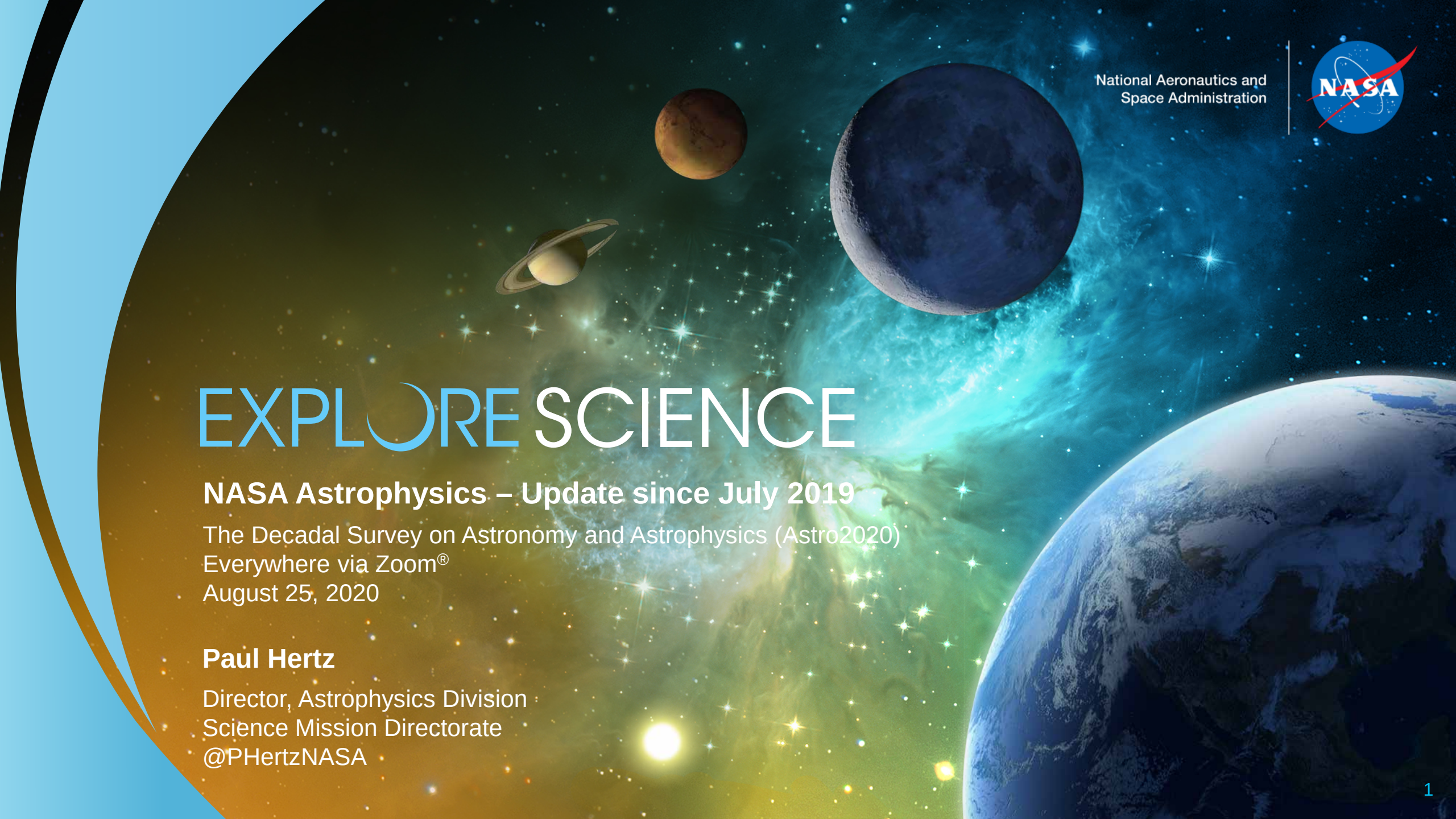


NASA Astrophysics – Update since July 2019

The Decadal Survey on Astronomy and Astrophysics (Astro2020)
Everywhere via Zoom®
August 25, 2020

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

Request from Decadal Survey Committee

For all Agencies:

It would be helpful if answers could be provided as numbers in an excel spreadsheet or table rather than sand charts (which are difficult to convert to numbers accurately). [Charts 30-31, also provided as a spreadsheet]

For NASA:

Please provide program updates relative to any assumptions presented to Astro2020 in July 2019. For example, this might include updates to launch dates for major missions, adjustment to Explorer launch rates, duration of operations funding for SOFIA, etc. Please also provide the Explorer launch rates assumed in the July 2019 presentation. [Charts 10-28]

Please provide planning numbers for funds available for new strategic initiatives between 2020 – 2040 for pessimistic, nominal, and most optimistic budget scenarios. [Charts 36-38]

Please provide the budget for the Explorers Program from 2020 through 2040. [Charts 34-35]

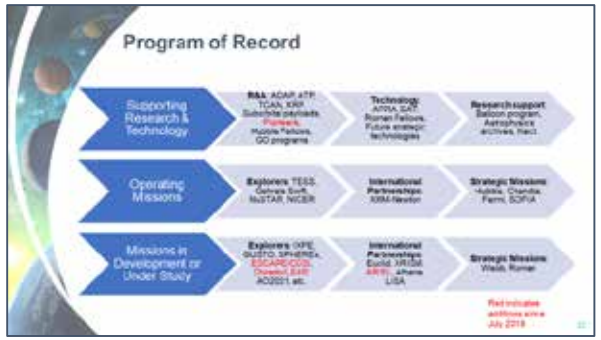
Decadal Survey Goal

- 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
- Now is the time to be ambitious

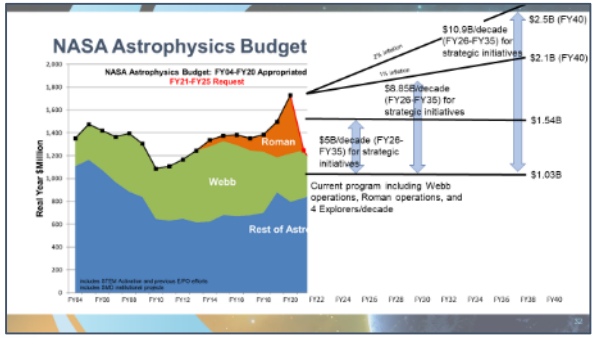
Outline

Context

Update to the Program of Record



Update to the Planning Guidelines



Context

NASA Core Values

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.*

State of the Profession and the Next Generation

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
- NASA and SMD are prioritizing diversity, inclusion, equity, and accessibility both internally and for NASA-selected and funded projects and teams

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

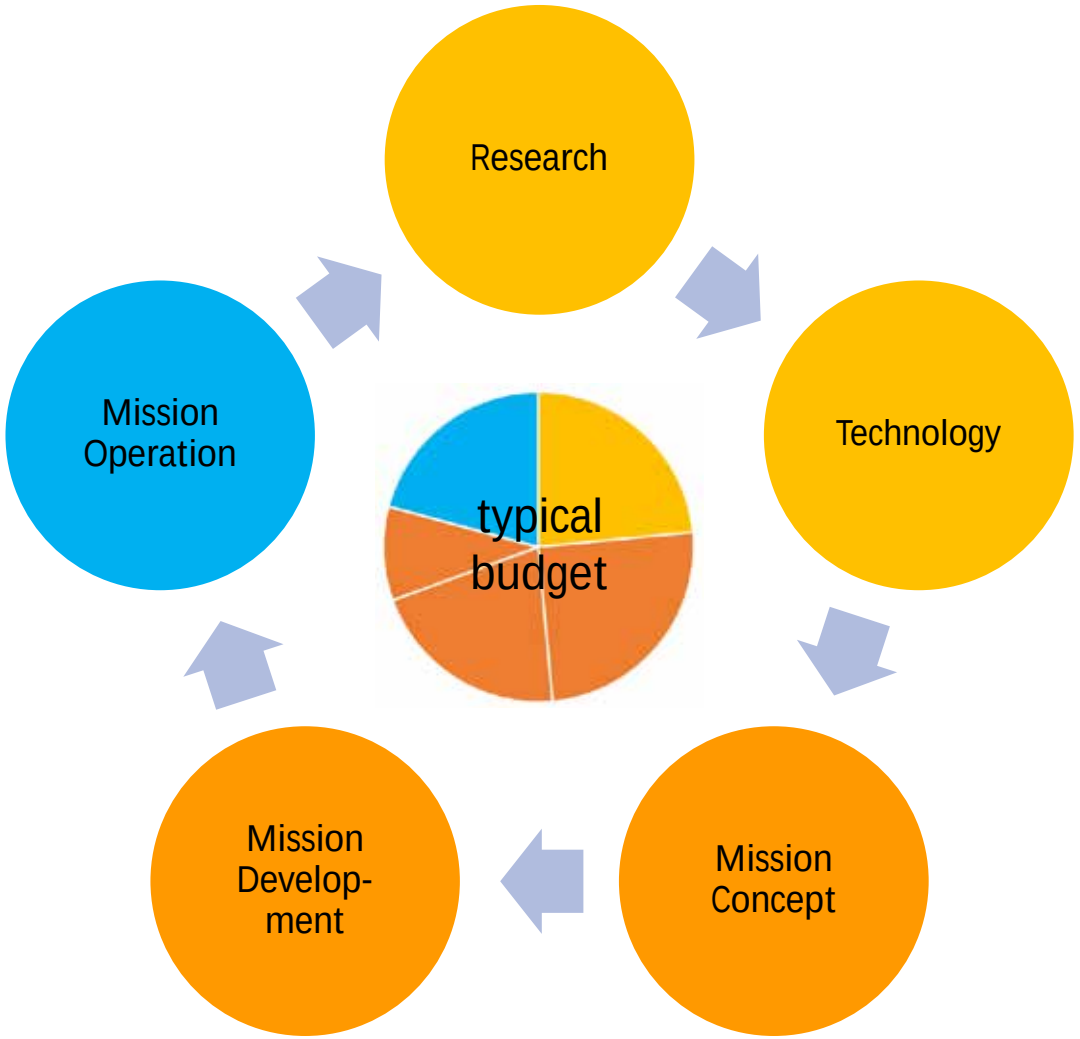
- SMD is prioritizing funded extensions to support graduate students, post docs, and early career researchers
- SMD is temporarily expanding the NASA Postdoctoral Program

