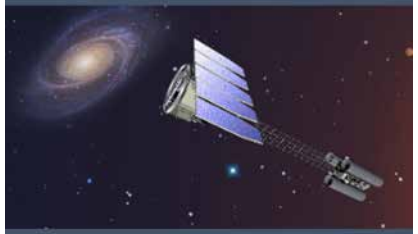
Astrophysics Missions in Development

Webb — 2021
NASA Mission



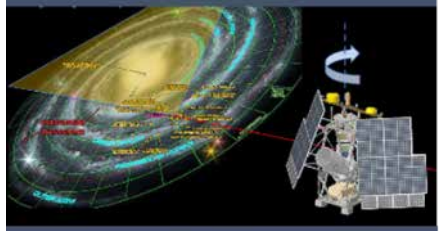
James Webb
Space Telescope

IXPE — 2021
NASA Mission



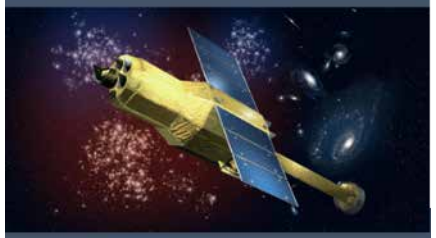
Imaging X-ray
Polarimetry Explorer

GUSTO — 2021
NASA Mission



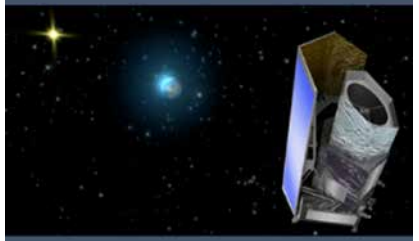
Galactic/ Extragalactic ULDB
Spectroscopic Terahertz Observatory

XRISM — 2022
JAXA-led Mission



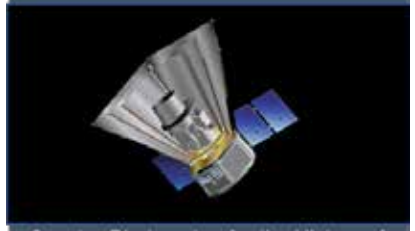
NASA is supplying the SXS
Detectors, ADRs, and SXTs

Euclid — 2022
ESA-led Mission



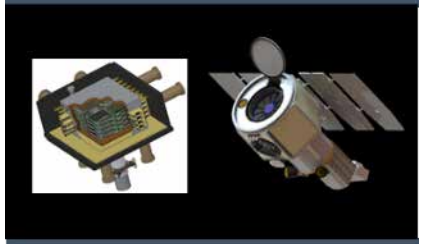
NASA is supplying the NISP
Sensor Chip System (SCS)

SPHEREx — 2024
NASA Mission



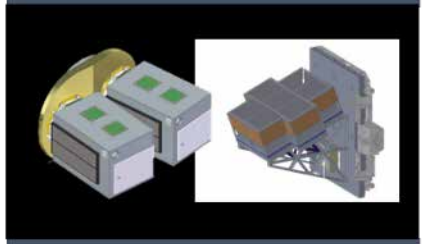
Spectro-Photometer for the History of
the Universe, Epoch of Reionization,
and Ices Explorer

SMEX — ~2025
NASA Mission



COSI or ESCAPE

Mission of Opportunity — ~2025
NASA Mission



Dorado or LEAP

Roman — 2025
NASA Mission

Nancy Grace Roman
Space Telescope

ARIEL — 2028
ESA-led Mission

NASA is supplying the CASE
fine guidance instrument

Launch dates are current project working dates; Agency Baseline Commitment launch date could be later; impacts of COVID-19 not yet known

Status of SMD Missions in Development

All SMD missions in Formulation are proceeding and most missions in Implementation are accomplishing some hands-on work. However, SMD continues to experience disruption to all missions due to COVID-related restrictions; we assume these disruptions will continue for the time being

- Reduced efficiency achieved at work sites and for those working from home, which includes reduced availability of workforce and reduced leave usage
- Travel restrictions, reduced availability of NASA facilities
- Disruptions to supply chain for current and future procurements

At the portfolio level, SMD is considering a series of short- and medium-term actions to mitigate COVID impacts in order to ensure mission success and overall portfolio health

- Within current budget, the use of HQ-held reserves and/or adjustment of launch date are being employed
- Where additional funds are necessary, SMD will consider delays or cancellations to planned missions in order to restore overall portfolio risk to acceptable levels

Life Cycle Reviews (LCR) and some Key Decision Points (KDPs) have continued to virtually report

- Some challenges/limitations have been observed in the LCR virtual environment regarding the ability of the review team members to have in-depth sidebar conversations

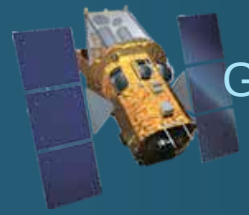
COVID Impacts to Astrophysics Missions in Development

Missions are in launch date order

Webb	Launch delay, cost impacts within reserves, replan approved July 2020
IXPE	Launch delay, KDP-D October 2020
GUSTO	Balloon program impact delays certification of super-pressure launch vessel
XRISM	JAXA announced launch delay
Euclid	ESA maintaining schedule
SPHEREx	Schedule and cost impacts likely, KDP-C December 2020
SMEX/MO	Phase A extended, further schedule and cost impacts TBD, KDP-B (downselect) late summer 2021
Roman	Schedule and cost impacts likely, mission CDR 2021
ARIEL	Too early to tell, KDP-C Fall 2022
Athena	Too early to tell, KDP-A 2021
LISA	Too early to tell, KDP-A 2022

Many missions' launch delay and cost impacts may be covered within project and HQ-held reserves

Astrophysics Explorers Program



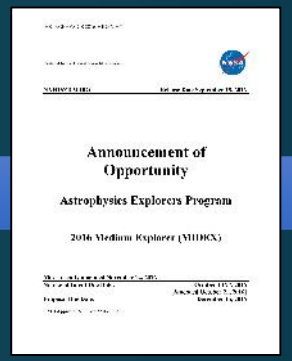
Gehrels
Swift

NuSTAR

4 AOs per decad

MIDEX
2011

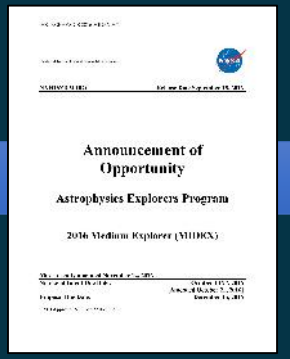
SMEX
2014



MIDEX
2016

SMEX
2019

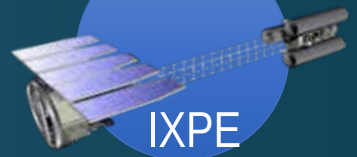
MIDEX 2021 Community Announcement planned for Sep/Oct 2020



