National Aeronautics and Space Administration

Paul Hertz
Michael Garcia
Stefan Immler
Mario Perez
Hashima Hasan
Patricia Knezek
Martin Still
Douglas Hudgins
William Latter

EXPLORE SCIENCE

NASA Town Hall

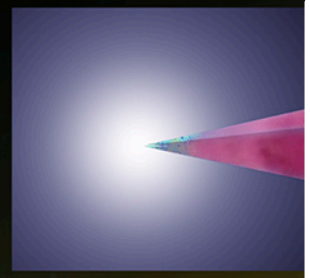
AAS 234th Meeting | June 10, 2019

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

Posted at **http://science.nasa.gov/astrophysics/documents**

Why Astrophysics?

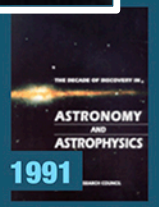


How did our universe

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

NASA Strategic Plan (2018)

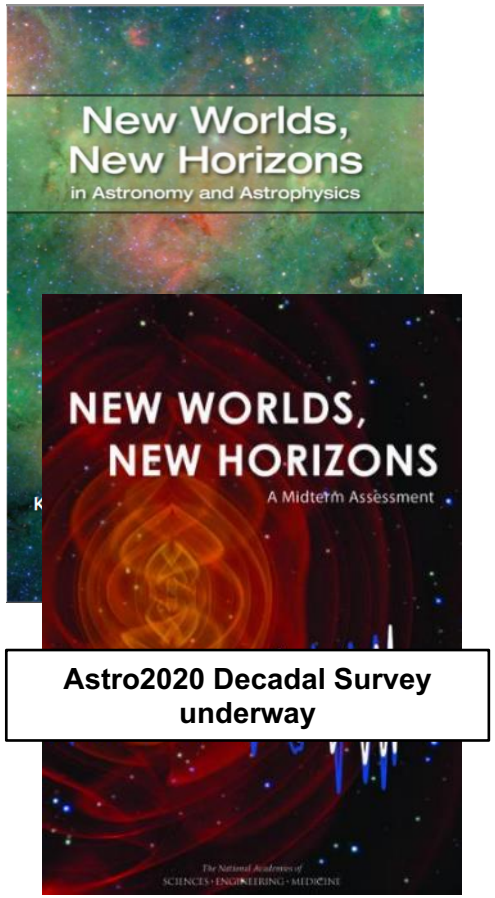
Enduring National Strategic Drivers



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

Astrophysics Strategic Planning

To be updated in 2019
(per GPRAMA)



Astro2020 Decadal Survey
underway

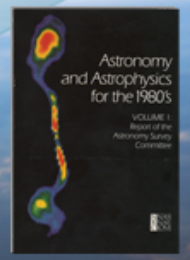
2018 update includes:
- Independent reviews of Webb & WFIRST
- Planning for 2020 Decadal Survey

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

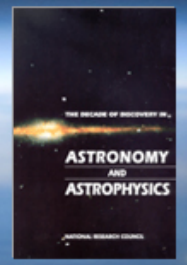
Astrophysics

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra

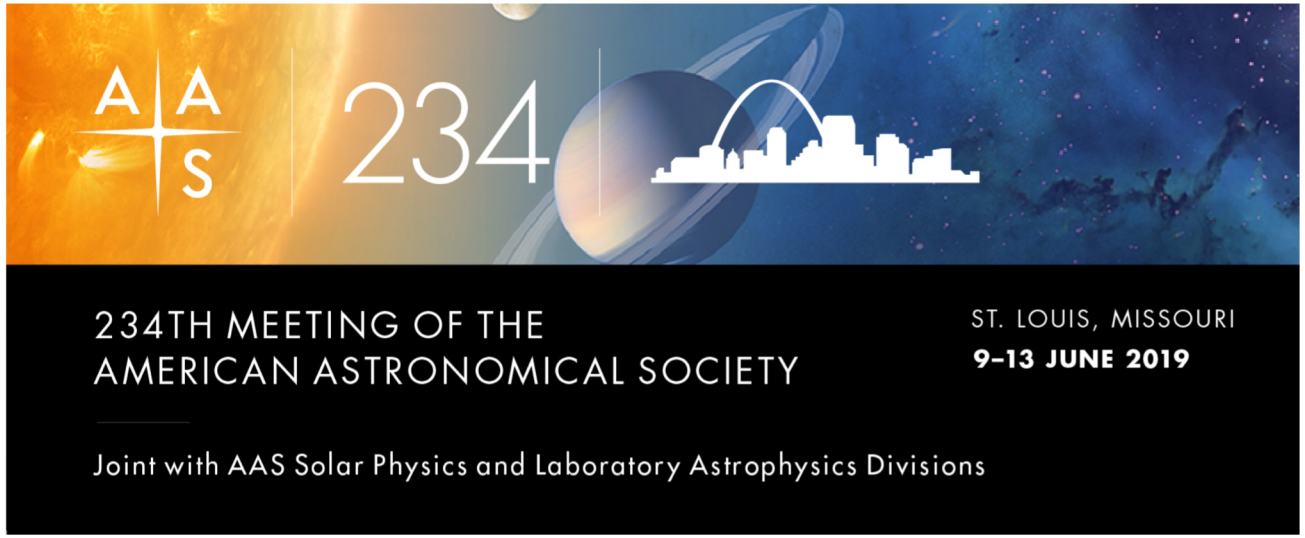


1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST

NASA Events at the 234th AAS Meeting



NASA Large Mission Concept Studies for the Decadal Survey
showcased at NASA Booth
Monday, June 10 – Thursday, June 13; Exhibit Hall

Monday, June 10

Exploring the Diversity and Habitability of Nearby Planetary Systems with HabEx – 2:30 PM; Midway 1&2

Revealing the Invisible Universe with the Lynx X-ray Observatory – 3:00 PM; Wabash Cannonball Room

NASA Heliophysics Town Hall – 6:30 PM; Regency C

Space Telescope Science Institute Town Hall – 7:30 PM; Grand Ballroom A

Tuesday, June 11

NASA Astrophysics Science SmallSat Studies – 10:40 AM; Grand Ballroom A

Learning to Utilize Kepler's Unique Dataset for Computing Exoplanet Occurrence Rates – 1:30 PM; Midway 7&8

NASA Living with a Star PAG Town Hall – 1:40 PM; Grand Ballroom B

WFIRST Ultra-deep Fields I - 2:50 PM; Grand Ballroom B

Origins Space Telescope Enables Community Science
– 3:30 PM; Jeffersonian/Knickerbocker

The Astronomy and Astrophysics Decadal Survey 2020 Town Hall – 6:30 PM; Grand Ballroom A

Wednesday, June 12

General Astrophysics and Solar System Science with HabEx - 9:30 AM; Midway 7&8

WFIRST Ultra-deep Fields II - 2:50 PM; Grand Ballroom B

Outline

- Community Involvement
  - Building Leaders and Teams for the Future
  - Connecting with NASA
- Program Update
  - Budget Update
  - Project Artemis
  - Research & Analysis
- Missions Update
  - Webb, WFIRST
  - TESS, SPHEREx, Explorers
  - Other missions
- Preparing for Astro2020
  - Large Mission (Flagship) Studies
  - Medium Mission (Probe) Studies
  - Program of the Future

NASA Astrophysics Community Involvement

Building Excellent Teams

- Excellent teams require diverse opinions and perspectives
- Teams must foster a community where everyone feels safe
- Encouraging healthy behavior through actions is paramount
- SMD is building excellent teams by:
  - Promoting diversity for both grants and PI-led missions
  - Providing resources to report concerns
  - Partnering with the Office of Diversity and Equal Opportunity
  - Examining barriers to diversity and inclusion within NASA and the broader science community

NASA Astrophysics Division

ASTROPHYSICS
NASA's Science Mission Directorate

Division Director

Paul Hertz
Astrophysics Division Director

Jeff Volosin
Astrophysics Deputy Division Director (Acting)

Program Executives

E. Lucien Cox
SOFIA, GUSTO

Shahid Habib
COR, ExEP, PCOS Programs
Athena, Euclid, LISA

Jeff Hayes
Astrophysics Operating missions

Tracy Osborne
WFIRST, XRISM

Mark Sistilli
Astrophysics Explorers Program
IXPE, Balloons

Cross Cutting

Eric Smith
Astrophysics Chief Scientist
JWST

Jackie Townsend
ASM Program Manager (Acting)

Nasser Barghouty
Astrophysics Technology Lead, SAT, RTF

Not Pictured

Lisa Wainio
Information Manager, Public Affairs Liaison

Administrative Support

Kelly Johnson
Administrative Assistant

Not Pictured

Matthew Riggs
Administrative Assistant

Not Pictured

Jackie Mackall
Program Support Specialist

Ingrid Farrell
Program Support Specialist

Program Scientists

Dominic Benford
APRA Lead
WFIRST

Valerie Connaughton
APRA (High Energy)
XRISM

Dan Evans
PCOS Program Sci.
APRA (High Energy)

Michael Garcia
APRA (UV/Optical), CubeSats/SmallSats
Hubble, Athena

Thomas Hams
APRA (CR, Fund. Phys.)
Rockets/Balloons
CREAM, GUSTO

Hashima Hasan
Education/Comms
Astrophysics Archives
Astro. Advisory Cmte.

Douglas Hudgins
ExEP Program Sci.
ADAP lead
APRA (Exopl. Tech.)

Stefan Immler
Astrophysics Research Program Manager
Chandra, Fermi

Patricia Knezek
APRA (UV/Optical)

William Latter
APRA (Lab Astro Lead)
Spitzer, SPHEREx

Mario Perez
COR Program Sci.
APRA (UV/Optical)
SAT (COR)

Rita Sambruna
APRA (Fund. Phys.)
ADAP, LISA, NICER, Decadal Studies

Evan Scannapieco
ATP, TCAN Lead
Swift

Kartik Sheth
APRA (IR/Submm)
SOFIA, JWST, Spitzer, NHFP

Linda Sparke
Astrophysics Explorers Program

Martin Still
XRP Lead
TESS

Eric Tollestrup
APRA (IR/Submm)
Euclid, IXPE

Others Not Pictured:

- **Larry Petro**
- **Panayiotis Tzanavaris**

Astrophysics Program Abbreviations: ASM – Astrophysics Strategic Missions; COR – Cosmic Origins; ExEP – Exoplanet Exploration Program; PCOS - Physics of the Cosmos

NASA Astrophysics Diversity and Inclusion

The NASA Astrophysics Division is actively taking steps to advance diversity, inclusion, and equal opportunity in the NASA workforce and among NASA grantee institutions.

NASA Astrophysics is committed to:

- Setting the expectancy of diversity and inclusion in the composition of: proposal teams, peer review panels, science and technology definition teams, and mission and instrument teams.
- Recruiting diversity on NASA-selected groups (e.g., advisory groups, peer review panels, science teams).
- Recruiting a diverse Astrophysics Division staff.
- Working with the NASA Office of the Chief Scientist and our peer review contractors to address unconscious bias in peer reviews.
- Establishing a Code of Conduct for peer review panel chairs and members
- Sharing best practices in peer reviews with other agencies.
- Observing the demographics of R&A proposers and awardees as an indicator of issues.

The demographics of R&A proposers and awardees – we notice that:

- The inferred gender balance of awardees does reflect that of proposers.
- The inferred gender balance of proposers does not always reflect that of the community.

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

Mission Principal Investigator Development

- Seek to increase the diversity of mission principal investigators and develop the next generation of mission leaders to ensure that new ideas and mission concepts are brought forward
- Based on feedback from November 2018 workshop, NASA Science
  - Developed a consolidated PI resources webpage at https://science.nasa.gov/researchers/new-pi-resources
  - Introduced a pre-reviews of mission peer review panels to ensure diversity and reduce conflicts of interest
  - Added a code of conduct requirement for SMD-funded conferences to ROSES 2019
  - Restarted proposal writing workshops at major science conferences
  - Included career development positions and associated evaluation criteria as part Discovery and New Frontiers AOs
  - Lessons learned presentation by NASA Science AA Thomas Zurbuchen on characteristics and key mistakes associated with proposal success at http://science.nasa.gov/researchers/new-pi-resources
- Upcoming activities include:
  - Information sessions at science conferences and stand-alone workshops to support people developing first proposal
  - Sign up to learn more at https://lists.hq.nasa.gov/mailman/listinfo/hq-smdpi-workshop-outreach

Why Volunteer to Serve on a NASA Peer Review Panel?

- Personal professional development:
  - See how the whole review process works
  - Learn what constitutes excellent proposals
  - Network with your professional colleagues and NASA scientific staff
- Institutional achievement:
  - Improve at competing for NASA money
  - Increase knowledge of NASA's educational programs and research technology
- Investment in the future:
  - Help select the most transformative science
  - Ensure that all proposals receive a fair and competent review
- Sign up to be a panel reviewer:

  https://science.nasa.gov/researchers/volunteer-review-panels

Keep Informed about NASA

NSPIRES mailing list – information about NASA solicitations

https://nspires.nasaprs.com/

Cosmic Origins mailing list, Exoplanet Exploration mailing list, Physics of the Cosmos mailing list – information about NASA missions and science

https://cor.gsfc.nasa.gov/cornews-mailing-list.php

https://exoplanets.nasa.gov/exep/exopag/announcementList/

https://pcos.gsfc.nasa.gov/pcosnews-mailing-list.php

NASA Astrophysics Federal Advisory Committees

Astrophysics Advisory Committee (APAC)
https://science.nasa.gov/researchers/nac/science-advisory-committees/apac

NAS Committee on Astronomy and Astrophysics (CAA)
http://sites.nationalacademies.org/bpa/bpa_048755

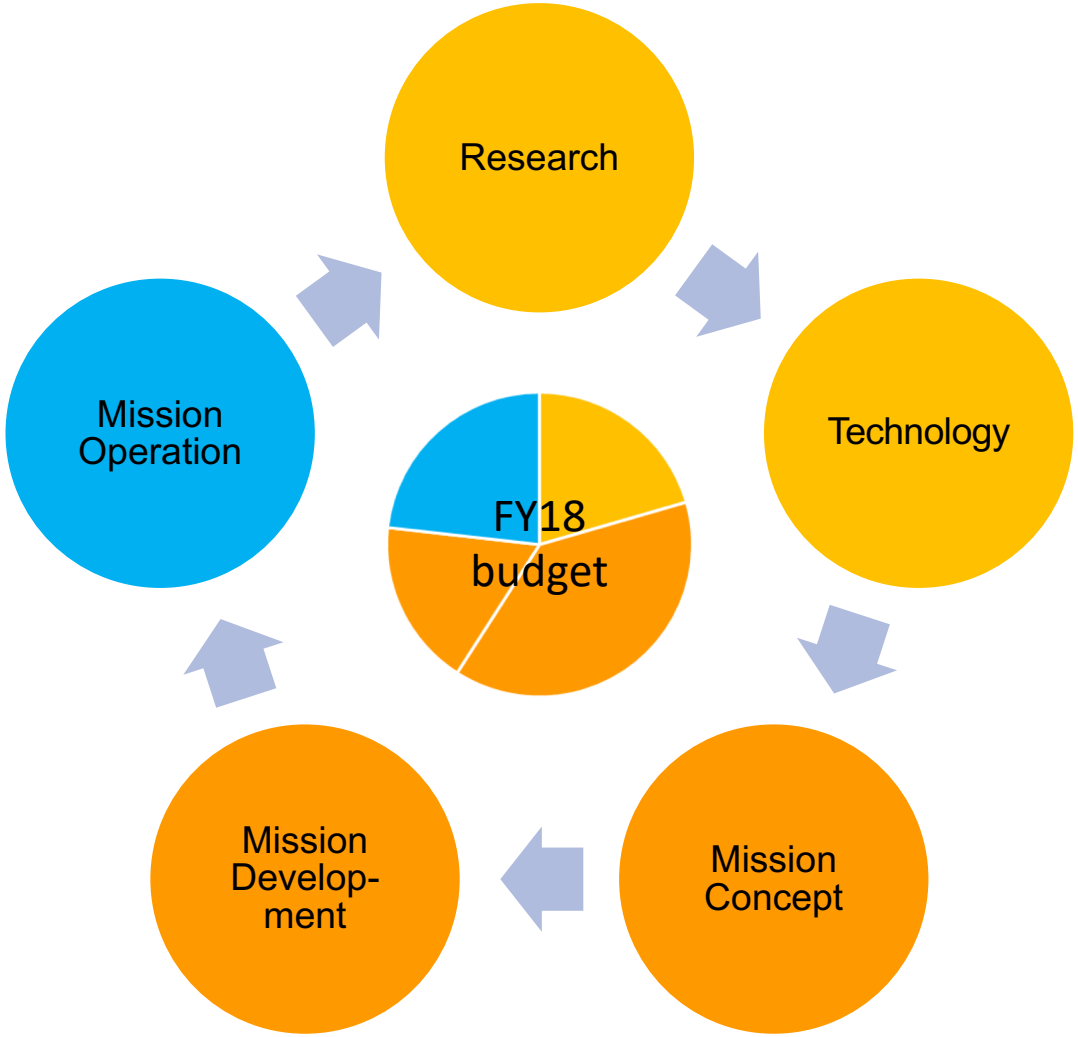
Astronomy and Astrophysics Advisory Committee (AAAC)
https://www.nsf.gov/mps/ast/aaac.jsp

