NASA Astrophysics Update

Committee on Astronomy and Astrophysics
March 31, 2020

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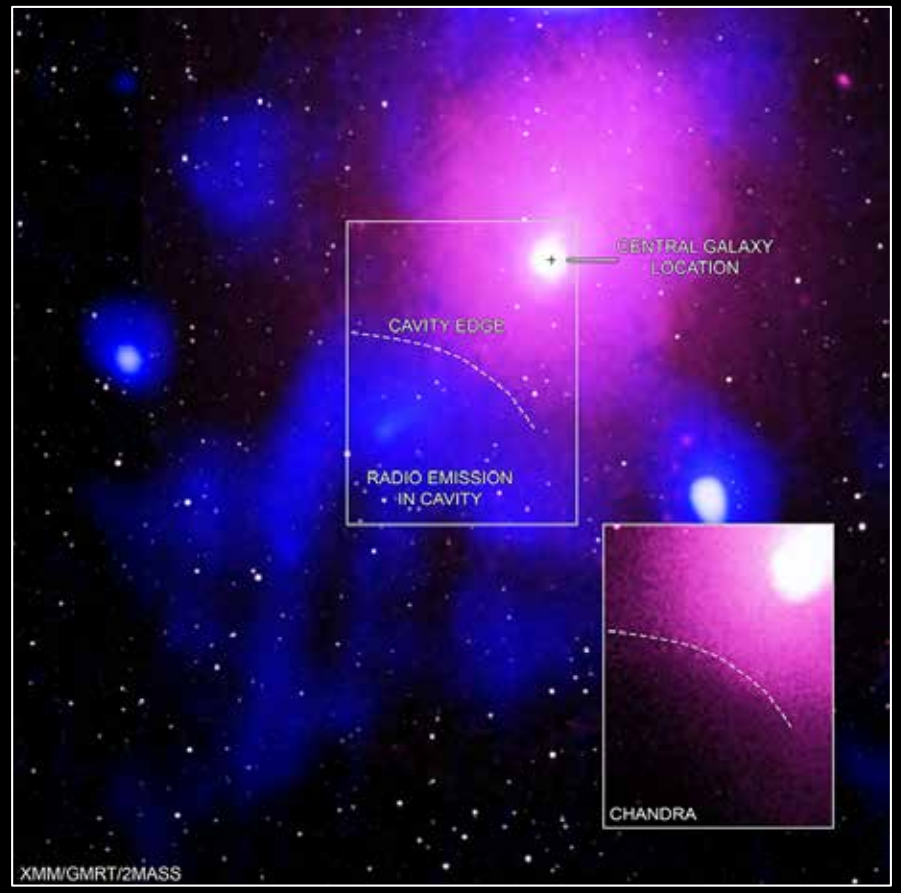
NASA Astrophysics Celebrate Accomplishments

https://www.nasa.gov/content/hubbles-30th-anniversary

Record-Breaking Explosion by Spotted by Chandra

Released February 27, 2020



Credit: X-ray: Chandra: NASA/CXC/NRL/S. Giacintucci, et al., XMM: ESA/XMM; Radio: NCRA/TIFR/GMRT; Infrared: 2MASS/UMass/IPAC-Caltech/NASA/NSF

Caption: Evidence for the biggest explosion seen in the Universe comes from a combination of X-ray data from Chandra and XMM-Newton (shown as pink in the inset and main panel, respectively), and the Murchison Widefield Array and Giant Metrewave Telescope (blue).

SCIENCE HIGHLIGHT

- The biggest explosion seen in the universe was detected in the Ophiuchus galaxy cluster, which is ~390 million light years from Earth.
- Astronomers made this record-breaking discovery using X-ray data from NASA's Chandra X-ray Observatory and ESA's XMM-Newton, and radio data from the Murchison Widefield Array in Australia and the Giant Metrewave Radio Telescope in India.
- In the center of the Ophiuchus cluster, there is a large galaxy that contains a supermassive black hole. Researchers have traced the likely source of this gigantic eruption to this black hole.
- Although black holes are famous for pulling material toward them, they often expel prodigious amounts of material and energy. This happens when matter falling toward the black hole is redirected into jets, or beams, that blast outward into space and slam into any surrounding material.
- Astronomers needed to combine the X-ray information along with the radio data in order to clinch this finding.
- They discovered that a cavity in the hot gas was filled almost perfectly with radio emission created by electrons that had been accelerated to nearly the speed of light.
- The amount of energy required to create the cavity in Ophiuchus is about five times greater than the previous record holder, MS 0735+74, and hundreds and thousands of times greater than typical clusters.

After 16.5 yrs of science exploration on the infrared cosmic frontier as one of NASA's Great Observatories, Spitzer ended its mission on 30 January 2020, 2:30 PST.

Engineering feats extended mission life post-cryo in 2009 and overcame challenges due to Spitzer's increasing distance from Earth.

Spitzer Space Telescope

Spitzer enabled discovery near and far, to the edge of the universe, yielding 8,800+ refereed papers.

- First detection of light from an exoplanet
- First detection of molecules in exoplanet atmospheres
- Measurement of star formation history of the Universe to z>2, looking back >10 Gyr
- Measurement of the stellar mass of the Universe to z>8, looking back ~13 Gyr

www.spitzer.caltech.edu/final-voyage

The Legacy of the Spitzer Space Telescope Celebrated

- Hosted by the California Institute of Technology and sponsored by Ball Aerospace
- 11-13 February 2020

https://conference.ipac.caltech.edu/legacyofspitzer/

TESS

Transiting Exoplanet Survey Satellite

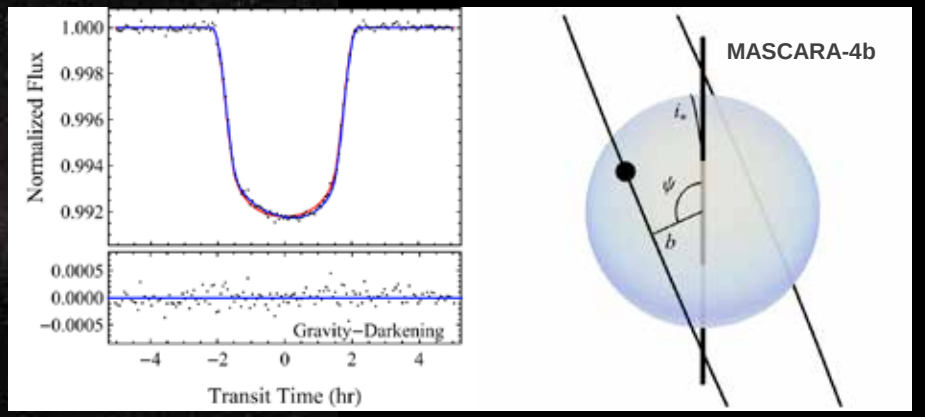
Observation Sector 22 (Orbit 51) in progress

41 confirmed planets
1700 planet candidates

223 publications submitted, 169 peer-reviewed (52% exoplanets, 48% astrophysics)

Last update: Feb **23**, 2020

TESS detects planets in misaligned orbits around rapidly rotating A-type stars



Oblate stars (due to rapid rotation) exhibit surface temperature gradients, with darkness near the stellar equator ('gravity-darkening')

Asymmetric transit shapes can reveal a planet in an orbit misaligned with the spin of a gravity-darkened star

- TESS observations of MASCARA-4b shows that it is a hot Jupiter in a highly misaligned orbit (Ahlers et al. 2020)
- TESS observations show Kepler-13Ab also exhibits spin-orbit misalignment (Szabo et al. 2020)
- TESS is expected to observe >400k rapid rotators and should find ~2k planets around A and F stars (Barclay et al. 2019), many of which will have spin-orbit misaligned orbits

WFIRST

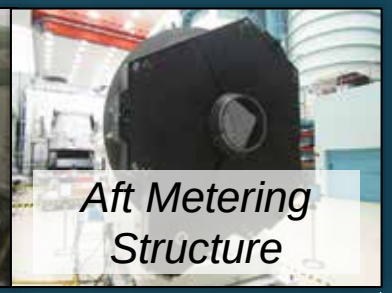
Confirmed and entered Phase C on Feb 28, 2020

https://www.nasa.gov/feature/nasa-approves-development-of-universe-studying-planet-finding-mission

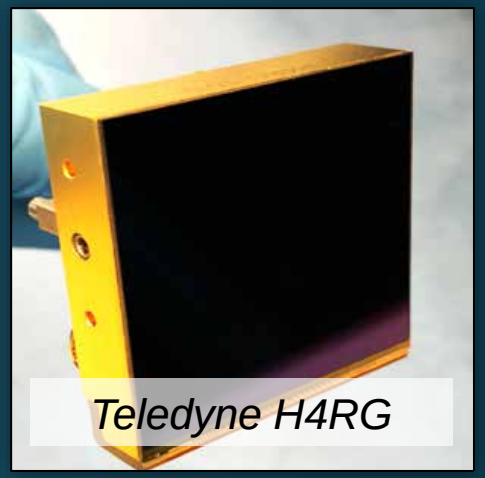
Progress on Hardware


Primary Mirror - Full Tool Polish (5/19)


Secondary Mirror


Aft Metering Structure

Telescope


Teledyne H4RG


Photon Counting CCD


Detector readout custom ASIC chip


F158 Filter


Prism assembly

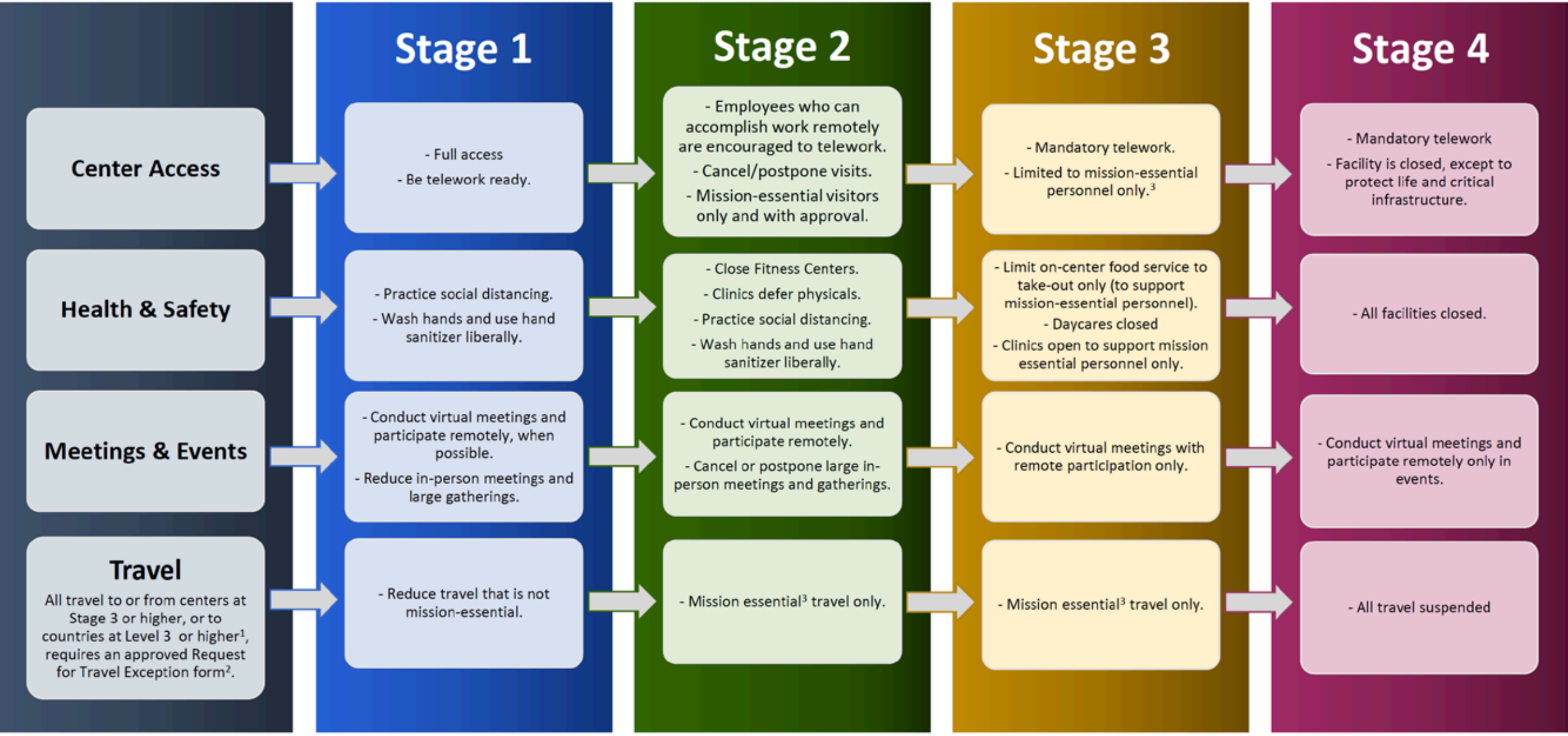

Deformable Mirrors

Instruments

NASA Science Coronavirus Status

NASA Response Framework

* This guidance applies to NASA civil servants. Contract employees should reach out to their contracting officer's representative.