NASA awaits actionable and practical recommendations from this Committee to advance the state of our profession

Astrophysics Advisory Committee recommendations on the State of the Profession

Recommendation (numbers added)		Snapshot August 25, 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 and recognizes their contributions to advancing the Astrophysics Division's strategic scientific, education, and technical enterprise.	Thomas Zurbuchen made such a clear statement at his recent SMD Town Hall. Paul Hertz is making such a statement at this meeting.
2	The APAC advises the Astrophysics Division to conduct a professionally led equity-audit of institutional racism within the Division.	This is under consideration by the SMD Anti-Racism Action Group and the SMD D&I Working Group.
3	The APAC strongly recommends ensuring BIPOC representation in future APAC membership.	BIPOC voices will continue be among the diverse set of voices on the APAC; BIPOC astrophysicists will be considered among the next set of new members .
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.	This is one of the objectives of the SMD Anti-Racism Action Group.
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 encouraging such authorization.
7	The APAC recommends establishing additional channels for more extensive community input in APAC discussions.	The Astrophysics Division is investigating alternative capabilities for allowing extensive community input during APAC meetings, beginning at the October 2020 meeting.

Update to the Program of Record



NASA's Astrophysics Program

Large (Flagship) Missions

- Conduct compelling science that only the U.S. has the capability to lead

Medium (Probe) and Small (Explorer) Missions

- Enable more focused or specialized capabilities and science objectives

International Partnerships

- Use scientific synergies between NASA and its international partners for a win-win outcome

Supporting Research and Technology

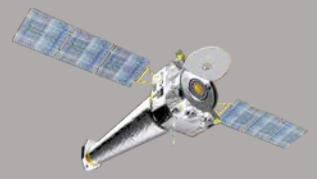
- Lay the foundation of the NASA science program
- Invest in the US scientific community and National capabilities
- Maximize scientific output of missions
- Develop innovative ideas and next generation technology for future missions
- Develop the next generation of scientists, engineers, and innovators

Astrophysics Missions in Operations

Hubble 4/90
NASA Strategic Mission

Operations Nominal

Chandra 7/99
NASA Strategic Mission



Operations Nominal

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

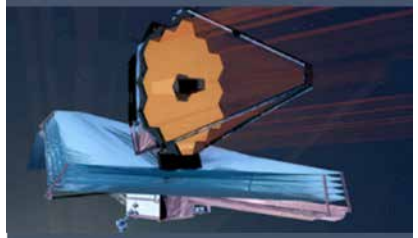
Operations Suspended

Data Archives
HEASARC, IPAC, MAST, etc.

Operations Nominal

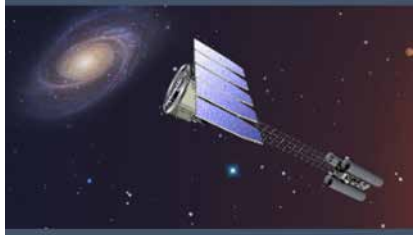
Astrophysics Missions in Development

Webb — 2021
NASA Mission



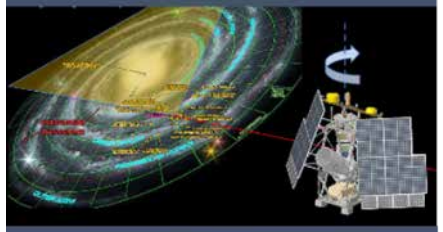
James Webb
Space Telescope

IXPE — 2021
NASA Mission



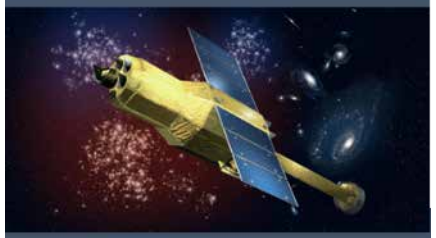
Imaging X-ray
Polarimetry Explorer

GUSTO — 2021
NASA Mission



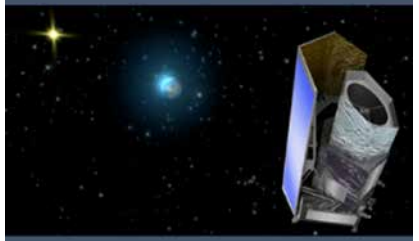
Galactic/ Extragalactic ULDB
Spectroscopic Terahertz Observatory

XRISM — 2022
JAXA-led Mission



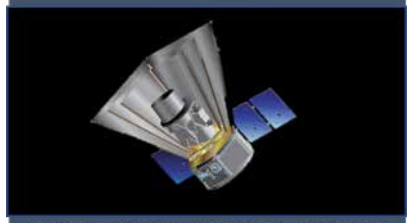
NASA is supplying the SXS
Detectors, ADRs, and SXTs

Euclid — 2022
ESA-led Mission



NASA is supplying the NISP
Sensor Chip System (SCS)

SPHEREx — 2023
NASA Mission



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

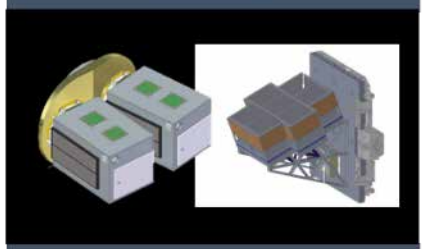
New

SMEX — ~2025
NASA Mission

COSI or ESCAPE

New

Mission of Opportunity — ~2025
NASA Mission



Dorado or LEAP

Roman — 2025
NASA Mission

Nancy Grace Roman
Space Telescope

New

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

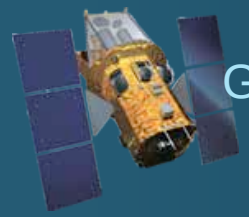
COVID Impacts to Missions in Development

