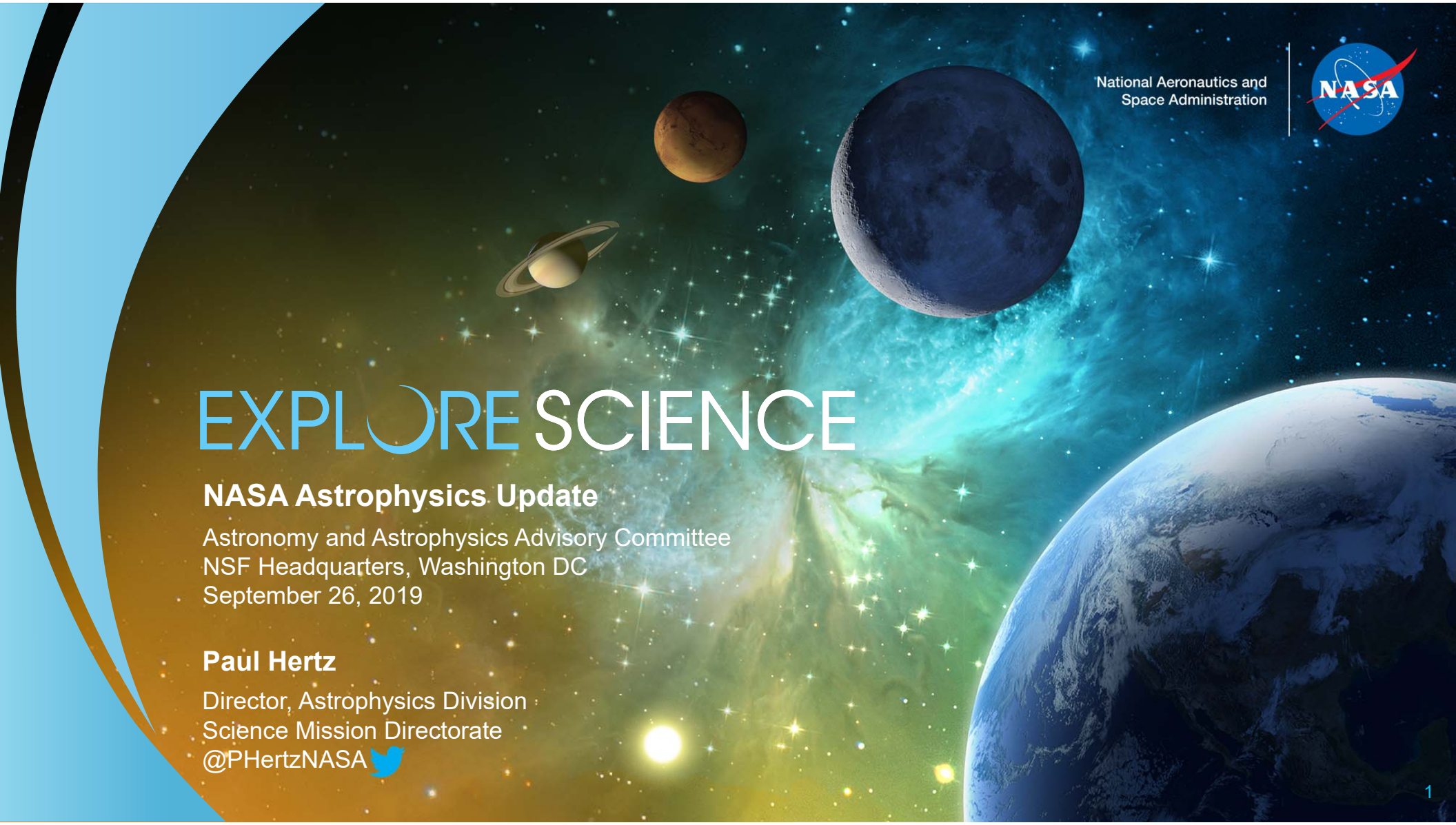


NASA Astrophysics Update

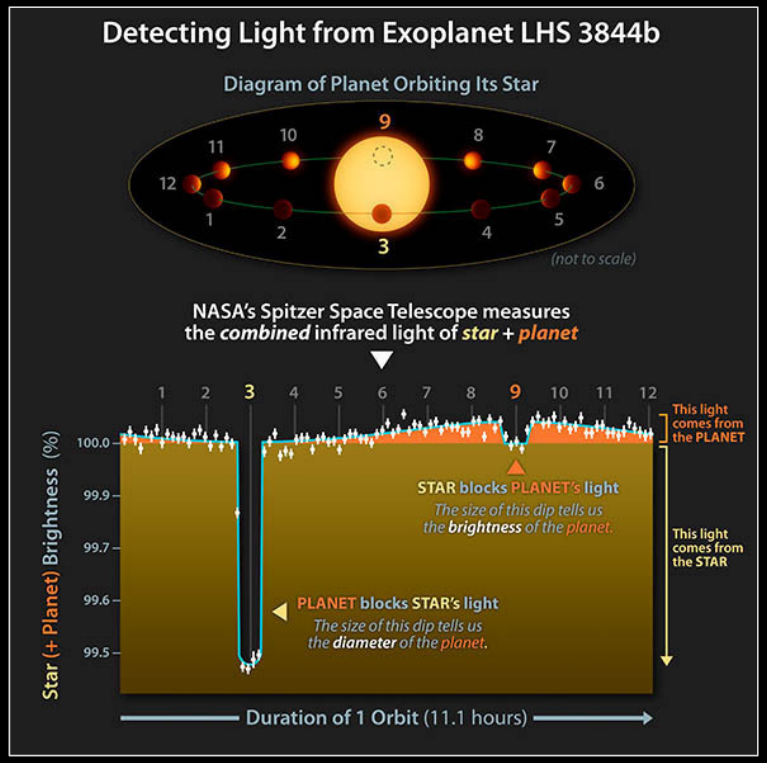
Astronomy and Astrophysics Advisory Committee
NSF Headquarters, Washington DC
September 26, 2019

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

A Rare Look at a Rocky Exoplanet's Surface

Released August 19, 2019



Credit: NASA/JPL-Caltech/L. Kreidberg (Harvard-Smithsonian CfA)

L. Kreidberg et al., 2019 (Nature, 573, pp 87–90)

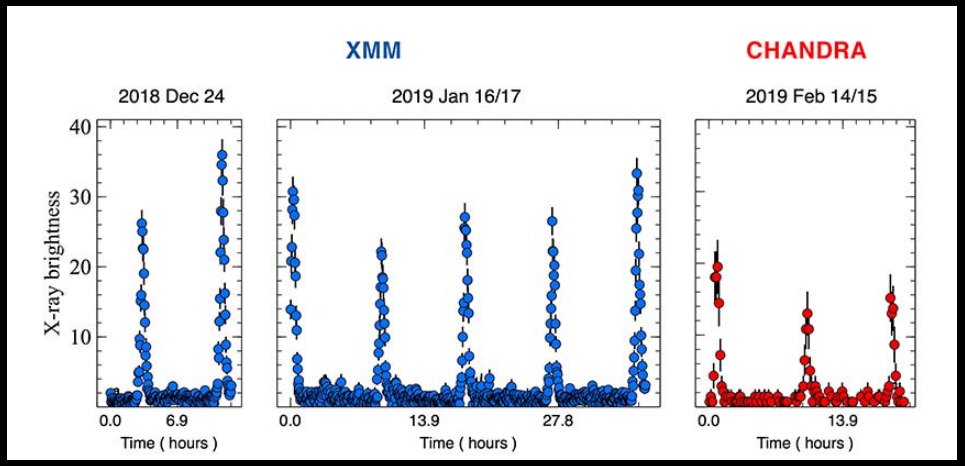
SCIENCE HIGHLIGHT

A new study using data from NASA's Spitzer Space Telescope provides a rare glimpse of conditions on the surface of a rocky planet orbiting a star beyond the Sun.

- Discovered in 2018 by NASA's Transiting Exoplanet Satellite Survey (TESS) mission, planet LHS 3844b is located 48.6 light-years from Earth and has a radius 1.3 times that of Earth.
  - It orbits a small, cool type of star called an M dwarf - the most common and long-lived type of star in the Milky Way galaxy.
  - The planet makes one full revolution around its parent star in just 11 hours.
    - With such a tight orbit, LHS 3844b is most likely "tidally locked," which is when one side of a planet permanently faces the star.
  - The star-facing side, or dayside, is about 1,410 degrees Fahrenheit (770 degrees Celsius). Being extremely hot, the planet radiates a lot of infrared light which Spitzer can see.
  - By measuring the temperature difference between the planet's hot and cold sides, the team found that there is a negligible amount of heat being transferred between the two.
    - If an atmosphere were present, hot air on the dayside would naturally expand and generate winds that would transfer heat around the planet.
- The study shows that the planet's surface may resemble those of Earth's Moon or Mercury: The planet likely has little to no atmosphere and could be covered in the same cooled volcanic material found in the dark areas of the Moon's surface, called mare.

Scientists Discover Black Hole Has Three Hot Meals a Day

Released September 11, 2019



Data from XMM-Newton and Chandra, taken over a span of 54 days, revealed that a supermassive black hole is blasting out X-rays about every nine hours. This indicates that this black hole is consuming significant amounts of material about three times per day. This is the first time such repetitive behavior has been seen in a supermassive black hole.