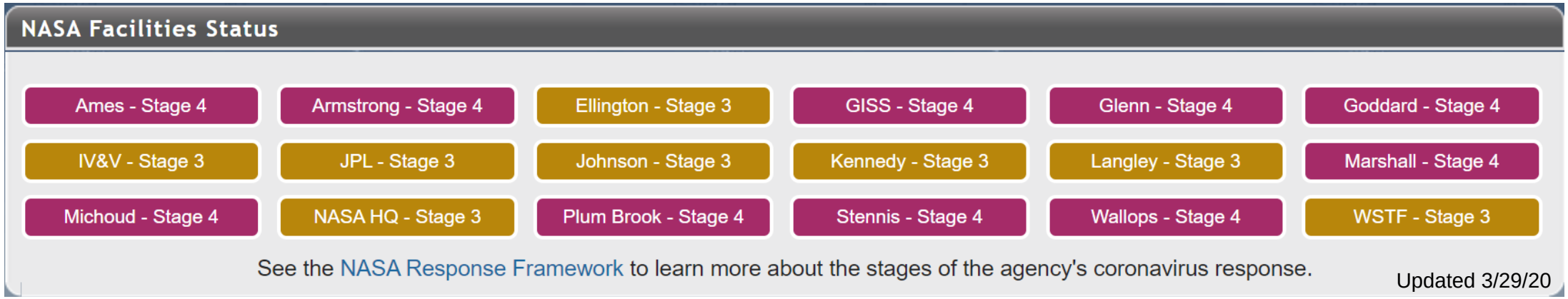
1. For the latest CDC international travel information, go to https://www.cdc.gov/coronavirus/2019-ncov/travelers/index.html
2. The Request for Travel Exception form is available on the NASA People website.

3. Mission Essential is defined as: work that must be performed to maintain mission/project operations or schedules AND cannot be performed remotely/virtually; OR work that has a justifiable impact on the safety of human life or the protection of property, AND there is a reasonable likelihood that the safety of human life or the protection of property would be compromised by a delay in the performance of the work.

Coronavirus (COVID-19) Response – Agency

Agency

- Agency leadership continues to monitor developments regarding coronavirus (COVID-19) around the nation, closely following the advice of health professionals and the White House Coronavirus Task Force to keep our workforce safe



- SLS and Orion manufacturing and testing activities at Michoud Assembly Facility and Stennis Space Center are temporarily on hold
- Ames Research Center is keeping the agency's supercomputing resources online
- Work associated with supporting International Space Station operations continues at Johnson Space Center

NASA updates available at: https://nasapeople.nasa.gov/coronavirus

Coronavirus (COVID-19) Response – SMD

Science Mission Directorate (SMD)

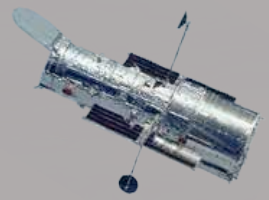
- There will be impacts, and we don't yet know the extent. We're working with each mission and project in detail based on where they are in development process
- Priority is everyone's safety and protecting hardware and integrity of data for operating missions
- Conducted status assessment of all 47 flight projects in the SMD Portfolio
- Many missions in early development phases (phases A-B-early C) where bulk of the work can be done virtually
- Missions in integration and testing (I&T) will continue to the extent possible with small teams
- Will work with domestic and international partners to refine prioritization of our projects, especially those in I&T
- Have consulted with the NASA Chief Medical Officer and have protocols for working in clean rooms
- Anticipate impact to solicitations and evaluations

Missions

- Mars 2020, which includes the Perseverance Rover and Mars Helicopter, remains a high priority for the agency, and launch and other mission preparations will continue
- James Webb Space Telescope is suspending integration and testing operations; the observatory remains safe in its cleanroom environment
- SOFIA observations suspended to ensure the safety of all staff and to comply with state and local county orders. The SOFIA Science Center remains active: data pipeline operations, the helpdesk, and user support are fully functioning.

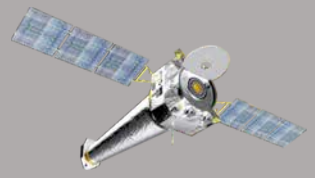
Astrophysics Operating Missions

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)

Spitzer 8/03
NASA Strategic Mission

Mission Complete!

Gehrels Swift 11/04
NASA MIDEX Mission

Operations Nominal

Fermi 6/08
NASA Strategic Mission

Operations Nominal

Kepler 3/09
NASA Discovery Mission

Mission Complete!

NuSTAR 6/12
NASA SMEX Mission

Operations Nominal

SOFIA 5/14
NASA Strategic Mission

Operations Suspended

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

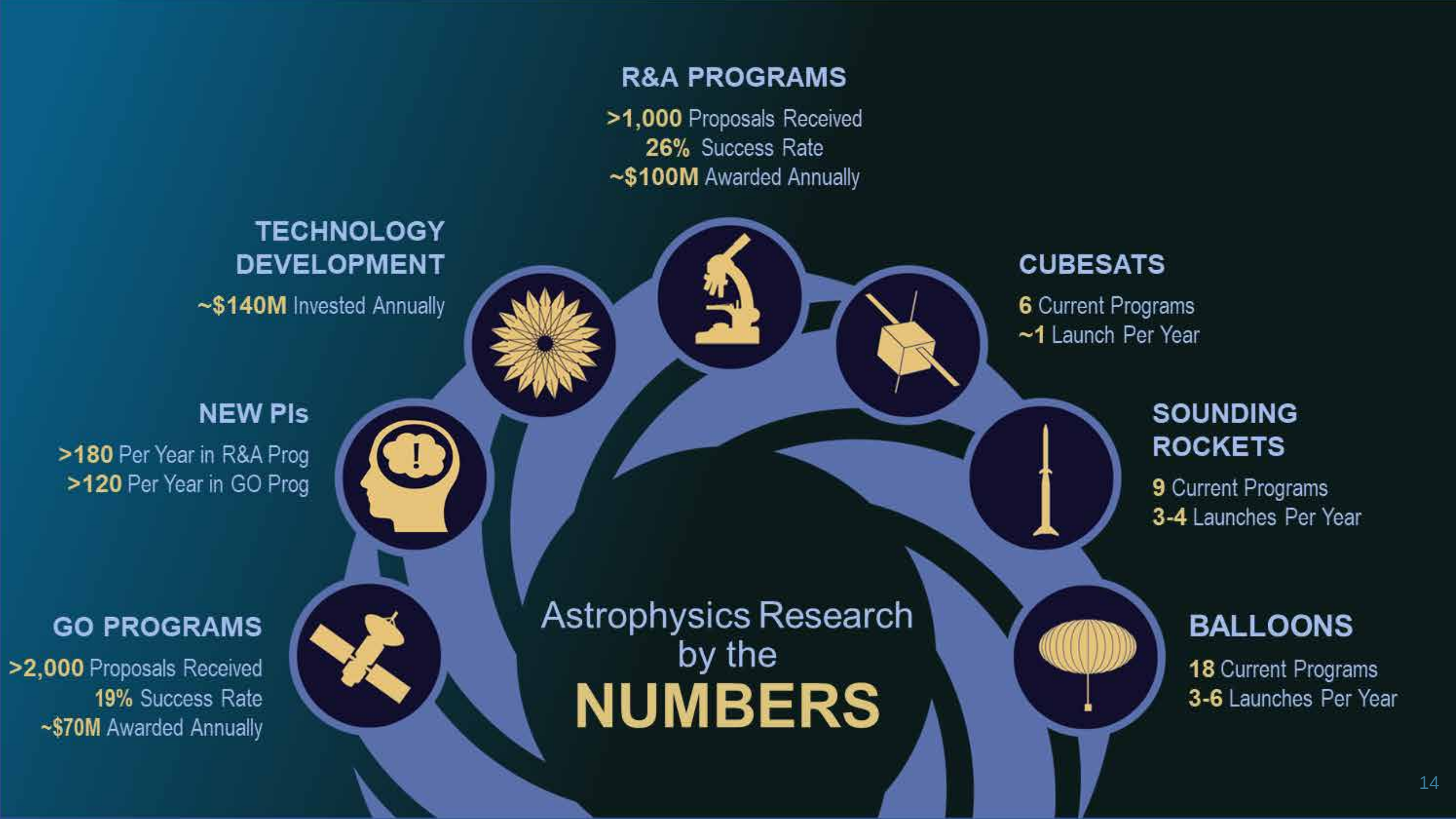
Operations Nominal

TESS 4/18
NASA MIDEX Mission

Operations Nominal

NASA Astrophysics R&A Program Update

including known Coronavirus Adjustments


R&A PROGRAMS
>1,000 Proposals Received
26% Success Rate
~$100M Awarded Annually
TECHNOLOGY DEVELOPMENT
~$140M Invested Annually
CUBESATS
6 Current Programs
~1 Launch Per Year
NEW PIs
>180 Per Year in R&A Prog
>120 Per Year in GO Prog
SOUNDING ROCKETS
9 Current Programs
3-4 Launches Per Year
GO PROGRAMS
>2,000 Proposals Received
19% Success Rate
~$70M Awarded Annually
Astrophysics Research by the NUMBERS
BALLOONS
18 Current Programs
3-6 Launches Per Year

Research and Analysis Initiatives

Dual Anonymous Peer Review

- SMD is strongly committed to ensuring that review of proposals is performed in an equitable and fair manner that reduces the impacts of any unconscious biases
- https://science.nasa.gov/researchers/dual-anonymous-peer-review

High-Risk/ High-Impact (HR/HI)

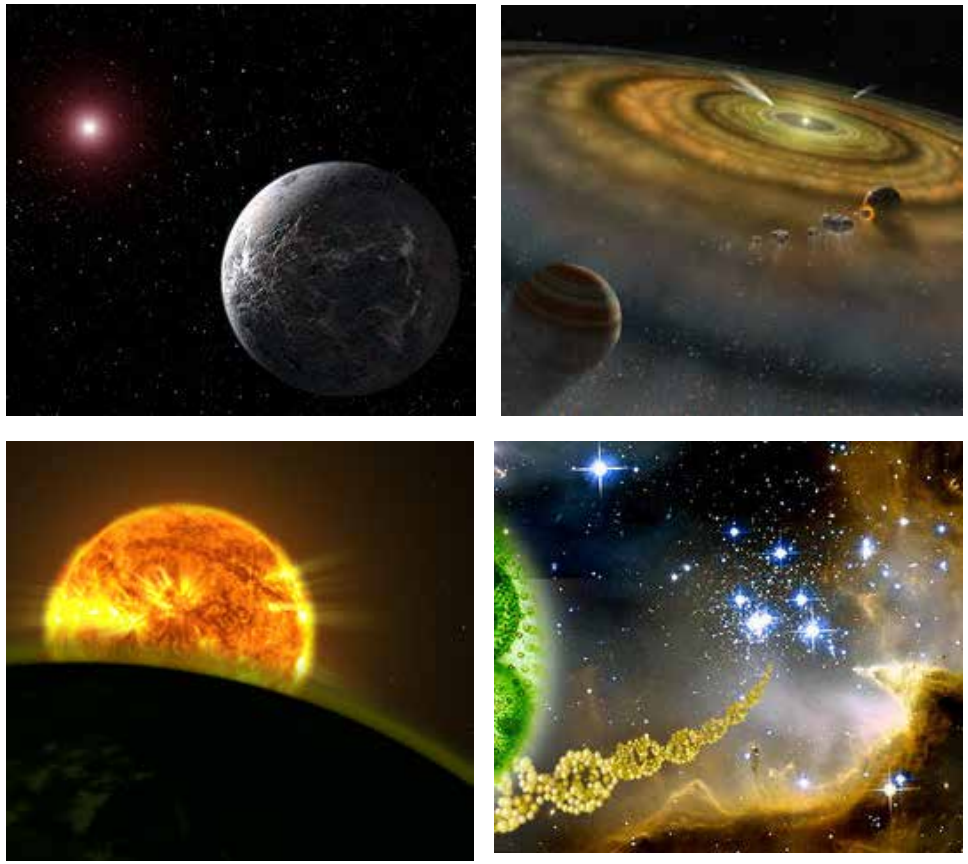
- To reinforce SMD's interest in High-Risk/High-Impact research, a special review process will be implemented in ROSES 2020 to review and select HR/HI proposals

Strategic Data Management

- SMD will be implementing changes to enable open data, open source code, and open model
- This will be a step wise process with the first changes coming in ROSES 2020
- https://science.nasa.gov/researchers/science-data

Request for Information:

Research That Falls in Gap between current SMD Solicitations



- Release Date: Dec 2, 2019 (Solicitation: NNH20ZDA003L)
- Response Date: Jan 31, 2020
- NASA SMD solicited information on research aligned with agency mission and SMD's Science Plan but falls in a gap between current solicitations, possibly because it's interdisciplinary or interdivisional
- Responses will be used by NASA to inform decision as to whether portfolio of current program elements in ROSES needs to be modified and/or expanded to provide the proper avenue for such research
- Full text of RFI on the NSPIRES website