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

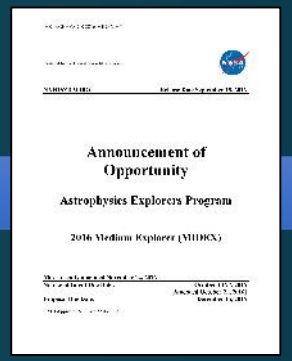
NuSTAR

MIDEX 2021 Community Announcement planned for August 2020

4 AOs per decade

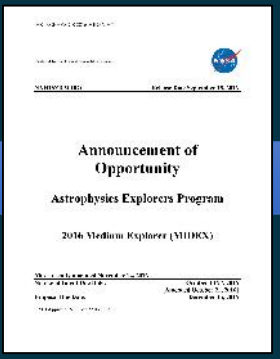
MIDEX 2011

SMEX 2014



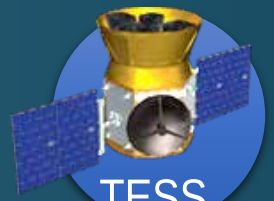
MIDEX 2016

SMEX 2019



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

Webb

The James Webb Space Telescope

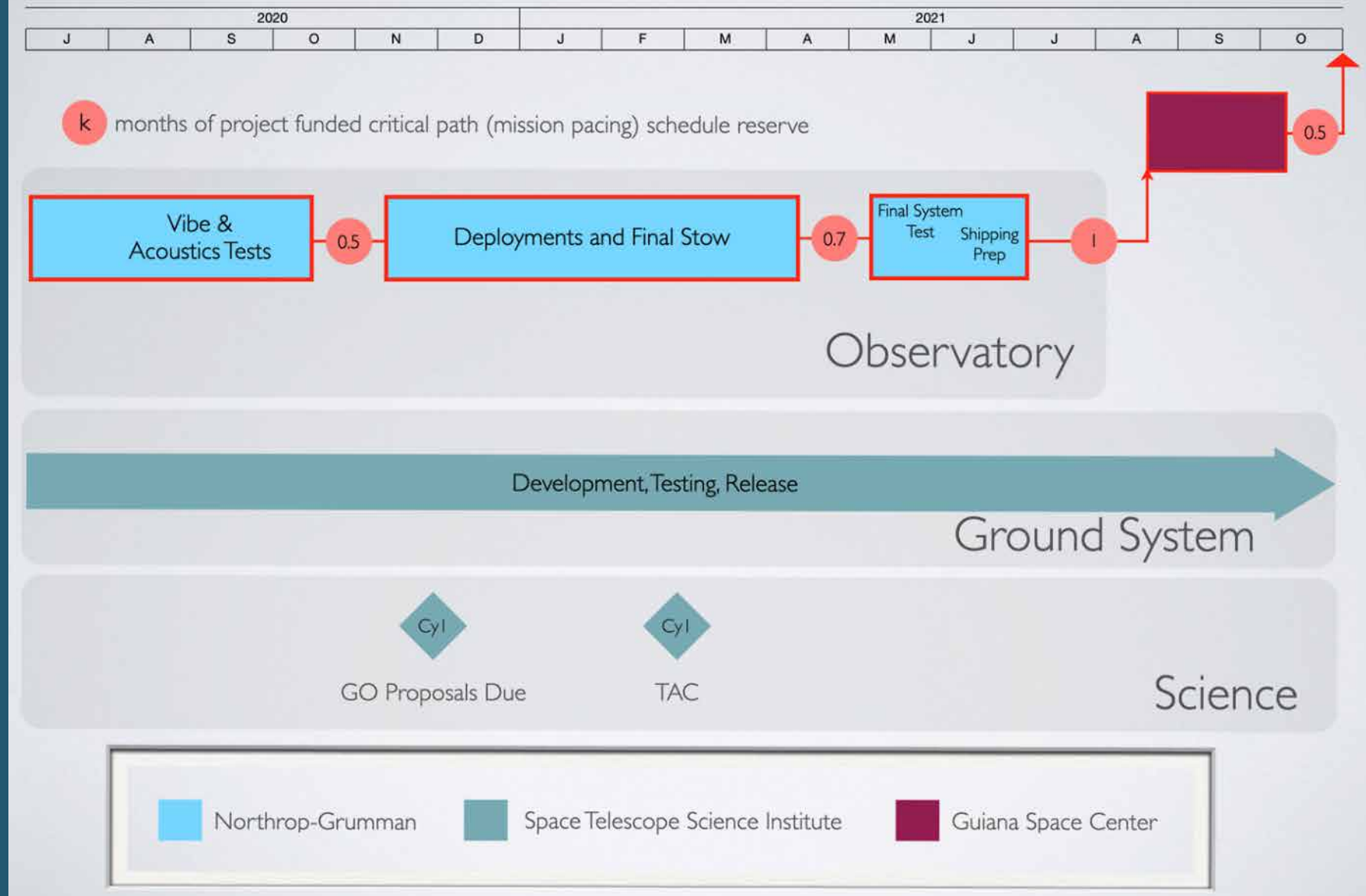
NASA's James Webb Space Telescope fully stowed into the same configuration it will have when loaded into an Ariane V rocket for launch. The image was taken from a webcam in the clean room at Northrop Grumman, in Redondo Beach, California. Image credit: Northrop Grumman

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
  - Vibration testing
- Following environmental testing
  - Deployment and folding
  - Shipping to Kourou
- Launch rehearsals resuming at STScI
- Ariane 5 rocket components being built for launch
- Cycle 1 proposals due Nov 24, 2020

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

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.

Roman Space Telescope

On February 28, 2020, Roman passed the Confirmation Review (KDP-C) and was approved by the Agency Program Management Council to begin implementation (Phase C in NASA terminology)

Only change is Coronagraph Instrument (CGI) Technology Demonstration programmatic status

- CGI is being managed like other SMD technology demonstration projects (Mars Helicopter, Deep Space Optical Communications)

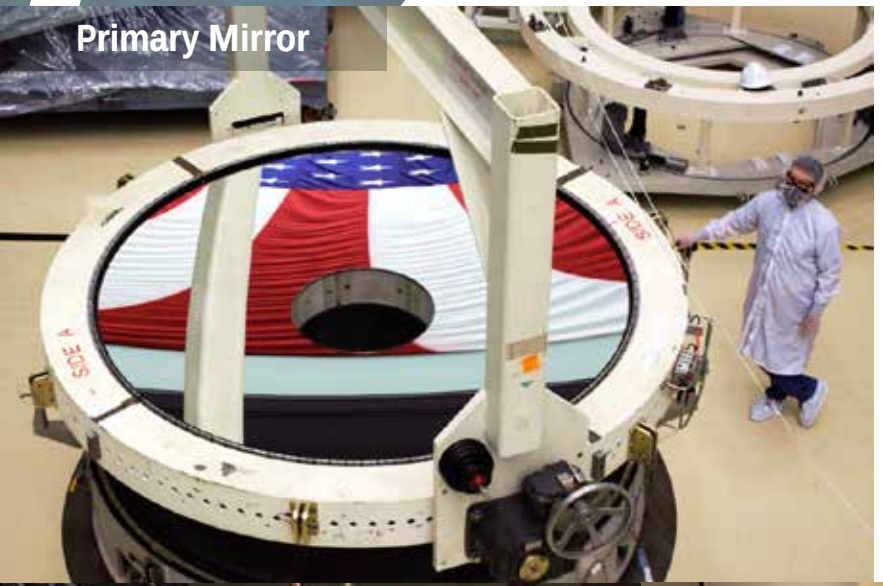
Roman has an expected development cost of $3.2 billion. Including the cost of five years of operations and science, and CGI development ($334M), brings the maximum cost of Roman to $3.934 billion.

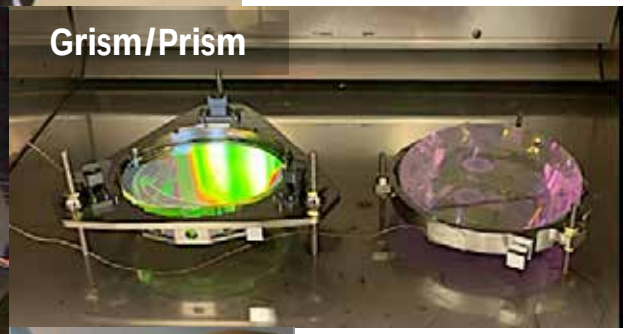
Cost and schedule commitments are unchanged since initial confirmation in 2018 (KDP-B or Phase B in NASA terminology)

COVID-19 update:

- Currently limited on-site work is taking place at GSFC and JPL per NASA plans for return-to-site (https://nasapeople.nasa.gov/coronavirus/).
- Work continues at many contractors, consistent with local situations
- Impacts to schedule and cost: work delayed at NASA, contractors, and suppliers

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; 10 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 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