Sign up to be a panel reviewer:

https://science.nasa.gov/researchers/volunteer-review-panels

NASA Astrophysics Program Update

NASA's Astrophysics Program



Large (Flagship) Missions

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

Medium (Probe) and Small (Explorer) Missions

- Lead missions with more focused or specialized capabilities and 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

NASA Astrophysics Program Summary

Supporting Research & Technology	R&A: ADAP, ATP, XRP, SmallSat Studies, Suborbital & CubeSat Projects	Technology: APRA, SAT, RTF, Future flagship technologies	Research support: Balloon project, Astrophysics archives
Operating Missions	Explorers: Gehrels Swift, NuSTAR, NICER, TESS	International Partnerships: XMM-Newton	Strategic Missions: Hubble, Chandra, Spitzer, Fermi, Kepler, SOFIA
Missions in Development or Under Study	Explorers: IXPE, GUSTO, SPHEREx	International Partnerships: Euclid, XRISM, Athena, LISA	Strategic Missions: Webb, WFIRST

FY19 Budget Appropriation

The FY19 appropriation (Feb 2019) provides an increased level of funding for NASA Astrophysics

- Total appropriated funding for FY19 (Astrophysics including Webb) is ~$1.496B, an increase of $112M (8%) from FY18 appropriation
- Webb funded as requested at $305M, request submitted before 2018 replan
  - Webb is reauthorized at 2018 replan level of $8.8B for development
- WFIRST funded at $312M, proposed termination not supported by Congressional appropriation
- Hubble and SOFIA received appropriations above requested levels
  - NASA is prohibited from including SOFIA in the 2019 Senior Review
- All other programs supported as proposed

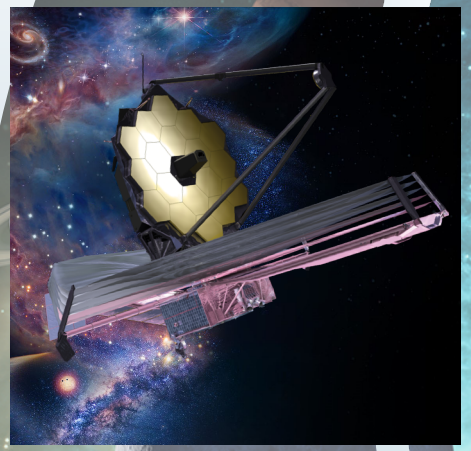
FY20 Budget Request

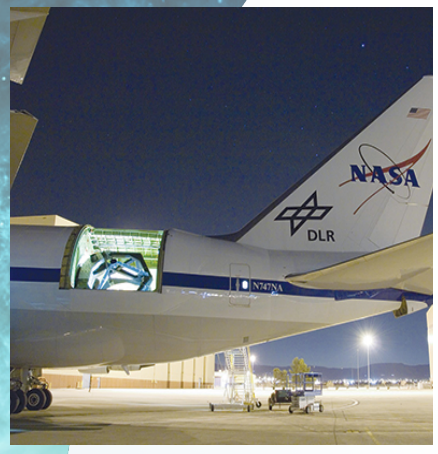
The FY20 President's Budget Request requests a decreased level of funding for NASA Astrophysics

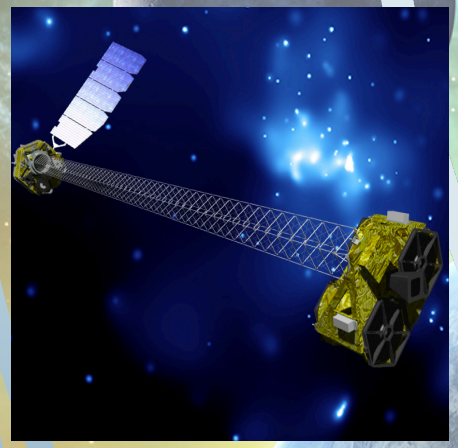
Total funding requested for FY20 (Astrophysics including Webb) is ~1.197B, a decrease of $187M (14%) from the FY18 appropriation and a decrease of $299M (20%) from the FY19 appropriation

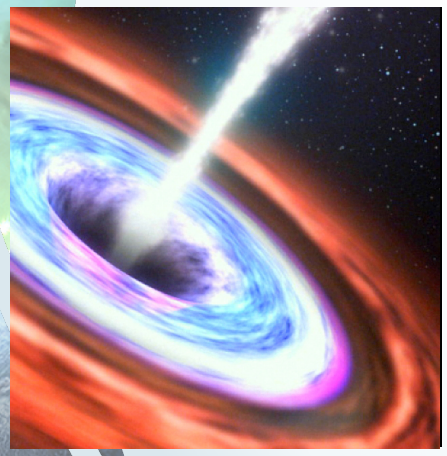
https://nasa.gov/budget

FY20 Budget Request









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

Congressional Markup of FY20 Budget Request

House has marked up NASA's FY20 budget request

- WFIRST is funded at $510.7M, with $65M for the coronagraph technology demonstration instrument; this is $510.7M above the request
- SOFIA is funded at $85.2M; this is $12.2M above the request
- Webb is funded at $352.6M; this is the request and supports the replan to a 2021 launch
- Astrophysics including Webb is funded at $1,720.3M; this is $522.9M above the request and supports the planned Astrophysics programs

Senate will mark up NASA's budget later (probably July)

Congressional Markup of FY20 Budget

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

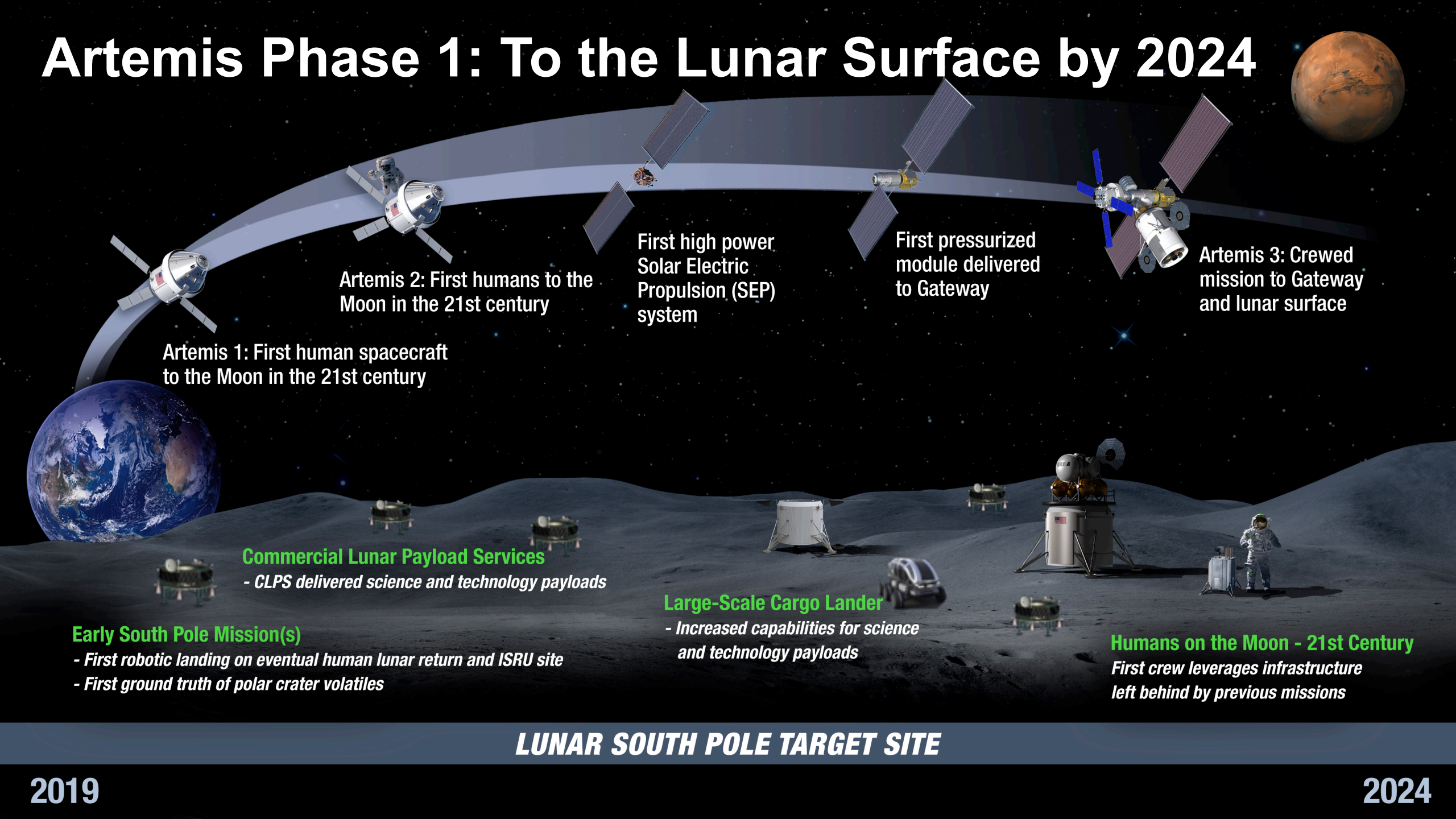
An Agency Budget Increase for the Artemis Program

- The FY2020 budget amendment provides an ***increase*** of **$1.6 billion** above the president's initial **$21 billion** budget request with no money taken from existing NASA programs. This is the ***boost*** NASA needs.

  - $1 billion to accelerate development of human lunar transportation systems to take astronauts to the surface and back to Gateway*
  - $651 million towards the completion of SLS and Orion to support a 2024 landing.
  - $132 million for new technologies to help astronauts live and work on the lunar surface and in deep space.
  - $90 million for Science to increase robotic exploration at the lunar South Pole in advance of astronauts.

** Focusing Gateway on just the capabilities needed for Phase 1 allowed for a $321M scope reduction and shifts potential development and expanded capabilities for Gateway into Phase 2.*

Artemis Phase 1: To the Lunar Surface by 2024



Lunar Science by 2024

Polar Landers and Rovers

- First direct measurement of polar volatiles, improving understanding of lateral and vertical distribution, physical state, and chemical composition
- Provide geology of the South-Pole Aitken basin, largest impact in the solar system

Non-Polar Landers and Rovers

- Explore scientifically valuable terrains not investigated by Apollo, including landing at a lunar swirl and making first surface magnetic measurement
- Using PI-led instruments to generate Discovery-class science, like establishing a geophysical network and visiting a lunar volcanic region to understand volcanic evolution

Orbital Data

- Deploy multiple CubeSats with Artemis 1
- Potential to acquire new scientifically valuable datasets through CubeSats delivered by CLPS providers or comm/relay spacecraft
- Global mineral mapping, including resource identification, global elemental maps, and improved volatile mapping

In-Situ Resource Initial Research

- Answering questions on composition and ability to use lunar ice for sustainment and fuel

Science After 2024

Human and Robotic Missions Provide Unique Science Opportunities

On Gateway

- Deep space testing of Mars-forward systems
- Hosts groundbreaking science for space weather forecasting, full-disc Earth observation, astrophysics, heliophysics, lunar and planetary science
- Mars transit testbed for reducing risk to humans

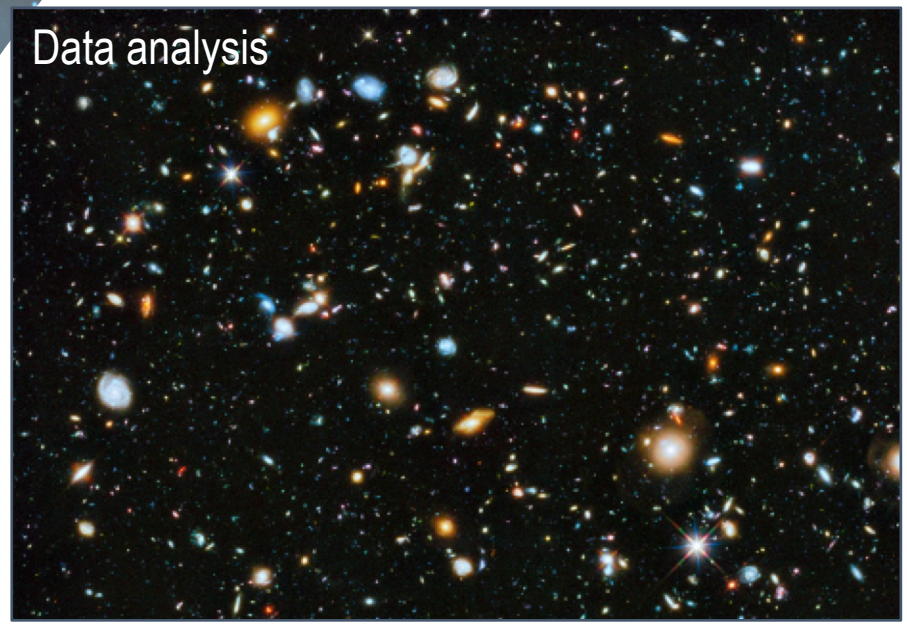
Surface Exploration

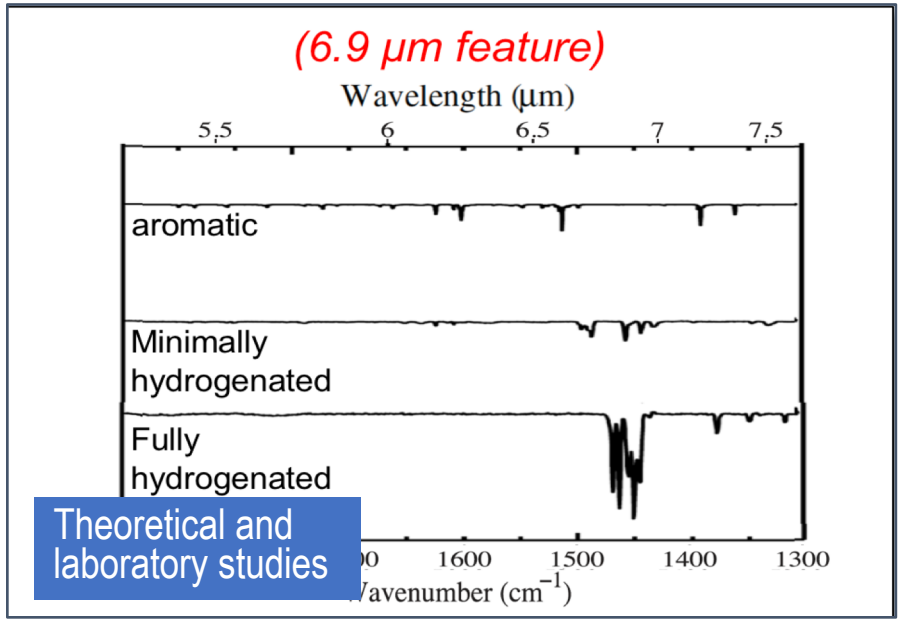
- Understanding how to use in-situ resources for fuel and life
- Revolutionizing the understanding of the origin and evolution of the Moon and inner solar system by conducting geophysical measurements and returning carefully selected samples to Earth
- Studying lunar impact craters to understand physics of the most prevalent geologic process in the solar system, impact cratering
- Setting up complex surface instrumentation for astrophysics, heliophysics and Earth observation
- Informing and supporting sustained human presence through partial gravity research in physical and life sciences, from combustion to plant growth

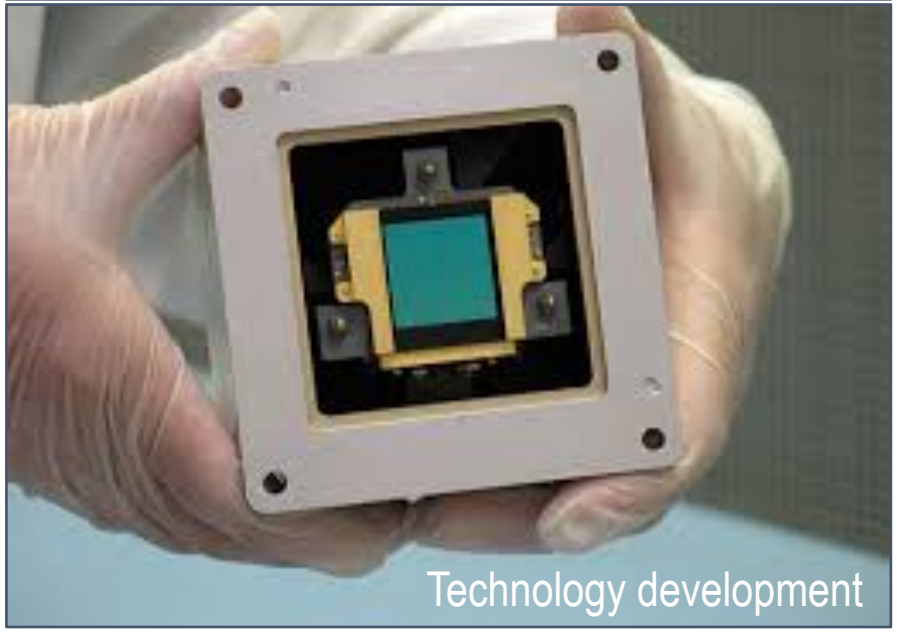
Surface Telerobotics to Provide Constant Science

- Sending rovers into areas too difficult for humans to explore; rovers can be teleoperated from Earth to maximize the scientific return