MIDEX
2021

Small and Mid-Size Missions

TESS



IXPE

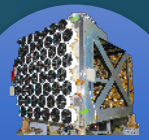
SPHEREx

ESCAPE
COSI

Directed
2013

Euclid

Missions of Opportunity



NICER

GUSTO

ARIEL

Dorado
LEAP

Directed
2017

XRISM

James Webb Space Telescope

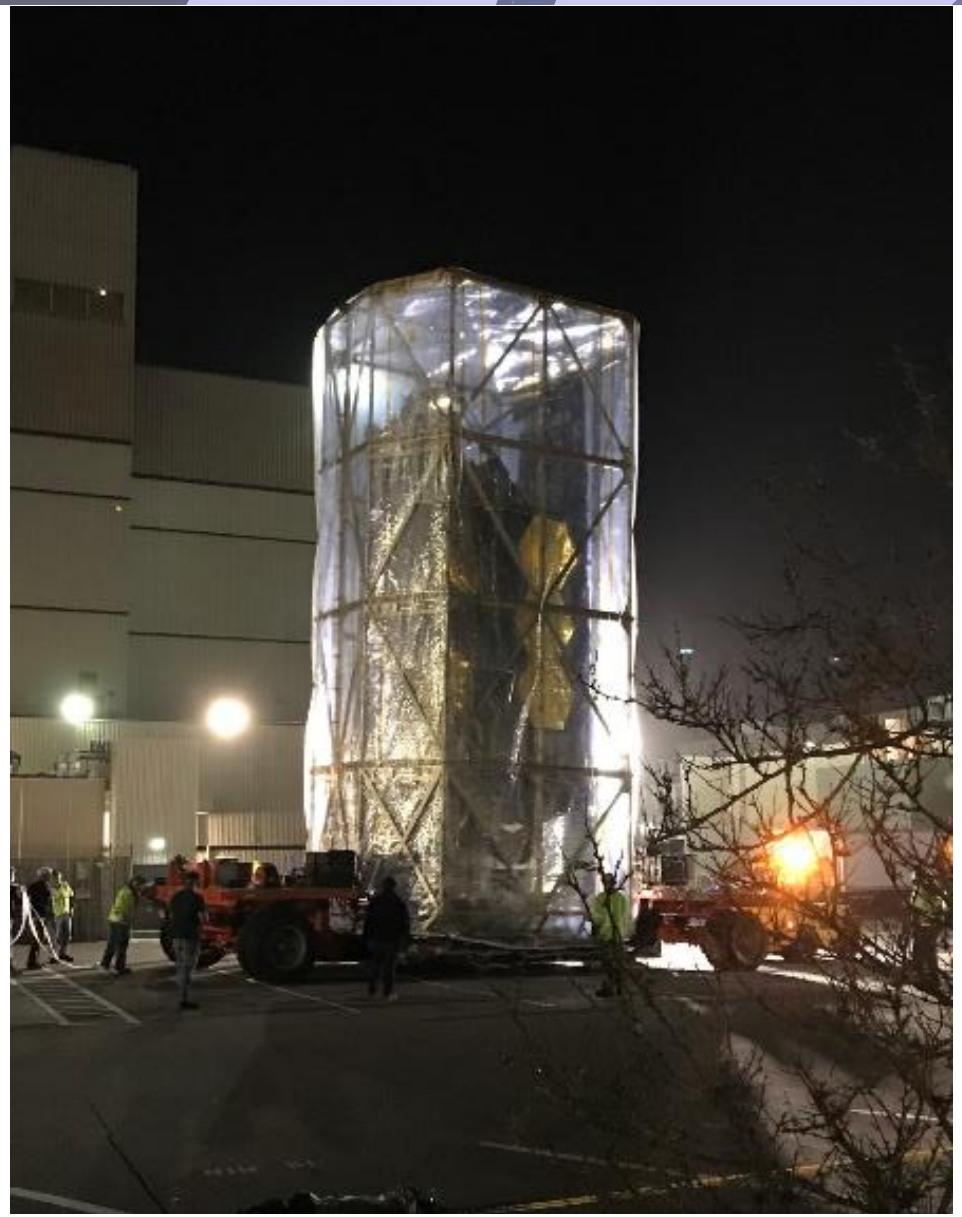
- Launch date revised to October 31, 2021
  - Delay covered within Agency cost commitment with existing Webb program reserve funds
- Observatory-level environmental testing is underway
  - Acoustics testing (completed)
  - Vibration testing (1 of 3 axes completed)
- Following environmental testing
  - Deployment and folding
  - Shipping to Kourou Space Center
- Launch rehearsals resuming at STScI
- Ariane 5 rocket components being built for launch
- Cycle 1 GO proposals due Nov 24, 2020

Stowed in launch configuration prior to undergoing environmental testing. Image credit: Northrop Grumman

James Webb Space Telescope

Fully Stowed Webb Observatory

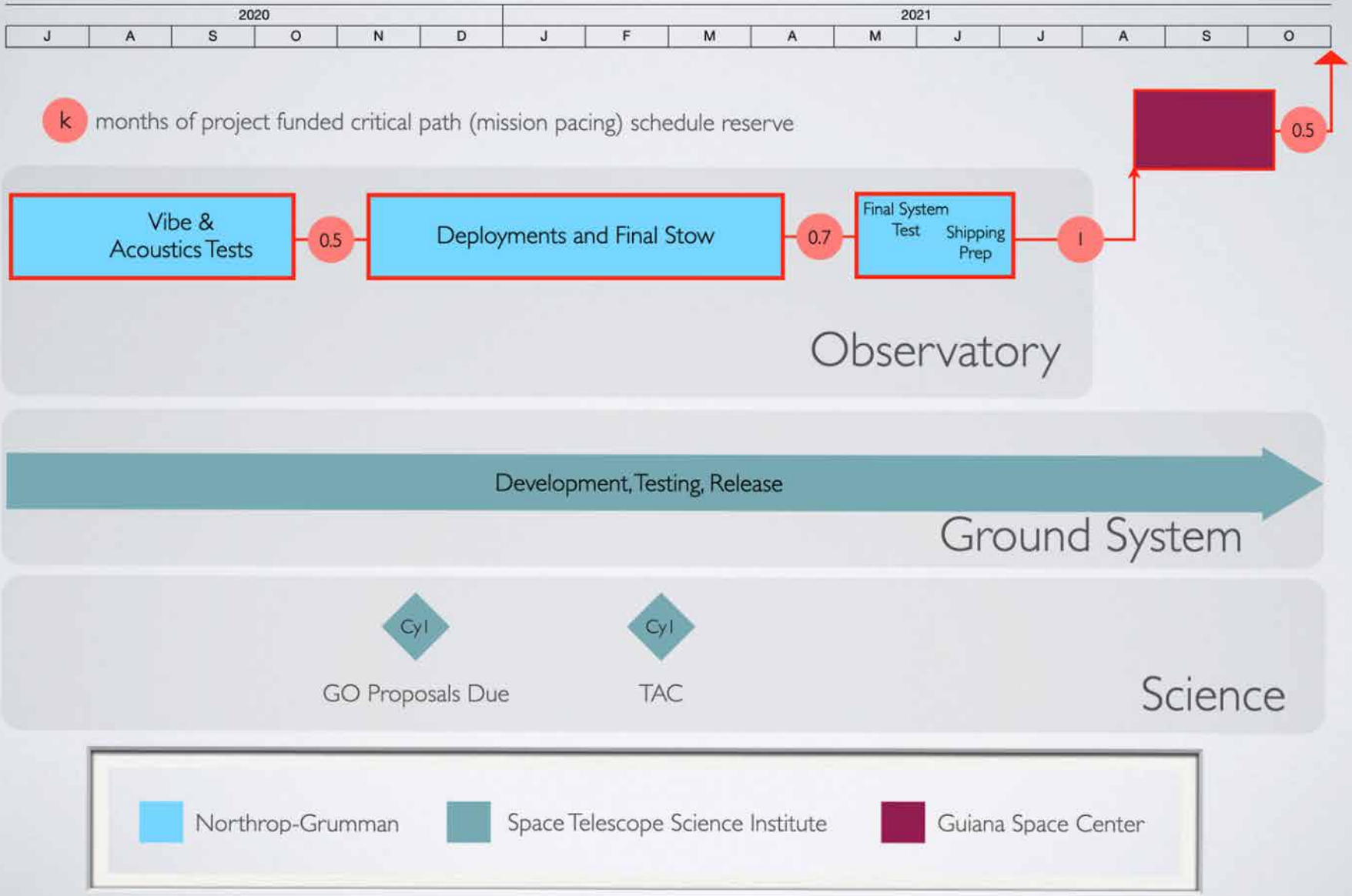
Webb Observatory readied for integration onto interplant transporter



Webb Observatory being transported to the Acoustics Facility

Webb Observatory in the Acoustics Facility

SIMPLIFIED SCHEDULE



Nancy Grace Roman Space Telescope

SCIENCE HIGHLIGHT

May 20, 2020 – NASA has named its Wide Field Infrared Survey Telescope (WFIRST), in honor of Nancy Grace Roman, NASA's first chief astronomer, who paved the way for space telescopes focused on the broader universe.