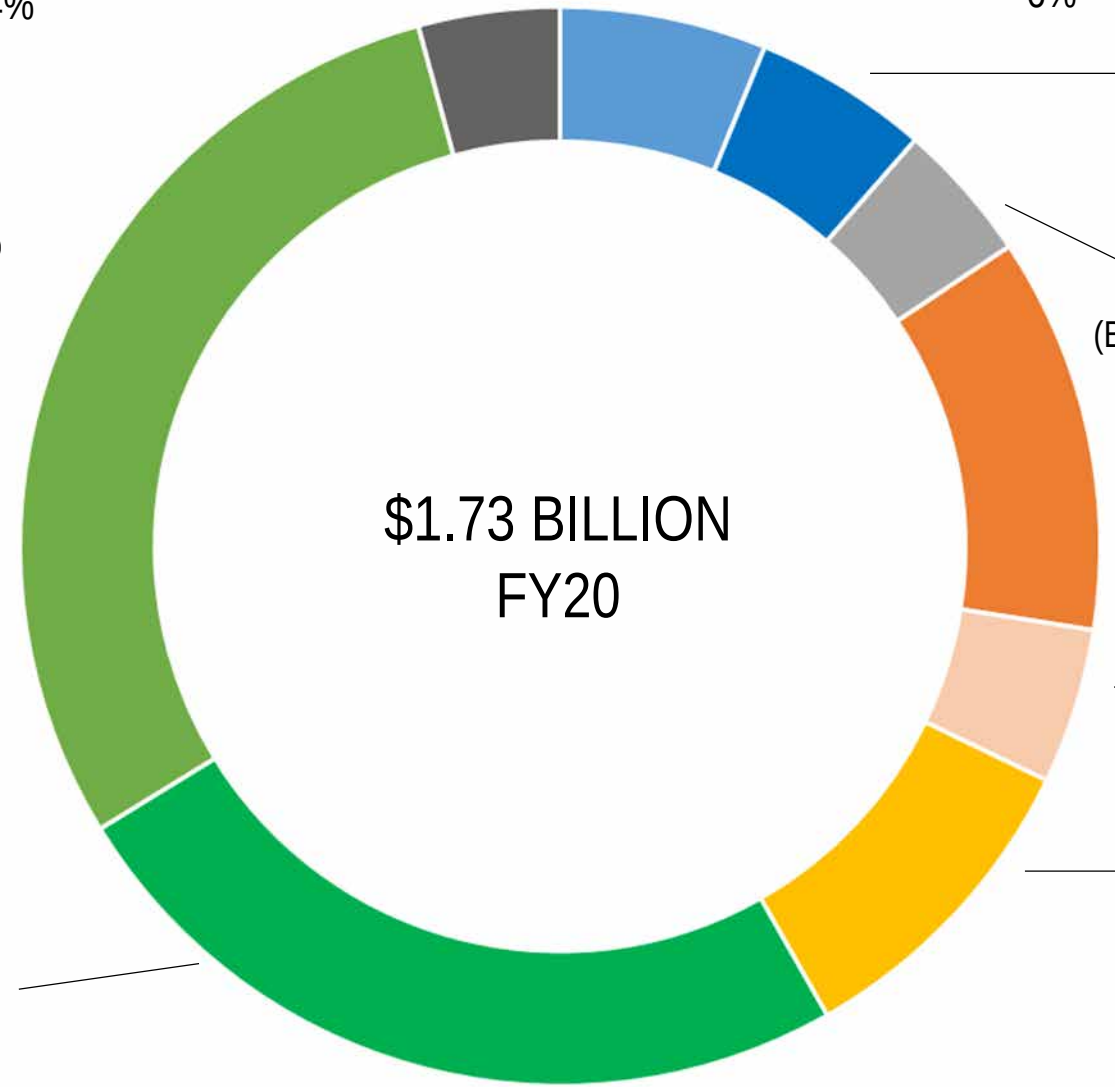
Roman Coronagraph Community Participation Program

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

Program of Record

Supporting Research & Technology	**R&A**: ADAP, ATP, TCAN, XRP, Suborbital payloads, Pioneers, Hubble Fellows, GO programs	**Technology**: APRA, SAT, Roman Fellows, Future strategic technologies	**Research support**: Balloon program, Astrophysics archives, Keck
Operating Missions	**Explorers**: TESS, Gehrels Swift, NuSTAR, NICER	**International Partnerships**: XMM-Newton	**Strategic Missions**: Hubble, Chandra, Fermi, SOFIA
Missions in Development or Under Study	**Explorers**: IXPE, GUSTO, SPHEREx, ESCAPE/COSI, Dorado/LEAP, AO2021, etc.	**International Partnerships**: Euclid, XRISM, ARIEL, Athena, LISA	**Strategic Missions**: Webb, Roman