G. Miniutti et al., 2019 (Nature, 573, pp 381–384)

SCIENCE HIGHLIGHT

- A team of astronomers using NASA's Chandra X-ray Observatory and ESA's XMM-Newton found X-ray bursts repeating about every nine hours indicating the supermassive black hole located at the center of galaxy GSN 069 is consuming large amounts of material on a regular schedule.
  - While scientists had previously found two "stellar-mass" black holes (that weigh about 10 times the Sun's mass) occasionally undergoing regular outbursts before, this behavior has never been detected from a supermassive black hole until now.
- The black hole at the center of GSN 069, located 250 million light years from Earth, contains about 400,000 times the mass of the Sun.
  - The researchers estimate that the black hole is consuming about four Moons' worth of material about three times a day.
    - That's equivalent to almost a million billion billion pounds going into the black hole per feeding.
- XMM-Newton was the first to observe this phenomenon in GSN 069 with the detection of two bursts on December 24, 2018. Observations by Chandra less than a month later, on February 14, revealed an additional three outbursts.
  - During the outbursts the X-ray emission becomes much brighter than during the quiet times.
  - The temperature of gas falling towards the black hole also climbs, from about one million degrees Fahrenheit during the quiet periods to about 2.5 million degrees Fahrenheit during the outbursts.
- The combination of data from Chandra and XMM-Newton implies that the size and duration of the black hole's meals have decreased slightly, and the gap between the meals has increased. Future observations will be crucial to see if the trend continues.

Hubble Finds Water Vapor on Habitable-Zone Exoplanet for the First Time

Released September 13, 2019

Credits: ESA/Hubble, M. Kornmesser

This artist's impression shows the planet K2-18b, its host star and an accompanying planet in this system.

B. Benneke et al. 2019 (arXiv:1909.04642)
A. Tsiaras et al. 2019 (Nature Astronomy, DOI:10.1038/s41550-019-0878-9)

SCIENCE HIGHLIGHT

- Astronomers used data from NASA's Hubble Space Telescope to find water vapor in the atmosphere of K2-18b, an exoplanet orbiting a small red dwarf star about 110 light-years away in the constellation Leo.
    - If confirmed by further studies, this will be the only exoplanet known to have both water in its atmosphere and temperatures that could sustain liquid water on a rocky surface.
        - Liquid water would only be possible if the planet turns out to be terrestrial in nature, rather than resembling a small version of Neptune.
- Given the high level of activity of its red dwarf star, K2-18b may be more hostile to life as we know it than Earth, as it is likely to be exposed to more high-energy radiation.
- The planet, discovered by NASA's Kepler Space Telescope in 2015, also has a mass eight times greater than Earth's.
    - That means the surface gravity on this planet would be significantly higher than on our planet.
- The team used archive data from 2016 and 2017 captured by Hubble and developed open-source algorithms to analyze the host star's light filtered through K2-18b's atmosphere.
    - The results revealed the molecular signature of water vapor, and also suggest the presence of hydrogen and helium in the planet's atmosphere.

TESS Observes the Kepler Field

Data Released to MAST: September 19, 2019

SCIENCE HIGHLIGHT

https://twitter.com/benmontet/status/1172583453113683968

- The TESS project released its first observations of the original Kepler field on September 19, 2019 (Sector 14).
- Within hours, 29 members of the Kepler/TESS community created an open collaboration space to coordinate the analysis of the new data set.
- Early investigations have focused on recovering long-period Kepler planets, identifying long-term changes in planet orbits (e.g. TTVs), and timing eclipsing binaries on the ~10-year baseline.
- One of the preliminary results is that Tabby's star does not appear to show significant dips in the 27-day TESS observations.

Embeds / POCs

Chief Engineer:
Joe Pellicciotti

Safety & Mission Assurance:
Pete Panetta

General Counsel:
Ellen Espenschied

Legislative & Intergovernmental Affairs:
Gabriel Adler

International & Interagency Relations:
Gib Kirkham

Public Affairs:
Grey Hautaluoma

Associate Administrator (AA)
Thomas Zurbuchen

Deputy AA
Dennis Andrucyk

James Webb Space Telescope Program Office
Director
Greg Robinson
Program Scientist
Eric Smith

Deputy AA - Programs
Sandra Connelly

Deputy AA - Management
Karen Flynn

Deputy AA - Research
Michael New

Deputy AA - Exploration
Steve Clarke

Chief Technologist
Michael Seablom

Executive Officer
Ellen Gertsen

Policy Branch
Chief
Jens Feeley

Administration Branch
Chief
(Vacant)

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

Science Engagement & Partnerships Division
Director
Kristen Erickson

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

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)

Astrophysics Division
Director
Paul Hertz
Deputy
Jeff Volosin (Acting)

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

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

Flight
(Vacant)

Updated: July 16, 2019

Astrophysics Division Hiring

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

All advertisements have closed

- NASA Astrophysics Division will be calling for IPA applications in the Fall

Building An Excellent Workforce

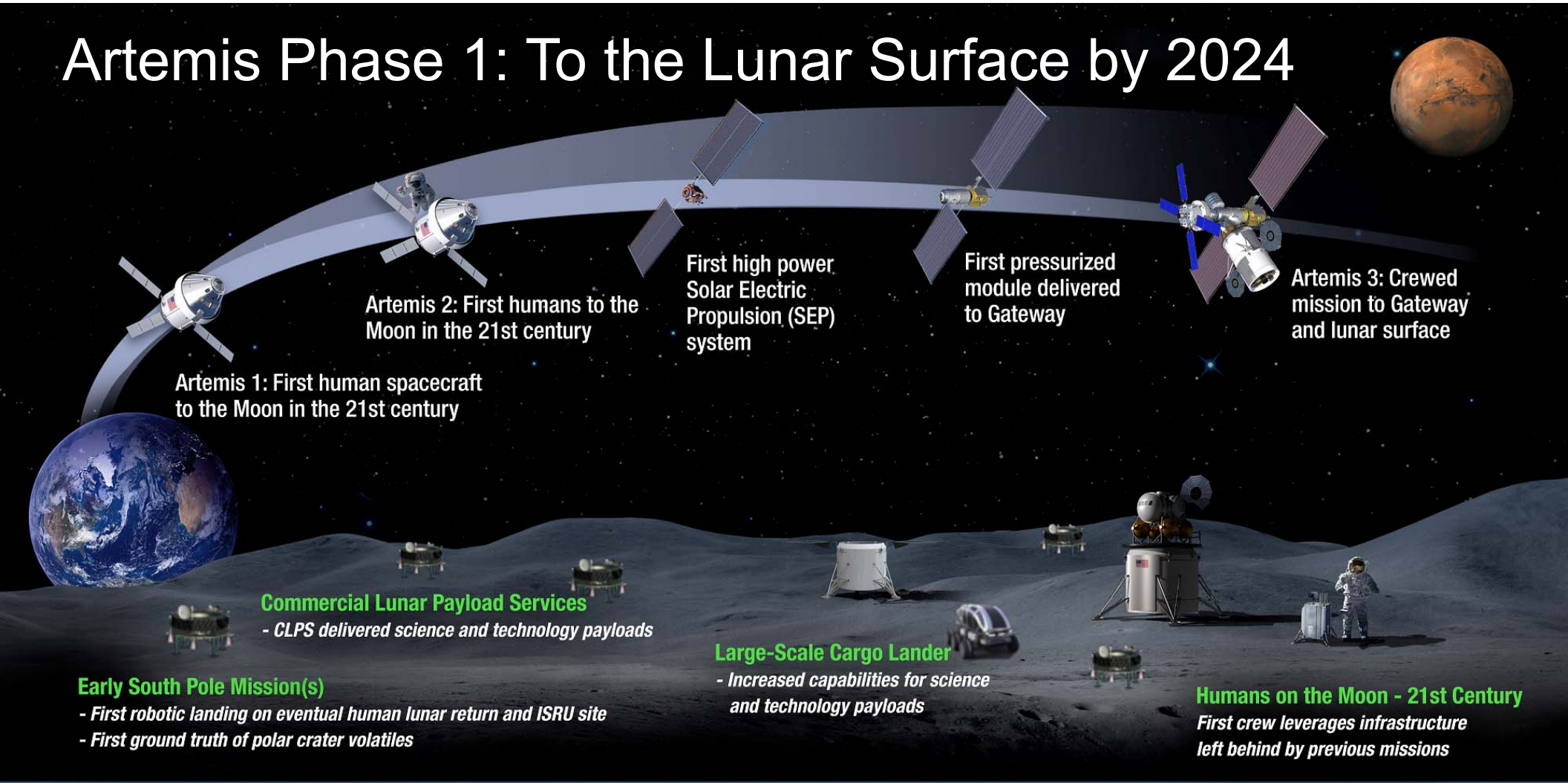
NASA achieves excellence by relying on diverse teams, both within and external to NASA, to most effectively perform NASA's work

NASA Science Mission Directorate

- Developed a PI resources webpage at https://science.nasa.gov/researchers/new-pi-resources
- Introduced pre-reviews of mission peer review panels to ensure diversity
- Added a code of conduct requirement for SMD-funded conferences to ROSES 2019
- Included career development positions and associated evaluation criteria as part of AOs
- Implemented a Code of Conduct and implicit bias training for all ROSES peer reviews
- Adopting dual anonymous reviews for all GO programs, and piloting them for other R&A programs, following successful demonstration by STScI for Hubble GO program
- Presented a national symposium by SMD AA Thomas Zurbuchen on lessons learned regarding mission proposal success
- Announced a workshop for potential mission PIs, see https://science.nasa.gov/researchers/pi-launchpad
- Is developing award terms and conditions mandating reporting harassment, similar to NSF's
- Is presenting information sessions at major conferences, including the Honolulu AAS Meeting, to support people developing their first proposal
- Tasked the Astro2020 Decadal Survey to "Assess the state of the profession. Identify areas of concern and importance [regarding] the future vitality and capability of the astronomy and astrophysics work force. Where possible, provide specific, actionable and practical recommendations to the agencies"