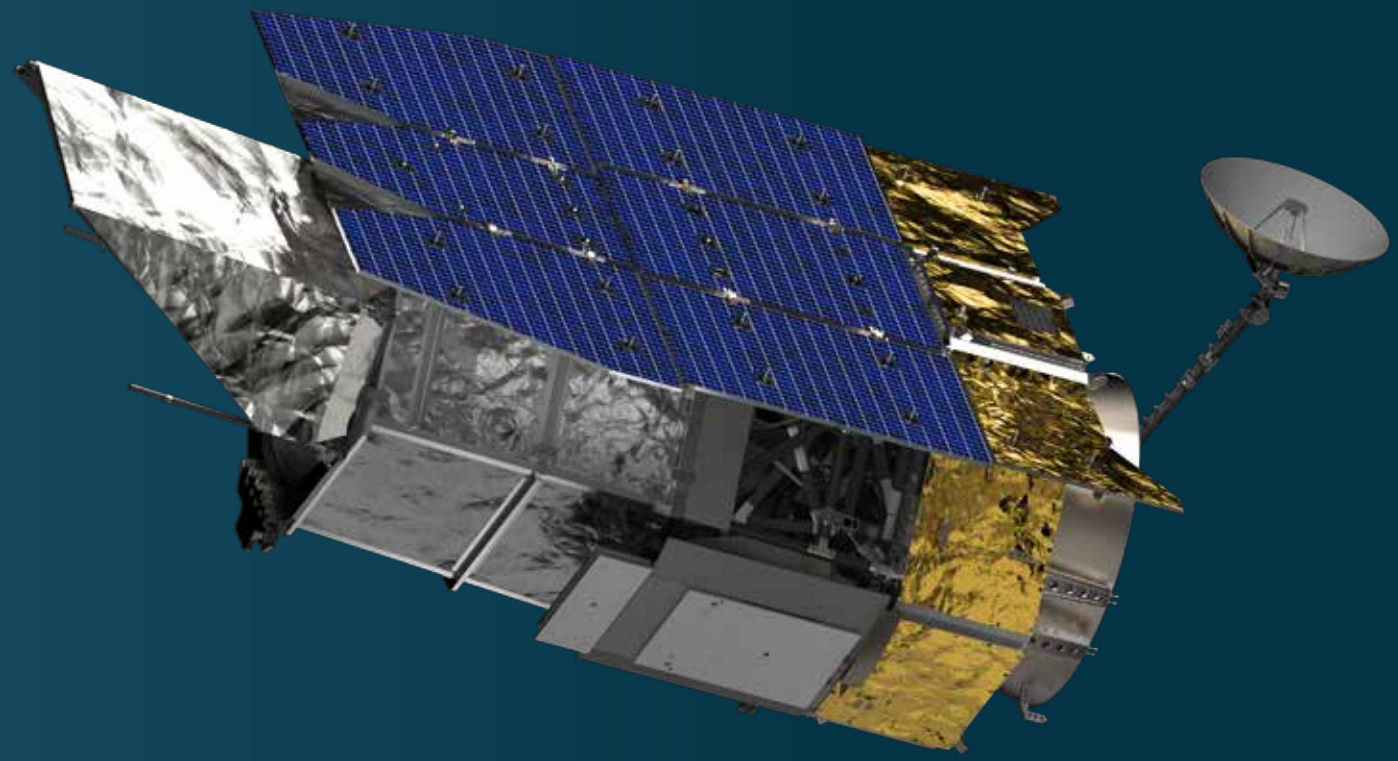
Nancy Grace Roman Space Telescope

Science Program

- Cosmology : Dark energy and the fate of the universe – wide field surveys to measure the expansion history and the growth of structure
- Exoplanet Demographics: The full distribution of planets around stars through a microlensing survey
- Astrophysics: Wide-field infrared surveys of the universe through General Observer and Archival Research programs

Technology development for the characterization of exoplanets through a Coronagraph Instrument Technology Demonstration

https://roman.gsfc.nasa.gov/



Roman field-of-view is 100x Hubble field-of-view

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

Nancy Grace Roman Space Telescope

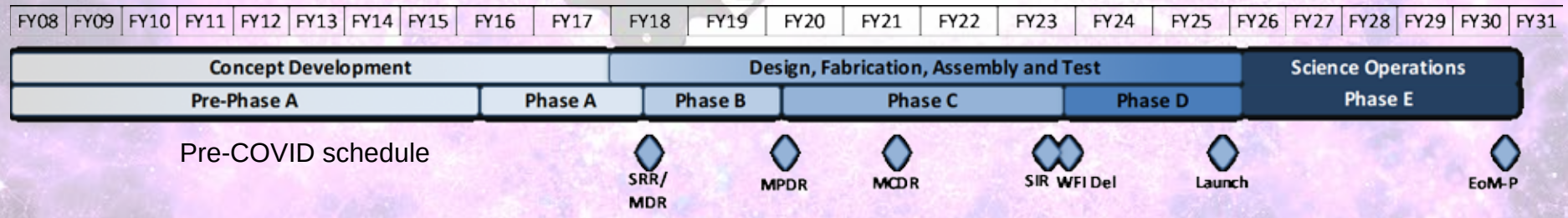
Driving Science Objectives:

- Characterize the history of cosmic acceleration and structure growth
- Understand how planetary systems form and evolve and determine the prevalence of planets in the colder outer regions
- Provide a peer-reviewed General Observer & Archival Research program
- Develop and fly a technology demonstration of advanced starlight suppression technology, which could be used for direct imaging and spectroscopy of planets and debris disks.

Capabilities:

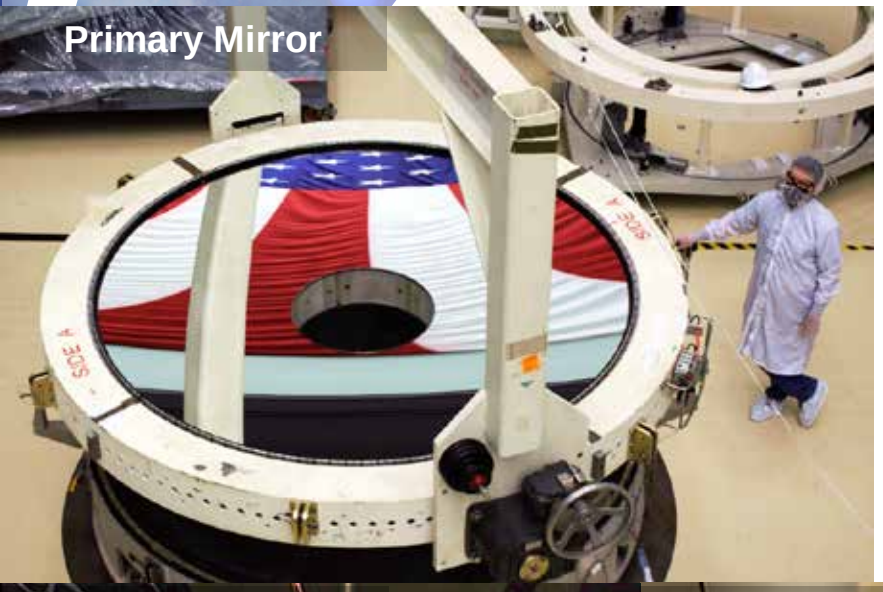
- Wide-field imaging 100-1,500 times faster than Hubble
- Near-infrared optimized; greater IR sensitivity than any prior mission à best wide field imaging ever achieved
- Camera 100× wider field of view than Hubble; angular resolution of ≈0.1" rivals Hubble
- Starlight suppression up to 100× better than previously achieved on ground, 1000× better than achieved in space

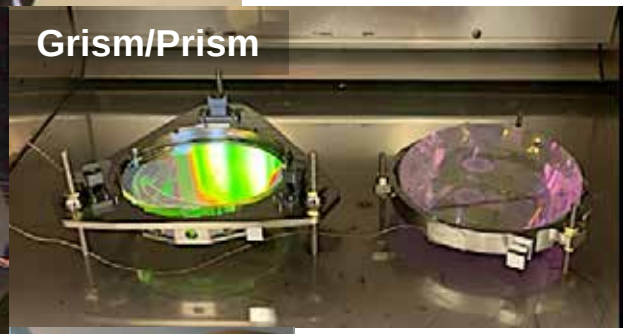
- **Mission Risk Class:** Class A tailored
- **Mission Duration:** 5 years science; designed for 10
- **Orbit:** around Sun-Earth L2
- **Ground Stations:** NEN, DSN, ESA (Australia), JAXA
- **Space Network:** S-band for launch
- **Ground System:** MOC/Science Ops Ctr/Science Support Ct
- **Launch Vehicle:** TBD
- **Launch Site:** Eastern Range
- **Launch Plng Date:** October 2025 (pre-COVID)
- **Telescope diam.:** 2.4m
- **Observatory size:** 12.4m
- **Dry Mass:** 7801kg
- **Data Volume:** 1.5 TB/day; 20PB after 5 years



Pre-COVID schedule

Roman Hardware Progress





Roman Space Telescope

- Primary mirror reflective coating is complete. Coating of the secondary mirror is in work and manufacturing has begun on the tertiary collimating assembly.
- Engineering Development unit for the Element Wheel and the mechanical model of the prism and grism will help finalize production specifications.
- Teledyne continues to deliver flight candidate detectors; 13 of 18 identified; continuing evaluation at GSFC
- Starting peer review process that will lead to Mission CDR next summer.