Red indicates additions since July 2019



Quick Summary

Community support: 20%

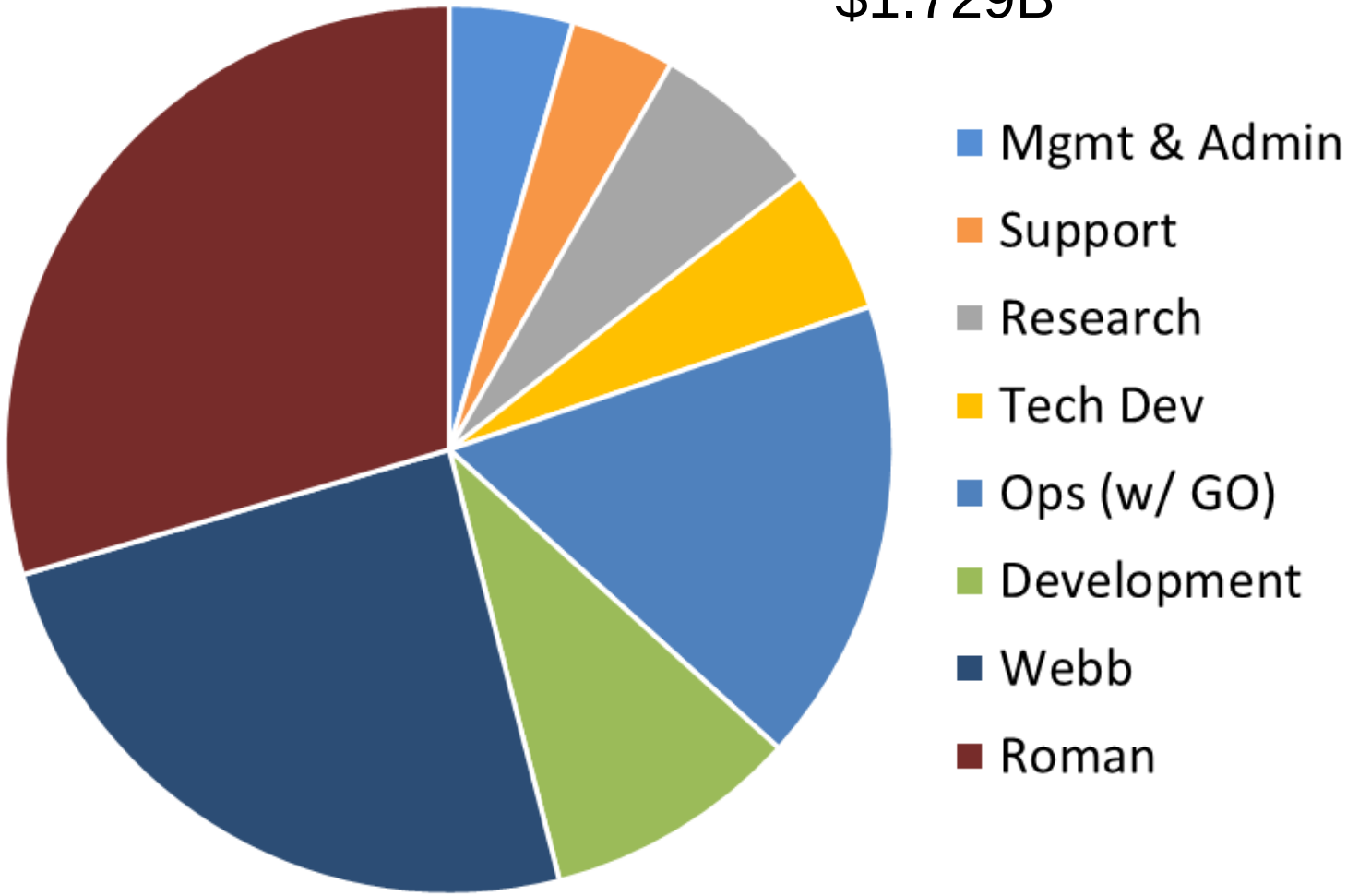
Operating missions: 12%

Building missions: 64%

Management: 4%

FY20 Budget Snapshot

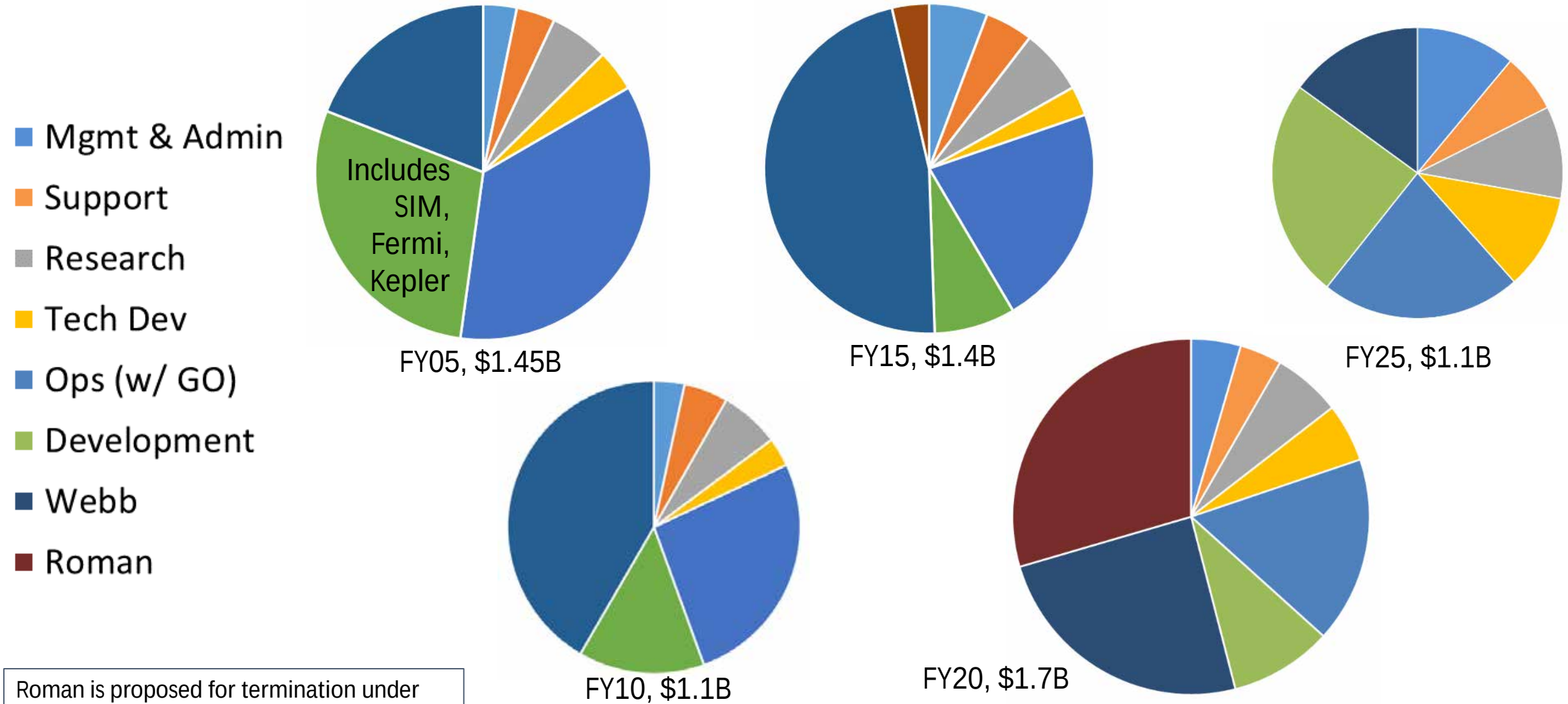
$1.729B



Flagship development is 54% of budget, which is historically in family

FY05, FY10, FY15, FY20, FY25 Budget Snapshots

In FY25, Webb is in Operation



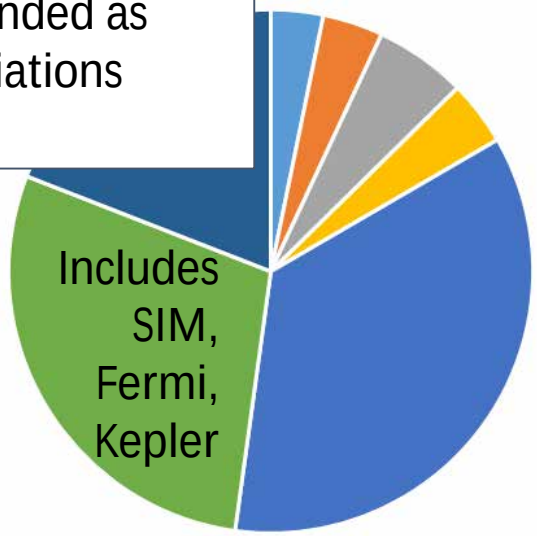
Roman is proposed for termination under the President's FY21 Budget Request

FY05, FY10, FY15, FY20, FY25 Budget Snapshots

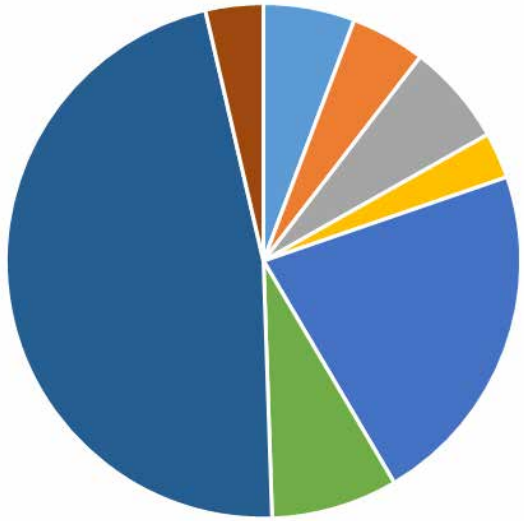
In FY25, Webb is in Operations

What if Roman is funded as part of the Appropriations process?

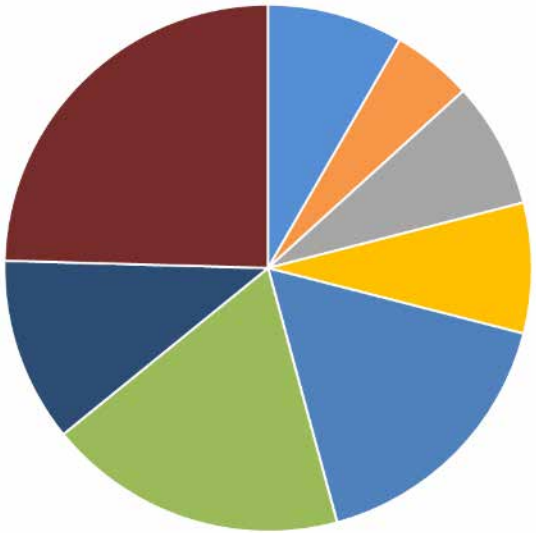
- Mgmt & Admin
- Support
- Research
- Tech Dev
- Ops (w/ GO)
- Development
- Webb
- Roman