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

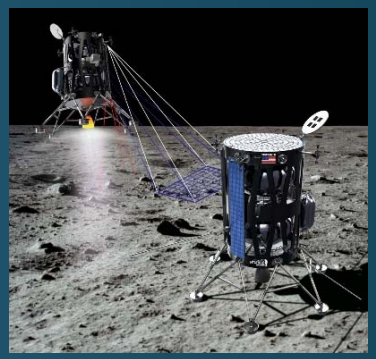
Artemis Phase 1: To the Lunar Surface by 2024



As of July 2019

LUNAR SOUTH POLE TARGET SITE

2019 2024



[1] https://www.nasa.gov/press-release/nasa-selects-experiments-for-possible-lunar-flights-in-2019

[2] https://www.nasa.gov/press-release/nasa-selects-12-new-lunar-science-technology-investigations

Partnerships in Innovation

- Under Commercial Lunar Payload Services (CLPS), nine U.S. companies selected to bid on specific task orders to develop landers delivering NASA payloads to Moon's surface
  - 12 science instrument payloads announced to be developed at NASA Centers[1]
    - Low-frequency Radio Observations from the Near Side Lunar Surface instrument (PI: Robert MacDowall, GSFC)
  - 12 additional instruments announced to be developed by industry and academia[2]
    - Next Generation Lunar Retroreflectors (PI: Douglas Currie, University of Maryland)
- Two of nine U.S. commercial space transportation services providers are currently under contract with NASA to deliver NASA payloads for Artemis Program
- 13 U.S. companies selected for 19 partnerships to mature industry-developed space technologies which will accelerate capabilities to benefit future NASA missions

Setting the Stage for the Decadal Survey

Why Astrophysics?

How did our universe

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

NASA Strategic Plan (2018)

Enduring National Strategic Drivers

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

Decadal Survey Goal

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

- The important science questions require new and ambitious capabilities

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

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

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

Does NASA stand for “Not A Science Agency”?

The National Science Foundation Act of 1950 (Public Law 81-507) creates the National Science Foundation. NSF’s mission is

> To promote the progress of science.
>
> For the purpose of advancing the national health, prosperity, and welfare; securing the national defense.

The National Aeronautics and Space Act of 1958 (Public Law 85–568) creates the National Aeronautics and Space Administration. NASA’s mission is

> To conduct aeronautical and space activities.
>
> For the purpose of expansion of human knowledge; improvement of aeronautical and space vehicles; development of vehicles capable of carrying instruments and humans through space; preservation of the role of the United States as a leader in space science and technology.

NASA is a mission-oriented agency, and science is the purpose and consequence of our space missions.

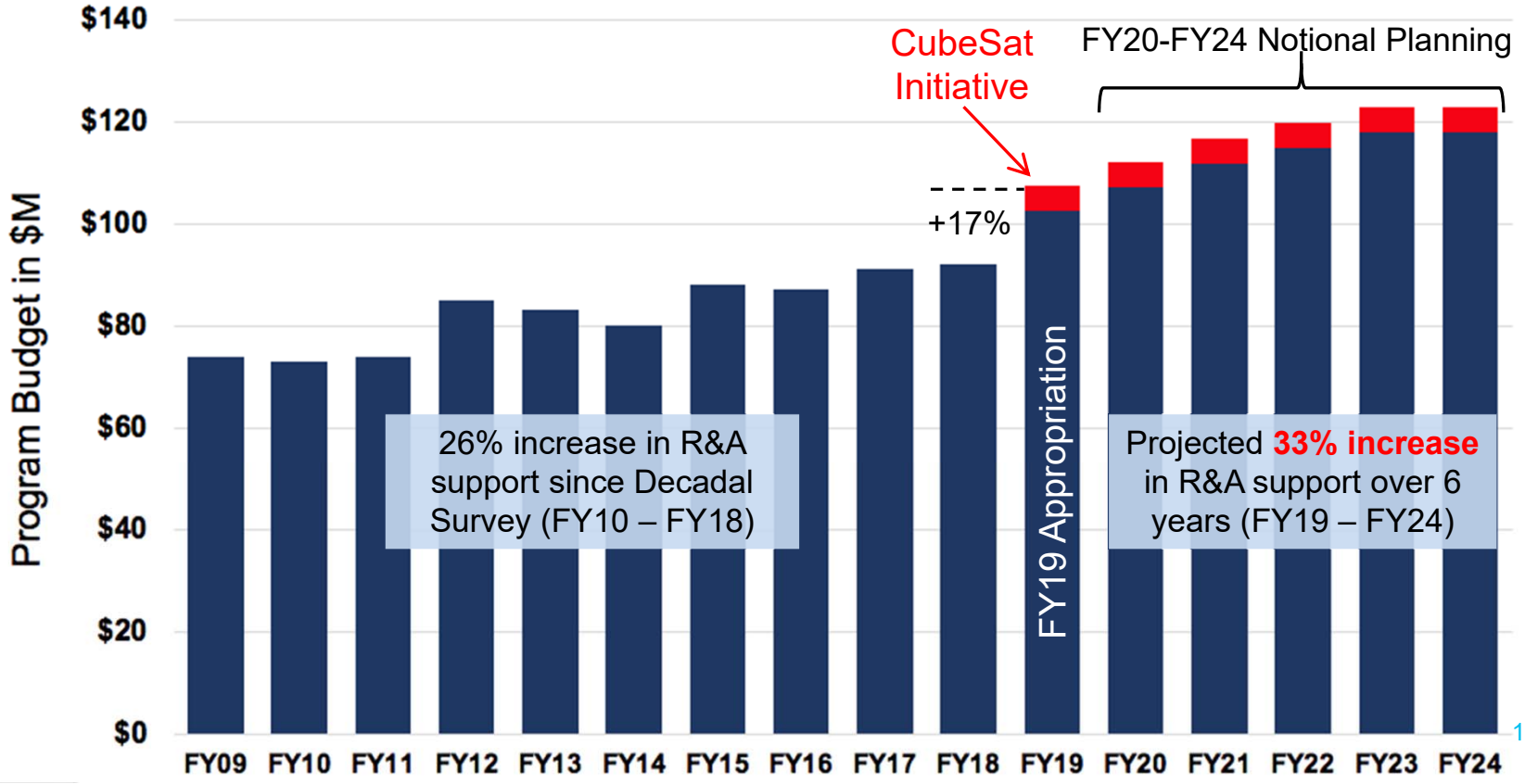
Program of Record

Program of Record

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

Growth in R&A Funding ($M)

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



R&A Proposal Status Update

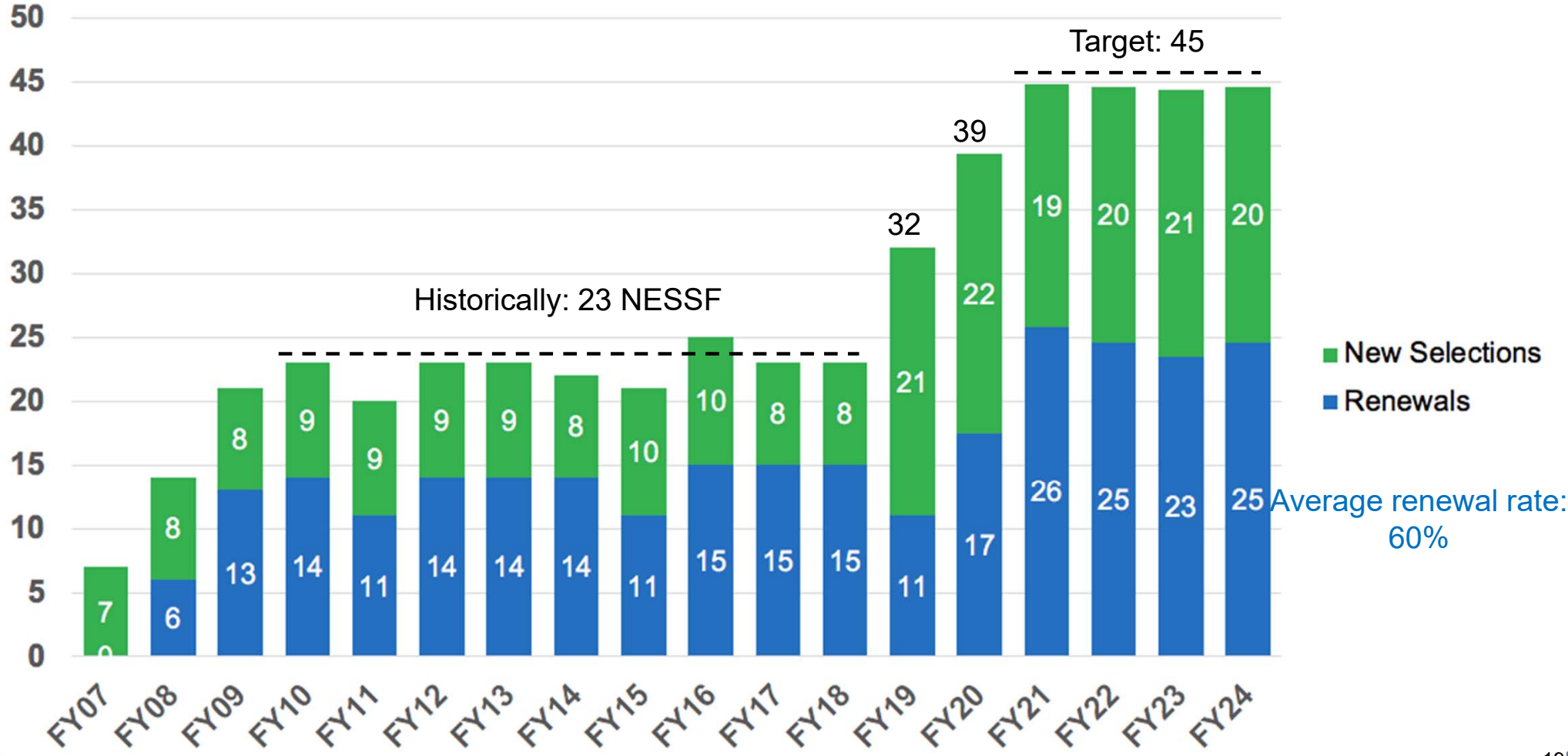
Average: 111 days (59 – 155 days)
80% PIs notified: 89 days
R&A Selection Rate = 21%
GO Selection Rate = 26%