Coronagraph Instrument Technology Demonstration

- JPL is making progress on schedule-critical Coronagraph work such as deformable mirror interconnect.
- e2v is progressing on photon counting EMCCD camera.

Roman is for the Community

All Roman observing time is available through open processes

- Major Legacy Surveys will be defined using a community-driven open process
- Key Projects – funded science investigations using these surveys – will be openly competed
- Roman observing time will be available for General Observer (GO) projects
- All data will be available to the community with no period of limited access

Roman operations will be based on community input

- NASA and STScI have convened community groups to provide input on balance among observing programs and on trades during development, integration, and test

Roman General Observers / Archival Researchers Program

- Use observing time for conducting wide-field infrared surveys of the universe
- Use data from Roman Legacy Surveys for compelling astrophysics investigations
- Calls for proposals to be issued before launch and subsequently

Roman Coronagraph Community Participation Program

- Ensure “as built” coronagraph is an effective demonstration
- Call for proposals at the appropriate time

Imaging X-ray Polarimetry Explorer

IXPE will study targets over a broad range of types of astronomical X-ray sources with emphasis on black holes and neutron stars

IXPE will accomplish, for the first time:

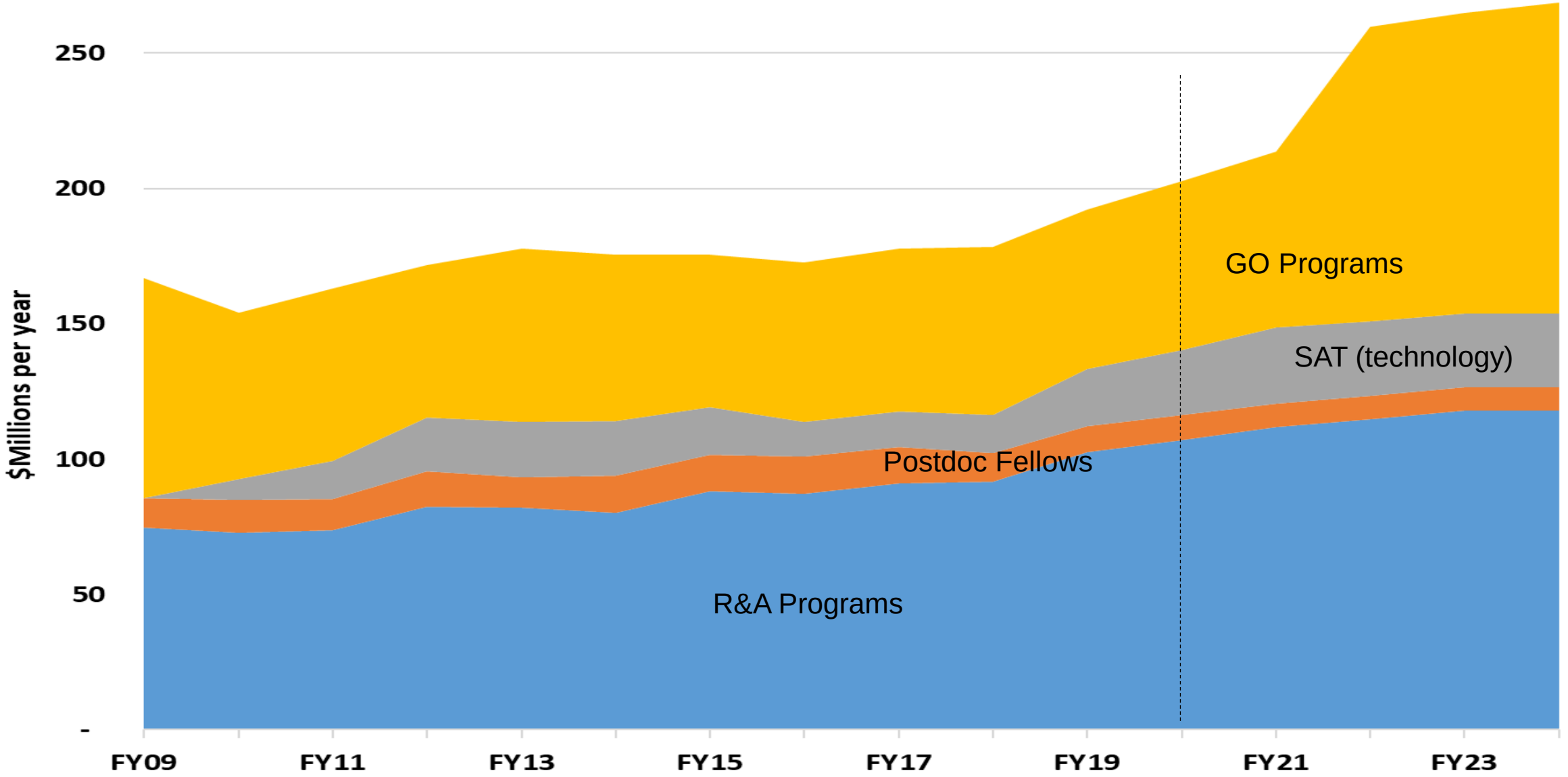
- High-sensitivity measurements of the polarization of X-rays coming to us from some of the most exciting types of astronomical objects
- Imaging X-ray polarization measurements from extended objects such as supernova remnants and at least one jet attached to super-massive black holes

IXPE measurements are astrophysically unique, adding two new dimensions to information space: Polarization degree & Polarization angle

Sep 22-23, 2020	System Integration Review (SIR)
Oct 20, 2020	KDP-D Directorate Program Management Council
September 2021	Target launch date, to be revised at KDP-D

https://ixpe.msfc.nasa.gov

Astrophysics Community Funding



ROSES-2020 Program Elements

Supporting Research and Technology

- Astrophysics Research & Analysis (APRA**),** includes Lab Astro equipment
- ~~Strategic Astrophysics Technology (SAT)~~ Canceled this year
- Roman Technology Fellowships (RTF)
- Astrophysics Theory Program (ATP) (biennial, not this year)
- Theoretical and Computational Astrophysics Networks (TCAN) (triennial, this year)
- Exoplanet Research Program (XRP) (cross-div)
- Topical Workshops, Symposia, and Conferences (TWSC)

Data Analysis

- Astrophysics Data Analysis (ADAP)
- GO/GI programs for:
  - Fermi
  - Swift
  - NuSTAR
  - TESS
  - NICER

Mission Science and Instrumentation

- Sounding rocket, balloon, cubesat, and ISS payloads solicited through APRA
- Astrophysics Pioneers
- ~~XRISM Guest Scientists~~ Deferred due to launch delay
- LISA Preparatory Science
- Astrophysics Explorers U.S. Participating Investigators (triennial, this year)