Response to “Research Gap” RFI

104 responses submitted

- ~40% NASA Centers, ~25% universities,~25% science centers/labs, ~10% private sector

Main themes:

- “Earth in context”: Earth / Sun interaction + upper atmosphere, Earth as one of the inner planets, Earth in an exoplanet context, ancient Earth & habitability
- Cross-divisional topics: technology, software & data analysis techniques, lab-astro
- Interdisciplinary / cross-divisional research submitted previously and not funded
- Requests for NASA to support ground based astronomy

Next Steps:

- Each response being reviewed and categorized by a cross-Division team
  - How does research fit within the mission of division / directorate / agency?
  - Can it be submitted within current ROSES elements as written or does it require modification of ROSES language?
  - Are there barriers to acceptance?
- Team will present analysis and recommendations to SMD leadership in a few months

ROSES-2020 R&A Elements

Supporting Research and Technology

- Astrophysics Research & Analysis (APRA)
- Strategic Astrophysics Technology (SAT)
- 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
- XRISM Guest Scientists (one time)
- Astrophysics Explorers U.S. Participating Investigators (triennial, this year)
- Astrophysics Pioneers

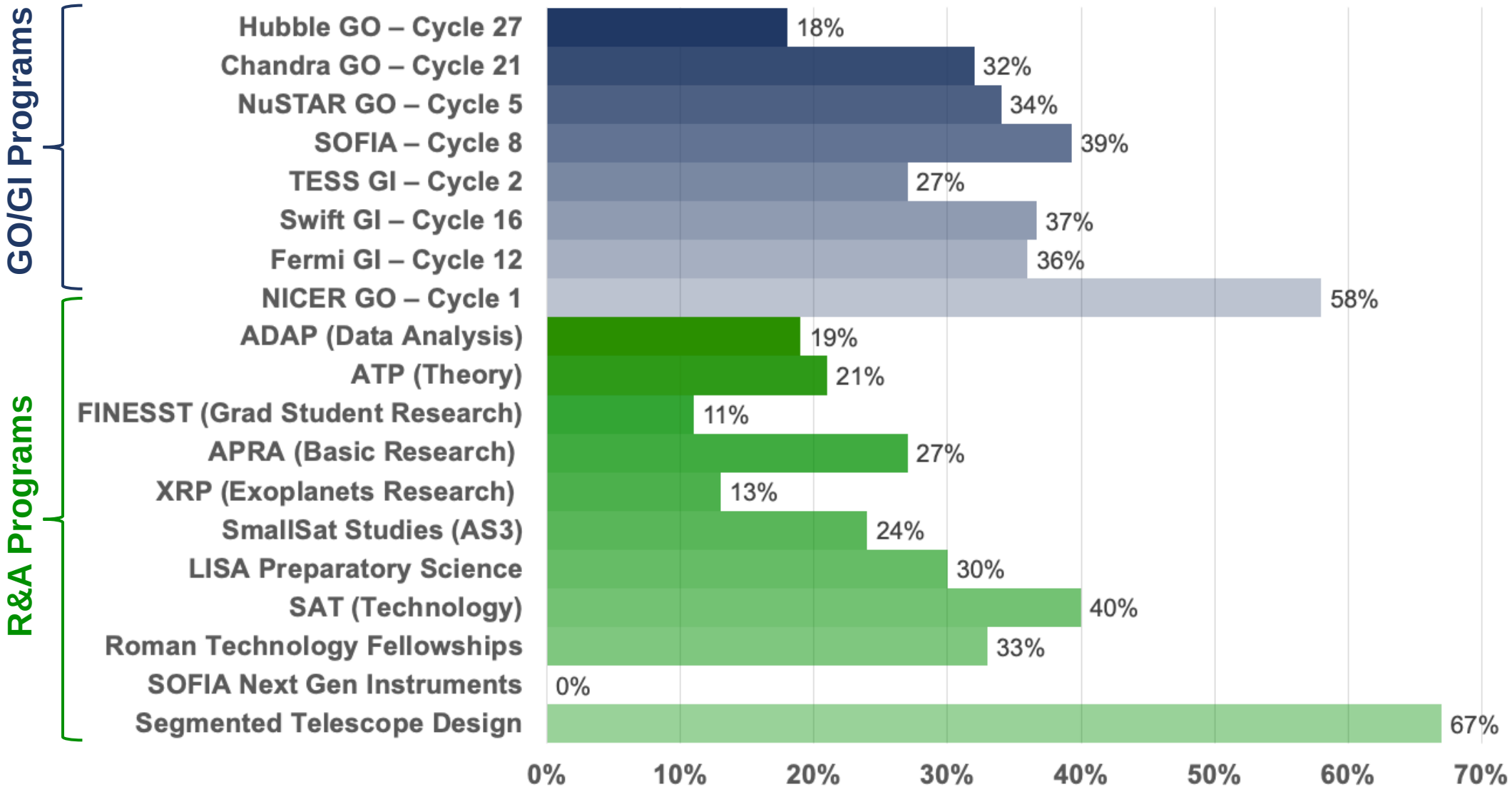
Separately Solicited

- 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 participates in cross-divisional TWSC
- XRISM Guest Scientist
- Astrophysics Explorers U.S. Participation Investigators (APEX USPI)
- Astrophysics Pioneers
- GO & ADAP proposals will be evaluated dual-anonymously
- Data Management Plan will be evaluated as part of the intrinsic merit of proposals
- High Risk / High Impact: special review process will be implemented
- Announcement that ROSES-2021 will enable open software/code/source/models

Selection Rates



GO/GI Programs: 26%

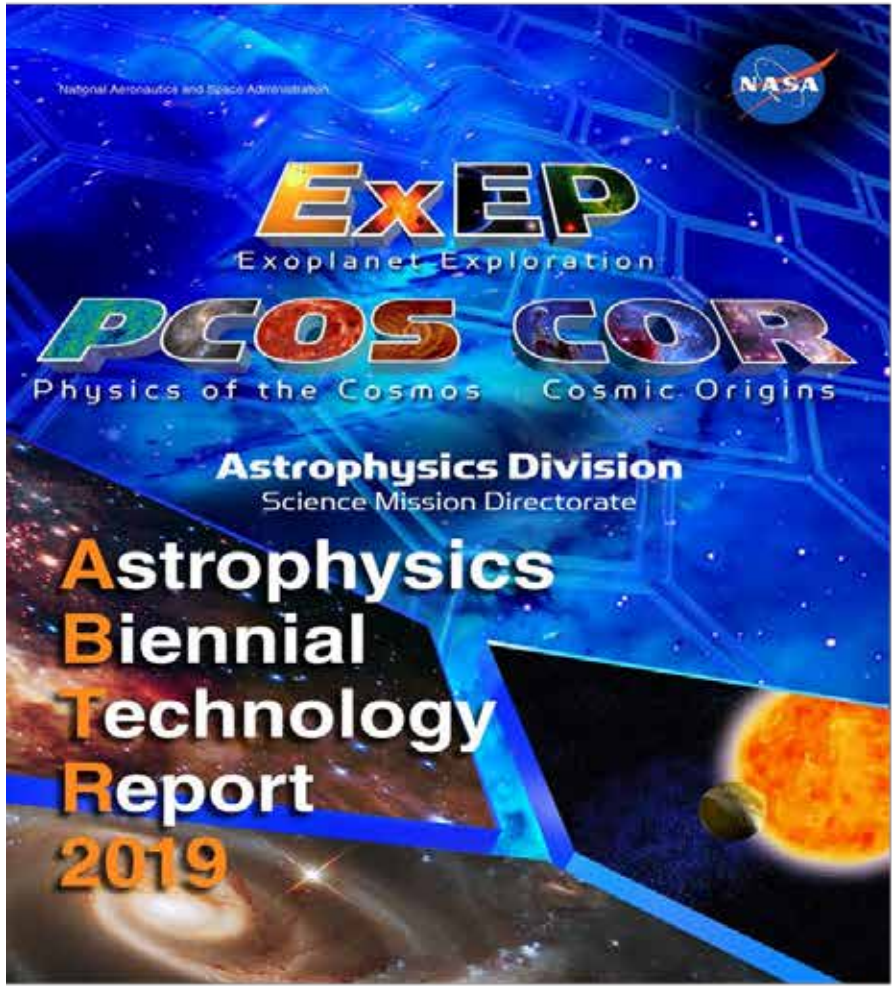
R&A Programs: 20%

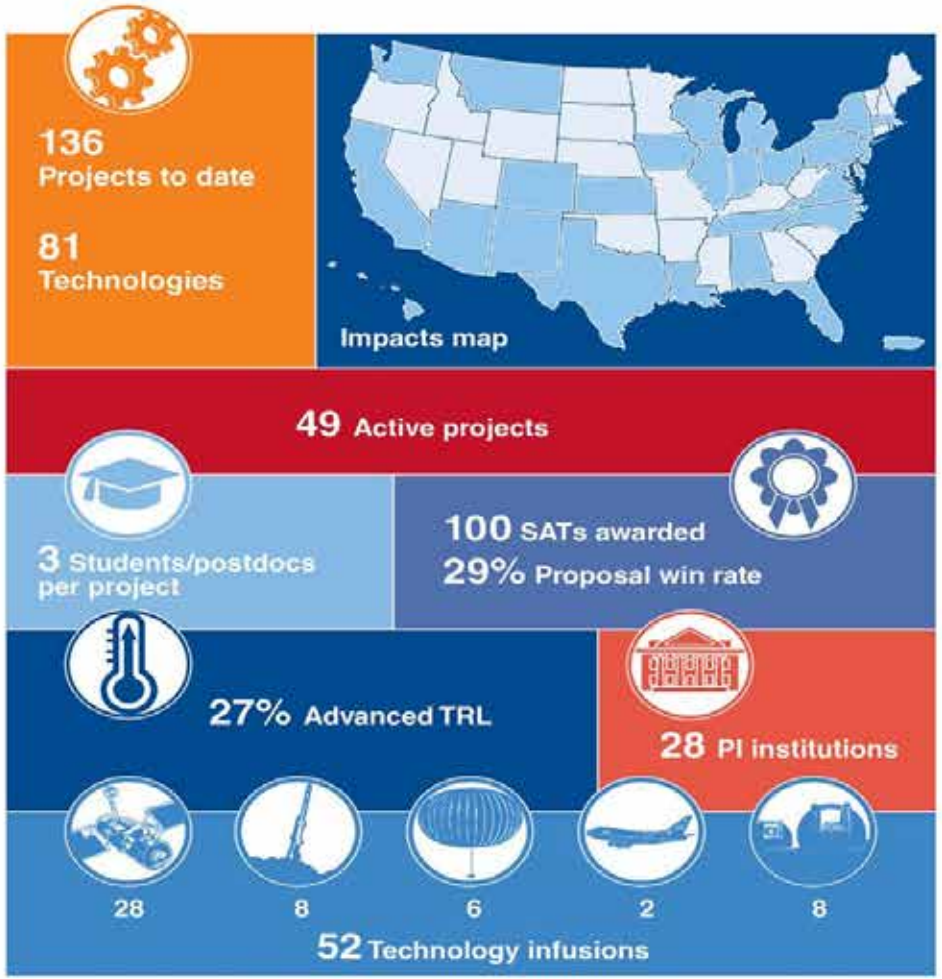
Astrophysics Pioneers

- The FY21 President's Budget Request contains a new initiative for Astrophysics – A new class of small missions

- Astrophysics Pioneers
  - Fills in the gap between existing ROSES investigations (<$10M for APRA) and existing Explorers MO investigations ($35M for SmallSats)
  - Managed as Research and Analysis projects with enhanced oversight
  - Will be solicited through ROSES; relieves burden of writing full Explorers MO proposal
  - Will include SmallSats, Large CubeSats, CubeSat constellations (all as rideshare/secondary payloads), major balloon missions, and ISS attached payloads

Integrated Strategic Technology Portfolio





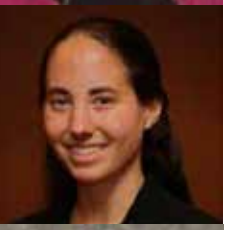
Astrophysics Biennial Technology Report: https://apd440.gsfc.nasa.gov/technology.html

Database of Astrophysics technology projects: http://www.astrostrategictech.us/

Inspiring Future Leaders

- Achieve excellence by relying on diverse teams, both within and external to NASA, to most effectively perform SMD's work
- Attract and retain talent by promoting a culture that actively encourages diversity and inclusion and removes barriers to participation
- Encourage development of future leaders, including the next generation of mission principal investigators, through targeted outreach and hands-on opportunities
- Support early-career scientists to build careers working with NASA
- Engage the general public in NASA Science, including opportunities for citizen scientists

[1] https://science.nasa.gov/researchers/new-pi-resources [2] https://science.nasa.gov/researchers/pi-launchpad





Nancy Grace Roman Technology Fellowships

2018:
Regina Caputo, NASA GSFC (cosmic rays/gamma-ray)
Sarah Heine, MIT (optics and gratings for polarimeters)
Gregory Mace, UT Austin (optics and spectroscopy)

2017:
Manel Errando, Washington University, St. Louis
Adam McCaughan, NIST/Boulder
Varun Verma, NIST/Boulder

2016:
Abigail Vieregg, University of Chicago
Omid Noroozian, NRAO

2015:
Erika Hamden, California Institute of Technology
Daniel Cunnane, NASA Jet Propulsion Lab
Eric Schindhelm, Southwest Research Institute

2014:
John Conklin, University of Florida
Brian Fleming, University of Colorado
Tyler Groff, Princeton University

2013:
Not solicited

2012:
Cullen Blake, University of Pennsylvania
Kevin France, University of Colorado

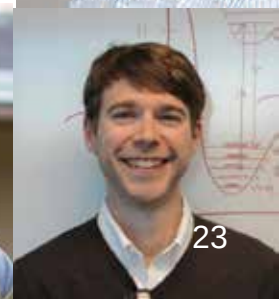
2011:
Judd Bowman, Arizona State University
Michael McElwain, NASA GSFC
Randall McEntaffer, University of Iowa











2020 NASA Hubble Fellowship Program

How does the universe work?
Einstein Fellows

How did we get here?
Hubble Fellows

Are we alone?
Sagan Fellows

https://hubblesite.org/contents/news-releases/2020/news-2020-20
http://www.stsci.edu/stsci-research/fellowships/nasa-hubble-fellowship-program/2020-nhfp-fellows

NASA Hubble Fellowship Program

Fellows are asking for the assurance of parental leave and the option of saving for their eventual retirement with the assistance of their employer.