Status: September 26, 2019

Solicitation	Proposal Due Date	Notify Date	Days since received	Number received	Number selected	% selected	New PIs
SmallSat Studies (AS^3)	July 13, 2018	Sep 10, 2018	59	38	9	24%	N/A
ADAP (Data Analysis)	May 17, 2018	Sep 17, 2018	123	242	53	22%	36 (68%)
XRP (Exoplanet Research)	May 30, 2018	Oct 19, 2018	142	67	8	12%	7 (88%)
LISA Preparatory Science	June 14, 2018	Nov 16, 2018	155	30	9	30%	N/A
SOFIA Next Gen Instruments	Aug 1, 2018	Oct 23, 2018	84	6	0	0%	N/A
Swift GI – Cycle 15 *	Sep 27, 2018	Feb 12, 2019	153 *	141	33	23%	4 (12%)
NICER GO – Cycle 1 *	Dec 20, 2018	Mar 4, 2019	75	84	49	58%	N/A
TESS GI – Cycle 2 *	Mar 14, 2019	June 21, 2019	99	134	38	27%	31 (78%)
Fermi GI – Cycle 12 *	Feb 23, 2019	July 1, 2019	128	97	35	36%	5 (14%)
NuSTAR GO – Cycle 5 *	Mar 29, 2019	June 17, 2019	80	198	67	34%	26 (39%)
FINESST-19	Mar 11, 2019	June 27, 2019	108	188	21	11%	N/A
Chandra GO – Cycle 21	Mar 14, 2019	July 24, 2019	132	516	168	32%	27 (17%)
Hubble GO – Cycle 27	Apr 4, 2019	June 28, 2019	86	1019	182	18%	51 (30%)
APRA (Basic Research)	Mar 29, 2019	Aug 21, 2019	145	164	40 (11)	27%	35 (88%)
SAT (Technology)	Mar 29, 2019	Aug 21, 2019	145	30	12	40%	7 (58%)
Roman Technology Fellowships	Mar 29, 2019	(pending)	(182) **	9			
ADAP (Data Analysis)	May 17, 2019	(pending)	(133)	242	38 (8)	16%	27 (71%)
XRP (Exoplanets Research)	May 30, 2019	(pending)	(120)	139			
Segmented Telescope Design	June 13, 2019	Aug 20, 2019	68	3	2	67%	N/A
ATP (Theory)	June 27, 2019	(pending)	(92)	236			

* affected by the partial government shutdown. ** RTF fellows are to be notified within 3 months after their APRA award.

FINESST Renewals and New Selections



Upcoming APD Sounding Rocket Launches

SISTINE (Sub-orbital Imaging Spectrograph for Transition Region Irradiance from Nearby Exoplanet Host Stars)

PI - **K. France** / Univ. Colorado (WSMR) **Aug 11, 2019**
Measurements UV spectra of M and K type dwarf stars. Goals assist in identification and characterization of nearby habitable exoplanets and advance TRL for future missions, such as LUVOIR.

DUST (Determining Unknown yet Significant Traits)

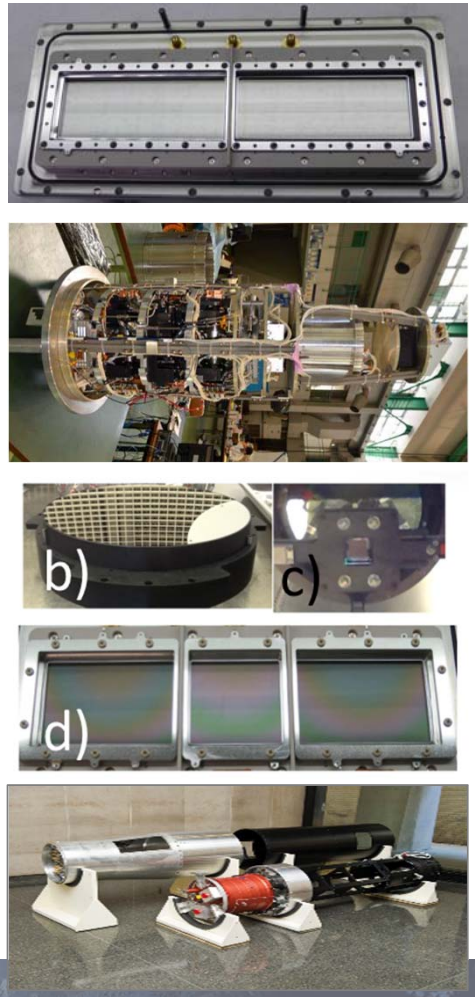
PI - **J. Nuth** / NASA/GSFC (WSMR) **Oct 7, 2019**
Measure infrared spectrum of analog dust grains during formation and agglomeration in microgravity, to determine variables in the end-to-end process of grain formation in circumstellar outflows around AGB stars.

FORTIS (Far-UV Off-Rowland circle Telescope for Imaging and Spectroscopy)

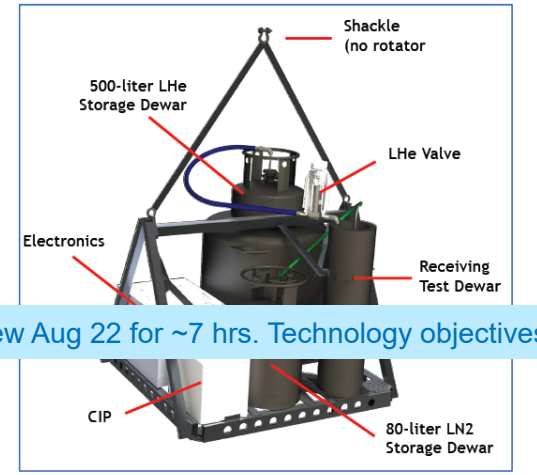
PI - **S. McCandliss** / Johns Hopkins Univ. (WSMR) **Oct 27, 2019**
Survey of H II regions and stellar populations in nearby star-forming galaxies (Magellanic Bridge).

Micro-X

PI - **E. Figueroa** / Northwestern Univ. (WSMR) **Dec 15, 2019**
Characterizing plasma conditions in Puppis A SNR using Transition-Edge Sensors.



Balloon Program - Fort Sumner Campaign



Flew Aug 22 for ~7 hrs. Technology objectives met.

BOBCAT *- (Kogut/GSFC) develops technology to improve far-IR sensitivity by a factor of 1000,000 compared to ground-based facilities or SOFIA. BOBCAT-1 is a technology demo of liquid nitrogen and liquid helium cryogen transfer. BOBCAT-2 is a demo of ultra-light balloon dewars.*

PICTURE-C - *Chakrabarti/Univ. of Mass.) will image five nearby star systems to search for dust and debris disks. PICTURE-C will demonstrate a balloon-based clear aperture telescope with low order wave front control, high performance vector vortex coronagraph, and a microwave kinetic inductance detector.*

PIPER - *(Kogut/GSFC) will attempt to measure CMB polarization in order to search for primordial gravity waves.*

HQ review of Leak Campaign on Aug 12 led to approval to proceed with Ft. Sumner campaign.

Wallops review gave authority-to-proceed with campaign Aug 13.

Campaign with Astrophysics, Heliophysics, and Earth Science missions, as well as engineering test flights has started. Astro missions shown above.