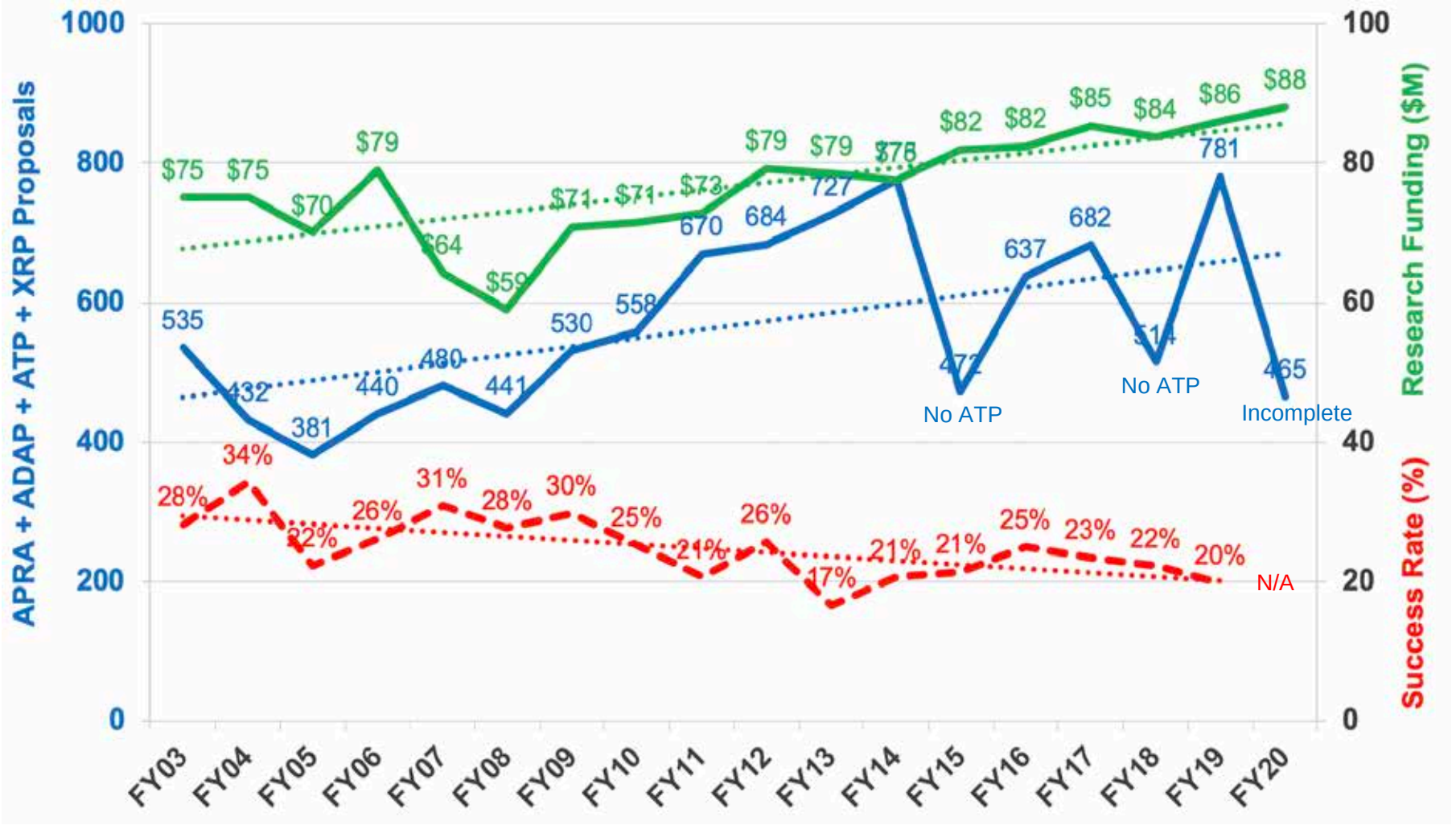
Separately Solicited

- GO/GI/Archive/Theory programs for:
  - Chandra
  - Hubble
  - SOFIA
  - Webb
- NASA Hubble Fellowship Program
- NASA Postdoctoral Program
- FINESST Graduate Student Research Awards

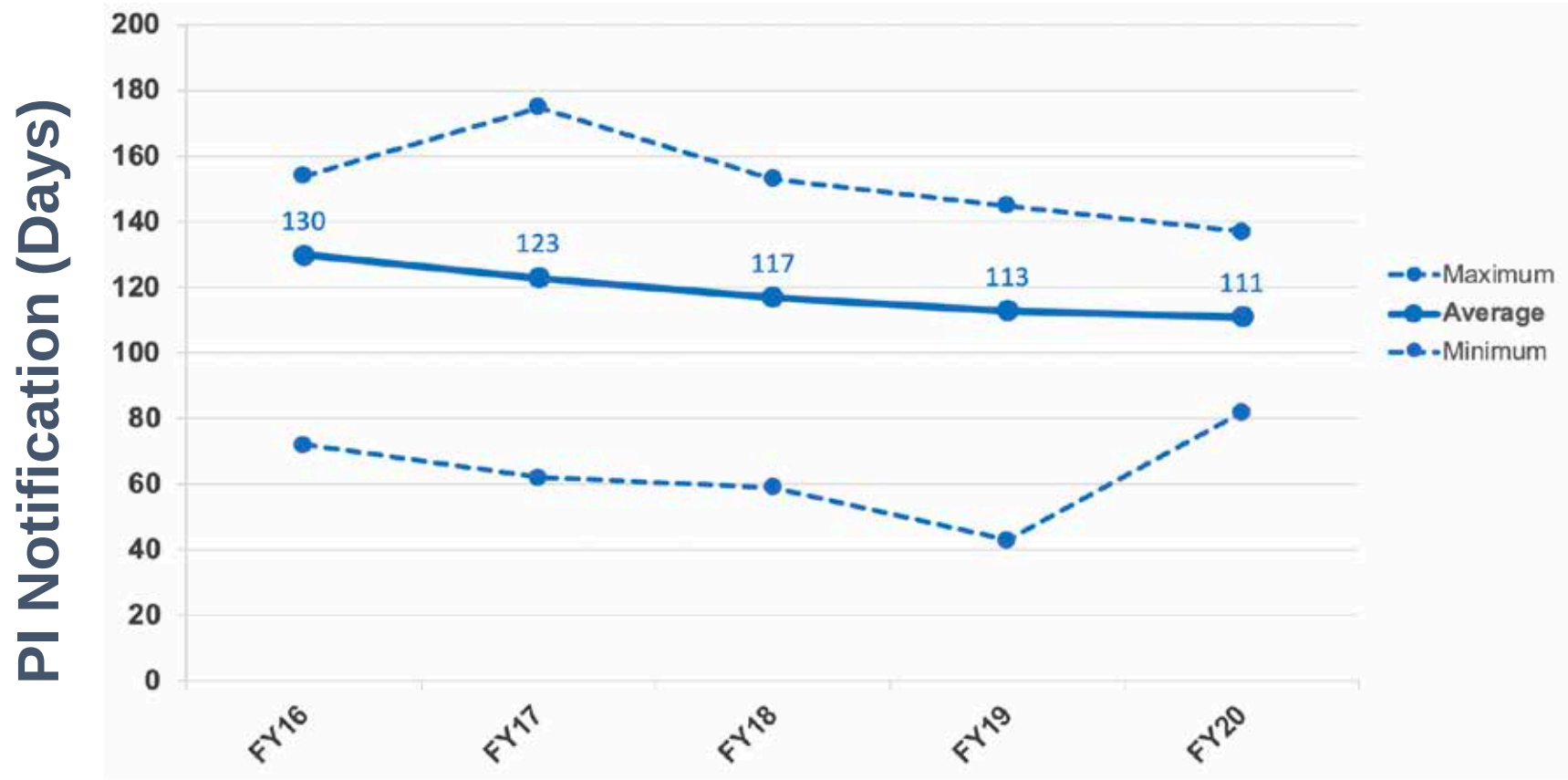
New in ROSES-2020:

- Astrophysics Pioneers
- Lab Astro equipment in APRA
- SAT canceled in anticipation of the 2020 Decadal Survey
- Exoplanet Research Program consolidates exoplanet proposals
- Astrophysics participates in cross-divisional TWSC
- XRISM Guest Scientist Program (deferred due to launch delay)
- LISA Preparatory Science
- Astrophysics Explorers U.S. Participation Investigators
- Data Management Plan will be evaluated as part of the intrinsic merit of proposals