Supporting Research and Technology

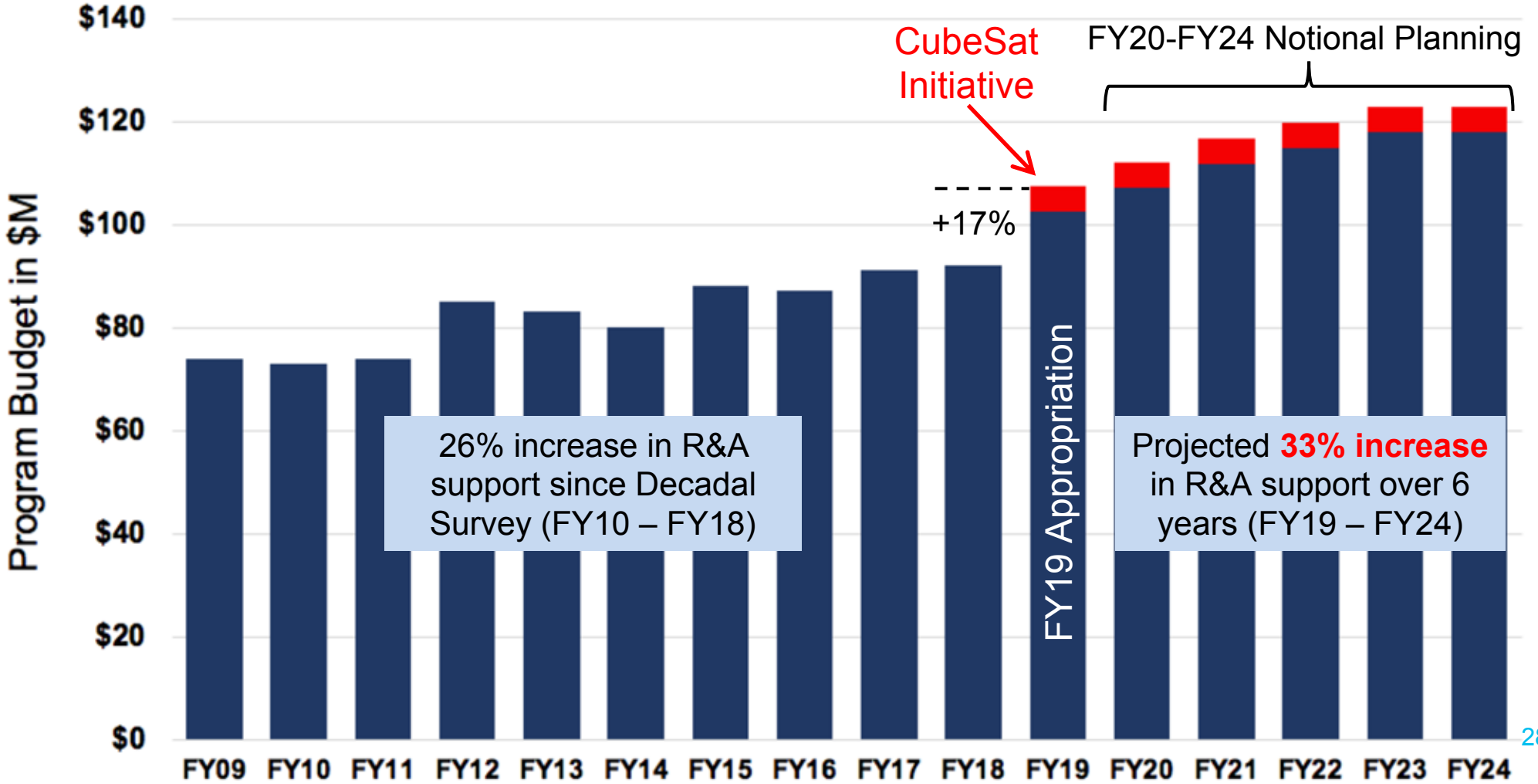






Growth in R&A Funding ($M)

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



Proposal Status Update

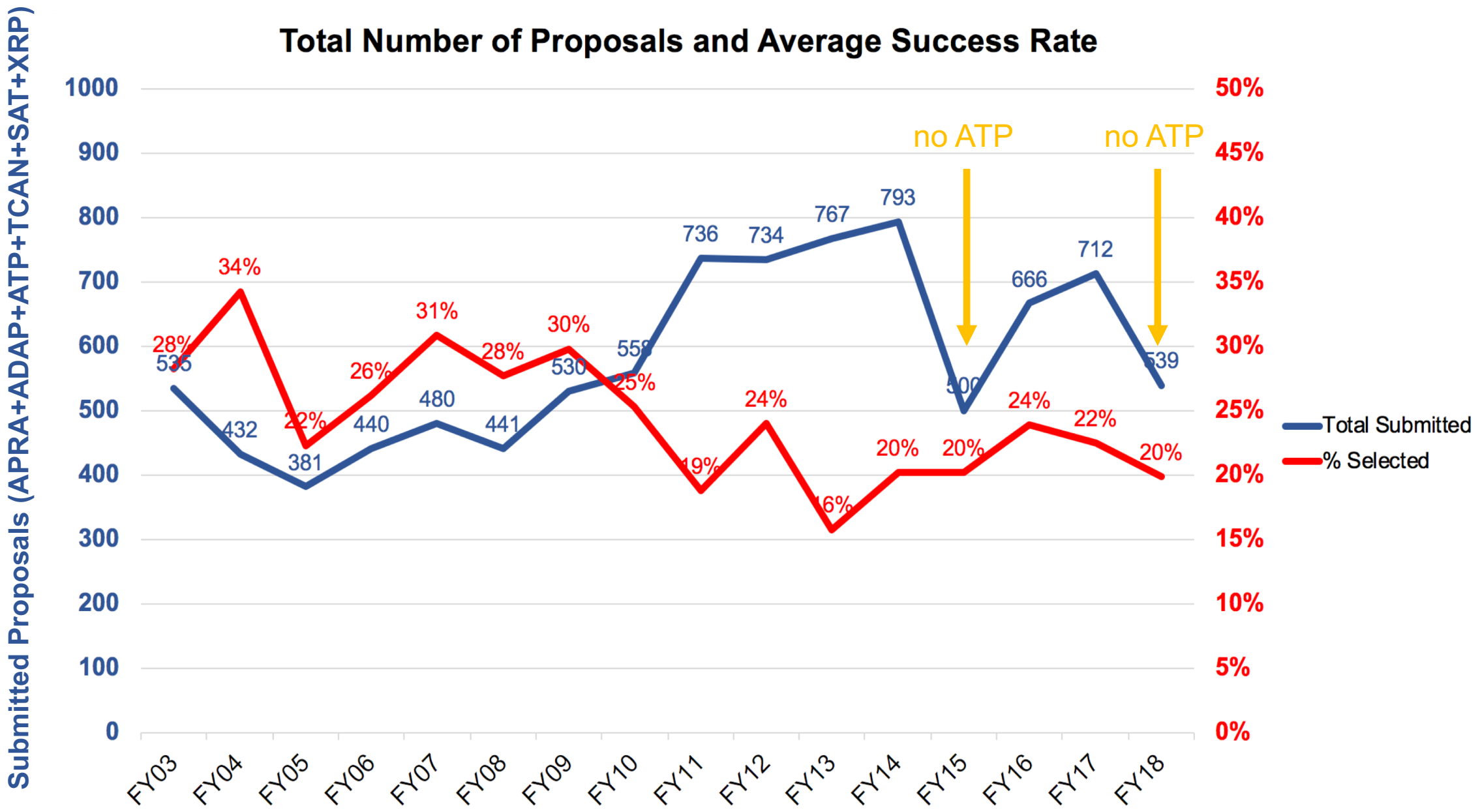
GO Selection Rate = 30%

R&A Selection Rate = 23%

Average: 107 days (44 – 155 days)
80% PIs notified: 85 days

Status: May 30, 2019

Solicitation5	Proposal Due Date	Notify Date	Days since received	Number received	Number selected	% selected
TESS – Cycle 1	Oct 6, 2017	Feb 3, 2018	132	143	38	27%
K2 – Cycle 6 (Phase 2)	Apr 19, 2018	June 25, 2018	67	41	23	56%
NESSF-18	Feb 1, 2018	May 15, 2018	103	176	8	4%
Chandra GO – Cycle 20	Mar 16, 2018	July 16, 2018	122	526	156	24%
XARM Participating Scientist	Dec 13, 2017	Feb 21, 2018	64	39	5	13%
NuSTAR – Cycle 4	Jan 19, 2018	April 17, 2018	88	196	83	42%
TCAN	Jan 26, 2018	June 21, 2018	146	32	3	9%
Segmented Telescope Design	Feb 1, 2018	Mar 16, 2018	44	5	2	40%
Fermi GI – Cycle 11	Feb 23, 2018	May 26, 2018	92	138	42	30%
Spitzer GI – Cycle 14	Mar 23, 2018	May 29, 2018	67	116	50	43%
APRA (Basic Research)	Mar 19, 2018	Aug 14, 2018	148	170	49	29%
SAT (Technology)	Mar 19, 2018	Aug 14, 2018	148	25	11	44%
SmallSat Studies (AS^3)	July 13, 2018	Sep 10, 2018	59	38	9	24%
ADAP (Data Analysis)	May 17, 2018	Sep 17, 2018	123	242	53	22%
XRP (Exoplanet Research)	May 30, 2018	Oct 19, 2018	142	67	8	12%
LISA Preparatory Science	June 14, 2018	Nov 16, 2018	155	30	8	40%
SOFIA Next Gen Instruments	Aug 1, 2018	Oct 23, 2018	84	6	0	0%
Swift GI – Cycle 15	Sep 27, 2018	Feb 12, 2019	153*	141	33	23%
NICER Cycle 1	Dec 20, 2018	Mar 4, 2019	75	84	49	58%
TESS, Fermi, NuSTAR*				* affected by partial government shutdown		


Total Number of Proposals and Average Success Rate
Submitted Proposals (APRA+ADAP+ATP+TCAN+SAT+XRP)
1000
900
800
700
600
500
400
300
200
100
0
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
no ATP
no ATP
535
432
381
440
480
441
530
558
736
734
767
793
500
666
712
539
28%
34%
22%
26%
31%
28%
30%
25%
19%
24%
16%
20%
20%
24%
22%
20%
FY03
FY04
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
FY18
Total Submitted
% Selected

NASA Earth and Space Science Fellowship (NESSF)

NESSF name is changing to FINESST (Future Investigators in NASA Earth and Space Science and Technology) 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%

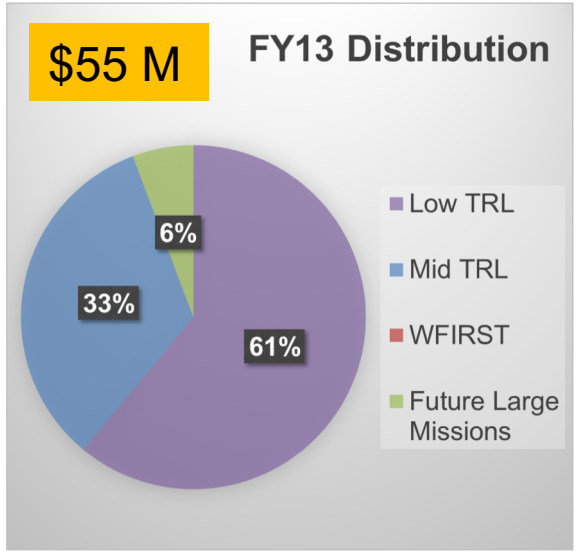
Community input has led to us doubling the Astrophysics NESSF / FINESST program effective in 2019

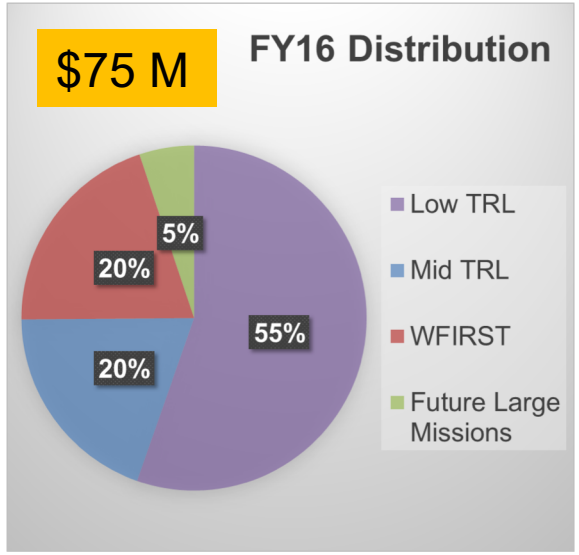
Astrophysics will now be funding 45-48 NESSF / FINESST Fellows at any given time

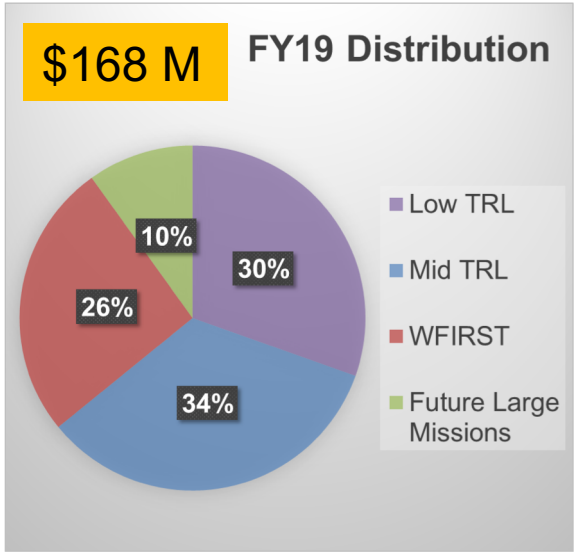
The selection rate will be ~10%

Astrophysics Technology Investment FY13-FY19

- More than 200% growth over 6 years in technology development (FY13-FY19); over $600M invested
- Distribution profile among the four sectors is agile even with a robust growth
- The low- and mid-TRL sectors together account for about 70% of technology investment profile
- Investment in future large missions' technologies is steadily growing
  - Low TRL: APRA (including suborbital-class payloads)
  - Mid TRL: SAT, Athena, LISA, X-ray Mirrors, Detectors, etc.
  - WFIRST: Detectors, Coronagraph
  - Future Large Missions: Ultrastable Telescope, Starshade, Next Gen Coronagraph

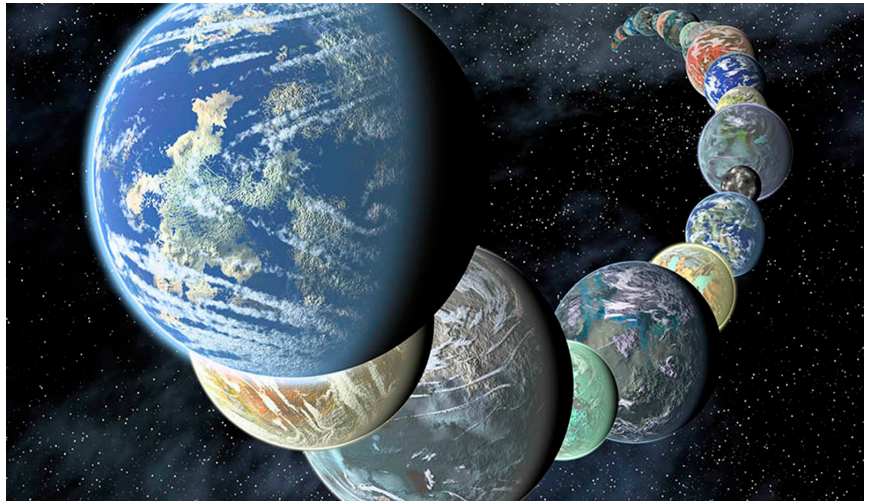






Exoplanet Research Program (XRP)

Within ROSES-19, proposals submitted to the Exoplanet Research Program (XRP, E.3) will be selected jointly by all four divisions of SMD in caucus: Astrophysics, Planetary Sciences, Heliophysics, and Earth Sciences.



- Combines resources across the divisions to make greater strides, more efficiently
- Encourages cross-cutting investigations that approach exoplanet research with fresh, broader perspectives
- Advances our understanding of exoplanetary systems and the Agency's strategic goals more effectively

NASEM Exoplanet Science Strategy
Extreme Precision Radial Velocity Initiative

Exoplanet Science Strategy Recommendation:

"NASA and NSF should establish a strategic initiative in extremely precise radial velocities (EPRVs) to develop methods and facilities for measuring the masses of temperate terrestrial planets orbiting Sun-like stars"

- Combine efforts in instrumentation, survey execution, and data analysis techniques involving stellar astrophysics and heliophysics
- Undertake the coordinated, sustained effort to tackle the myriad of error terms that currently limit RV precision.
- Assess ultimate goal to control systematics at ~1 cm/s, accounting for stellar variability and tellurics

Response: NASA and NSF have jointly commissioned a community-based "Extreme Precision Radial Velocity (EPRV) Working Group" (EPRV-WG) to develop a blueprint for a strategic EPRV initiative.