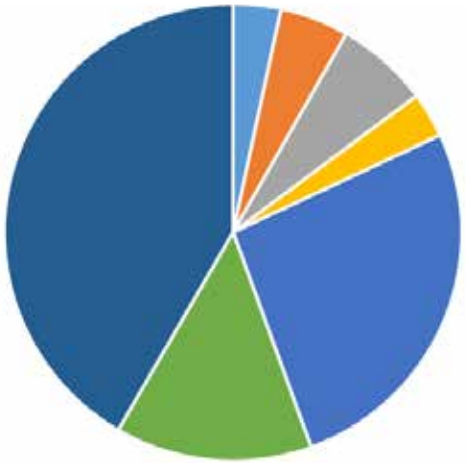
FY05, $1.45B



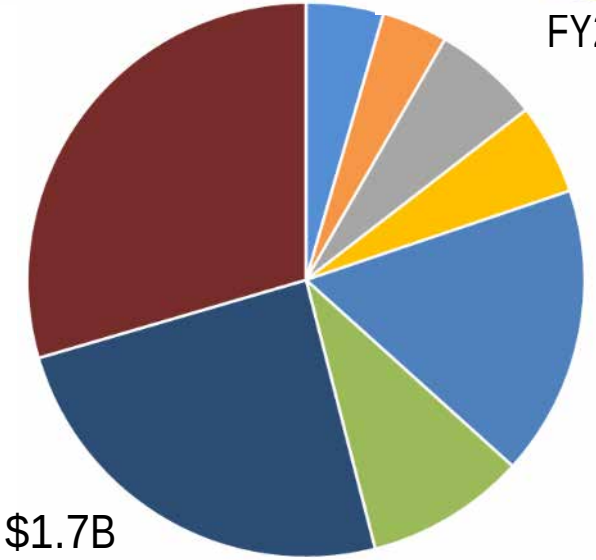
FY15, $1.4B



FY25, $1.5B

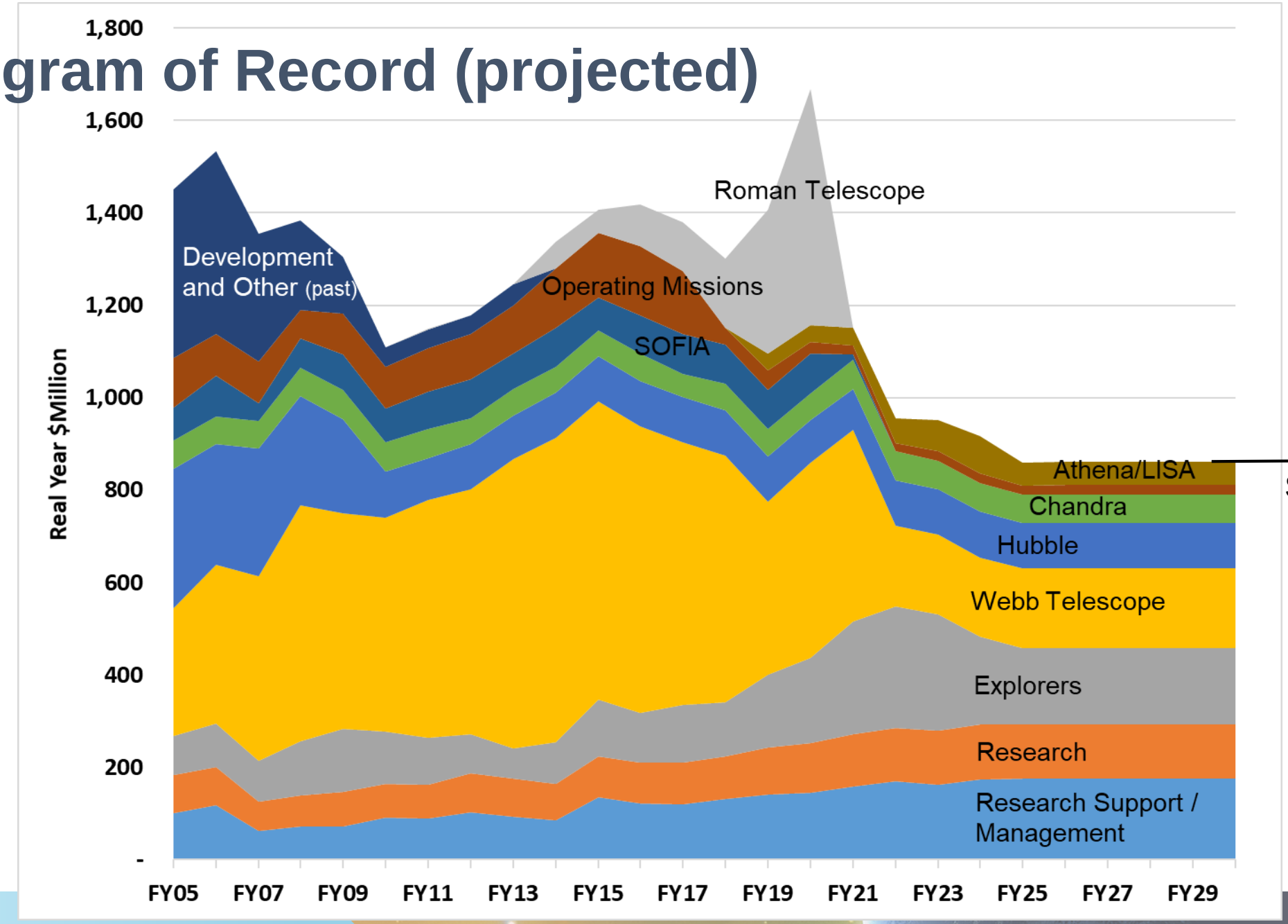


FY10, $1.1B



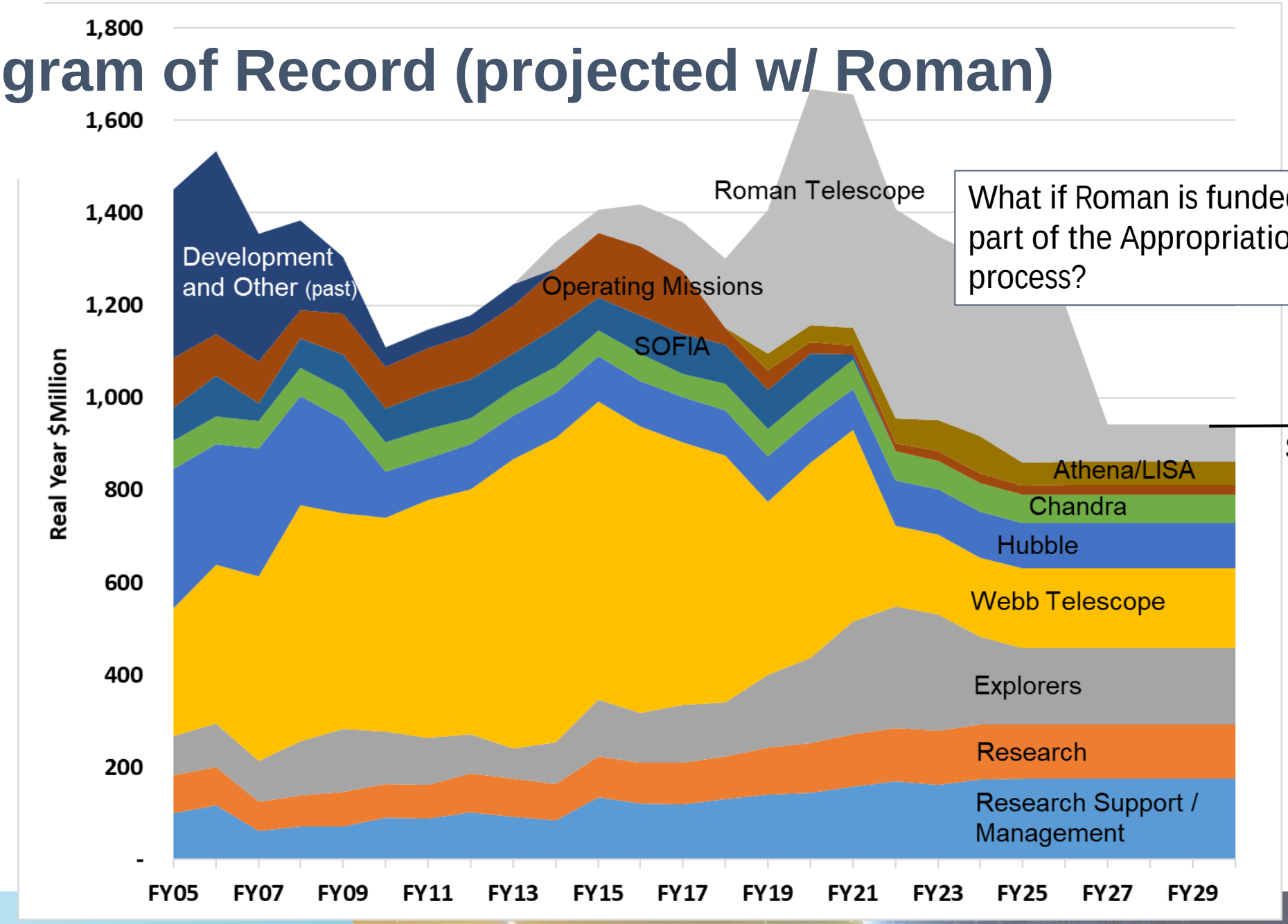
FY20, $1.7B

Program of Record (projected)



$860M

Program of Record (projected w/ Roman)