- Fellows who are employees of their host institutions typically have these benefits.
- Stipendiary fellows to do not receive employee benefits even though the NHFP is willing to pay the full cost of the employee benefits package.

The Space Telescope Science Institute (STScI) is proposing a change to the requirements for NHFP host institutions.

> *Starting with academic year 2022-2023, in order to host new NASA Hubble Fellowship Program (NHFP) Fellows, host institutions must offer their NHFP Fellows the opportunity to be employees. Employee status is being required to afford NHFP Fellows the same leave, vacation, retirement and health benefits (as applicable) given by these institutions to their postdoctoral fellows hired on grants or contracts as employees. Host institutions are also encouraged, but not required, to offer Fellows the option of choosing to be a stipendiary fellow rather than an employee if that is a better match to the Fellow's needs.*

STScI solicited comments from host institutions, see the letter from STScI Director Ken Sembach at http://www.stsci.edu/stsci-research/fellowships/nasa-hubble-fellowship-program/nhfp-host-institution-employment-policy.

Direct any questions or comments on this policy to nhfp@stsci.edu.

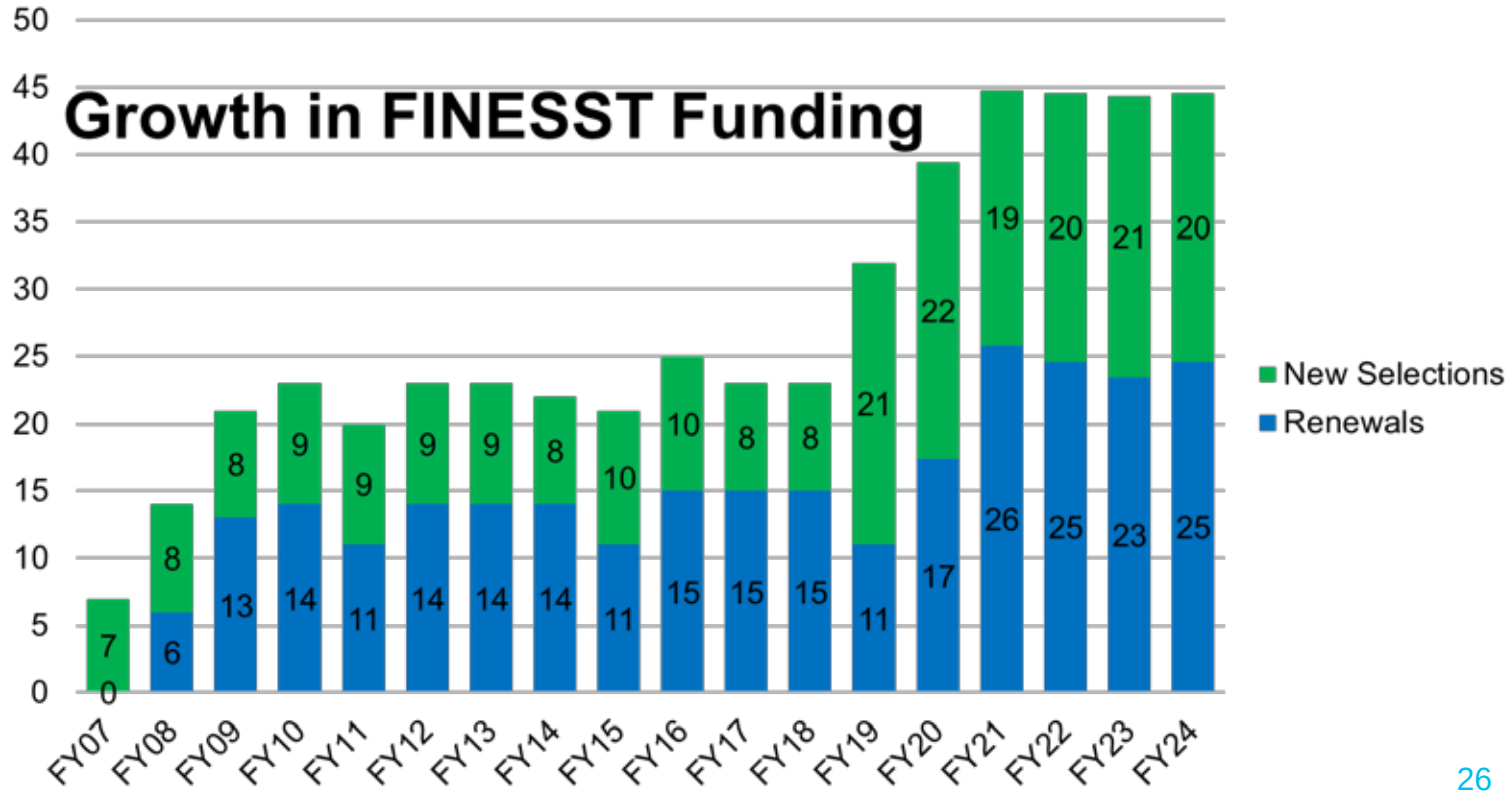
Graduate Student Research Awards

NASA Earth and Space Science Fellowship (NESSF) program name changed to Future Investigators in NASA Earth and Space Science and Technology (FINESST) in 2019 to more accurately capture the nature of awards.

Historically Astrophysics has funded 24 NESSF / FINESST fellows at any given time. With 150-200 proposals received annually, the selection rate has been ~6%.

Community input has led to us doubling the Astrophysics NESSF / FINESST program effective in 2019.

Astrophysics will now be funding 45-48 NESSF / FINESST Fellows at any given time. The selection rate will be ~10%.



Coronavirus (COVID-19) Response – ROSES 2020

- We know that progress on funded research may slow and in some cases even stop due to necessary telework, lack of access to facilities and labs, and other family obligations
- SMD understands this potential outcome and will work with the research community and its institutions to mitigate any impacts and to make plans, when possible, for a way forward
- NASA has instituted a number of grant administration flexibilities to ease the burden on grant recipients during the COVID-19 emergency (see next slide).
- SMD is considering converting all Step-1 proposals due within the next 30 days into mandatory NOIs to alleviate pressure on Sponsored Projects Offices (already done for XRP)
- SMD's policy on late proposals will be applied leniently on a case-by-case basis (see next slide)
- Expect that research progress may slow or stop; SMD is prepared to rephase or no-cost extend awards as needed on a case-by-case basis
- SMD is encouraging all to continue to pay graduate students, post-docs, and lab staff (see next slide)
- Watch the NSPIRES email lists for up-to-the-minute changes in due dates or policies

Coronavirus (COVID-19) Response – R&A FAQs

- OMB has issued guidance in Memo M-20-17
  - Available at https://www.whitehouse.gov/wp-content/uploads/2020/03/M-20-17.pdf
- Allows for paying soft-money researchers as well as graduate students, post-docs, and other lab staff during the COVID-19 epidemic, if the institution's own policies allow for it
- Allows for institutions to charge restart costs to their grants
  - Assuming sufficient funding is available, SMD will make use of this authority to allow other costs associated with resuming funded grant activities to be charged to currently active grants
  - It is likely that any policy or practice on augmentations will not be issued until the impacts of the pandemic are understood better
- Provides agencies flexibility with regard to the submission of proposals
  - SMD's policy on late proposals will be applied leniently on a case-by-case basis
  - Proposals started before the due date but not completely submitted until after the due date because of the impacts of the COVID-19 epidemic will be strongly considered for acceptance if they are submitted within seven calendar days of the due date.
  - Proposals not yet started in NSPIRES by the time of the due date and submitted after the due date will only be accepted after an analysis of the particular reasons for the late start/late submission by the program element point of contact and with the agreement of the selecting official.

Updates to Grant Policy

- OMB issued memo M-20-17 which affords grant-issuing agencies the authority to institute a number of administrative flexibilities over the next 90 days.
- The memo allows for the following flexibilities, which NASA has adopted:
  1. Grantees have been given an automatic 60-day extension to their SAM.gov registrations
  2. NASA program offices have been given the ability to extend funding opportunity deadlines or review proposals submitted after deadlines if those proposals were submitted late due to COVID-19
  3. Program offices may now publish funding opportunities to NSPIRES for less than 30 days without justification
  4. Grantees have been given additional flexibilities in initiating no-cost extensions to their awards
  5. Grantees may charge salary and benefits to their grants as long as there is funding available, including staff who are not able to work if:

  1. Salaries and benefits are budgeted items of the award
  2. It is consistent with the entity's policy for paying salaries

  6. Grantees can charge expenses incurred due to COVID-19, such as event and travel cancellation fees to their grants as long as funding is available.
  7. Various grant-related activities previously requiring NASA prior approval are now exempt from prior approval requirements (See NASA issued guidance)
  8. Various procurement requirements required by 2 CFR § 200 have been waived (See NASA issued guidance)

  OMB memo M-20-17: https://www.whitehouse.gov/wp-content/uploads/2020/03/M-20-17.pdf

ROSES-2020 R&A Changes

We are working hard and are implementing extra steps to fund NASA awardees as quickly as possible and we continue to make new selections as quickly as possible.

All astrophysics peer reviews through June 2020 will be virtual panels; decisions on future peer review panels will be made on a rolling basis

- Conducted 4 peer reviews virtually, one of them dual-anonymous, and the feedback from reviewers who served is very positive

Virtual panels often take more days to complete, so due dates and peer review dates for XRP, TCAN, ADAP, and Webb Cycle 1 (all peer reviews in July/August) will be assessed to delay some and spread out the work

XRP was changed from a Step 1 proposal to a mandatory NOI; Astrophysics will have no Step 1 proposals so there is no AOR in the NOI process

ADAP will not be offered in 2021 to reduce the work next year as we recover from the impacts of COVID-19: focus efforts without reducing opportunity space

- The selection rate this year will approximately double
- All of the funding planned for selections in both 2020 and 2021 will be committed in 2020 – no reduction in funding to the community
- This reduces the work for both NASA and the community without reducing the opportunity space for community funding
- This allows more awardees to be assured of funding this year
- Note: as planned, ADAP will be dual anonymous this year