Ft. Sumner manifest
Kogut / GSFC / BOBCAT [Astrophysics] 08/22 SUCCESS
Gopalswamy / GSFC / BITSE [Heliophysics] 09/18 SUCCESS
Fields / CSBF / LDB test [Engineering]
3 small payloads flight [Engineering] 09/04 SUCCESS
Guzik / LSU / HASP [Student flight projects] 09/05 SUCCESS
Fischer / GSFC / Big 60 Qual [Engineering]
Chakrabarti / UMass / PICTURE-C [Astrophysics]
Toon/JPL/Remote/Bailey / VATech / GLO [Earth Science]
Kogut / GSFC / PIPER [Astrophysics]
+3 hand launches

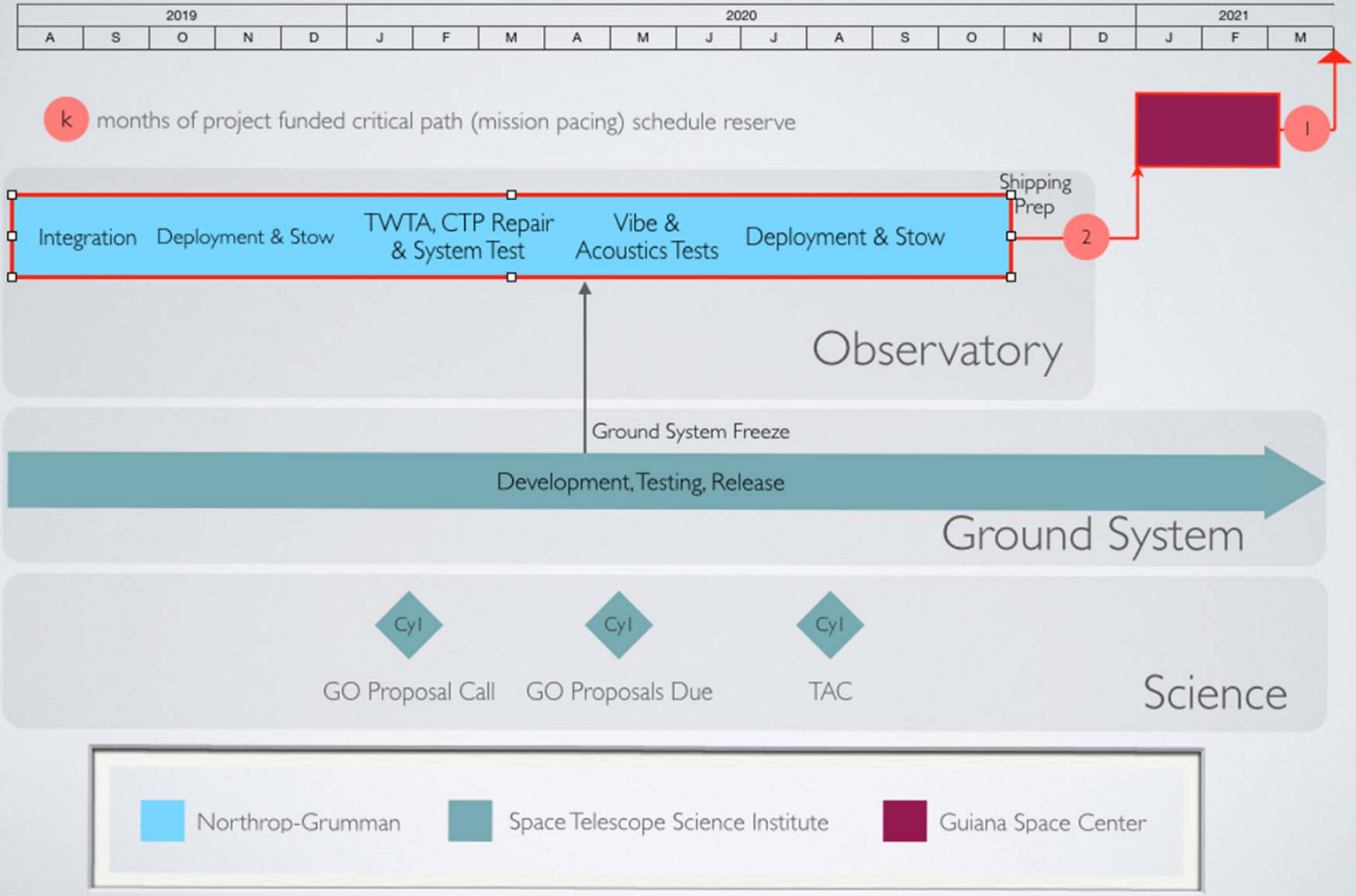
The Webb observatory in the clean room in Redondo Beach, CA before observatory environmental testing and observatory deployment tests

Webb

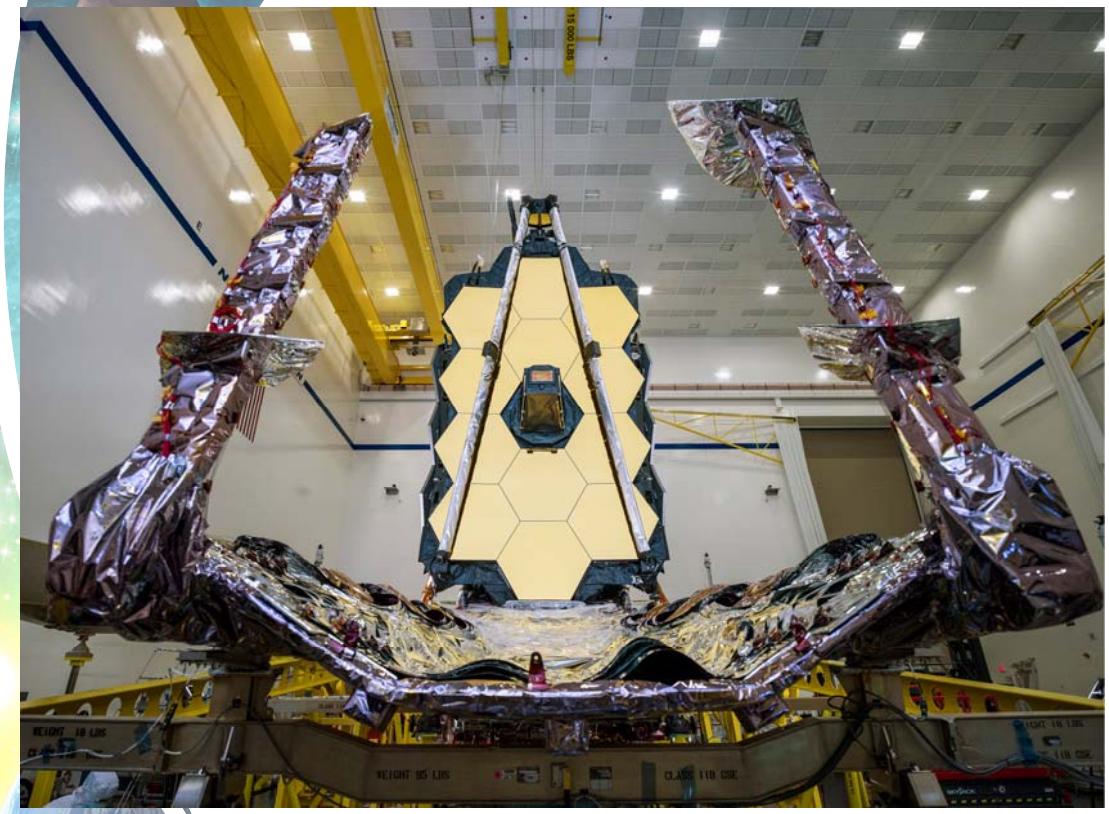
The James Webb Space Telescope

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

SIMPLIFIED SCHEDULE



Remaining I&T Activities*



Post SCE-Environmental Sunshield Deployments & Repairs

Observatory Pre-environmental Deployments

System (electrical) test

Vibration and acoustics tests

Observatory Post-environmental deployments

Final system test

Observatory fold and stow for launch

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

2021 – Call for Core Surveys

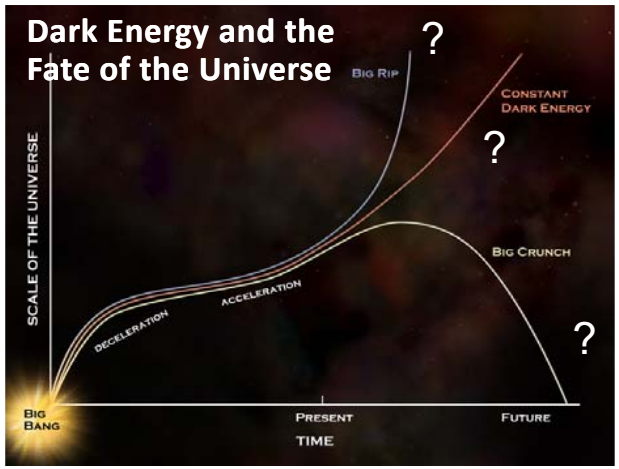
Mid-2020s – Launch

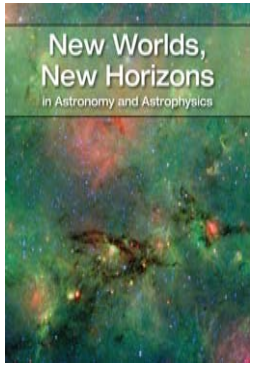
WFIRST is 100 to 1500 times faster than Hubble for large surveys at equivalent area and depth