- Working Group formed, first in-person workshop June 13-14, 2019
- EPRV-WG to submit a candidate program architecture by Feb 2020 for consideration by Agencies during annual budget formulation process

Multi Messenger Astronomy Coordination and Support

- Multi Messenger Astronomy Science Analysis Group (MMA SAG)
  - Self-organized community group, Co-Chairs J. Conklin, S. Gezari, J. Tomsick
  - Report to APAC in mid-2019 (after coordinating Decadal Survey white papers)
  - https://pcos.gsfc.nasa.gov/sags/mmasag.php
- Gravitational Wave – Electromagnetic Counterpart Task Force (GW-EM TF)
  - NASA ad hoc group with NASA scientists and community consultants
  - Assess the role of NASA in GW-EM astrophysics, in particular in the EM prompt and follow-up observations of LIGO sources
  - Report to NASA in 6-8 months
  - https://pcos.gsfc.nasa.gov/news/NASA_GW-EM_final_signed.pdf
- Interagency Working Group with NSF
  - Coordinate NASA contributions with NSF's Big Idea
- Ad Hoc Mission Utilization
  - EM follow-up as TOOs using all NASA space telescopes
  - GRB alerts from Swift and Fermi, enables search for sub-threshold LIGO events
- Development of tools and alerts
  - GCN alerts now, task at GSFC to specify a Next Generation GCN
  - Tools at NASA archives, e.g. NED to automatically search all LIGO event regions

NASA Astrophysics Missions Update

Astrophysics Missions in Development

TESS 4/2018
NASA Mission

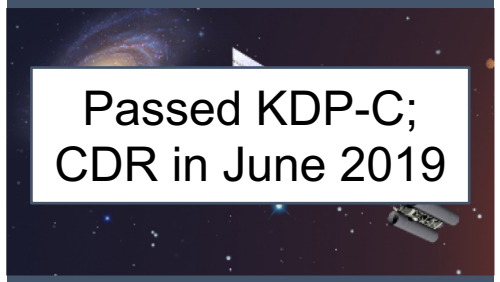
Transiting Exoplanet Survey Satellite

Webb 2021
NASA Mission

Replanned SIR now in Sep 2019

James Webb Space Telescope

IXPE 2021
NASA Mission



Passed KDP-C; CDR in June 2019

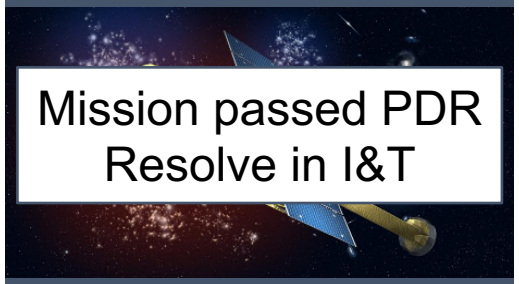
Imaging X-ray Polarimetry Explorer

GUSTO 2021
NASA Mission

Passed KDP-C; CDR in July 2019

Galactic/ Extragalactic ULDB Spectroscopic Terahertz Observatory

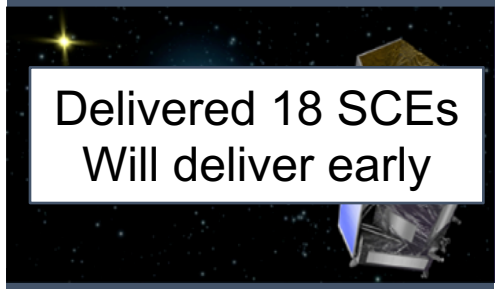
XRISM 2022
JAXA-led Mission



Mission passed PDR Resolve in I&T

NASA is supplying the SXS Detectors, ADRs, and SXTs

Euclid 2022
ESA-led Mission



Delivered 18 SCEs Will deliver early

NASA is supplying the NISP Sensor Chip System (SCS)

SPHEREx 2023
NASA Mission

Downselected in February 2019

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

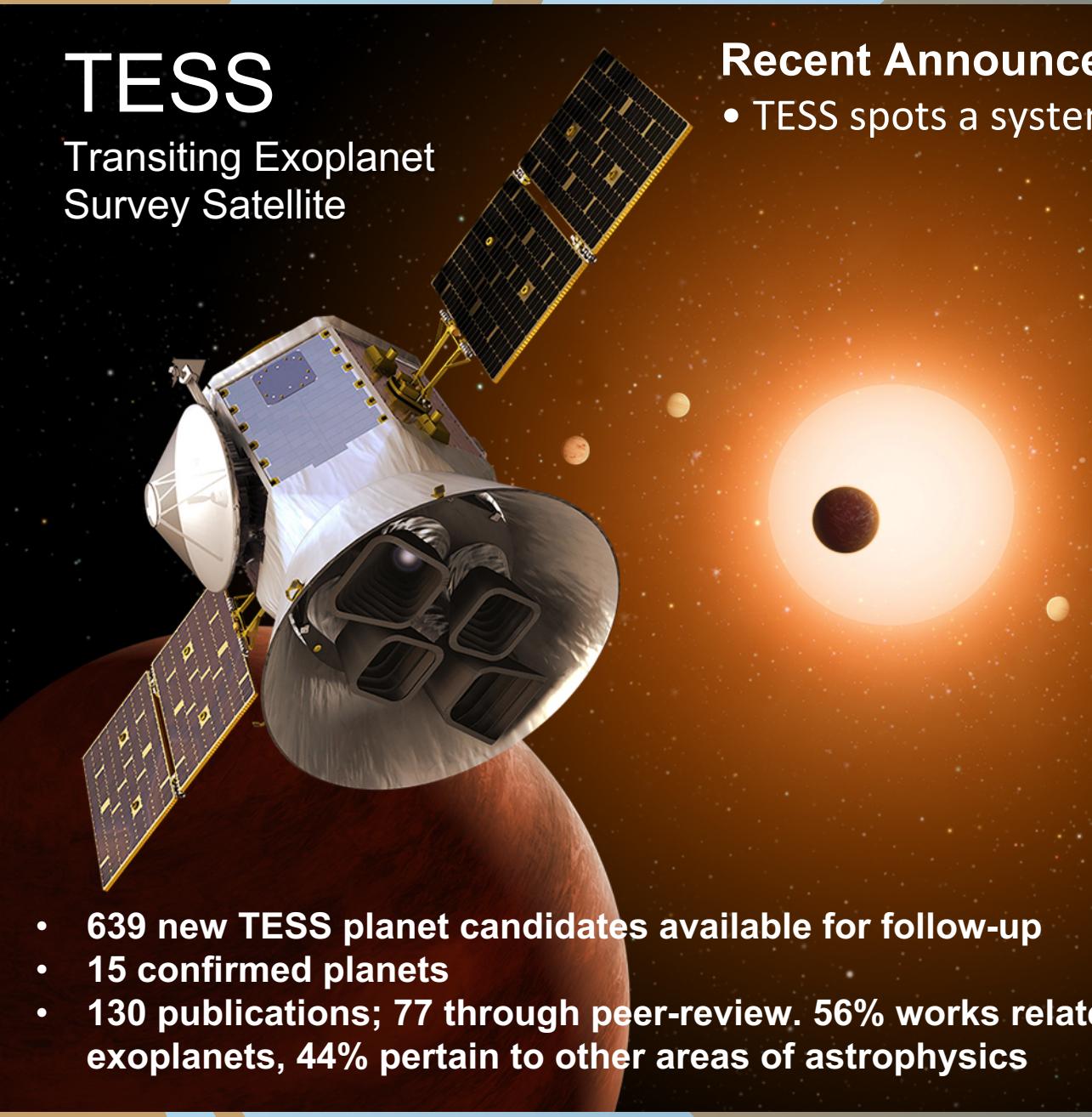
WFIRST Mid 2020s
NASA Mission

Mission PDR in October 2019

Wide-Field Infrared Survey Telescope

TESS

Transiting Exoplanet Survey Satellite



Recent Announcements

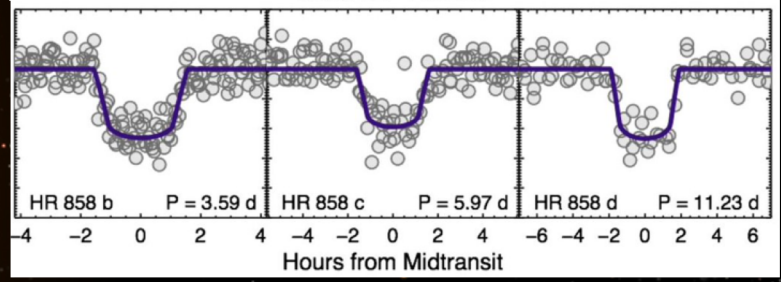
- TESS spots a system of Super-Earths around the Naked-Eye Star HR 858

HR 858

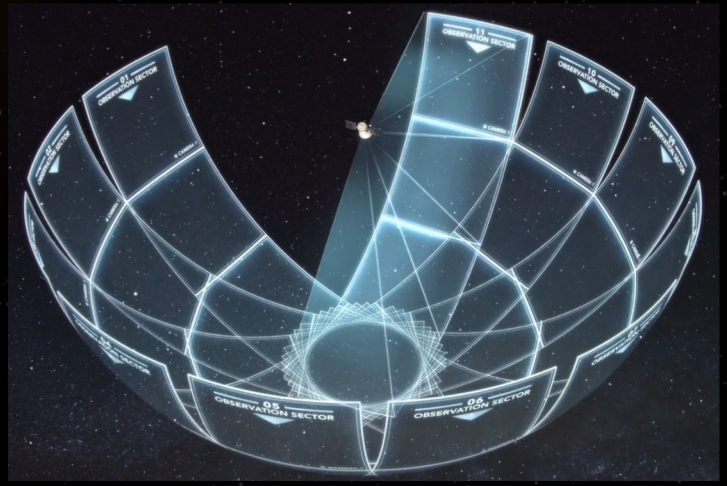
simbad.u-strasbg.fr

Hugh Osborn @exohugh

Whoah! @NASA_TESS has detected a triumvirate of small planets around a 6th magnitude (i.e. almost naked-eye) star. That makes this sun-like star one of the brightest in the sky to have ever been found hosting transiting planets! And it's has three of them! arxiv.org/abs/1905.05193

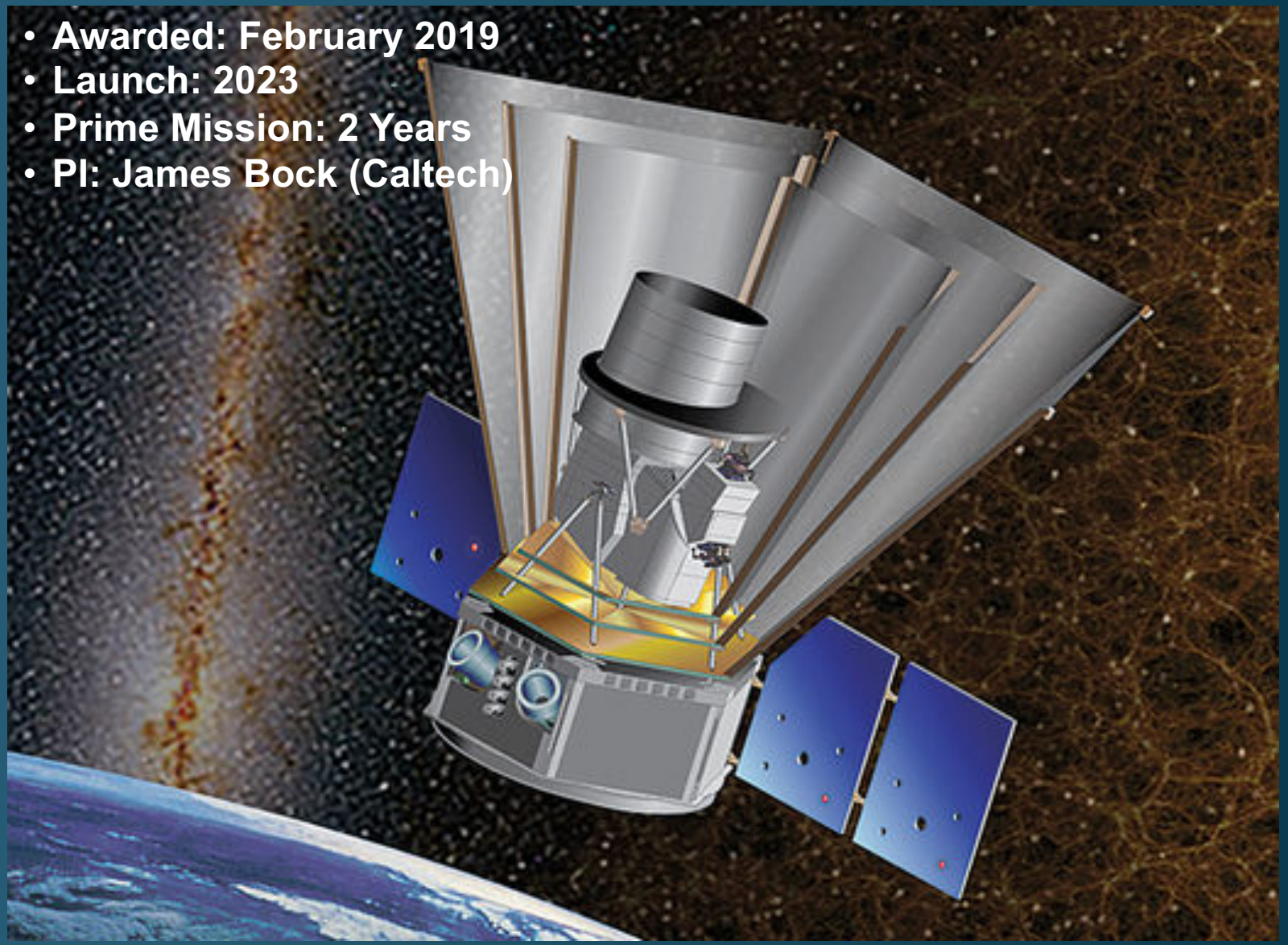


- **639 new TESS planet candidates available for follow-up**
- **15 confirmed planets**
- **130 publications; 77 through peer-review. 56% works relate to exoplanets, 44% pertain to other areas of astrophysics**



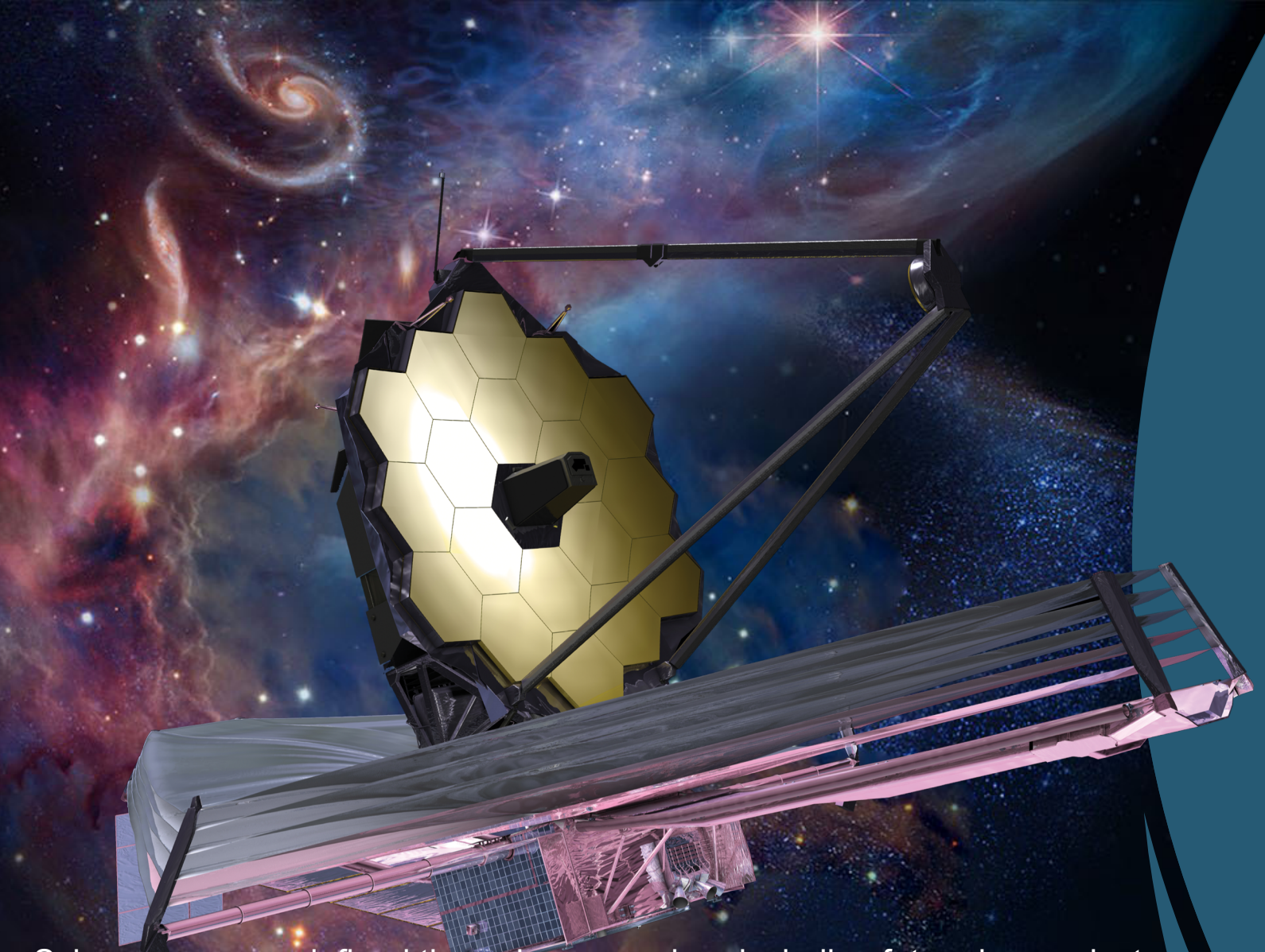
Observation Sector 11 in progress, 11 of 26 observing sectors complete, 9 sectors publically available ahead of schedule