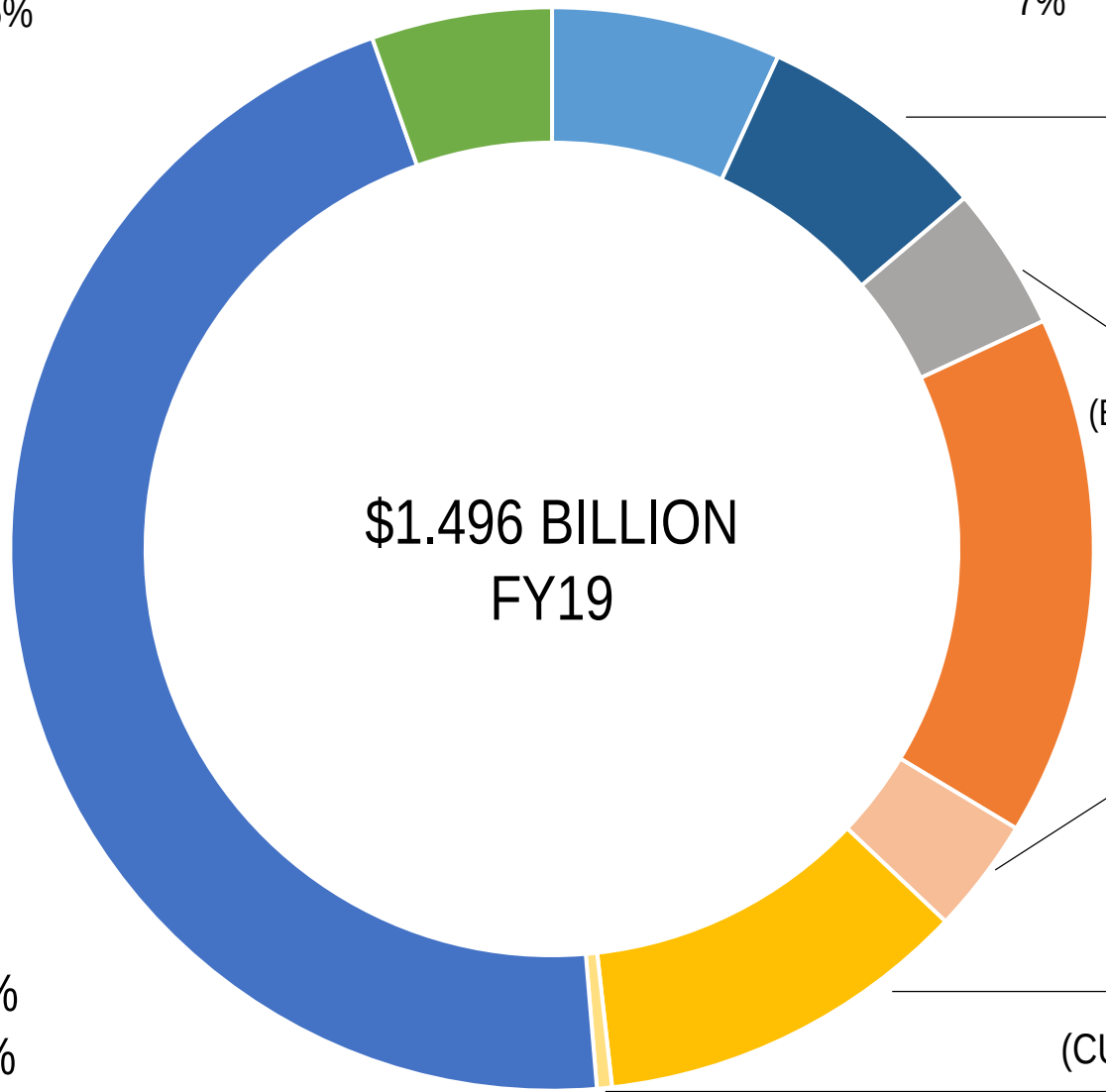
NASA Astrophysics Peer Reviews

Program Element	NOIs	Proposals Due	Review Date	Dual Anonymous	Review Format	Comment
Astropysics Archives Programmatic Review 2020	N/A	02/03/20	Mar 2020	traditional	virtual	Changed to a virtual review with 2 days notice
FINESST	N/A	02/03/20	Mar 2020	traditional	write-in	Proposals peer reviewed by write-in reviewers and HQ panels
TESS GI – Cycle 2	N/A	01/16/20	Mar 2020	traditional	virtual	
NuSTAR GO – Cycle 6	N/A	01/24/20	Mar 2020	dual anonymous	virtual	Pilot program for GI/GO DAPR *and* virtual panels
Astrophysics SmallSat Studies	N/A	12/19/19	Mar/Apr 2020	traditional	virtual	
Fermi GI – Cycle 13	N/A	02/19/20	May 2020	traditional	virtual	
Hubble GO – Cycle 28	N/A	03/12/20	Jun 2020	dual anonymous	virtual	Will accept late proposals from scientists impacted by corona virus
Chandra GO – Cycle 22	N/A	04/02/20	Jun 2020	traditional	virtual	Proposal due date postponed by 2 weeks due to corona virus
XRP (Exoplanets Research)	3/27/20	05/29/20	Jul 2020	traditional	TBD	
TCAN (Theory)	N/A	05/28/20	Jul 2020	traditional	TBD	
ADAP (Data Analysis)	3/31/20	TBD	TBD	dual anonymous	TBD	Pilot program for APD R&A DAPR
Webb GO – Cycle 1	N/A	05/27/20	Aug 2020	dual anonymous	TBD	Proposal due date postponed by 4 weeks due to corona virus
SOFIA GO – Cycle 9 TAC	N/A	09/03/20	Oct 2020	traditional	TBD	
Swift GO – Cycle 17	N/A	09/25/20	Nov 2020	dual anonymous	TBD	
Astrophysics Explorers US PIs	NOIs	TBD	TBD	traditional	TBD	
Pioneers (Suborbital Programs)	TBD	September	Nov/Dec 2020	traditional	TBD	
NICER GO – Cycle 3	N/A	November	Jan 2021	dual anonymous	TBD	
APRA (Basic research)	10/23/20	12/17/20	Feb 2021	traditional	TBD	
SAT (Technology)	10/23/20	12/17/20	Feb 2021	traditional	TBD	
XRISM Guest Scientists	TBD	TBD	TBD	dual anonymous	TBD	Amendment 18 months prior to launch and after PV target selection
LISA Preparatory Science	October	December	Feb 2021	dual anonymous	TBD	

* sorted by review dates

NASA Astrophysics Webinar: Dual-Anonymous Peer Review for ADAP-2020
April 2, 2020 @ 1-2 pm ET

NASA Astrophysics Budget Update including FY21 Budget Request



MANAGEMENT
INCL. STEM ACTIVATION
5%

RESEARCH
(ADAP, APRA, ATP, ETC.)
7%

TECHNOLOGY
(SR&T, ATHENA, LISA, ETC.)
7%

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

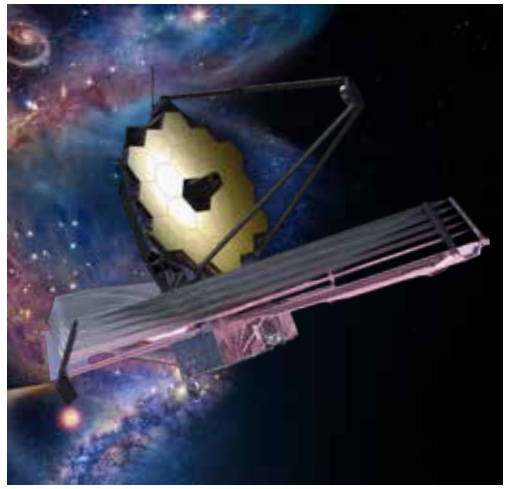
OP. MISSIONS
(INCL. GO PROGRAMS)
19%

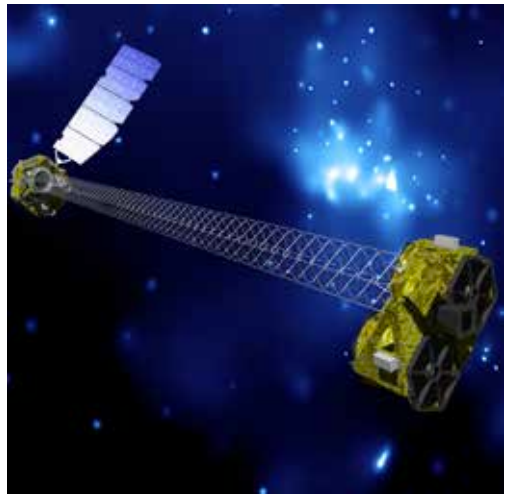
EXPLORERS
(CURRENT AND FUTURE, INCL. GO)
11%

DEVELOPMENT
(WEBB, WFIRST)
46%

<u>Quick Summary</u>
Community support: 20%
Operating missions: 20%
Building missions: 55%
Management: 5%

FY20 Appropriation

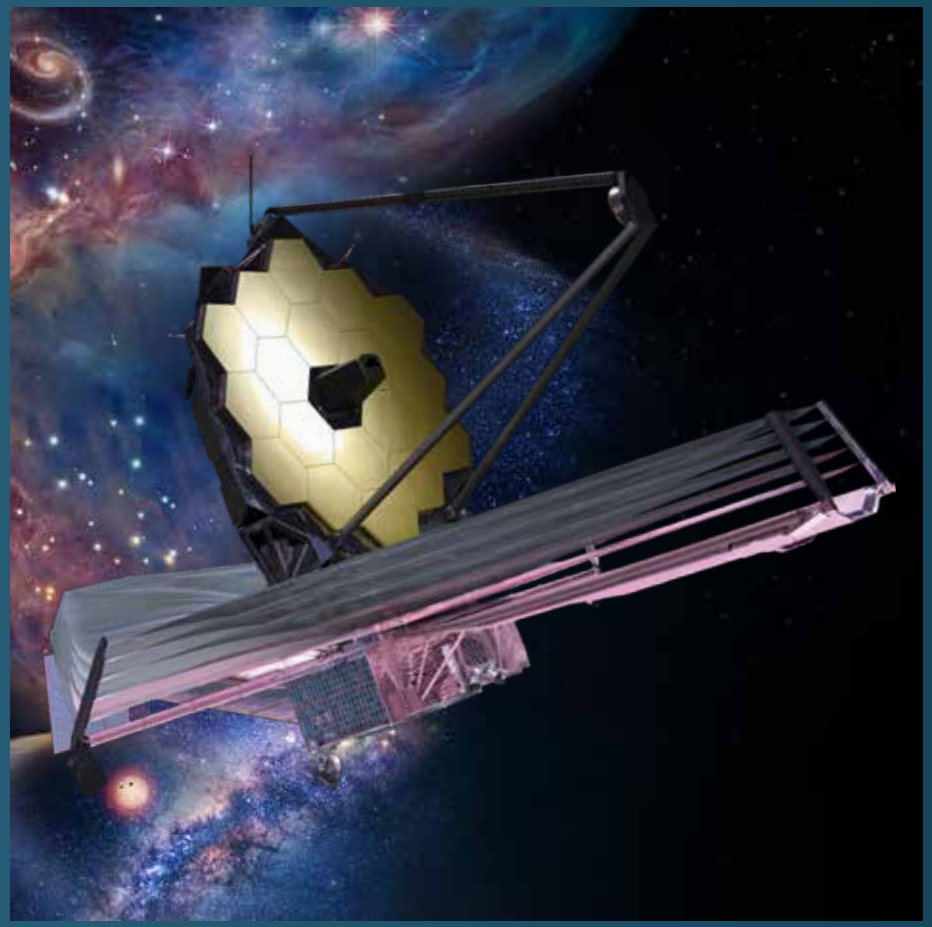




- FY20 appropriation for NASA Astrophysics (including Webb Telescope) is $1.73B; up by $233M from FY19 appropriation and by $532M from FY20 President's Budget Request
- Fully funds Webb for replan to March 2021 launch date
- Fully funds WFIRST, including the coronagraph technology demonstration instrument, through KDP-C and into Phase C
- Specifies funding levels for Hubble, SOFIA, and the Astrophysics Research Program
- Provides adequate funding to continue with the rest of the planned Astrophysics programs and projects including:
  - Operating missions with GO programs as planned following the Senior Review
  - Development of Explorers missions (IXPE, GUSTO, SPHEREx) and international contributions (Euclid, XRISM, ARIEL, Athena, LISA)
  - Initiation of Phase A studies for selected SMEX and MO proposals from the 2019 Announcement of Opportunity
  - Continued technology development for the future

FY21 Budget Agency Highlights

- One of the strongest budgets in NASA's history, investing more than $25 billion dollars for America's future in space; funding proposed represents an increase of about 12% over last year's request
- Keeps the agency on track to land the first woman and the next man on the Moon by 2024 and enables development of more than 15 science missions (including lunar, Mars, and Heliophysics) that inform Artemis work
- Provides valuable precursor experience for human exploration of Mars with bold new missions such as Mars Sample Return and Ice Mapper
- Implements a balanced and integrated science program with over 40 missions in formulation and development in FY 2021, including over 25 small missions
- Advances compelling science with priorities identified by the National Academies' decadal surveys including the James Webb Space Telescope, Europa Clipper, IMAP, and the first Earth Science Designated Observables mission
- Executes innovative partnerships with commercial and international partners; including through our Commercial Lunar Payload Services initiative, our industry partners will begin in 2021 to deliver science and tech payloads to virtually anywhere on the Moon, including the poles and far side