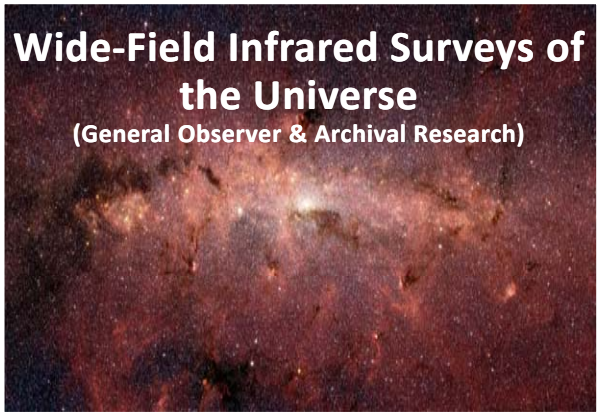
Science Program includes

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

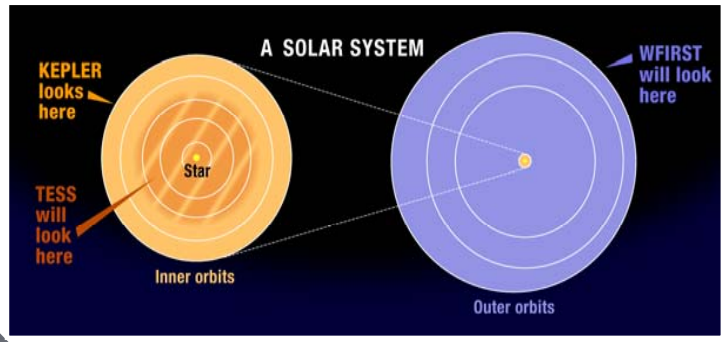
WFIRST Science Program (no changes)







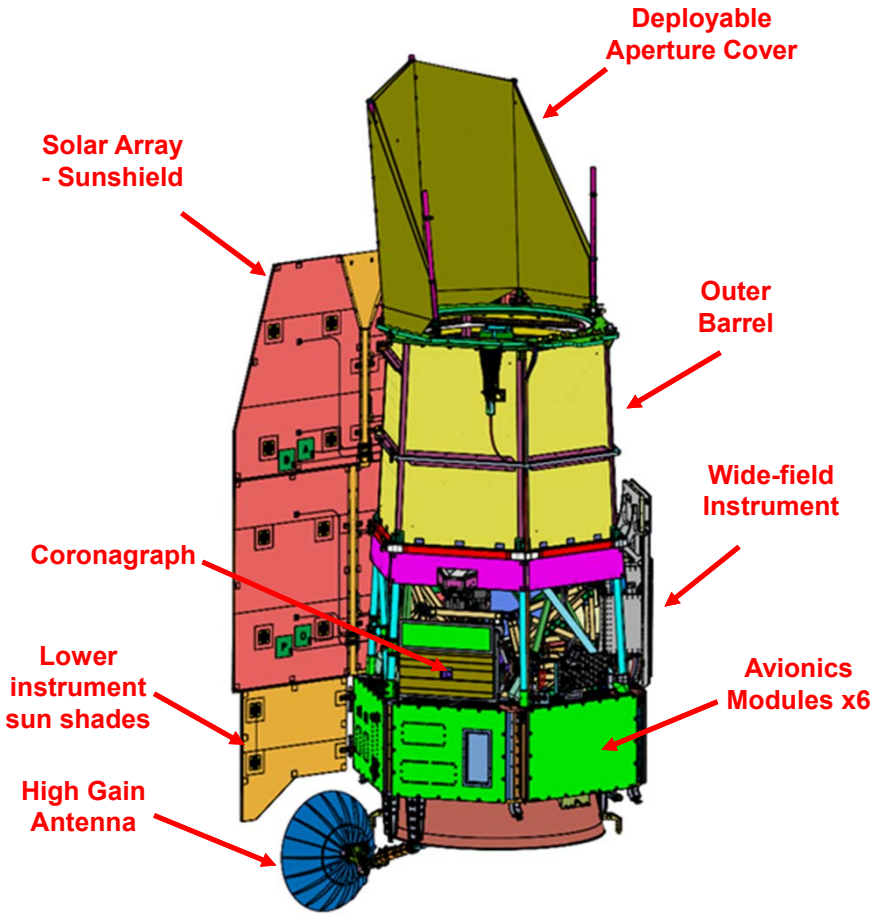
The full distribution of planets around stars



WFIRST
Programmatics

- Operating within approved FY19 budget and planning future years based on optimal funding profile
  - Reserve posture remains healthy, exceeding requirement
- Maintaining the schedule; absorbed furlough impacts and recovered
  - Delays were in detectors, instrument carrier and systems. These have been made up in revised schedule to KDP-C.
  - Reserve posture is still healthy, meeting requirement
- Have successfully ramped up the work force heading toward our peak budget year, FY20
- Mission architecture is in great shape
  - Technical budgets remain healthy, exceeding PDR requirements
- JCL (Joint Confidence Level) assessment has begun in preparation for Mission PDR
  - Independent assessment of budget/schedule confidence will be used for KDP-C

WFIRST
Observatory Concept



Key Features

Telescope: 2.4m aperture

Instruments:

- Wide Field Imager / Slitless Spectrometer
- Internal Coronagraph with Integral Field Spectrometer