Spectro-Photometer for the History of the Universe Epoch of Reionization and Ices Explorer (SPHEREx)



Science Highlights include:

- Survey the entire sky every 6 months
- Optical and infrared survey mission (96 bands/pixel)
- Observe hundreds of millions of galaxies
  - Measure redshifts to probe the statistical distribution of inflationary ripples
  - Measure spatial fluctuations in the Extragalactic Background Light to support studies of the origin and history of galaxy formation.
- Survey Galactic Molecular Clouds for water and organic molecules (H_2O, CO, CO_2, CH_3OH)



Webb

The James Webb Space Telescope

An international mission to seek first light of stars and galaxies in the early universe and explore distant planets

Seeking Light from the First Stars and Galaxies

Exploring Distant Worlds—Exoplanets & the Outer Solar System

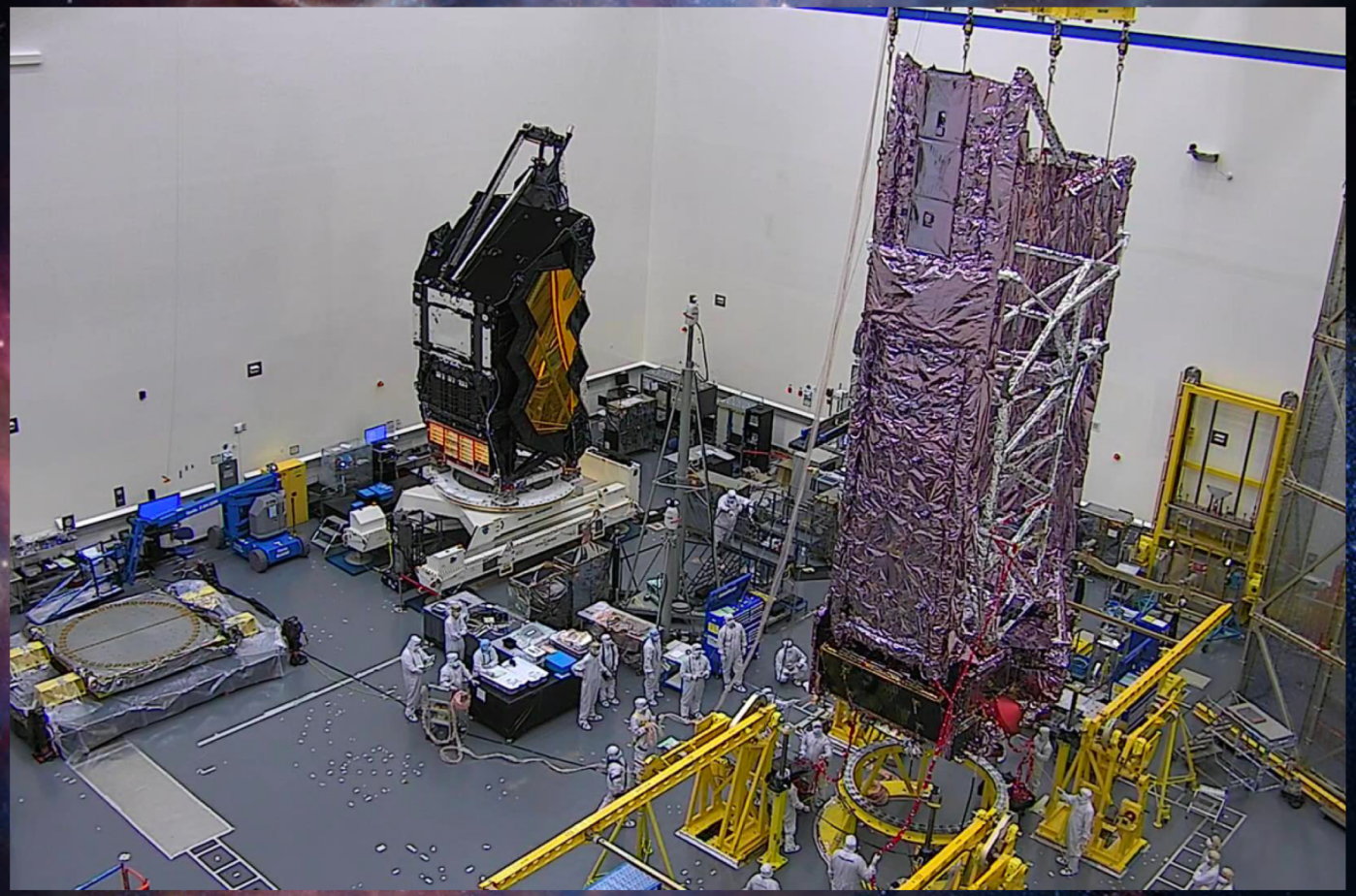
Led by NASA, in partnership with ESA and CSA

Science program defined through peer-review, including future key projects

Observations spanning a wide variety of Astrophysics are already in the works through the Guaranteed Time Observers programs and the Early Release Science program

Webb

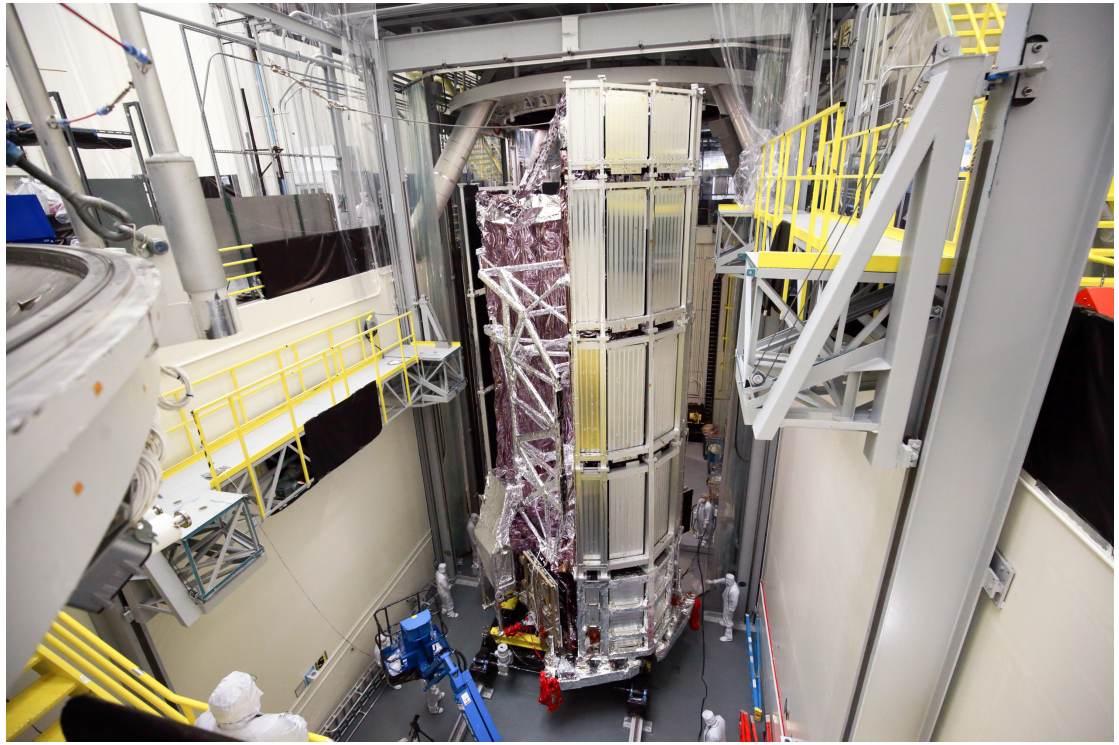
The James Webb Space Telescope



The Webb payload (telescope + instruments, left) and spacecraft element (spacecraft + sunshield, right) in the clean room in Redondo Beach, CA before spacecraft element environmental testing and observatory integration

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

Webb Spacecraft Thermal Vacuum Testing

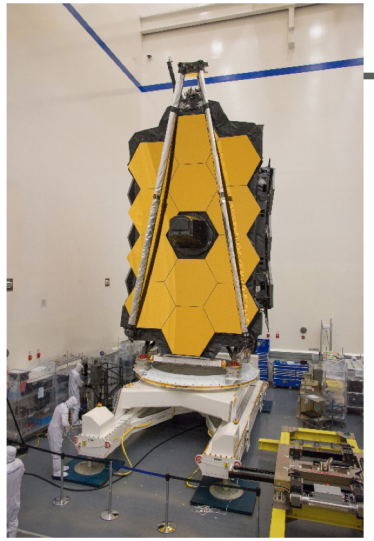


Webb's spacecraft being prepared for thermal vacuum testing and being lifted into Northrop Grumman's thermal vacuum chamber for environmental testing to ensure that its hardware will function in the vacuum of space. ***Credits: Northrop Grumman***

Remaining Webb I&T Activities*

Science Payload

- OTIS Deployment at NGAS
  (secondary mirror)



Spacecraft Element

Observatory Integration

- Post SCE-Environmental Sunshield deployment
- Observatory fold and stow
- Observatory system (electrical) test
- Observatory vibration, acoustics tests
- Observatory deployment
- Observatory fold and stow for launch
- Observatory final system test

First-time activity

NOTE: *Top-level tasks to go. Many activities are associated with each of these steps

Wide-Field Infrared Survey Telescope

Work continues with FY19 funding

2016 – Completed Mission Concept review and began Phase A

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

2019 – Completing Preliminary Design Reviews

2020 – Complete Confirmation Review and begin Phase C

Mid-2020s – Launch

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

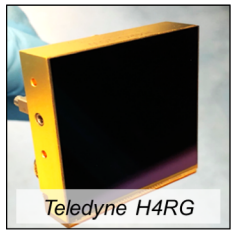
Science Program includes

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

Wide-Field Infrared Survey Telescope

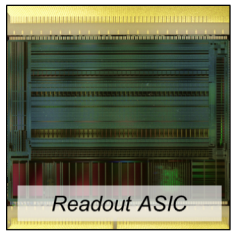
- **NASA continuing work on WFIRST as planned**
  - Work continues under recently approved FY19 appropriation; appropriation enacted in February 2019 includes $312M for WFIRST
  - WFIRST remains on the plan approved at the beginning of Phase B: Lifecycle cost range $3.2B -$3.9B, launch range is in late 2025 - 2026
  - Formal cost and schedule commitments, including Headquarters held reserves to increase confidence level to 70%, will be made at Confirmation in early 2020
- **Major milestones in 2018:**
  - WFIRST passed System Requirements Review / Mission Design Review
  - Approved in May 2018 to enter Phase B (preliminary design phase)
  - Completed System Requirements Reviews for all primary mission elements (Wide Field Instrument, Coronagraph, Optical Telescope)
  - All major contracts awarded: Telescope (Harris), Wide Field Instrument (Ball), Detectors (Teledyne)
- **Work Plan for 2019**
  - Significant flight hardware in production
  - Significant engineering work in progress
  - Proceeding during FY19 toward Mission Preliminary Design Review and Confirmation
  - Four element Preliminary Design Reviews by September 2019

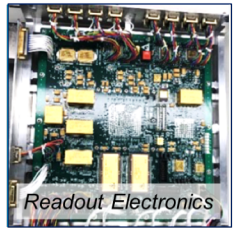
WFIRST Progress

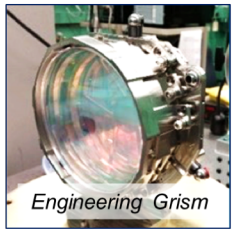

Teledyne H4RG

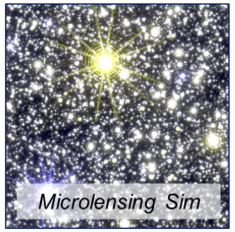
Detector First Light

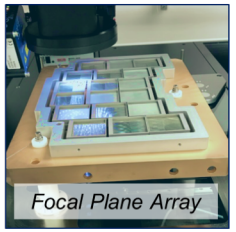
Wide Field Instrument

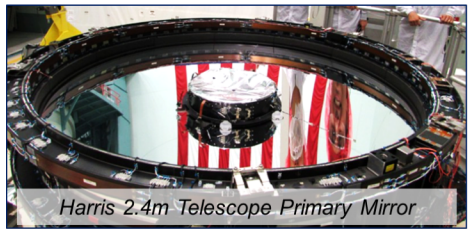

Readout ASIC


Readout Electronics


Engineering Grism

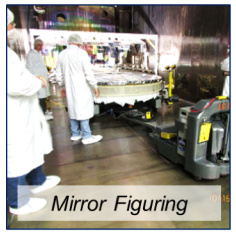

Microlensing Sim


Focal Plane Array

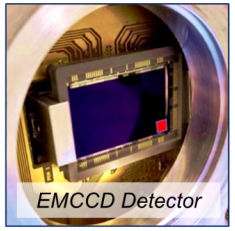

Harris 2.4m Telescope Primary Mirror

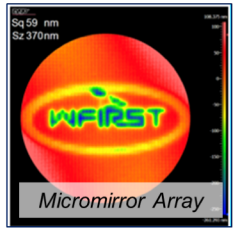
Telescope

Coronagraph Technology Demonstration Instrument

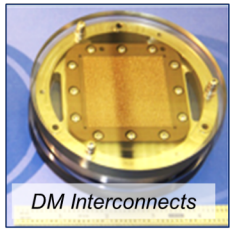

Mirror Figuring

Telescope Contract

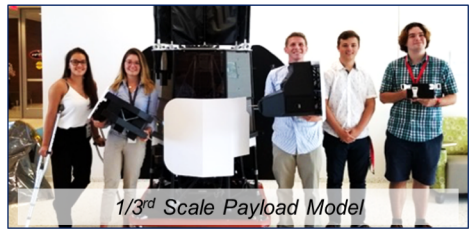

EMCCD Detector



Micromirror Array

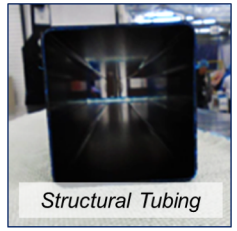

DM Interconnects

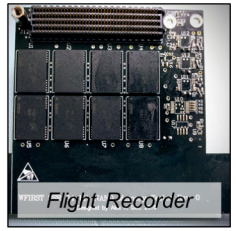
- WFIRST included in final FY19 appropriation
- Core survey science teams anticipated to be selected in 2021 by open competition
- All mission elements making excellent technical progress; expecting to go through Preliminary Design Reviews Jun-Oct 2019
- Mission being prepared for review to enter Implementation phase in early 2020

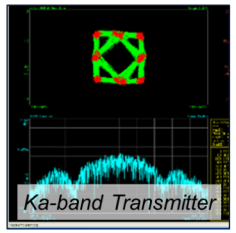

1/3rd Scale Payload Model

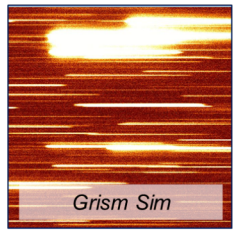
Spacecraft/Observatory

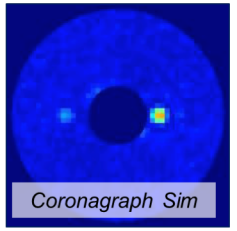
Science Preparation


Structural Tubing


Flight Recorder


Ka-band Transmitter


Grism Sim


Coronagraph Sim

Euclid

Near Infrared Spectrometer and Photometer - fully populated focal plane includes NASA provided 16 (2K x 2K each) Sensor Chip Systems

Science Program Includes

- Dark Energy and Dark Matter
- Initial conditions of the Universe
- Conduct deep NIR survey to explore high redshift
- Relationship between dark matter matter and baryons

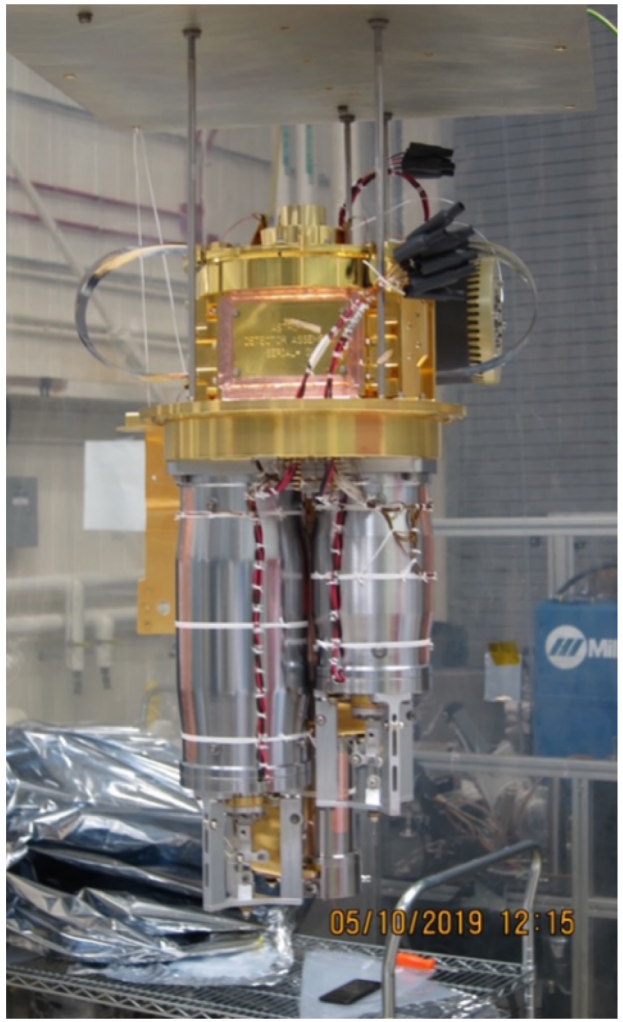
ESA led mission with NASA partnership

- Completed mission CDR in November 2018
- NASA completed all flight hardware Sensor Chip Systems deliveries in June 2019 for the NISP instrument focal plane
- Mission In Assembly, Integration and Test phase
- Mission Launch ~ June 2022

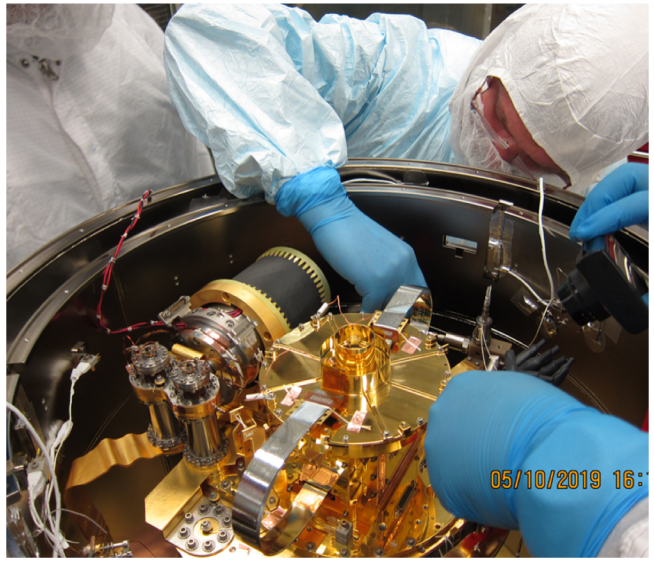
Science Participation

- US Euclid Science teams integrated into Euclid Consortium science planning activities
- General US science participation to be through archival data research after Euclid data products release

XRISM: X-ray Imaging and Spectroscopy Mission

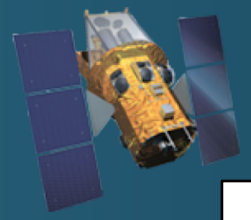


- Passed the Integrated Systems Preliminary Design Review which was held in Japan in March 2019.
- Resolve instrument currently integrated in test Dewar at GSFC, undergoing environmental testing.
- US-built hardware to be delivered to JAXA in stages beginning October 2019.