Update to the Planning Guidelines

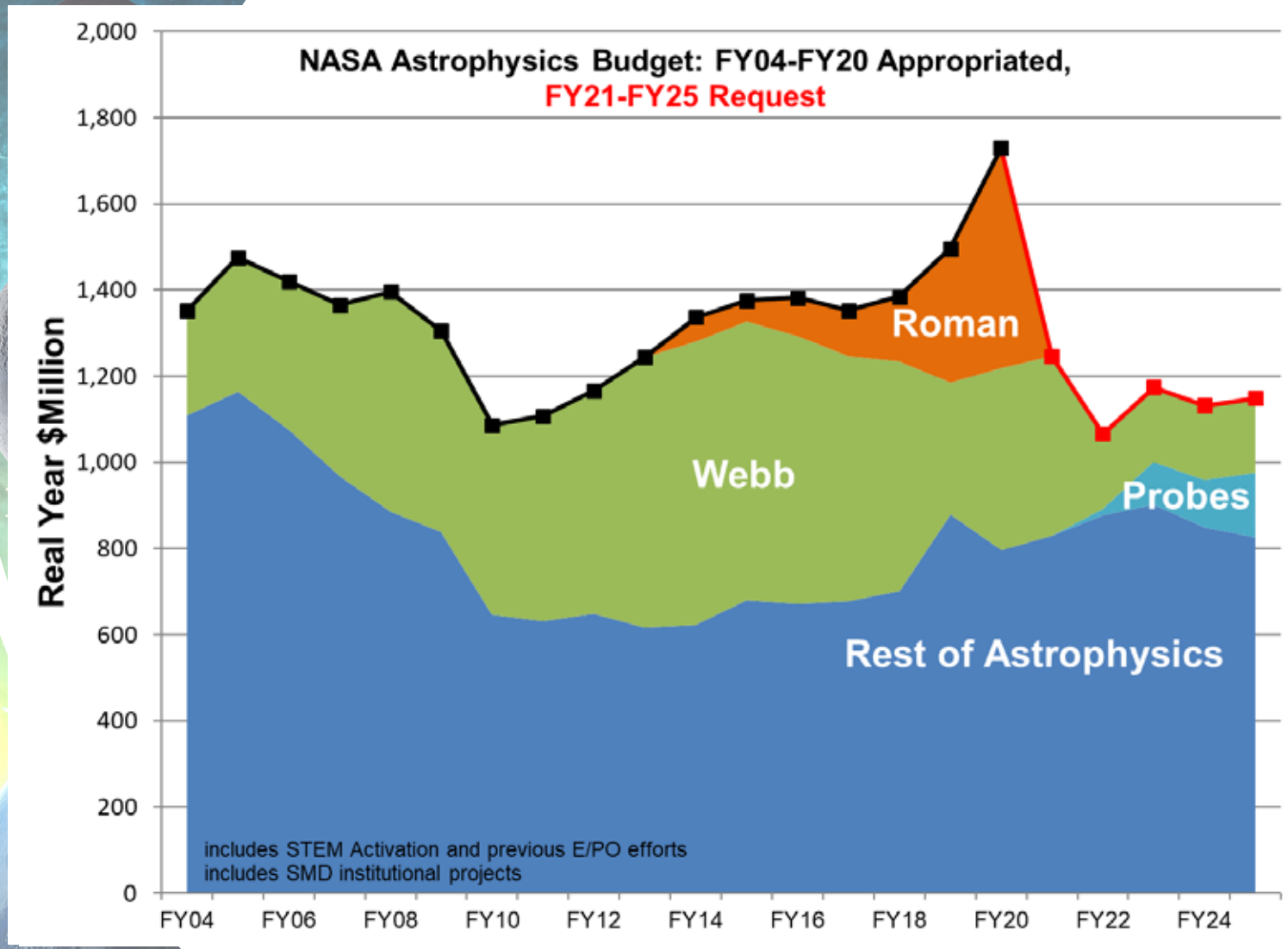
Astrophysics Budget

	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**

NASA Astrophysics Budget



Update on FY21 Appropriation

$M	Request	House	Senate	Comments
Astrophysics w/ Webb	1,245.7	1,729.2		
Astrophysics	831.0	1306.2		House mark equals FY20 appropriation, increase of $475.2M over request
Webb	414.7	423.0		House mark equals FY20 appropriation
Roman	0	505.2		House mark fully funds requirement
SOFIA	12.0	85.2		House mark equals FY20 appropriation
Everything else	819.0	715.8		House mark requires flat funding from FY20, reduction from FY21 planning of $103.2M

Explorers Program Planning

Total cost of a MIDEX

- Agency Baseline Commitment includes PI cost cap, launch vehicle, HQ reserves
  - TESS (actual) $333M (Phase B/C/D/E in FY13-FY20)
  - SPHEREx (estimated) $395M-$427M (Phase B/C/D/E in FY19-FY26)
  - MIDEX 2021 AO (planned) ~$450M (Phase B/C/D/E in FY24-FY31)

Total cost of a SMEX

- Agency Baseline Commitment includes PI cost cap, launch vehicle, HQ reserves
  - IXPE (committed) $213M (Phase B/C/D/E in FY17-FY23)
  - ESCAPE/COSI (planned) ~$240M (Phase B/C/D/E in FY21-FY27)

Total cost of a MO

- Agency Baseline Commitment includes PI cost cap, HQ reserves
  - NICER (actual) $62M (Phase B/C/D/E in FY13-FY19)
  - GUSTO (committed) $46M (Phase B/C/D/E in FY17-FY22)
  - ARIEL (estimated) $62M-$71M (Phase B/C/D/E in FY20-FY31)
  - Dorado/LEAP (planned) ~$80M (Phase B/C/D/E in FY21-FY26)
- Also need to budget for extended mission and GO/GI program
  - Extended Ops + GO/GI program is $5/10M/15M per year (MO/SMEX/MIDEX)
  - Partner MO requires a US data center, est. $3M-$5M per year

Key to cost terms used as a function of mission phase:

- Actual (Phase E) – Post-launch actual cost realized
- Committed (Phase C/D) – Post-confirmation baseline cost commitment
- Estimated (Phase B) – Pre-confirmation estimated range of costs
- Planned (Pre-Phase A and Phase A) – Future selection planning wedge

Explorers Program Planning

Current Snapshot:

- 2 MIDEX ($450M each)+ 2 SMEX ($240M each) + 4 MOs ($80M each) per decade
- Extended missions for 1 MIDEX ($15M/yr each) + 1 SMEX ($10M/yr each) + 1 MO ($5M/yr each) + 1 US Data Center ($5M/yr)
- Total: $205M/yr average (actually oscillates between SMEX and MIDEX peak spending years; currently also developing XRISM)

FY20 Appropriation + FY21 Budget Request:

	FY20	FY21	FY22	FY23	FY24	FY25
Proposed Explorers Budget	$185M	$245M	$278M*	$351M*	$301M*	$316M*
Planning for notional probe			$15M	$99M	$111M	$150M
Planning for Explorers	$185M	$245M	$263M	$251M	$190M	$165M

Guidance on Future Budgets

All guidance is for Astrophysics including Webb Telescope

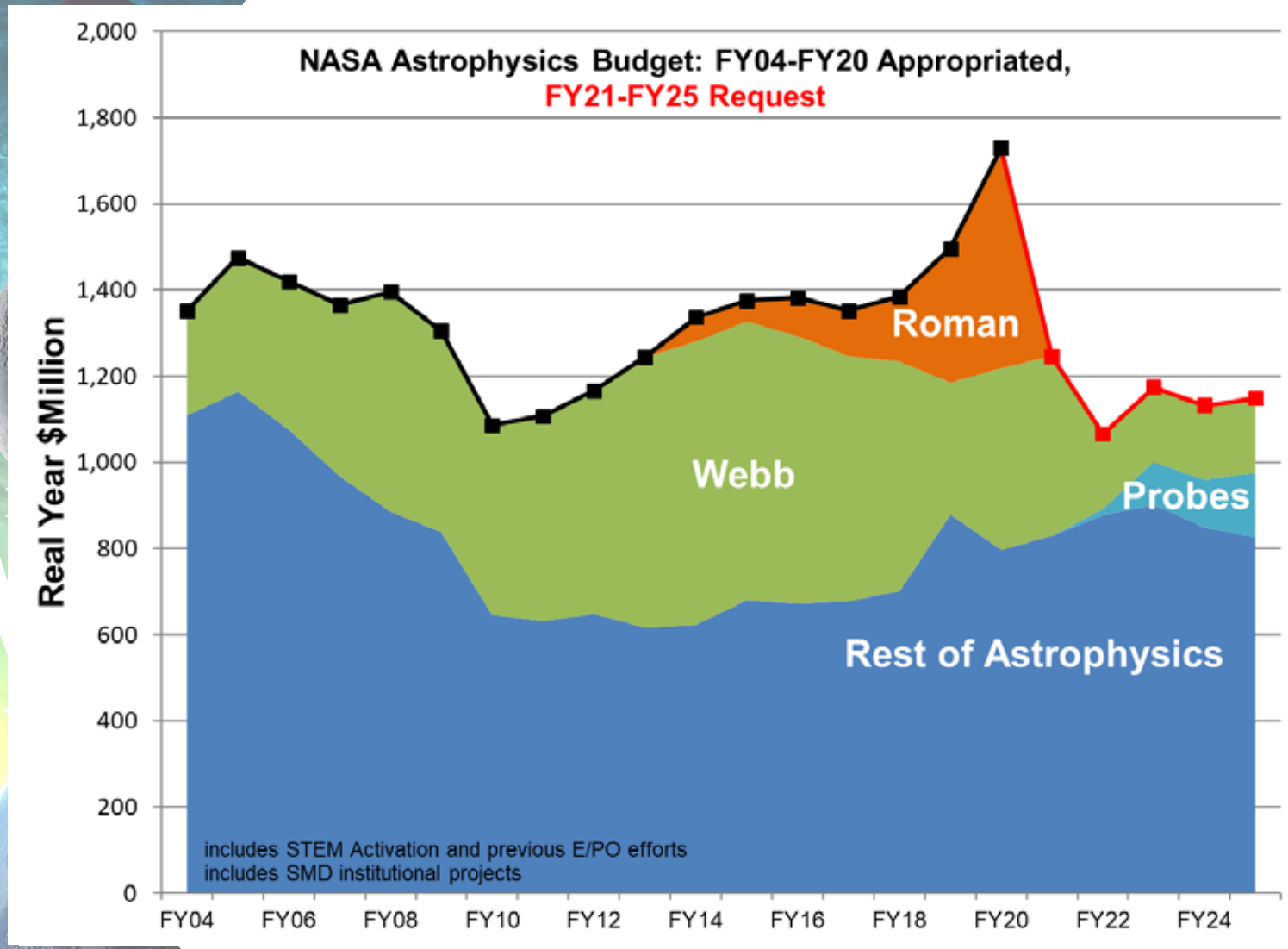
Lower bound budget projection – Extrapolation of out year planning numbers for President's FY21 budget request. Average of FY22-FY25 planning numbers is $1.1B/yr

Empirical budget projection – Extrapolation of recent NASA Astrophysics appropriations. Average of FY18-FY20 appropriations is $1.54B/yr