Data Downlink: 275 Mbps

Data Volume: 11 Tb/day

Orbit: Sun-Earth L2

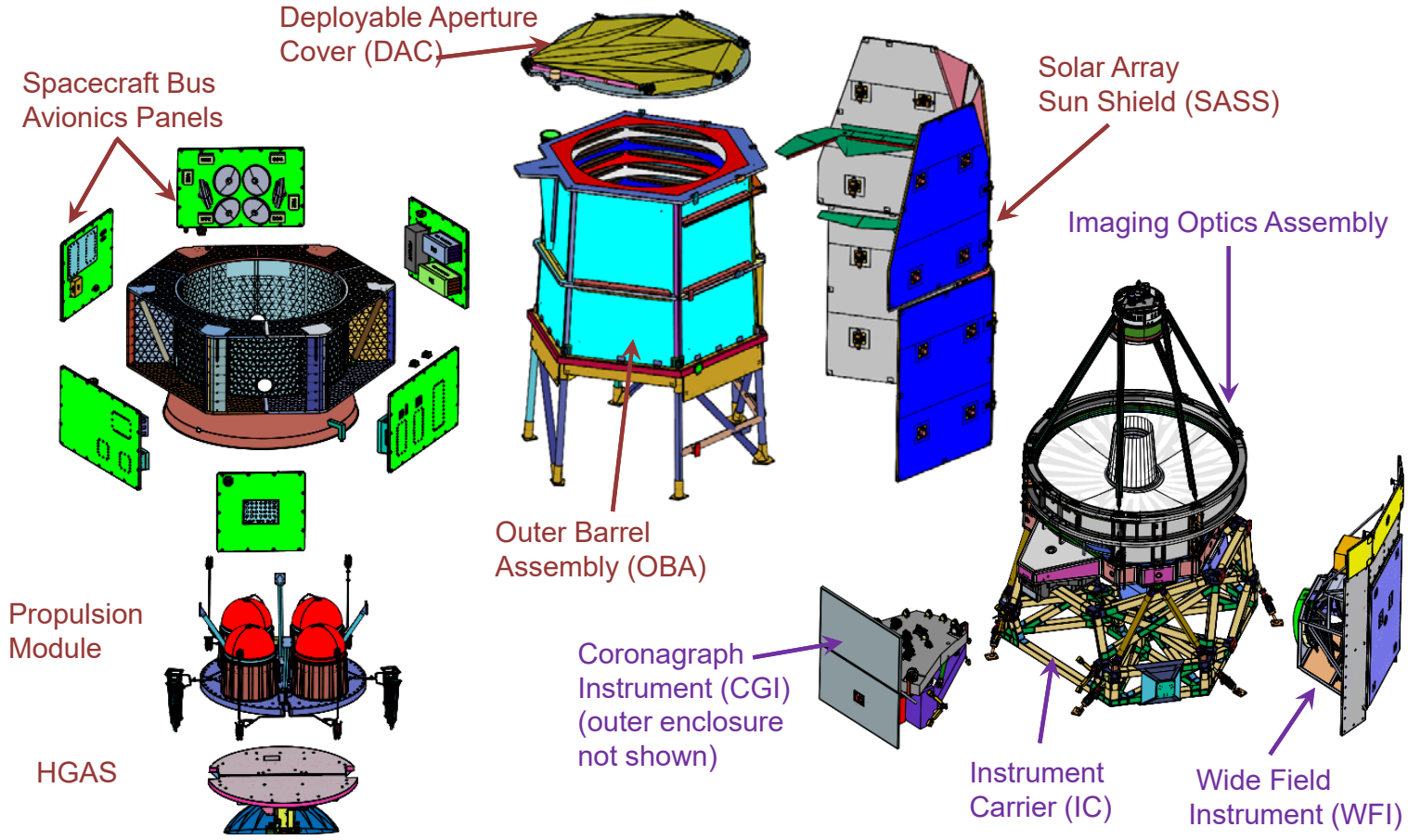
Launch Vehicle: 3 options

Mission Duration: 5 yr, 10 yr goal

Serviceability: Observatory designed to be robotically serviceable

Starshade compatible

WFIRST
Observatory Expanded View



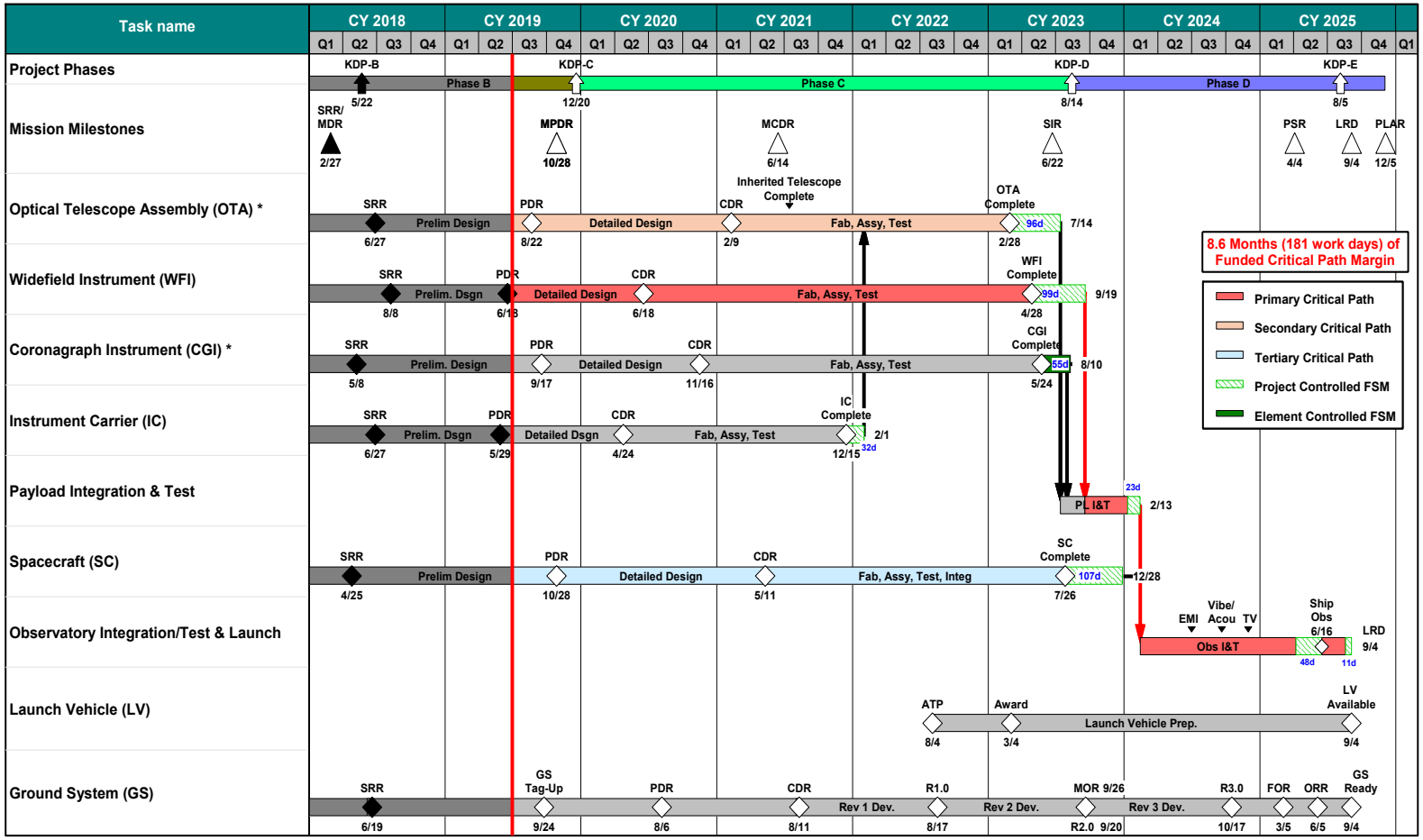
WFIRST
Technical Progress (1 of 2)

- WFIRST continues making excellent progress this year
  - Preliminary Design Review season is in full swing:
    - ~130 internal reviews in 2019 in preparation for element PDRs
    - Instrument Carrier: Complete
    - Wide Field Instrument: Complete
    - Telescope: Complete
    - CGI: Complete
    - Mission/Spacecraft: Oct 28-Nov 1
  - Telescope work is progressing on plan
    - Primary mirror figuring is on track; full tool polishing complete, ion figuring run #3 complete
  - Spacecraft
    - Working with LSP on an Coupled Loads Analysis for multiple launch vehicles by next year
    - Design complete for PDR; most subsystems ready for prototyping; procurements underway
  - Instrument Carrier
    - Interface details for instrument latches being negotiated; structure procurement activities are on track

WFIRST
Technical Progress (2 of 2)

- WFIRST continues making excellent progress this year
  - Wide-Field Instrument
    - Thermal control of filters improved; minimize changes to wavefront when filters are changed
    - Prism design finalized (optimized for SNIa spectroscopy)
    - Second-generation ASIC design complete & sent to foundry
  - Coronagraph Instrument
    - Grassroots exercise completed; re-scope efforts conducted with science teams and project management.
    - HQ concurred with proposed plan to rescope Integral Field Spectrograph (IFS) to address cost, schedule, mass, & power issues
      - Formal change to Level-1 requirements at KDP-C
    - Assessment of design with prism + direct imaging camera in place of IFS to be conducted at CGI and Mission PDRs
      - Preliminary assessment for single planet spectroscopy is favorable
      - Lose ability to observe multiple planets simultaneously, to monitor changing speckle backgrounds, to demonstrate IFS wavefront sensing (not one of the critical technology demonstration objectives)
    - Mask design optimization continues; throughput improvement from pupil design
  - Ground System (PDR next Summer)
    - MOC and ground station design is on track
      - Technical interchanges on ground stations w/ international partners continuing

WFIRST
Project Master Schedule



*Secondary critical path is occupied by the Optical Telescope Assembly (OTA) in lieu of the Coronagraph Instrument (CGI), which is designated as a technology demonstration

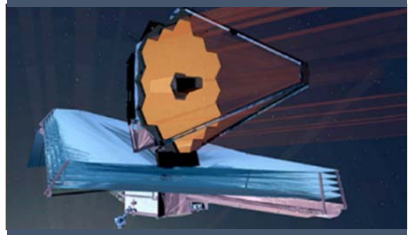
*CGI schedule is draft pending review of direct imaging spectroscopy implementation

WFIRST
The Year Ahead

- Fabrication/testing of engineering development/test unit hardware ramping up; a few examples
  - Launch lock & vibration isolation system
  - Instrument latches
  - WFI focal plane electronics, grism
- Beginning/continuation of flight hardware fabrication
  - Detectors
  - Instrument latches
  - Instrument carrier structure
  - Completion of primary mirror figuring
  - Spacecraft components
- Beginning of flight hardware integration
  - OTA Tertiary Optical Mirror Assembly

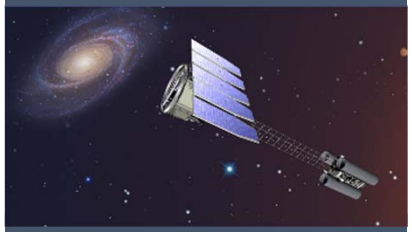
Missions in Development or Under Study

Webb 2021
NASA Strategic Mission



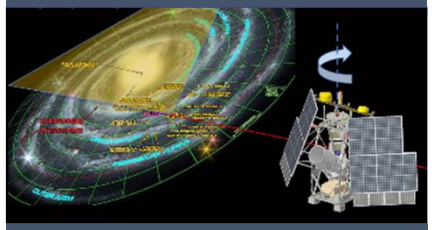
James Webb
Space Telescope

IXPE 2021
NASA Explorers Mission



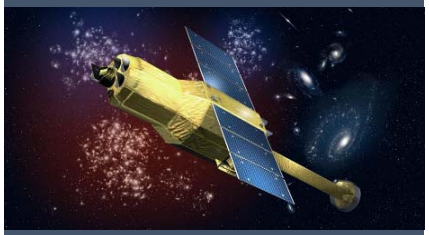
Imaging X-ray
Polarimetry Explorer

GUSTO 2021
NASA Explorers Mission



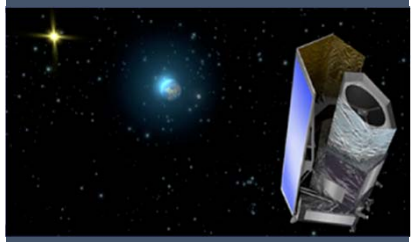
Galactic/ Extragalactic ULDB
Spectroscopic Terahertz Observatory

XRISM 2022
JAXA-led Mission



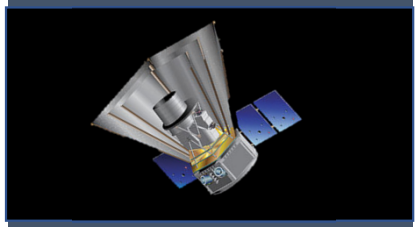
NASA is supplying the Resolve
detector and X-ray mirrors

Euclid 2022
ESA-led Mission



NASA is supplying the NISP
sensor chip system

SPHEREx 2023
NASA Explorers Mission



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

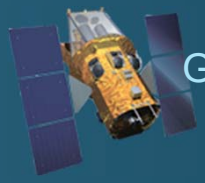
WFIRST Mid 2020s
NASA Strategic Mission

Wide Field Infrared
Survey Telescope

Athena / LISA 2030s
ESA-led Missions

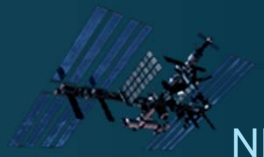
NASA is supplying instrument
and mission systems