Increasing the Total R&A Funding…



…And Taking Less Time to Award It



R&A Grant Extensions

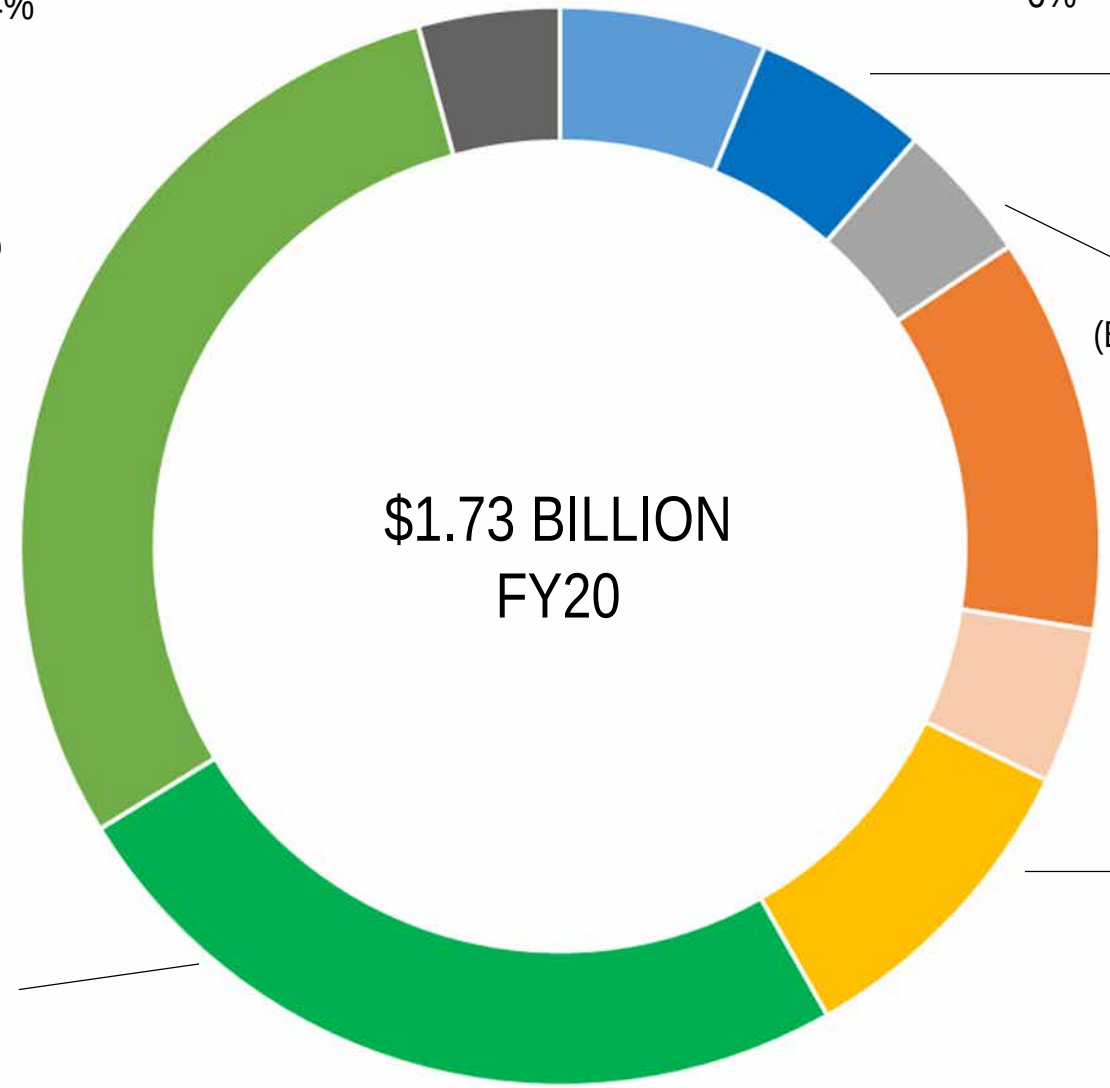
SMD does not want the COVID-19 epidemic to derail the careers of future leaders; we continue to focus on mitigating the impacts of the epidemic

Pursuing a three-pronged strategy for early career researchers

- SMD Policy (SPD-36): Current grantees may request funded extensions starting on October 1, 2020
  - Highest priority for funding is to support graduate students and postdocs
  - Next highest priority is for funding to support soft-money, early-career researchers
- Temporary expansion of the NASA Postdoctoral Program (NPP) to more than the 124 Fellows funded by HQ
  - Size of expansion to be no more than 50%, but still under discussion as we learn more
- Working with Centers to support/fund additional term CS hires focused on additional training and career growth (2-6 years)

Since all three of these actions must be funded from the R&A Program, size of commitment for all three is expected to be approx. 15% of funding available for new awards