FY21 SMD Budget Strategy

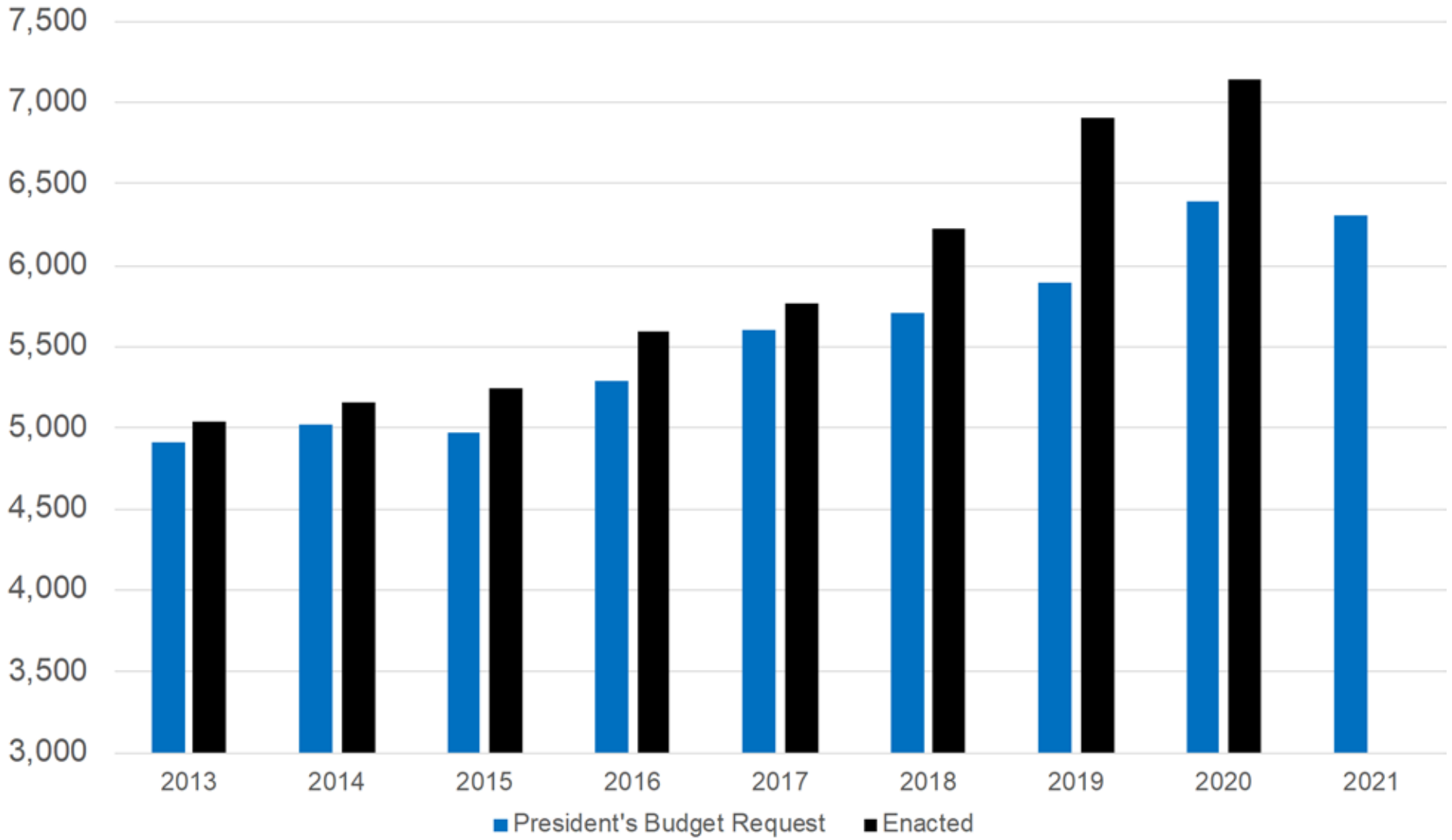
Support Artemis

Implement a Balanced and Integrated Science Program

Advance Compelling Science Program with Highest National Priorities

Execute Innovative Partnerships

President's NASA Science Budget Request and Enacted



Cost Performance of Recently Launched Missions

NASA Science is providing reliable cost estimates for its missions, contributing to program stability

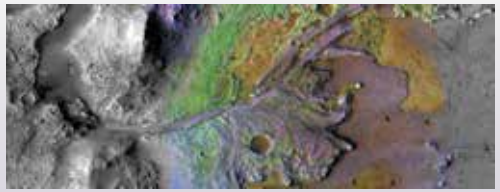
	KDP-C Baseline	Actual/ Estimated	Actual vs. Original
NuSTAR	109.9	116.0	6%
Landsat 8	583.4	502.8	-14%
IRIS	140.7	143.0	2%
LADEE	168.2	188.2	12%
MAVEN	567.2	472.0	-17%
GPM	555.2	484.3	-13%
OCO-2	249.0	320.3	29%
SMAP	485.7	454.3	-6%
MMS	857.3	875.3	2%
Astro-H	44.9	71.2	59%
OSIRIS-REx	778.6	620.8	-20%
CYGNSS	151.1	127.1	-16%
SAGE-III	64.6	88.2	37%
TSIS-1	49.8	19.8	-60%
TESS	323.2	273.4	-15%
InSight	541.8	635.8	17%
GRACE-FO	264.0	238.1	-10%
Parker	1055.7	955.7	-9%
ICESat 2	558.8	713.2	28%
GEDI	91.2	85.5	-6%
OCO-3	62.5	62.2	-1%
ICON	196.0	205.4	5%
Total	7898.7	7652.8	-3%

Science missions launched since the requirement for a 70% JCL have *underrun* Phase C/D budget commitments by a net 3%

FY21 Budget

Program Highlights

Planetary Science

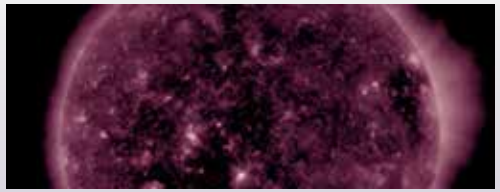


- Lunar Discovery and Exploration grows commercial partnerships and innovative approaches to science, technology, and human exploration objectives
- Enables Mars Sample Return launch in 2026, begin planning Ice Mapper mission
- Supports Europa Clipper on SLS in 2025: proposes commercial launch in 2024 to save ~$1.5 billion

Astrophysics

- Accommodates Webb re-plan for 2021 launch
- Maintains regular cadence of Astrophysics Explorers and Missions of Opportunity
- Initiates Pioneers, an innovative new line of SmallSats and major balloon missions
- Given significant cost and competing priorities within NASA, provides no funding for WFIRST
- Proposes termination of SOFIA due to its cost and lower productivity than other missions

Heliophysics

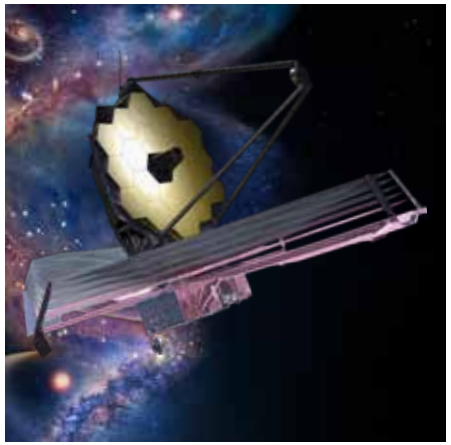


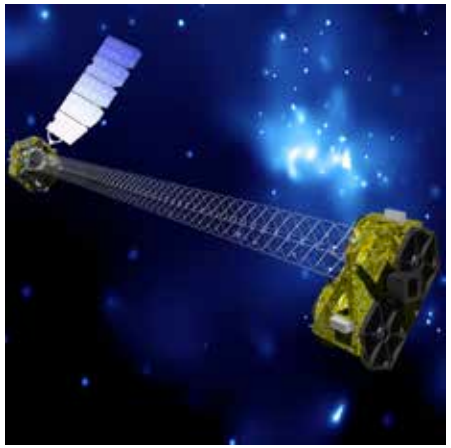
- Space Weather increase strengthens cross-agency collaboration on Research-to-Operations/Operations-to-Research
- Enables launch of Global Dynamics Constellation, the next LWS mission, as early as 2026
- Provides for a balanced Heliophysics portfolio, including enhanced emphasis on small missions, technology development and expanded opportunities for R&A

Earth Science

- Advances focused, balanced Earth science portfolio
- Maintains regular cadence of Venture Class solicitations
- Initiates the first Designated Observable mission from the most recent Decadal Survey
- Enables healthy research and applied science programs, and SmallSat/CubeSat investments

Astrophysics






- Supports Webb launch in 2021
- Maintains decadal cadence of four AOs per decade for Astrophysics Explorers and Missions of Opportunity
- Maintains healthy research program including CubeSats, suborbital missions, technology development, data analysis, theoretical and computational investigations, and laboratory astrophysics
- Initiates new class of Astrophysics Pioneers: SmallSats and major balloon missions with reduced management overhead compared to traditional Astrophysics Explorers
- Extends operating missions beyond FY20 with GO programs following 2019 Senior Review
- Supports formulation of a probe mission as early as 2022
- Supports mission concept studies and technology investments to implement Astrophysics Decadal Survey priorities starting in 2022
- Terminates SOFIA due to high operating costs and lower science productivity to date
- Given its significant cost and competing priorities within NASA, provides no funding for WFIRST space telescope

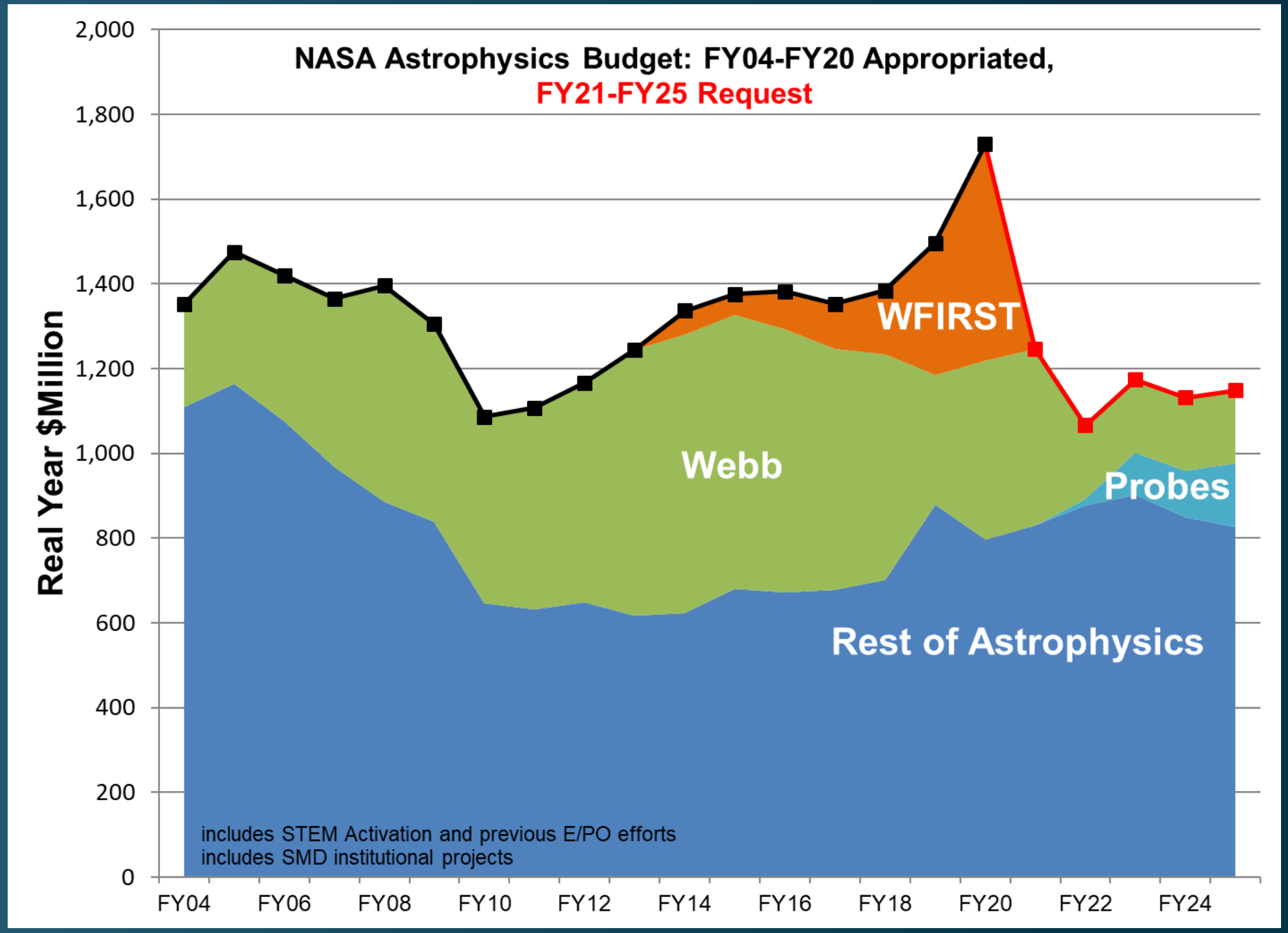
Astrophysics Budget Features

What's the Same (as the FY20 Budget Proposal)