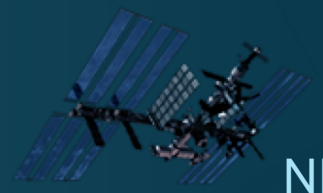
- XRISM science team meeting held in Tokyo in May 2019. Beginning process of target selection for Performance Verification phase of mission.
- Call for US Performance Verification phase Participating Scientists anticipated in ROSES 2020.
- XRISM launch, by JAXA ,currently planned for early 2022.

Astrophysics Explorers Program



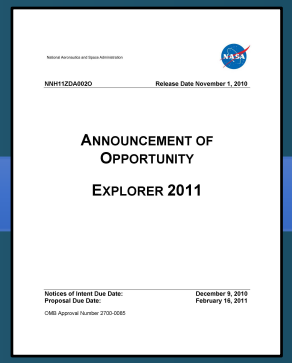
Swift

NuSTAR



NICER

TESS



National Aeronautics and Space Administration

NNH11ZDA002O — Release Date November 1, 2010

ANNOUNCEMENT OF OPPORTUNITY

EXPLORER 2011

Notices of Intent Due Date: December 9, 2010
Proposal Due Date: February 10, 2011

OMB Approval Number 2700-0085

MIDEX 2011

National Aeronautics and Space Administration

NNH14ZDA010O — Release Date September 17, 2014

Announcement of Opportunity

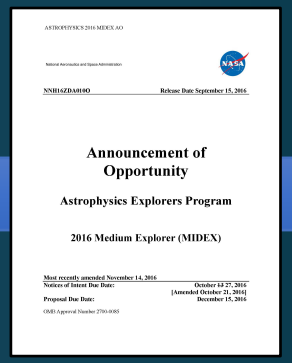
Astrophysics Explorers Program

2014 Small Explorer (SMEX)

Notices of Intent Due Date: October 15, 2014
Proposal Due Date: December 18, 2014

OMB Approval Number 2700-0085

SMEX 2014



ASTROPHYSICS 2016 MIDEX AO

National Aeronautics and Space Administration

NNH16ZDA010O — Release Date September 15, 2016

Announcement of Opportunity

Astrophysics Explorers Program

2016 Medium Explorer (MIDEX)

Most recently amended November 14, 2016
Notices of Intent Due Date: October 13-27, 2016 [Amended October 21, 2016]
Proposal Due Date: December 15, 2016

OMB Approval Number 2700-0085

MIDEX 2016

National Aeronautics and Space Administration

NNH14ZDA010O — Release Date Septe

Released!

Announ

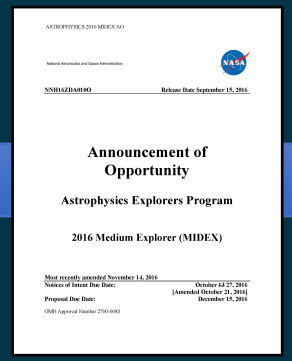
As rogram

orer (SMEX)

ss of Intent Due Date: October 15, 2014
oposal Due Date: December 18, 2014

OMB Approval Number 2700-0085

SMEX 2019



ASTROPHYSICS 2016 MIDEX AO

National Aeronautics and Space Administration

NNH16ZDA010O — Release Date September 15, 2016

Announcement of Opportunity

Astrophysics Explorers Program

2016 Medium Explorer (MIDEX)

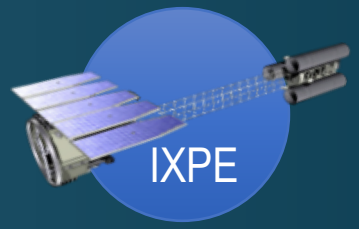
Most recently amended November 14, 2016
Notices of Intent Due Date: October 13-27, 2016 [Amended October 21, 2016]
Proposal Due Date: December 15, 2016

OMB Approval Number 2700-0085

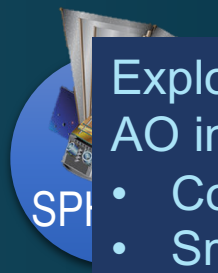
MIDEX 2021

Small and Mid-Size Missions

TESS



IXPE



SPI

Missions of Opportunity

NICER

GUSTO

MO

XRISM

Explorers Mission of Opportunity AO includes:

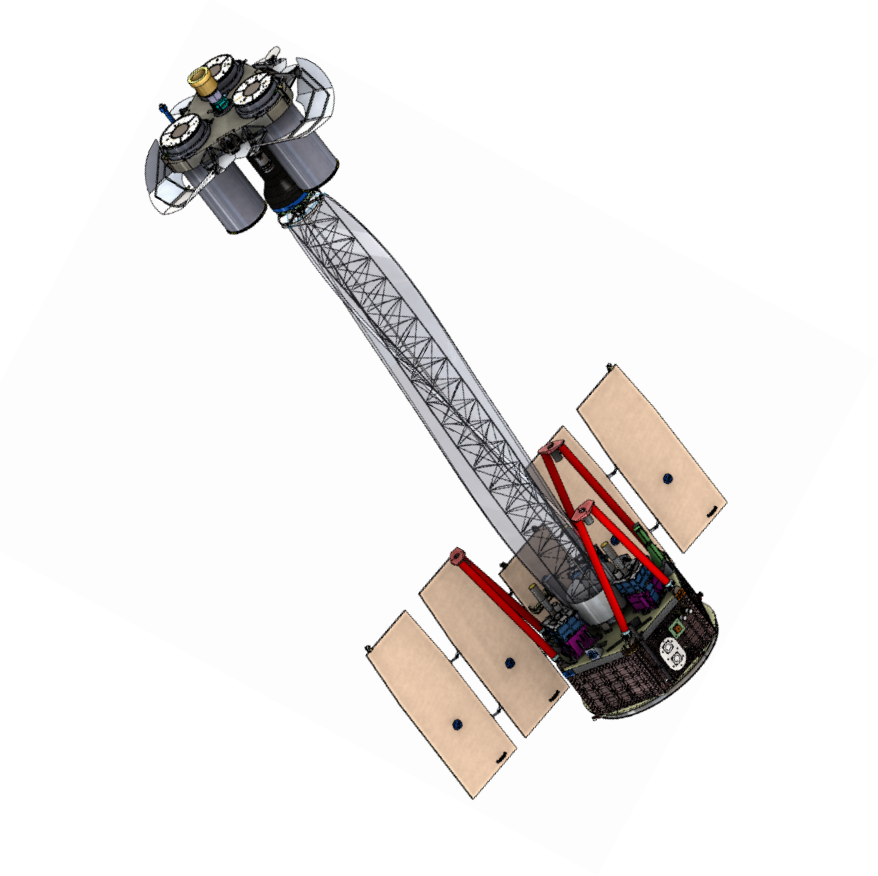
- Contributions to Partner Mission
- Small Complete Mission on ISS
- SmallSat Secondary Payloads
- Opportunities enabled by Project Artemis

Astrophysics Science SmallSat Studies

- NASA selected 9 Astrophysics Science SmallSat Studies in ROSES 2018. These studies will report out at a special session of the June 2019 AAS meeting in St. Louis
  - Tuesday Session 212: 10:40 am–12:10 pm, Grand Ballroom A
- The 2019 Astrophysics Explorers Mission of Opportunity AO includes SmallSats and CubeSats launched using rideshare on ESPA or ESPA Grande
  - NASA received many Notices of Intent (NOIs) for Astrophysics SmallSat Explorers
- A second Astrophysics Science SmallSat Studies solicitation is planned as an amendment to ROSES 2019 later this year
- NASA has selected 5 Astrophysics CubeSats through ROSES/APRA:
- NASA is convening the 2019 NASA SmallSat Mission Technical Interchange Meeting on Jun 24-16 at NASA Ames research Center
  - Applications for consideration as an attendee are due Jun 14, 2019

    https://science.nasa.gov/technology/smallsat-tim

Imaging X-ray Polarimetry Explorer (IXPE)



Progress

- Rework, which resulted from Nov 2018 vibration test failure, is ongoing for the engineering X-ray Modular Mirror Assembly (MMA)
    - Expect new vibration test results by July 2019
- Development of Italian X-ray detector units (DU) is ongoing, with the delivery of engineering DU expected by July 2019
    - First flight DU expected by December 2019

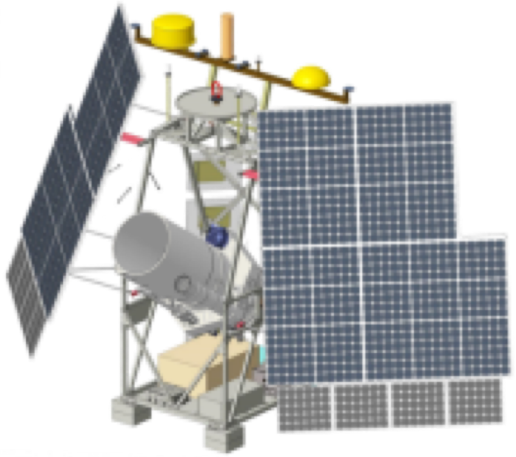
Milestones

- Mission Critical Design Review planned for June 25-28, 2019
- Delivery of flight hardware expected in Fall 2019, with both instrument and spacecraft integration beginning in Spring 2020
- Launch currently planned for April 2021

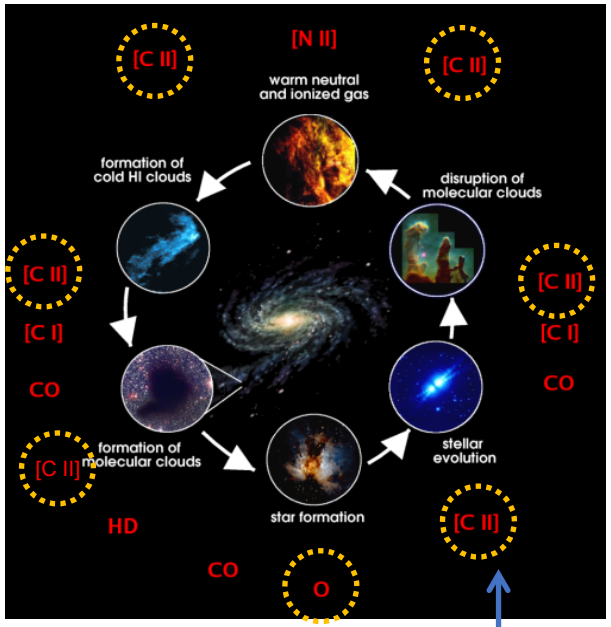
GUSTO Suborbital Explorer

GUSTO (Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory) led by PI Chris Walker (University of Arizona), is an Astrophysics Explorer (MO) balloon mission and is an advanced version of the STO-2 balloon payload.

GUSTO uses large-scale surveys & spectral diagnostics of the Interstellar Medium (ISM) to answer key questions about the full Life Cycle of the ISM and massive star formation.



GUSTO Payload



GUSTO Lines

Brightest Line in *the FIR over cosmic times.*

~300 dedicated SOFIA flights would be required to equal the GUSTO survey

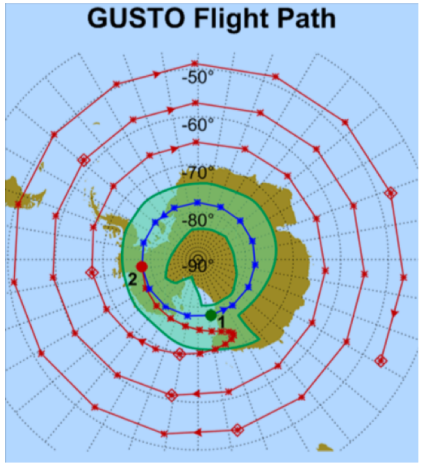
<u>Milestones:</u>

Mission Preliminary Design Review: Nov 15, 2018

Confirmation Review (KDP-C): Mar 12, 2019

Mission Critical Design Review (CDR): Summer 2019

Launch from McMurdo Station, Antarctica: Dec 2021



Flight Strategy, Launch (Dec 2021) from McMurdo on a superpressure balloon and allow payload to leave the continent. Instrument recovery preferred, but optional. Target survey duration 75 day, accept-able base-line 20 days, cryogenic for 100 days.

Operating Missions

Hubble 4/90
NASA Strategic Mission
Senior Review
Hubble Space Telescope

Chandra 7/99
NASA Strategic Mission
Senior Review
Chandra X-ray Observatory

XMM-Newton 12/99
ESA-led Mission
Senior Review
X-ray Multi Mirror - Newton

Spitzer 8/03
NASA Strategic Mission
Began Final Year
Spitzer Space Telescope

Gehrels Swift 11/04
NASA MIDEX Mission
Senior Review
Neil Gehrels Swift Gamma-ray Burst Explorer

Fermi 6/08
NASA Strategic Mission
Senior Review
Fermi Gamma-ray Space Telescope

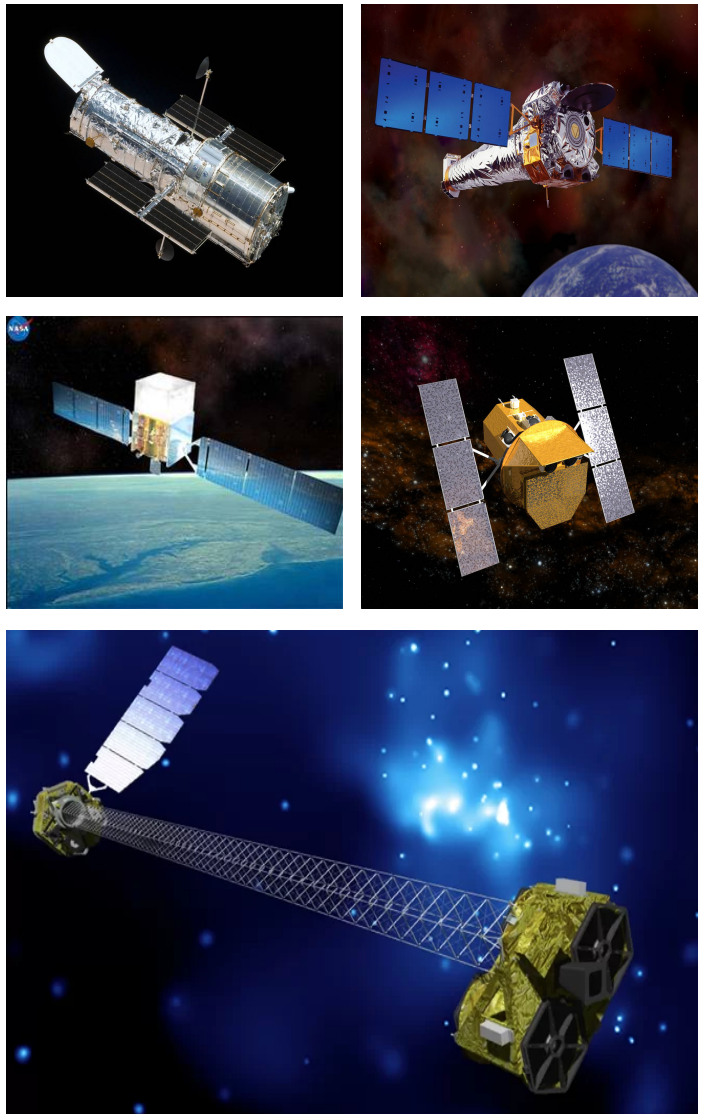
Kepler 3/09
NASA Discovery Mission
Mission Complete!
Kepler Space Telescope