Astrophysics Budget – FY20 Plan



MANAGEMENT
INCL. STEM ACTIVATION
4%

RESEARCH
(ADAP, APRA, ATP, ETC.)
6%

TECHNOLOGY
(SR&T, ATHENA, LISA, ETC.)
5%

INFRASTRUCTURE
(BALLOON PROGRAM, ARCHIVES, ETC.)
4%

OP. MISSIONS
(INCL. GO PROGRAMS)
17%

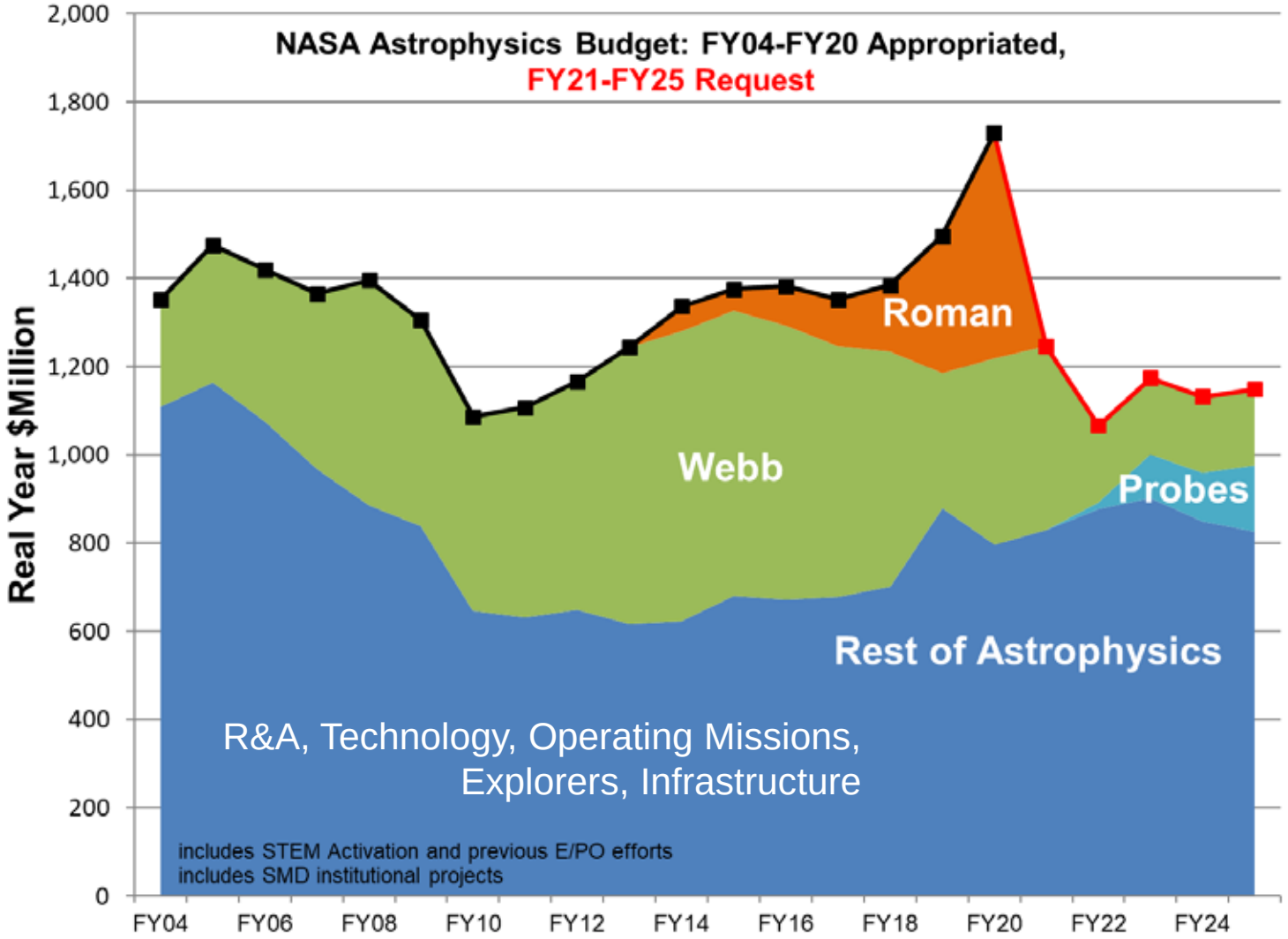
EXPLORERS
DEVELOPMENT
10%

WEBB
DEVELOPMENT
25%

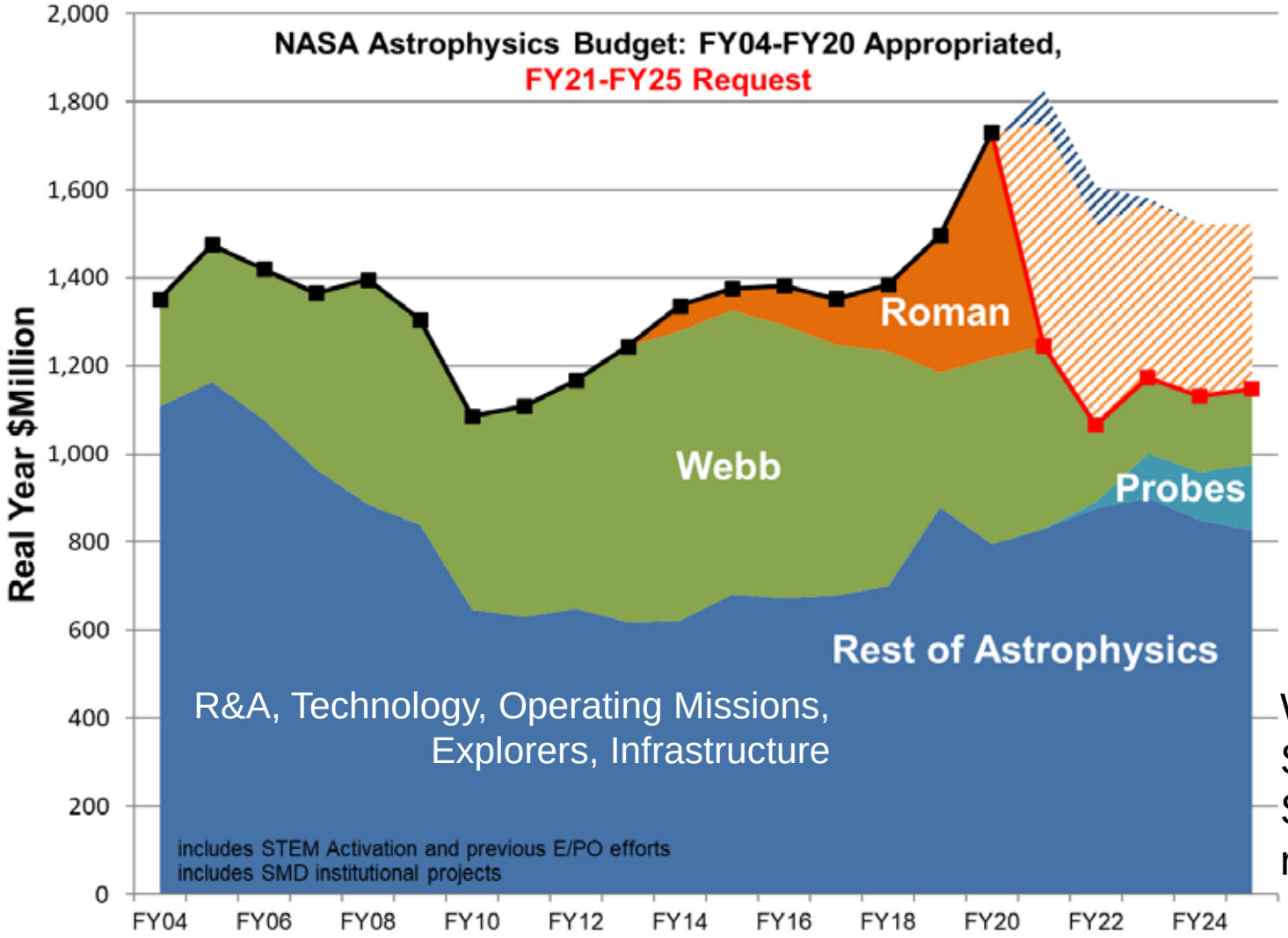
ROMAN
DEVELOPMENT
29%

Quick Summary
Community support: 20%
Operating missions: 12%
Building missions: 64%
Management: 4%

Astrophysics Budget – FY21 Request



Astrophysics Budget – FY21 Request



What if the Roman Space Telescope and SOFIA continue to receive appropriations?

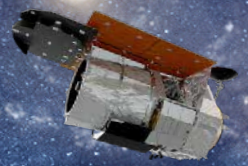
FY21 Astrophysics Budget Update

	Request ($M)	Full Year CR or House Markup ($M)	Comments
Astrophysics w/ Webb	1,245.7	1,729.2	FY20 appropriation is an increase of $483.5M over FY21 request
Webb	414.7	423.0	FY20 appropriation is an increase of $8.3M over FY21 request
Astrophysics	831.0	1306.2	FY20 appropriation is an increase of $475.2M over FY21 request
Roman	0	505.2	Roman requirement in FY21 is an increase of $505.2M over FY21 request
SOFIA	12.0	85.2	SOFIA historical appropriation is an increase of $73.2M over FY21 request
Everything else	819.0	715.8	Continuing resolution requires a reduction of $103.2M from FY21 request (planning budget)

+ SMEX/MO (2025), MIDEX/MO (2028), etc.

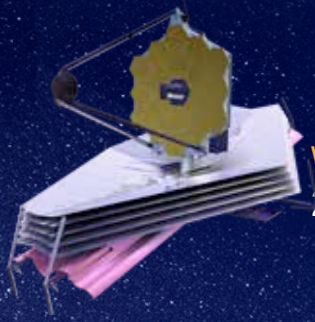
Formulation
Implementation
Primary Ops
Extended Ops