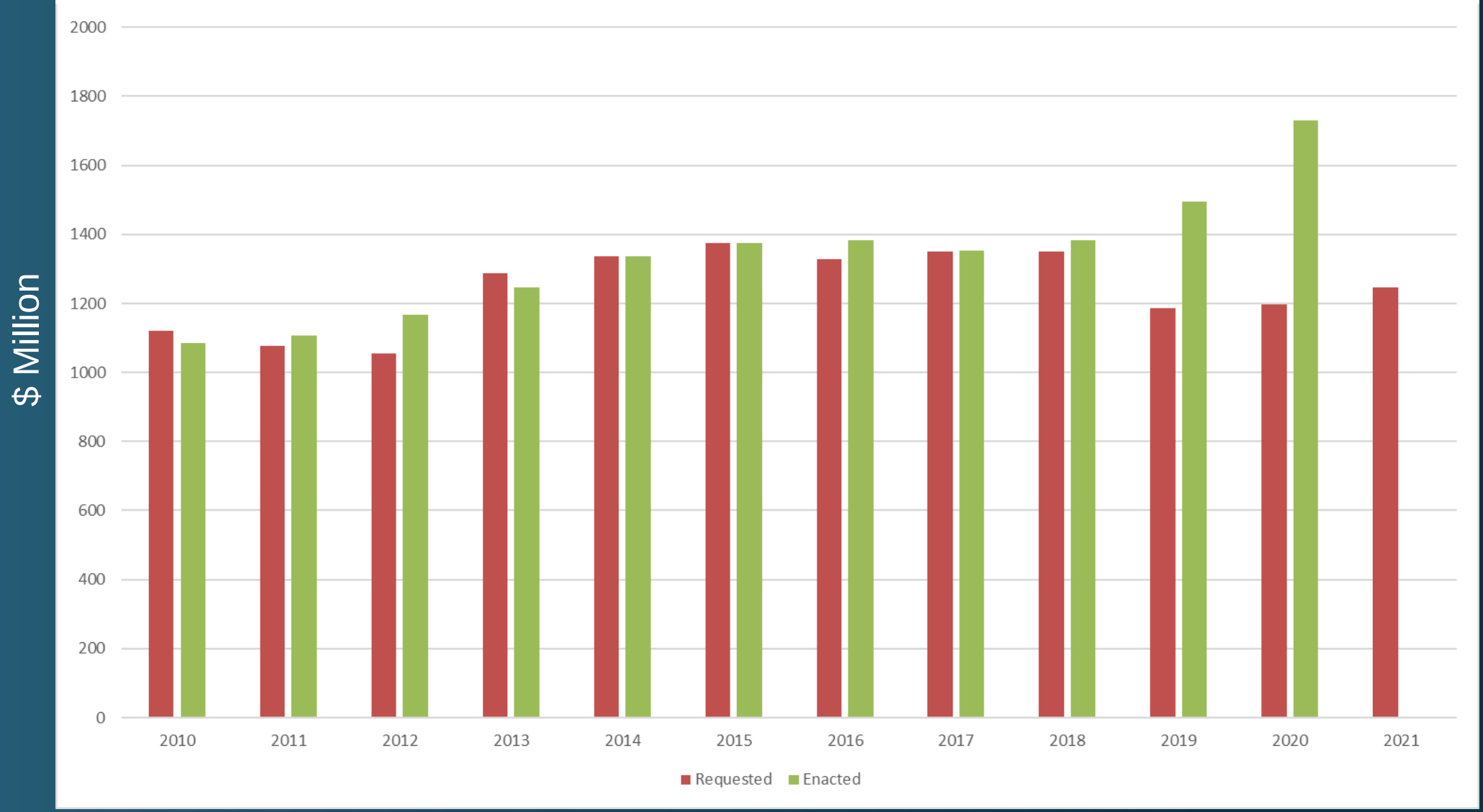
- Webb proceeding toward launch in 2021
- Provides no funding for WFIRST space telescope; instead, focuses on completing Webb
- Spitzer operations ended January 2020
- IXPE, GUSTO, XRISM, and Euclid development on track and within budget
- CubeSat initiative and balloon campaigns within healthy research program
- Science Activation at $45.6M/year

What's Changed (from the FY20 Budget Proposal)

- Astrophysics Pioneers initiated for SmallSats and major balloon missions
- SPHEREx selected as next Astrophysics Medium Explorer
- CASE selected as Explorer Mission of Opportunity on ESA's ARIEL mission
- Hubble, Chandra, and other operating missions continue per 2019 Senior Review
- Proposes termination of SOFIA due to its high cost and lower scientific productivity than other missions


NASA Astrophysics Budget: FY04-FY20 Appropriated,
FY21-FY25 Request
Real Year $Million
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
FY04
FY06
FY08
FY10
FY12
FY14
FY16
FY18
FY20
FY22
FY24
WFIRST
Webb
Probes
Rest of Astrophysics
includes STEM Activation and previous E/PO efforts
includes SMD institutional projects

Astrophysics Budget Requested and Enacted



NASA Astrophysics Missions Update

WFIRST: Wide-Field Infrared Survey Telescope

WFIRST is fully funded in FY20

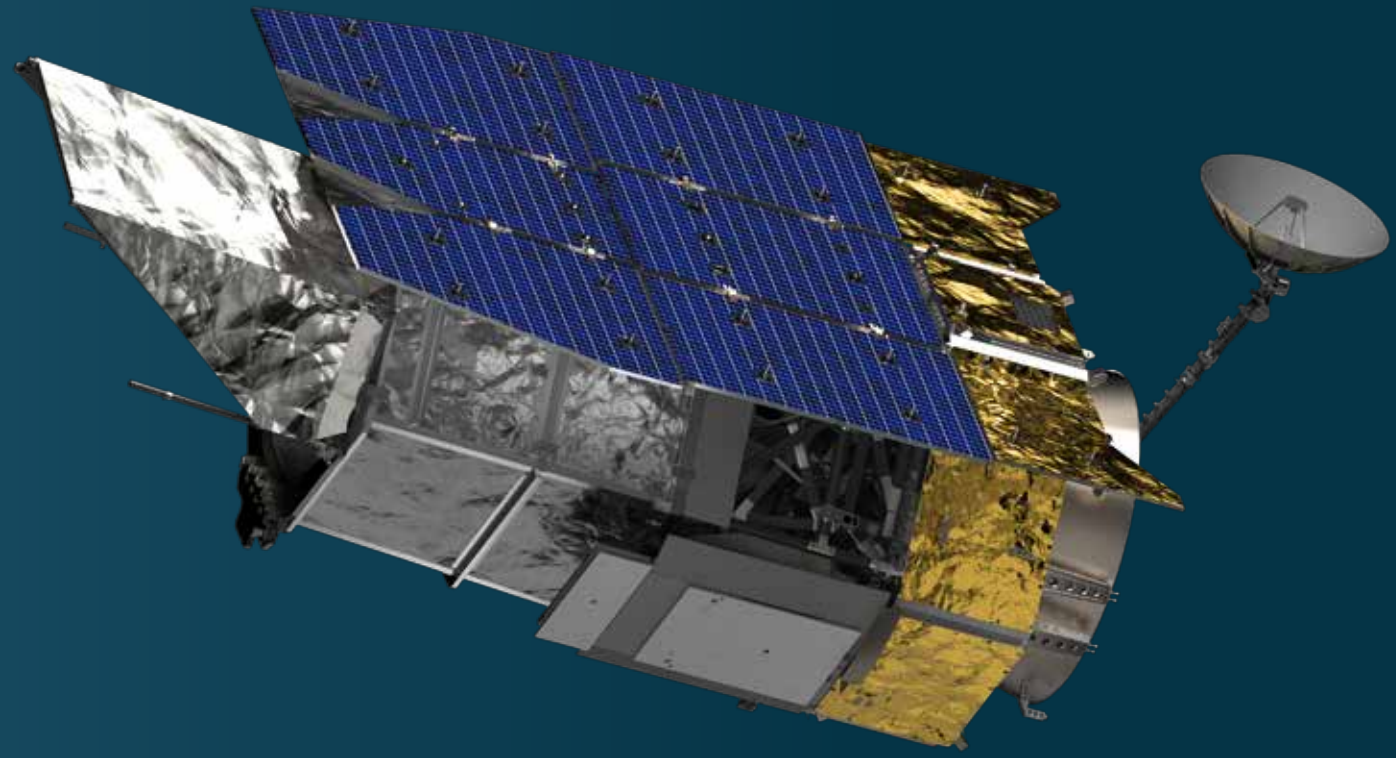
Nov 2019 -– Completed Preliminary Design Reviews

Feb 2020 – Complete Confirmation Review and begin Implementation (Phase C)

2020: Flight hardware being developed: mirror being figured, detectors being fabricated, spacecraft subsystems being delivered, coronagraph demo unit in testbed

2021 – Complete Critical Design Reviews

Mid-2020s – Launch



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

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

WFIRST Update

On Feb 28, 2020, WFIRST passed the Confirmation Review (KDP-C) and was approved by the Agency Program Management Council to begin Phase C

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

- CGI is being managed like other SMD technology demonstration projects (Mars Helicopter, Deep Space Optical Communications)
- Risk Class D (was Class C, WFIRST is Class A)
- Only one set of requirements (not baseline and threshold)
- Separate cost cap and schedule commitment
- Increased flexibility to respond to potential schedule issues
- No changes to design

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

COVID-19 update:

- Currently on-site work has stopped at GSFC and JPL per NASA Framework
- Work continues at several contractors, consistent with local situations

Webb

The James Webb Space Telescope

The Webb observatory in the clean room in Redondo Beach, CA in August 2019

- Observatory is fully integrated
- Observatory-level environmental testing (vibration and acoustics) happening this Spring
- Final deployments follow environmental testing through the Summer
- Numerous launch and commissioning exercises occurring through the year at STScI
- Cycle 1 proposals due 27-May-2020
- Launch Readiness Date 31-March-2

Webb Update

Programmatic

- Agency Program Management Council (APMC) approved Webb to enter Phase D (integration and test) on November 20, 2019.
- Annual GAO audit received. No recommendations.
- Currently working to March 31, 2021 LRD. Schedule will be assessed in mid-May, prior to entry into Observatory Environments testing [pre-COVID-19]

Observatory

- Successfully completed post Spacecraft Element testing and repairs

Science and Operations

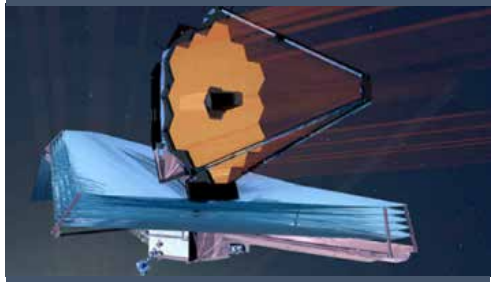
- Ground segment testing and operations rehearsals continuing (e.g., science operations, contingencies, launch and deployments)
- All Software elements at better than 98% requirements delivered to-date
- Call for Cycle 1 GO proposals released January 23, 2020; proposal deadline no earlier than May 27, 2020; next schedule update on April 15, 2020.

COVID-19 update

- Suspended integration and testing operations; resumed at reduced efficiency
- The observatory remains safe in its cleanroom environment

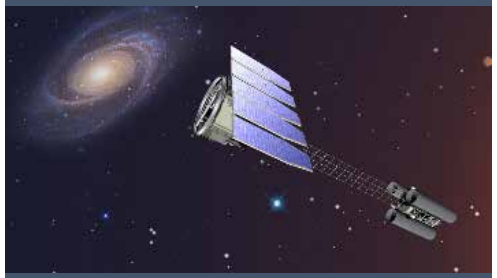
Astrophysics Missions in Development

Webb — 2021
NASA Mission



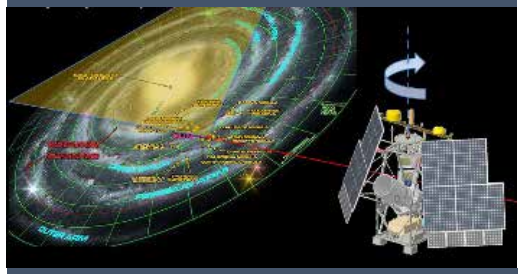
James Webb
Space Telescope

IXPE — 2021
NASA Mission



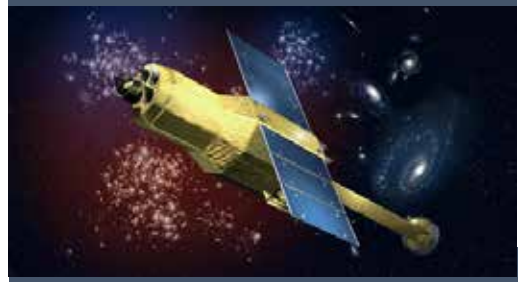
Imaging X-ray
Polarimetry Explorer

GUSTO — 2021
NASA Mission



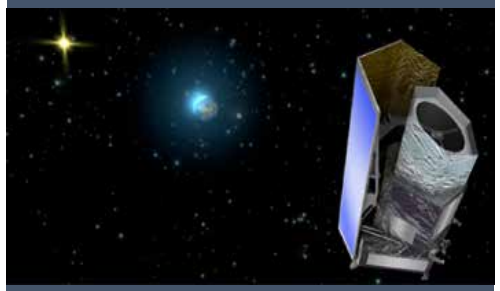
Galactic/ Extragalactic ULDB
Spectroscopic Terahertz Observatory