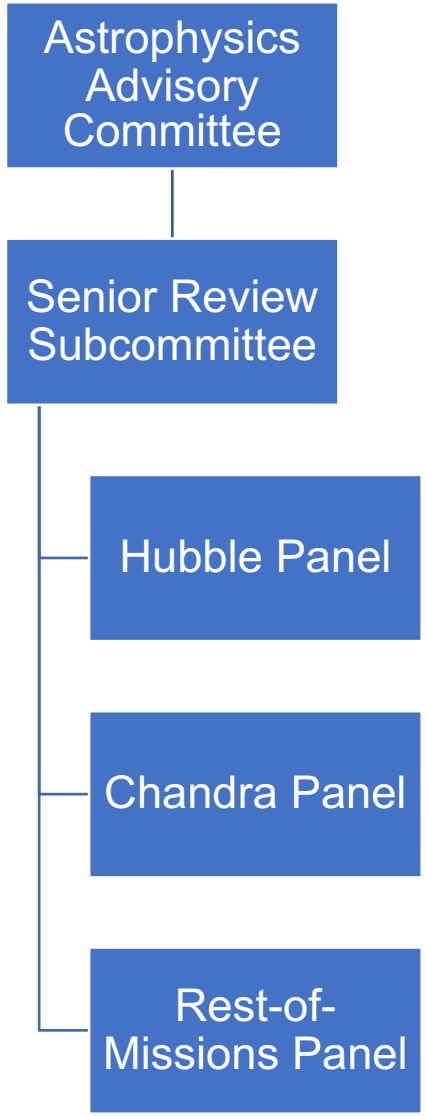
NuSTAR 6/12
NASA SMEX Mission
Senior Review
Nuclear Spectroscopic Telescope Array

SOFIA 5/14
NASA Strategic Mission
Two External Reviews
Stratospheric Observatory for Infrared Astronomy

ISS-NICER 6/17
NASA Explorers Miss. of Oppty
Senior Review
Neutron Star Interior Composition Explorer

TESS 4/18
NASA MIDEX Mission
Senior Review
Transiting Exoplanet Survey Satellite





Senior Review 2019

- Chandra X-ray Observatory (Chandra)
- Fermi Gamma-ray Space Telescope (Fermi)
- Hubble Space Telescope (Hubble)
- Neutron star Interior Composition Explorer (NICER)
- Nuclear Spectroscopic Telescope Array (NuSTAR)
- Neil Gehrels Swift Observatory (Swift)
- Transiting Exoplanet Survey Satellite (TESS)
- X-ray Multi-mirror Mission-Newton (XMM-Newton)

Not in Senior Review: Kepler, SOFIA, Spitzer

SOFIA

Stratospheric Observatory for Infrared Astronomy

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

NASA Astrophysics
Preparation for 2020 Decadal Survey

Decadal Survey Planning

- 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

What is a Balanced Program?

Balanced among multiple goals and priorities

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

Balanced through time

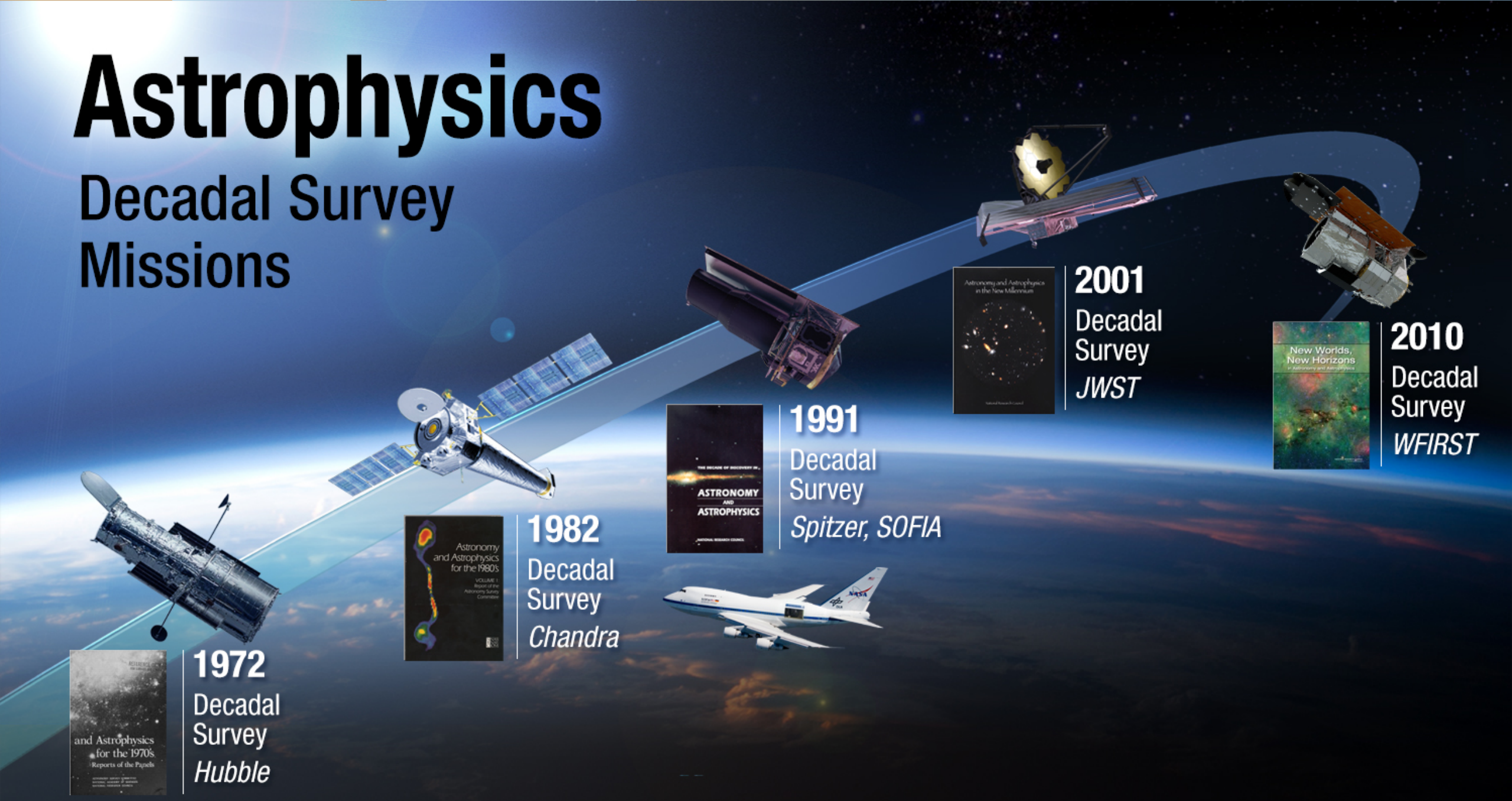
- Yields science discoveries today
- Enables science discoveries tomorrow
- Is sustainable: maintains necessary National capabilities

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

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

Astrophysics

Decadal Survey Missions



Why Flagships

Flagships drive science

Flagships drive US capabilities and contribute to US leadership

Flagships drive NASA budget and create stakeholder support

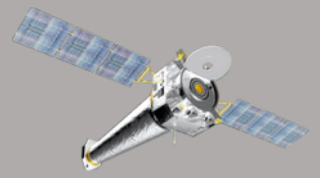
Hubble 04/90
NASA Great Observatory

Hubble Space Telescope

Compton 05/91
NASA Great Observatory

Compton Gamma Ray Observatory

Chandra 09/99
NASA Great Observatory



Chandra X-ray Observatory

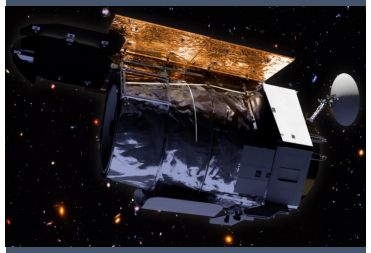
Spitzer 8/03
NASA Great Observatory

Spitzer Space Telescope

Webb 2021
NASA Mission

James Webb Space Telescope

WFIRST Mid 2020s
NASA Mission



Wide-Field Infrared Survey Telescope

"NASA should continue to plan for large strategic missions as a primary component for all science disciplines as part of a balanced program." – Powering Science: NASA's Large Strategic Science Missions (NASEM, 2017)

Why Flagships

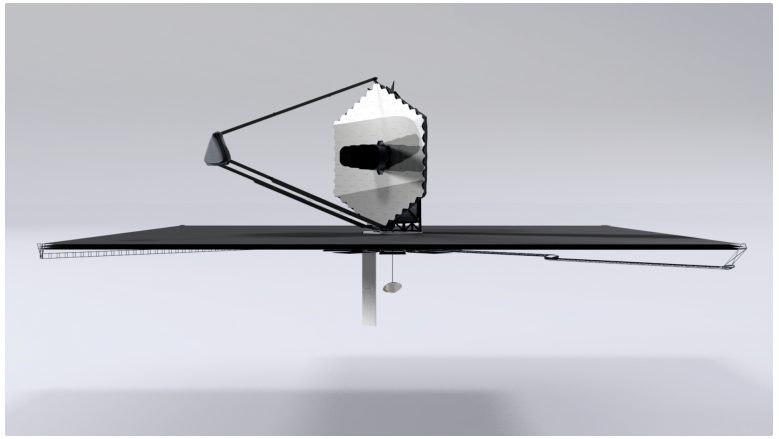
Large strategic missions have multiple benefits.

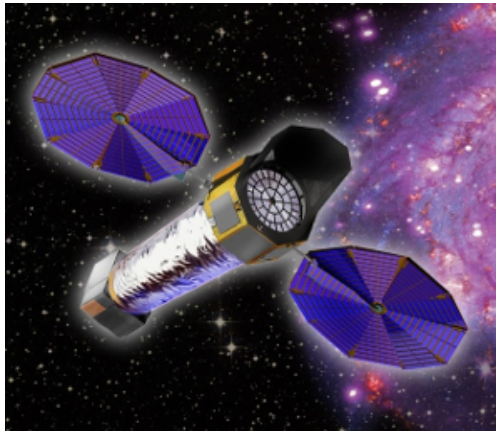
- Open new windows of scientific inquiry and answer many of the most compelling scientific questions
- Develop and deepen humanity's understanding of the universe
- Capture science data that cannot be obtained in any other way
- Provide new technology that can benefit future small, medium, and large missions
- Support the workforce, the industrial base, and technology development
- Maintain U.S. leadership in space
- Maintain U.S. scientific leadership
- Produce discoveries that capture the public's imagination and encourage science and technical careers
- Receive a high degree of external visibility, often representing NASA's science program as a whole
- Provide greater opportunities for international participation, cooperation, and collaboration

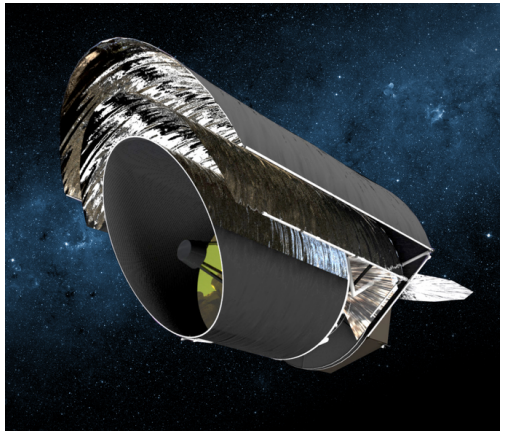
"NASA should continue to plan for large strategic missions as a primary component for all science disciplines as part of a balanced program." – Powering Science: NASA's Large Strategic Science Missions (NASEM, 2017)

Large Mission Concepts

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







HabEx	LUVOIR	Lynx	Origins
Monday 2:30 pm–4:30 pm Midway 1&2	Monday 10:40 am–12:10 pm Jeffersonian/ Knickerbocker Room	Monday 3:00 pm–4:30 pm Wabash Cannonball Room	Tuesday 3:30 pm–4:30 pm Jeffersonian/ Knickerbocker Room

NASA Large Mission Concept Decadal Studies showcased at NASA Booth
Monday, June 10 – Thursday, June 13; Exhibit Hall

Preparing for the 2020 Decadal Survey Technology Development

HabEx

Starshade Petal Deployment Position Accuracy, Starshade Petal Shape and Stability, Large Mirror Fabrication, Large Mirror Coating Uniformity, Coronagraph Architecture, Low-order wavefront Sense/Control, Deformable Mirrors, Starshade Edge Scattering, Starshade Starlight Suppression and Modeling, Starshade Lateral Formation Sensing, Microthrusters, Laser Metrology, electron multiplication CCDs, near-IR avalanche photodiodes

LUVOIR

Coronagraph Architecture, Deformable Mirrors, LOWFS/OBWFS, UV & Red-enhanced EMCCDs, Mirror Segment Substrate, Mirror Segment Metrology, Picometer Rigid Body Actuators, Far-UV Broadband Coating, Active Dynamic Isolation, Thermal Sensing & Control, Ultra-stable System Architecture, Large-format CMOS Arrays, GaN Microchannel Plates, Next-generation Microshutter Arrays

Lynx X-ray Surveyor

High-resolution, lightweight X-ray optics, low-stress X-ray reflecting coatings, megapixel X-ray imaging detectors, large-format, high resolution X-ray detectors, X-ray grating arrays

Origins Space Telescope

Far IR Detectors, Cryogenic Readouts for Far IR Detectors, Warm readout electronics for large format Far IR detectors, Mid IR detectors, Sub-Kelvin Coolers, 4.5 K cryocoolers

- Each study identified technology gaps and developed a technology maturation roadmap
- Most technology gaps are being addressed through NASA astrophysics technology development programs
- A well-planned technology roadmap and aggressive technology development reduces the risk for the next mission

Cost Estimation of Flagships

Why is it hard?

- Flagship missions, due to the unprecedented nature of their science and their significant complexity and, are inherently difficult to estimate.
- NASA mission costs are typically estimated given cost model or analogy cost based on historical cost and technical data. Given that Flagship missions are first of a kind, there are no comparable costs to use as an estimate.
- Design trades and options are numerous through the formulation phase. Establishing a robust, stable technical baseline prior to the start of development, and therefore developing a robust, stable cost estimate, is extremely challenging.

What are best practices?

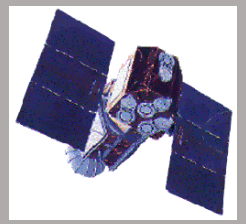
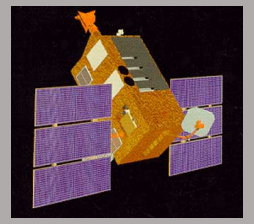
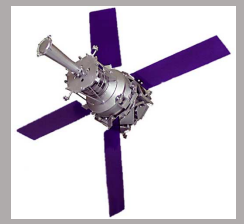
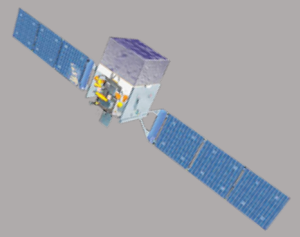
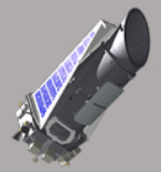
- Conduct a science assessment and concept feasibility study to determine the value of the science and define technology challenges.
- Fund technology development with defined pass/fail gates for each technology and each technology readiness level.
- Provide a funding profile that allows work to be done at the most efficient time. Include adequate reserves and use them to solve problems at the optimal time.
- Establish stable science and measurement requirements early. Avoid mission creep.