Spitzer
8/25/2003
1/30/2020


Roman
2025/2026


Euclid (ESA)
2022


SXG (RSA)
7/13/2019


Webb
2021


Ariel (ESA)
2028


Chandra
7/23/1999

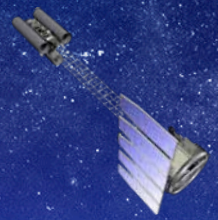

XMM-Newton (ESA)
12/10/1999

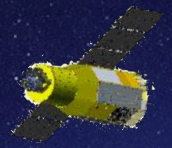

TESS
4/18/2018

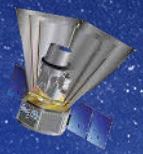

NuSTAR
6/13/2012

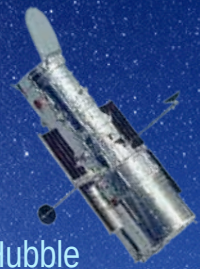

Swift
11/20/2004


Fermi
6/11/2008


IXPE
2021

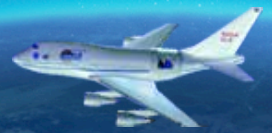

XRISM (JAXA)
2022


SPHEREx
2023


Hubble
4/24/1990


ISS-NICER
6/3/2017


GUSTO
2021


SOFIA
Full Ops 5/2014

Revised July 4, 2020

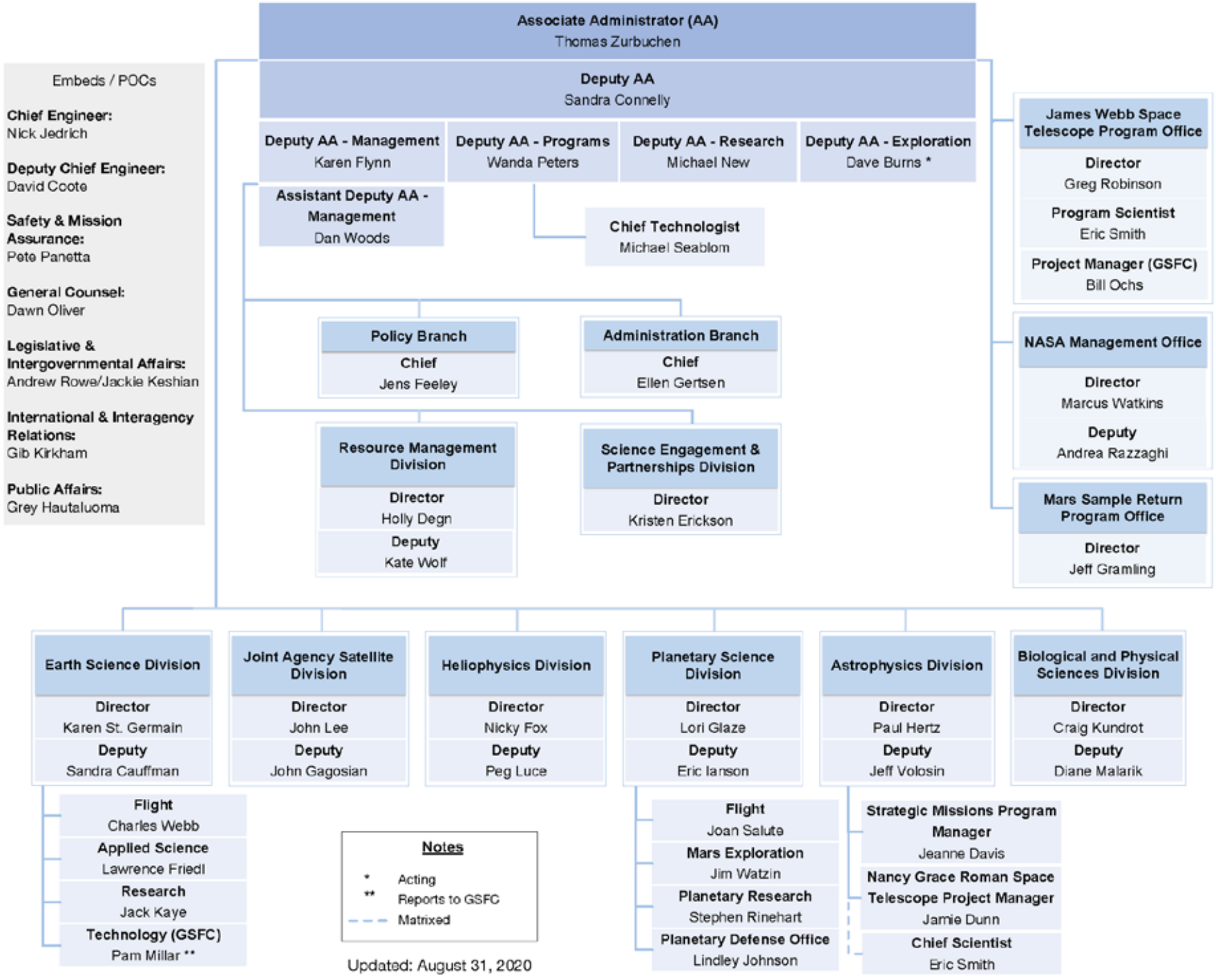
+ Athena (early 2030s), LISA (early 2030s)

Astrophysics Budget

	Actual 2019	Actual 2020	Request 2021	Out-years 2022	2023	2024	2025
Astrophysics	**1,191.1**	**1,306.1**	**831.0**	**891.2**	**1,000.9**	**959.7**	**975.5**
Astrophysics Research	222.8	231.2	269.7	279.1	327.2	314.9	331.1
Astrophysics Research and Analysis	83.4	86.6	90.2	92.2	94.2	94.2	94.2
Balloon Project	40.2	44.8	44.8	45.8	45.7	46.3	46.3
Science Activation	45.0	45.6	45.6	45.6	45.6	45.6	45.6
Astrophysics Directed R&T	4.5	-	25.7	29.4	23.3	9.0	25.5
Other Missions and Data Analysis	49.7	54.3	63.4	66.1	118.4	119.8	119.5
Cosmic Origins	222.8	202.7	124.0	123.2	120.0	122.4	122.4
Hubble Space Telescope Operations	98.3	90.8	88.3	98.3	98.3	98.3	98.3
SOFIA	85.2	85.2	12.0	-	-	-	-
Other Missions and Data Analysis	39.3	26.7	23.7	24.9	21.7	24.1	24.1
Physics of the Cosmos	151.2	132.8	143.9	160.8	155.3	169.8	154.1
Euclid	17.2	7.1	11.0	8.9	9.9	10.3	9.5
Fermi Gamma-ray Space Telescope	16.5	13.1	13.8	13.9	-	-	-
Chandra X-Ray Observatory	61.7	60.2	62.3	62.8	62.8	62.8	62.8
XMM	4.5	3.5	3.5	3.5	-	-	-

Astrophysics Budget

	Actual 2019	Actual 2020	Request 2021	Out-years 2022	2023	2024	2025
Exoplanet Exploration	367.9	554.2	47.2	50.4	47.6	51.6	52.2
WFIRST	312.2	510.7	-	-	-	-	-
Keck Operations	6.5	6.6	6.9	7.0	7.2	7.4	7.4
Kepler	8.9	1.3	-	-	-	-	-
Astrophysics Explorer	226.5	185.3	246.2	277.7	350.8	301.0	315.6
X-Ray Imaging and Spectroscopy Mission	23.2	24.2	25.1	36.3	17.7	15.9	14.4
Spectro-Photometer for the History of th	22.2	58.7	90.8	109.1	87.7	28.4	13.0
Contribution to ARIEL Spectroscopy of Ex	-	1.0	11.9	10.2	10.0	6.4	1.0
Astrophysics Explorer Future Missions	2.3	7.6	10.6	58.0	219.2	241.5	278.1
Astrophysics Explorer Program Management	4.9	5.0	20.7	18.0	10.7	8.3	9.1
Neutron Star Interior Composition Explor	3.8	4.8	4.8	4.4	-	-	-
Transiting Exoplanet Survey Satellite	7.7	7.4	14.7	14.1	-	-	-
Imaging X-Ray Polarimetry Explorer	57.0	59.5	45.3	7.4	4.5	0.5	-
Galactic/Extragalactic ULDB Spectroscopi	19.9	3.4	7.8	5.8	1.0	-	-
Neil Gehrels Swift Observatory	7.0	6.0	5.8	5.8	-	-	-
Nuclear Spectroscopic Telescope Array	8.5	7.8	8.6	8.6	-	-	-
James Webb Space Telescope	**305.1**	**423.0**	**414.7**	**175.4**	**172.0**	**172.0**	**172.0**
Astrophysics + Webb Total	**1,496.2**	**1,729.1**	**1,245.7**	**1,066.6**	**1,172.9**	**1,131.7**	**1,147.5**


Associate Administrator (AA)
Thomas Zurbuchen
Deputy AA
Sandra Connelly
Deputy AA - Management
Karen Flynn
Deputy AA - Programs
Wanda Peters
Deputy AA - Research
Michael New
Deputy AA - Exploration
Dave Burns *
Assistant Deputy AA - Management
Dan Woods
Chief Technologist
Michael Seablom
Policy Branch
Chief
Jens Feeley
Administration Branch
Chief
Ellen Gertsen
Resource Management Division
Director
Holly Degn
Deputy
Kate Wolf
Science Engagement & Partnerships Division
Director
Kristen Erickson
James Webb Space Telescope Program Office
Director
Greg Robinson
Program Scientist
Eric Smith
Project Manager (GSFC)
Bill Ochs
NASA Management Office
Director
Marcus Watkins
Deputy
Andrea Razzaghi
Mars Sample Return Program Office
Director
Jeff Gramling
Embeds / POCs
Chief Engineer:
Nick Jedrich
Deputy Chief Engineer:
David Coote
Safety & Mission Assurance:
Pete Panetta
General Counsel:
Dawn Oliver
Legislative & Intergovernmental Affairs:
Andrew Rowe/Jackie Keshian
International & Interagency Relations:
Gib Kirkham
Public Affairs:
Grey Hautaluoma
Earth Science Division
Director
Karen St. Germain
Deputy
Sandra Cauffman
Joint Agency Satellite Division
Director
John Lee
Deputy
John Gagosian
Heliophysics Division
Director
Nicky Fox
Deputy
Peg Luce
Planetary Science Division
Director
Lori Glaze
Deputy
Eric Ianson
Astrophysics Division
Director
Paul Hertz
Deputy
Jeff Volosin
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Director
Craig Kundrot
Deputy
Diane Malarik
Flight
Charles Webb
Applied Science
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Research
Jack Kaye
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Jeanne Davis
Nancy Grace Roman Space Telescope Project Manager
Jamie Dunn
Chief Scientist
Eric Smith
Notes
* Acting
** Reports to GSFC
Matrixed
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