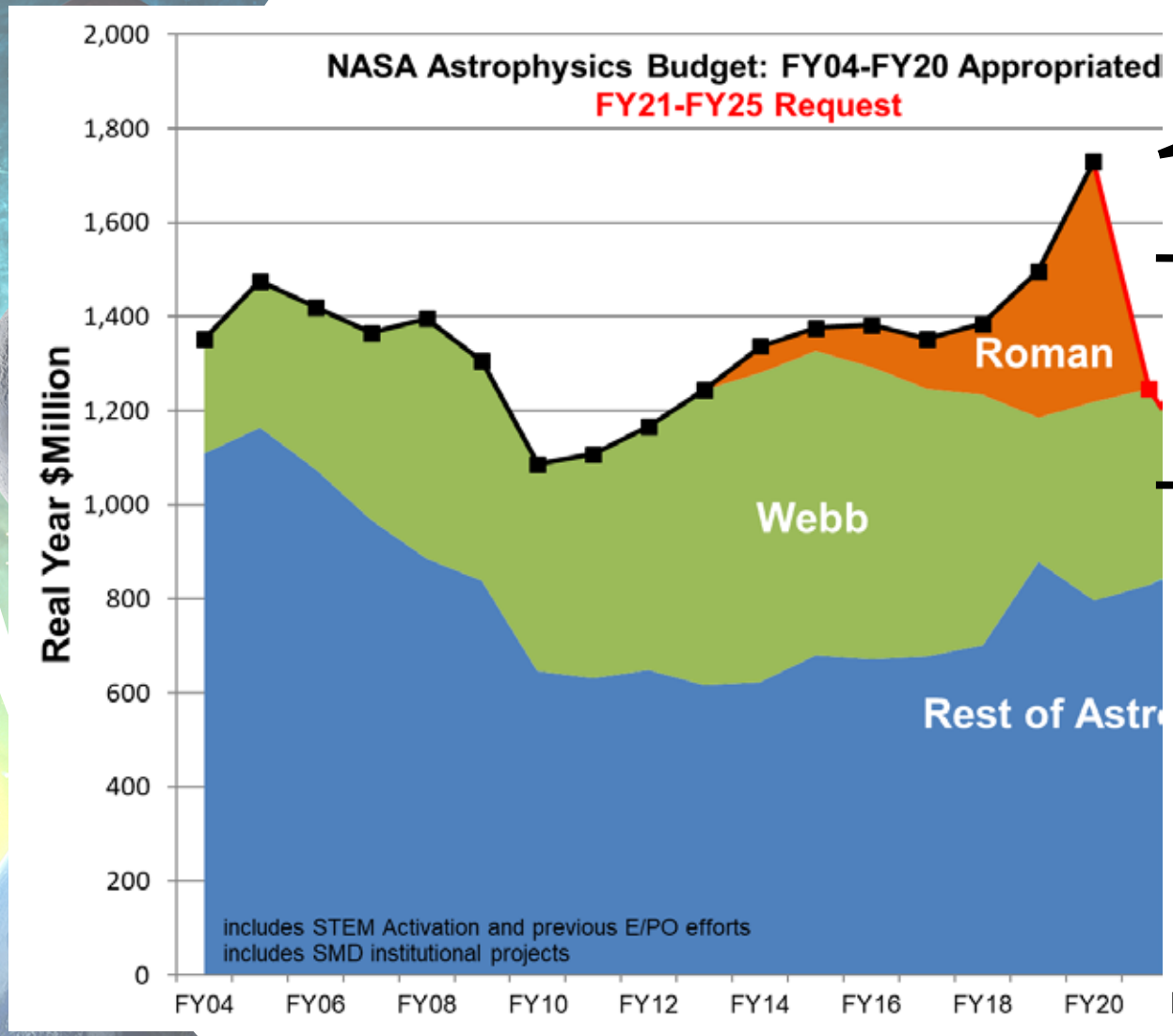
Optimistic budget projection – Empirical budget projection plus 1% inflationary growth in the out years. Budget grows from $1.7B (FY20) to $1.8B (FY25) to $1.9B (FY30) to $2.0B (FY35) to $2.1B (FY40)

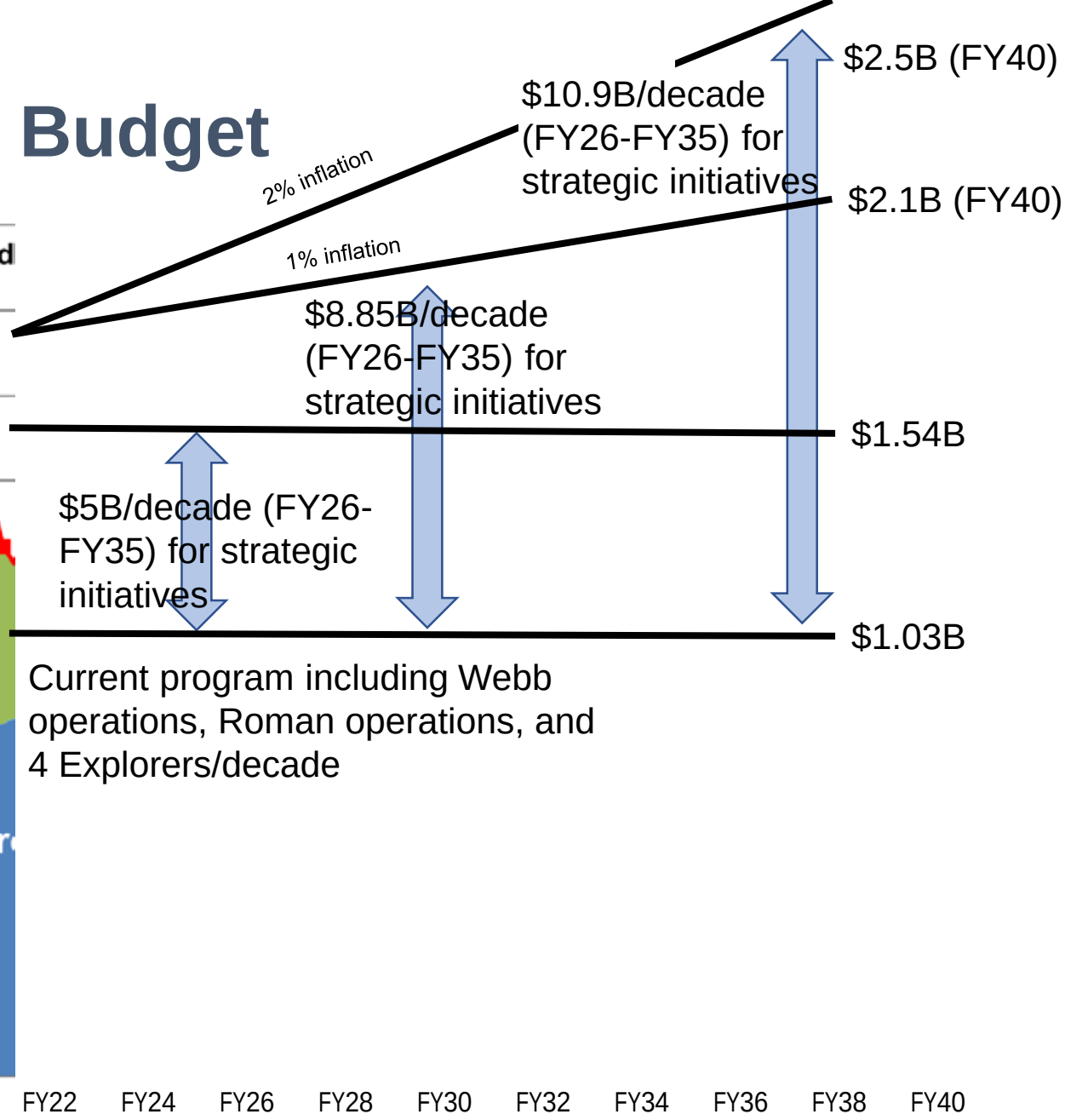
Upper bound budget projection – Empirical budget projection plus 2% inflationary growth in the out years. Budget grows from $1.7B (FY20) to $1.9B (FY25) to $2.1B (FY30) to $2.3B (FY35) to $2.5B (FY40)

NASA Astrophysics Budget



NASA Astrophysics Budget





Current program including Webb operations, Roman operations, and 4 Explorers/decade

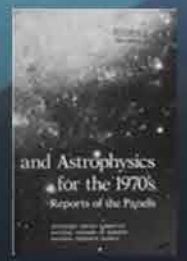
Decadal Survey Goal

- 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
- Now is the time to be ambitious

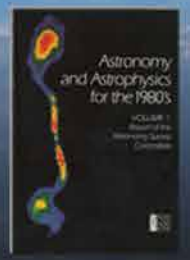
Carpe Posterum

Astrophysics

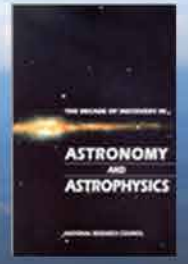
Decadal Survey Missions



1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer

2001
Decadal Survey
Webb

2010
Decadal Survey
Roman

2021
Decadal Survey