NASA Assessment: Large Mission Concept Studies

- NASA has assembled a Large Mission Concept Independent Assessment Team (LCIT) to conduct a technical, risk, and cost assessment of the four large-scale mission concept studies
  - The LCIT includes experienced technical and cost reviewers with expertise in large space missions and in science, instrumentation, and technology.
- The purpose of the LCIT is twofold:
  - Provide feedback to the STDTs that can be used to improve the Final STDT Reports that will be presented to the Decadal Survey
  - Provide NASA Headquarters confidence in the science, technical, cost, and risk conclusions of the Final STDT Reports that will be presented to the Decadal Survey
- The Terms of Reference for the LCIT are posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning

Medium Mission Concepts (Probes)

Probes have had a strong impact on some areas of astrophysics

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

Ten Probe Concepts are under study as input to 2020 Decadal Survey

Options for 2020 Decadal Survey

- Recommend specific probe(s) as medium-size strategic missions
- Recommend several specific concepts for an AO (New Frontiers)
- Recommend an unconstrained AO (Super-Explorer)

NASA Assessment: Probe Concept Studies

- NASA has requested GSFC and JPL's costing offices to perform independent cost assessments of the Probe mission concepts that used the resources of their respective Centers
- In order to provide an independent, non-advocate assessment of the costing offices' results, NASA is assembling an independent Probes Concept Assessment Team (PCAT)
  - The PCAT will validate the cost estimates provided by the costing offices, the design labs, and the PI-led studies
  - The PCAT is composed of scientists and subject matter experts who will work with the costing offices and the study teams
- The purpose of conducting a cost and technical validation of the Probe mission concept studies is to provide NASA Headquarters confidence in the science, technical, cost, and risk conclusions of the Probe Mission Concept Reports that will be presented to the Decadal Survey
- The Terms of Reference for the PCAT are posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning

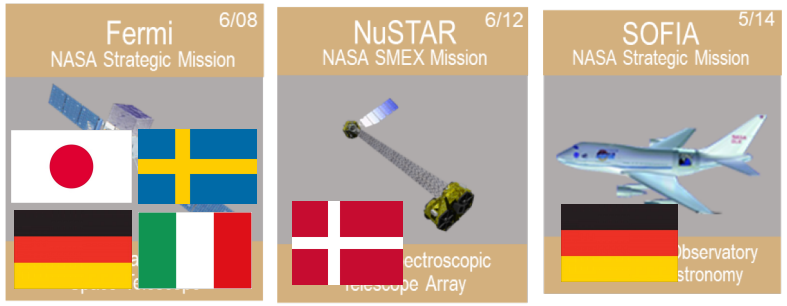
International Partnerships

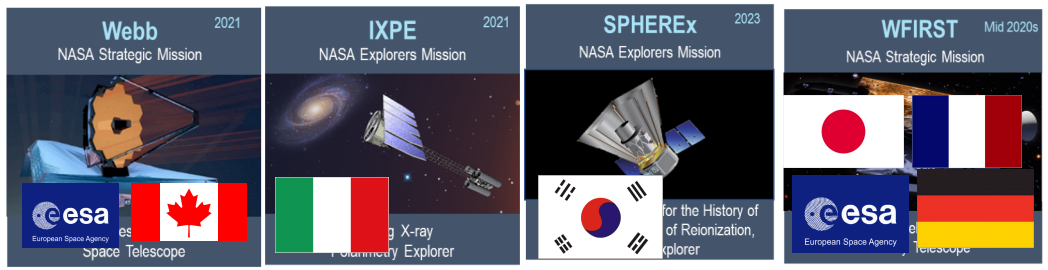
“Complex and high-cost facilities are essential to major progress in astronomy and astrophysics and typically involve collaboration of multiple nations and/or collaboration of federal and non-federal institutions. These partnerships bring great opportunities for pooling resources and expertise to fulfill scientific goals that are beyond the reach of any single country.” – New Worlds, New Horizons in Astronomy and Astrophysics (NASEM, 2010)

“Since its establishment in 1958, international cooperation has been a significant component of NASA's missions, playing a unique role in U.S. global engagement and diplomacy. This role extends from data sharing agreements to joint science and technology payloads, all the way up to major diplomatic initiatives. Over two-thirds of NASA’s science missions have foreign partners who enhance missions in ways NASA could not achieve on its own.” – NASA FY2020 Budget Estimates

- Scientific synergies between NASA and its international partners yields a win-win outcome
- Continued NASA international collaborations and leadership in unique areas maintains US status as preferred partner
- Good partners must be good leaders and good followers

International Partnerships





US Lead

Instrument elements

X-ray microcalorimeter, X-ray mirrors

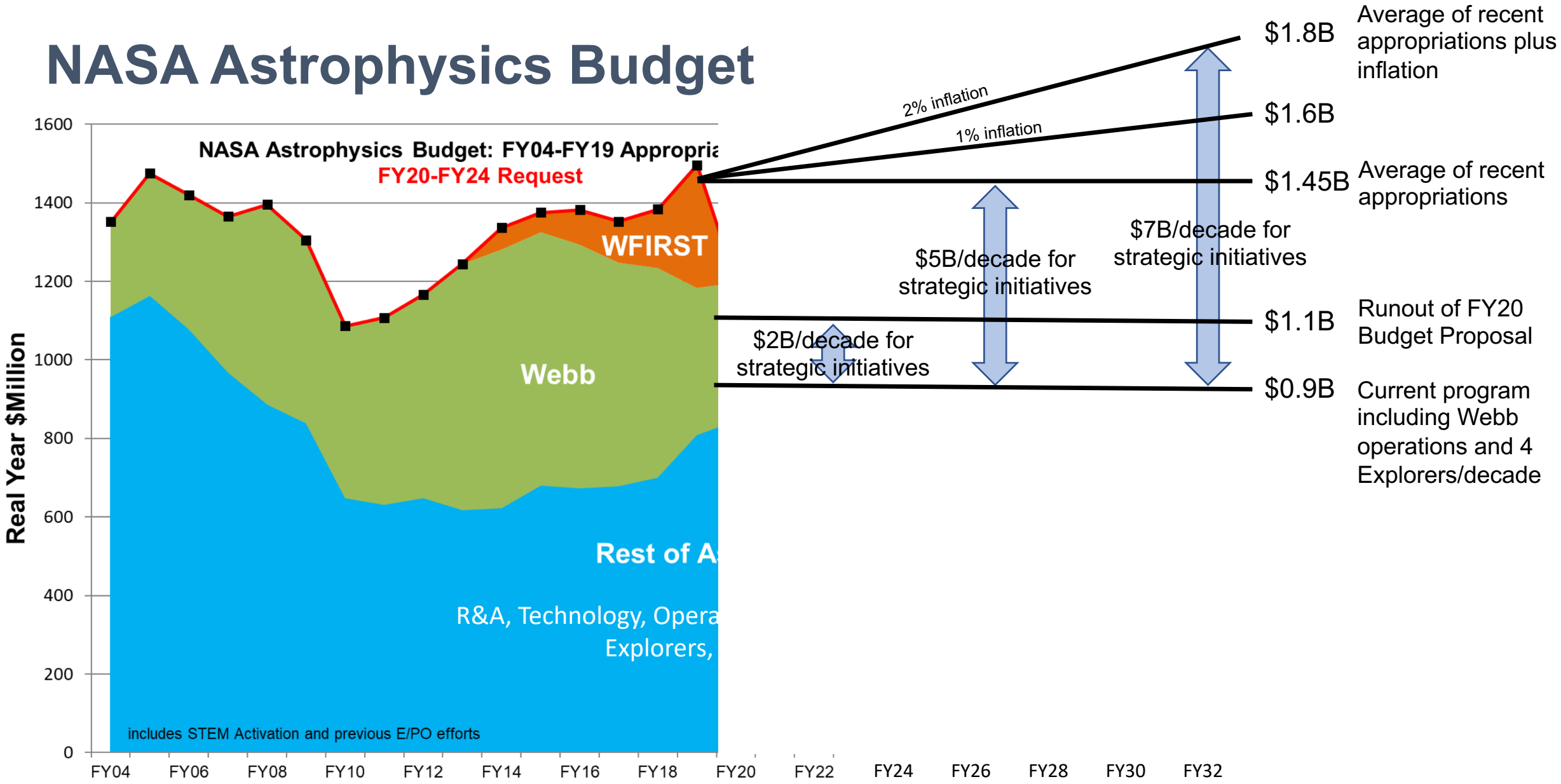
NIR sensor chip systems

X-ray microcalorimeter, X-ray calibration facility

Instrument and mission systems

Partner Lead / US Contribute

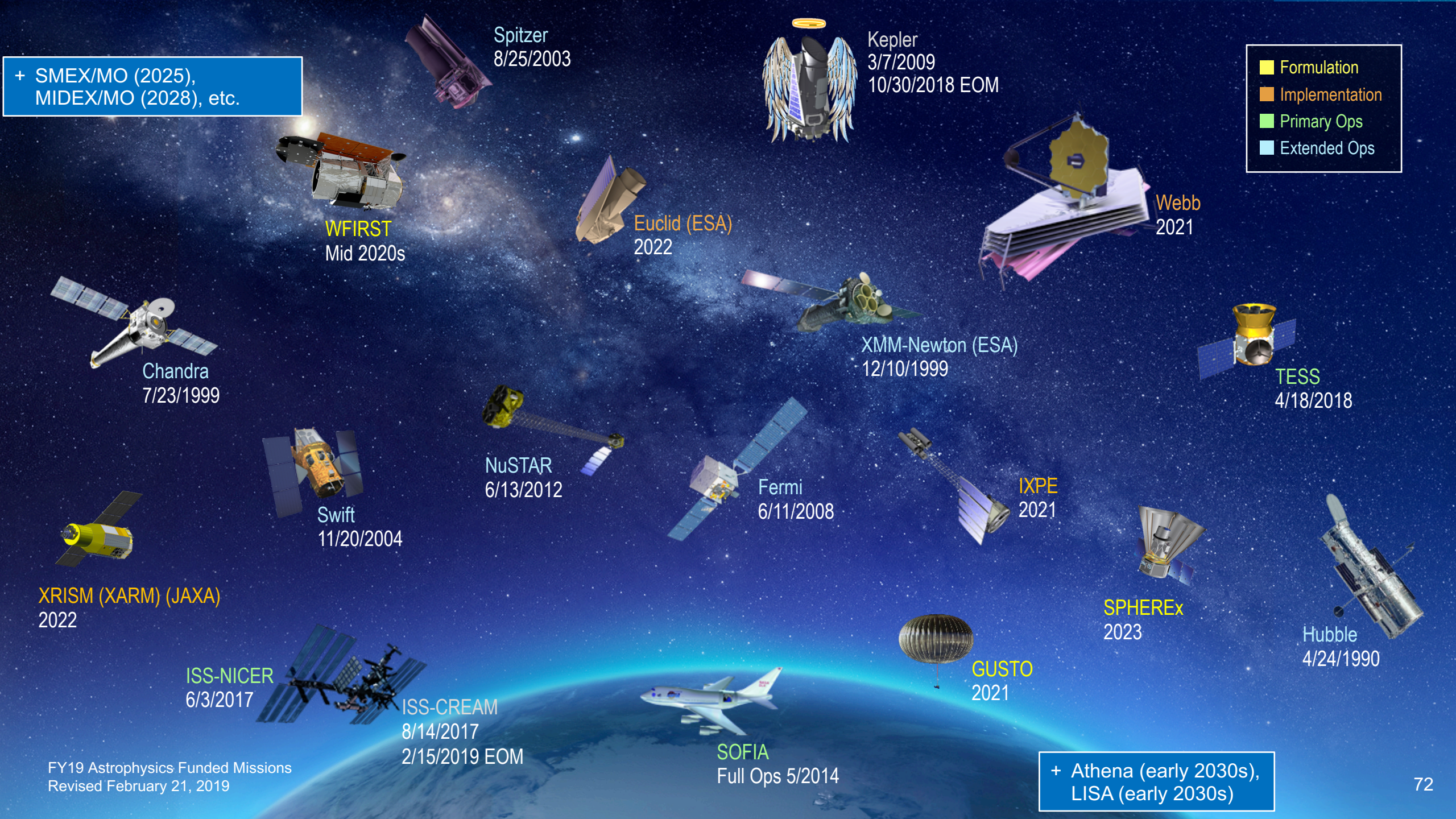
NASA Astrophysics Budget



Decadal Survey Planning

- 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 shrinking budget, you get a shrinking program.
  - Great visions inspire (and justify) great budgets.

Carpe Posterum



FY19 Astrophysics Funded Missions
Revised February 21, 2019

BACKUP

Astrophysics Program Content (FY20 Request)

	Actual FY 18	Enacted FY 19	Request FY 20	Out-years FY 21	FY 22	FY 23	FY 24
Astrophysics	**850.4**	**1,191.6**	**844.8**	**902.4**	**965.2**	**913.5**	**907.7**
Astrophysics Research	203.1		250.7	309.3	302.5	299.1	298.8
Astrophysics Research and Analysis	74.1	83.4	86.6	90.2	92.2	94.2	94.2
Balloon Project	36.6		44.8	44.8	44.8	44.8	44.8
Science Activation	44.0	45.0	45.6	45.6	45.6	45.6	45.6
Other Missions and Data Analysis	48.5		73.7	128.7	119.9	114.5	114.2
Astrophysics Data Curation and Archival	18.2		21.2	21.2	21.5	22.0	22.0
Astrophysics Data Program	17.6		20.4	21.6	22.6	23.6	23.6
Astrophysics Senior Review				33.5	20.5	27.3	31.6
Contract Administration, Audit & QA Svcs	12.7		12.7	12.7	12.7	12.7	12.7
Astrophysics Directed R&T			19.4	39.7	42.7	28.9	24.3
Cosmic Origins	211.2		185.3	173.9	181.7	121.7	121.7
Hubble Space Telescope (HST)	98.3	98.3	83.3	93.3	98.3	98.3	98.3
Stratospheric Observatory for Infrared Astronomy	85.2	85.2	73.0	60.0	60.0		
Other Missions and Data Analysis	27.7		29.0	20.6	23.4	23.4	23.4
Cosmic Origins SR&T	15.5		17.1	18.4	18.4	18.4	18.4
SIRTF/Spitzer	11.2		8.5	1.0			
Cosmic Origins Future Missions	1.0		2.2	0.0	3.8	3.8	3.8
Astrophysics Strategic Mission Prog Mgmt			1.2	1.2	1.2	1.2	1.2

Astrophysics Program Content (FY20 Request)

	Actual FY 18	Enacted FY 19	Request FY 20	Out-years FY 21	FY 22	FY 23	FY 24
Physics of the Cosmos	118.0		148.4	128.5	123.3	117.8	117.4
Euclid	19.8		13.7	11.0	8.9	9.9	10.3
Physics of the Cosmos Future Missions	0.2		2.0	1.1	3.8	3.5	3.7
Chandra X-Ray Observatory	56.9		58.4	58.4	58.4	58.4	58.4
Fermi Gamma-ray Space Telescope	13.0		14.0				
XMM	2.5		3.5				
Physics of the Cosmos SR&T	20.9		50.9	52.1	46.3	40.1	39.0
PCOS/COR Technology Office Management	4.6		5.9	5.9	6.0	6.0	6.0
Exoplanet Exploration	200.8		46.4	44.3	45.6	46.1	48.5
WFIRST	150.0	312.2					
Kepler	10.0		1.3				
Keck Operations	6.2		6.7	6.9	7.0	7.2	7.4
Large Binocular Telescope Interferometer	1.8						
Exoplanet Exploration SR&T	26.4		29.1	30.0	28.9	28.9	28.6
Exoplanet Exploration Tech Office Mgmt	5.3		6.5	6.8	7.3	7.7	7.7
Exoplanet Exploration Future Missions	1.0		2.8	0.6	2.4	2.2	4.7

Astrophysics Program Content (FY20 Request)

	Actual FY 18	Enacted FY 19	Request FY 20	Out-years FY 21	FY 22	FY 23	FY 24
Astrophysics Explorer	117.4		214.1	246.4	312.0	328.8	321.4
Imaging X-Ray Polarimetry Explorer	23.5		70.2	45.3	7.4	4.5	0.5
X-Ray Imaging and Spectroscopy Mission	22.0		29.7	25.7	22.5	17.6	15.8
GUSTO	4.7		11.1	7.8	6.3	1.0	
Nuclear Spectroscopic Telescope Array	4.8		7.8				
Neil Gehrels Swift Observatory	3.9		5.5				
Transiting Exoplanet Survey Satellite	33.5		5.0	0.2			
Neutron Star Interior Composition Explor	2.1						
Astrophysics Explorer Future Missions	11.8		84.8	154.2	267.0	295.1	299.2
Astrophysics Explorer Program Managemen	11.1			13.3	8.8	10.7	5.9
James Webb Space Telescope	**533.7**	**304.6**	**352.6**	**415.1**	**175.4**	**172.0**	**172.0**

SMD Organization Chart

Associate Administrator (AA)
Thomas Zurbuchen

Deputy AA
Dennis Andrucyk

Deputy AA - Programs
Sandra Connelly

Deputy AA - Management
Karen Flynn

Deputy AA - Research
Michael New

Deputy AA - Exploration
Steve Clarke

James Webb Space Telescope Program Office

Director
Greg Robinson

Senior Science Advisor
Eric Smith

Chief Technologist
Michael Seablom

Executive Officer
Ellen Gertsen

Resource Management Division
Director
Craig Tupper
Deputy
Holly Degn (Acting)

Strategic Integration & Management Division
Director
Dan Woods
Deputy
Jens Feeley

Science Engagement & Partnerships Division
Director
Kristen Erickson

Earth Science Division
Director
Sandra Cauffman (Acting)
Deputy
Paula Bontempi (Acting)

Flight
Eric Ianson
Applied Science
Lawrence Friedl
Research
Jack Kaye
Technology (GSFC)
Pam Millar

Joint Agency Satellite Division
Director
John Lee
Deputy
John Gagosian (Acting)

Heliophysics Division
Director
Nicky Fox
Deputy
Peg Luce

Planetary Science Division
Director
Lori Glaze
Deputy
Kate Wolf (Acting)

Solar System Exploration
Joan Salute (Acting)
Mars Exploration
Jim Watzin
Planetary Research
Jonathan Rall
Planetary Defense Office
Lindley Johnson

Astrophysics Division
Director
Paul Hertz
Deputy
Jeff Volosin (Acting)

Astrophysics Strategic Missions
Jackie Townsend (Interim)

Chief Scientist
Eric Smith

Embeds / POCs

Chief Engineer:
Joe Gasbarre (Acting)

Safety & Msn Assurance:
Pete Panetta

General Counsel:
Ellen Espenschied

Legislative & Intergovernmental Affairs:
Gabriel Adler

International & Interagency Relations:
Gib Kirkham

Public Affairs:
Grey Hautaluoma

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