XRISM — 2022
JAXA-led Mission



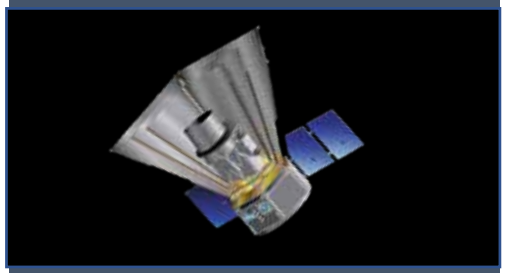
NASA is supplying the SXS
Detectors, ADRs, and SXTs

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

WFIRST — 2025
NASA Mission

Wide-Field Infrared
Survey Telescope

ARIEL — 2028
ESA-led Mission

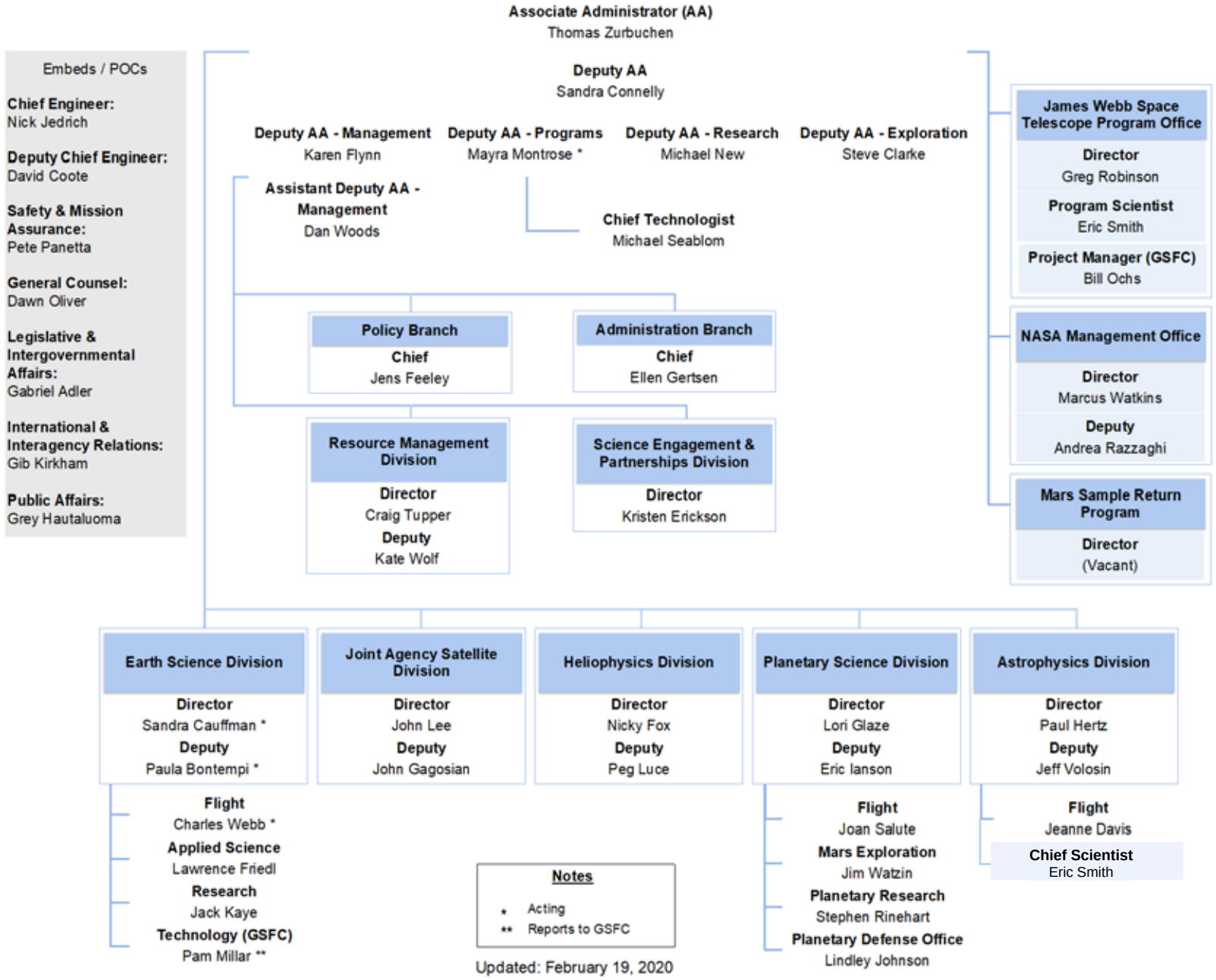
NASA is supplying the CASE
fine guidance instrument

Launch dates are current project working dates; Agency Baseline Commitment launch date could be later

Revised February 28, 2020

BACKUP

SMD Organization Chart



Science Budget Request Summary ($M)

	Actual FY 19	Request FY 20	Enacted FY 20	Request FY 21	Out-years FY 22	FY 23	FY 24	FY 25
Science	**6,886.6**	**6,393.7**	**7,138.9**	**6,306.5**	**6,553.5**	**6,575.7**	**6,705.2**	**6,766.9**
Earth Science	**1,931.0**	**1,779.8**	**1,971.8**	**1,768.1**	**1,878.2**	**1,846.1**	**1,834.5**	**1,984.6**
Earth Science Research	454.1	447.9		447.3	471.9	494.1	528.5	530.3
Earth Systematic Missions	932.7	719.2		608.3	706.1	695.6	640.7	797.3
Earth System Science Pathfinder	223.8	275.4		338.9	301.2	251.6	241.8	234.4
Earth Science Data Systems	202.0	214.4		245.4	259.9	263.2	278.7	277.7
Earth Science Technology	63.4	69.6		74.2	82.8	84.6	86.4	86.4
Applied Sciences	55.1	53.3		53.9	56.3	57.0	58.5	58.5
Planetary Science	**2,746.7**	**2,712.1**	**2,713.4**	**2,659.6**	**2,800.9**	**2,714.9**	**2,904.8**	**2,830.7**
Planetary Science Research	276.6	266.2		305.4	288.6	285.1	295.2	286.7
Planetary Defense	150.0	150.0	160.0	150.0	147.2	97.6	98.0	98.0
Lunar Discovery and Exploration	188.0	300.0	300.0	451.5	517.3	491.3	458.3	458.3
Discovery	409.5	502.7		484.3	424.4	434.8	570.1	505.8
New Frontiers	93.0	190.4		179.0	314.3	332.8	326.9	285.0
Mars Exploration	712.7	546.5	570.0	528.5	588.4	671.2	798.7	855.3
Outer Planets and Ocean Worlds	793.6	608.4		414.4	370.7	239.4	192.3	171.7
Radioisotope Power	123.3	147.9	147.9	146.3	150.1	162.8	165.4	169.8
Astrophysics	**1,191.1**	**844.8**	**1,306.2**	**831.0**	**891.2**	**1,000.9**	**959.7**	**975.5**
Astrophysics Research	222.8	250.7		269.7	279.1	327.2	314.9	331.1
Cosmic Origins	222.8	185.3		124.0	123.2	120.0	122.4	122.4
Physics of the Cosmos	151.2	148.4		143.9	160.8	155.3	169.8	154.1
Exoplanet Exploration	367.9	46.4		47.2	50.4	47.6	51.6	52.2
Astrophysics Explorer	226.5	214.1		246.2	277.7	350.8	301.0	315.6
James Webb Space Telescope	**305.1**	**352.6**	**423.0**	**414.7**	**175.4**	**172.0**	**172.0**	**172.0**
Heliophysics	**712.7**	**704.5**	**724.5**	**633.1**	**807.8**	**841.8**	**834.1**	**804.1**
Heliophysics Research	248.9	237.0		230.5	218.7	225.2	224.0	224.5
Living with a Star	135.3	107.6		127.9	134.5	246.4	225.5	233.3
Solar Terrestrial Probes	180.5	177.9	183.2	126.3	262.2	202.6	195.6	115.5
Heliophysics Explorer Program	147.9	182.0	182.0	148.4	192.4	167.6	189.0	230.8

Astrophysics Program Content

	Actual FY 19	Request FY 20	Enacted FY 20	Request FY 21	Out-years FY 22	FY 23	FY 24	FY 25
Astrophysics	**1,191.1**	**844.8**	**1,306.2**	**831.0**	**891.2**	**1,000.9**	**959.7**	**975.5**
Astrophysics Research	222.8	250.7	250.7	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	45.6
Other Missions and Data Analysis	54.2	73.7		89.1	95.5	141.7	128.8	145.0
Astrophysics Data Curation and Archival	17.9	21.2		24.5	26.3	26.4	28.5	28.7
Astrophysics Data Program	19.1	20.4		21.6	22.6	23.6	23.6	23.6
Astrophysics Senior Review		-				51.2	50.4	49.9
Contract Administration, Audit & QA Svcs	12.7	12.7		17.3	17.3	17.3	17.3	17.3
Astrophysics Directed R&T	4.5	19.4		25.7	29.4	23.3	9.0	25.5
Cosmic Origins	222.8	185.3		124.0	123.2	120.0	122.4	122.4
Hubble Space Telescope	98.3	83.3	90.8	88.3	98.3	98.3	98.3	98.3
SOFIA	85.2	73.0	85.2	12.0				
Other Missions and Data Analysis (development / formulation / technology)	39.3	29.0		23.7	24.9	21.7	24.1	24.1
Cosmic Origins SR&T	24.8	17.1		18.4	18.4	18.4	18.4	18.4
Cosmic Origins Future Missions (operating)	0.8	2.2		2.7	4.6	1.6	3.8	3.8
Spitzer (research and management)	13.2	8.5		1.0				
Astrophysics Strategic Mission Prog Mgmt	0.4	1.2		1.6	1.9	1.7	1.9	2.0

Astrophysics Program Content

	Actual FY 19	Request FY 20	Enacted FY 20	Request FY 21	Out-years FY 22	FY 23	FY 24	FY 25
Physics of the Cosmos	151.2	148.4		143.9	160.8	155.3	169.8	154.1
(development / formulation / technology)								
Euclid	17.2	13.7		11.0	8.9	9.9	10.3	9.5
Physics of the Cosmos SR&T	45.7	50.9		45.9	61.2	75.2	87.0	72.1
Physics of the Cosmos Future Missions	0.0	2.0		1.6	4.6	2.0	3.7	3.7
(operating)								
Chandra X-Ray Observatory	61.7	58.4		62.3	62.8	62.8	62.8	62.8
Fermi Gamma-ray Space Telescope	16.5	14.0		13.8	13.9			
XMM	4.5	3.5		3.5	3.5			
(research and management)								
PCOS/COR Technology Office Management	5.6	5.9		5.9	6.0	5.4	6.0	6.0
Exoplanet Exploration	367.9	46.4		47.2	50.4	47.6	51.6	52.2
(development / formulation / technology)								
WFIRST	312.2		510.7					
Exoplanet Exploration SR&T	32.1	29.1		31.5	32.0	31.3	30.5	31.2
Exoplanet Exploration Future Missions	0.7	2.8		1.7	3.5	1.6	5.4	5.4
(operating)								
Keck Operations	6.5	6.7		6.9	7.0	7.2	7.4	7.4
Kepler	8.9	1.3						
(research and management)								
Exoplanet Exploration Technoloy Off Mgmt	7.5	6.5		7.1	7.8	7.4	8.2	8.1

Astrophysics Program Content

	Actual FY 19	Request FY 20	Enacted FY 20	Request FY 21	Out-years FY 22	FY 23	FY 24	FY 25
Astrophysics Explorer	226.5	214.1		246.2	277.7	350.8	301.0	315.6
(development / formulation / technology)								
SPHEREx	22.2			90.8	109.1	87.7	28.4	13.0
Imaging X-Ray Polarimetry Explorer	57.0	70.2		45.3	7.4	4.5	0.5	
X-Ray Imaging and Spectroscopy Mission	23.2	29.7		25.1	36.3	17.7	15.9	14.4
CASE				11.9	10.2	10.0	6.4	1.0
GUSTO	19.9	11.1		7.8	5.8	1.0		
Astrophysics Explorer Future Missions	2.3	84.8		10.6	58.0	219.2	241.5	278.1
Universe Explorer Prior Hist Projects	70.0							
(operating)								
Transiting Exoplanet Survey Satellite	7.7	5.0		14.7	14.1			
Nuclear Spectroscopic Telescope Array	8.5	7.8		8.6	8.6			
Neil Gehrels Swift Observatory	7.0	5.5		5.8	5.8			
NICER	3.8			4.8	4.4			
(research and management)								
Astrophysics Explorer Program Management	4.9			20.7	18.0	10.7	8.3	9.1
James Webb Space Telescope	**305.1**	**352.6**	**423.0**	**414.7**	**175.4**	**172.0**	**172.0**	**172.0**
Astrophysics + Webb Total	**1,496.2**	**1,197.3**	**1,729.2**	**1,245.7**	**1,066.6**	**1,172.9**	**1,131.7**	**1,147.5**