Astrophysics Explorers Program



Gehrels Swift

NuSTAR

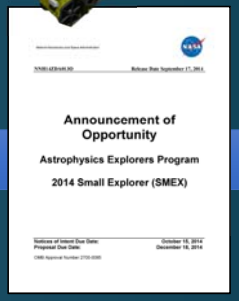


NICER

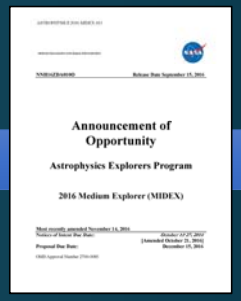
TESS

4 AOs per decade

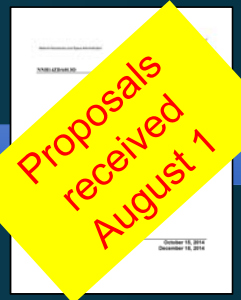
MIDEX 2011



SMEX 2014

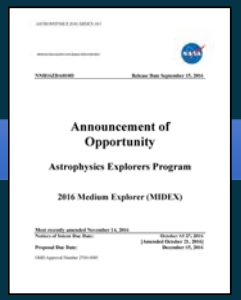


MIDEX 2016



Proposals received August 1

SMEX 2019



MIDEX 2021

Small and Mid-Size Missions

TESS

IXPE

SPHEREx

Missions of Opportunity

NICER

GUSTO

MO TBD

XRISM

Explorers Mission of Opportunity AO includes new opportunities:

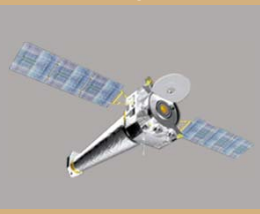
- NASA-provided RideShare
- SmallSat Secondary Payloads
- Opportunities enabled by the Artemis Program

Operating Missions

Hubble 4/90
NASA Strategic Mission

Hubble Space Telescope

Chandra 7/99
NASA Strategic Mission



Chandra X-ray Observatory

XMM-Newton 12/99
ESA-led Mission

X-ray Multi Mirror - Newton

Spitzer 8/03
NASA Strategic Mission

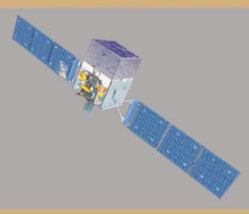
Mission ending Jan 31, 2020

Spitzer Space Telescope

Gehrels Swift 11/04
NASA MIDEX Mission

Neil Gehrels Swift Gamma-ray Burst Explorer

Fermi 6/08
NASA Strategic Mission



Fermi Gamma-ray Space Telescope

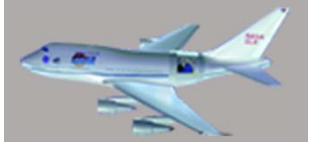
Kepler 3/09
NASA Discovery Mission

Mission Complete!

NuSTAR 6/12
NASA SMEX Mission

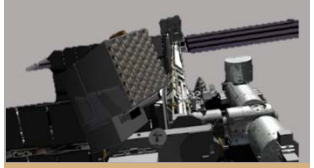
Nuclear Spectroscopic Telescope Array

SOFIA 5/14
NASA Strategic Mission



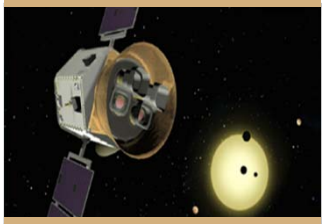
Stratospheric Observatory for Infrared Astronomy

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



Neutron Star Interior Composition Explorer

TESS 4/18
NASA MIDEX Mission



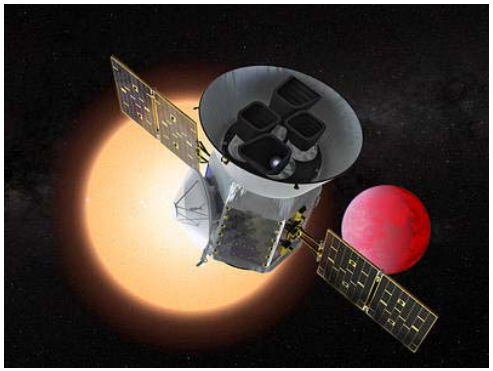
Transiting Exoplanet Survey Satellite

SOFIA

Stratospheric Observatory for Infrared Astronomy

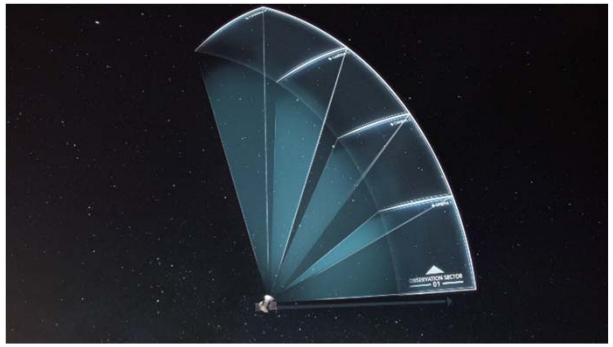
- SOFIA's 5-year prime mission will be completed at the end of FY19
- Given that the program has finished 5 years of operations, NASA has conducted two reviews of the SOFIA project to make changes directed at increasing the science productivity of SOFIA in FY20 and beyond
  - Review of SOFIA's maintenance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

Summary of reviews and NASA response posted at: https://science.nasa.gov/astrophysics/documents

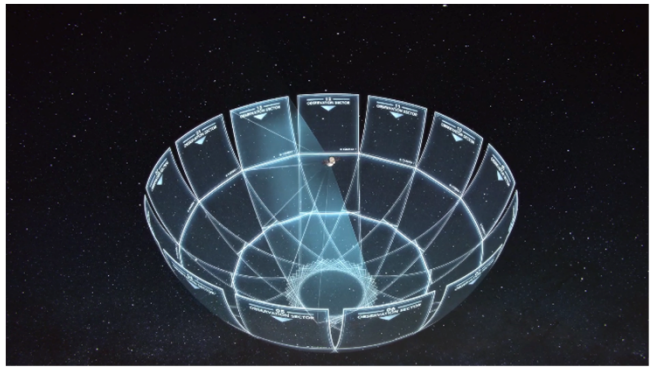


Transiting Exoplanet Survey Satellite (TESS)

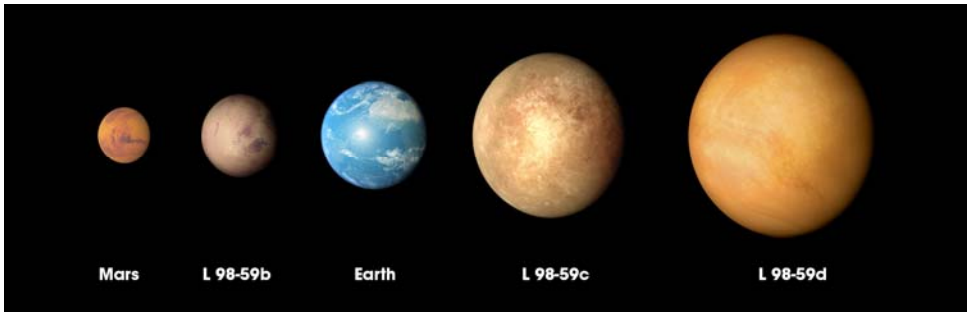
- TESS completed its year long survey of the southern sky on July 18.
- The spacecraft has now transitioned to scanning the northern sky for the next year.
  - In its first year, TESS has found:
    - 21 confirmed planets
    - ~1000 planet candidates (project)
    - ~300 planet candidates (science community)
    - 6 supernovae
    - 3 exocomets
    - Solar system bodies including comets and asteroids
    - >100,000,000 light curves released to the public



Using four cameras TESS watches a 24x96 degree section of the sky for 27 days at a time.

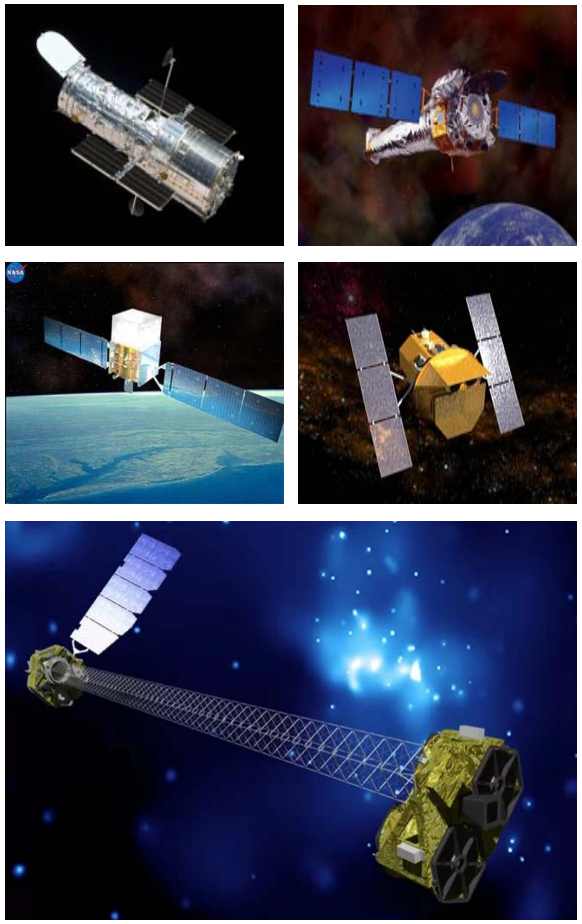


TESS has now completed scanning the southern sky and transitioned to scanning the northern sky.



TESS discovered three planets in the L98-59 system


EXPLORING
the EXTREME
20 YEARS OF CHANDRA
In 2019, NASA's Chandra X-ray Observatory celebrates its 20th year in space exploring the Universe.



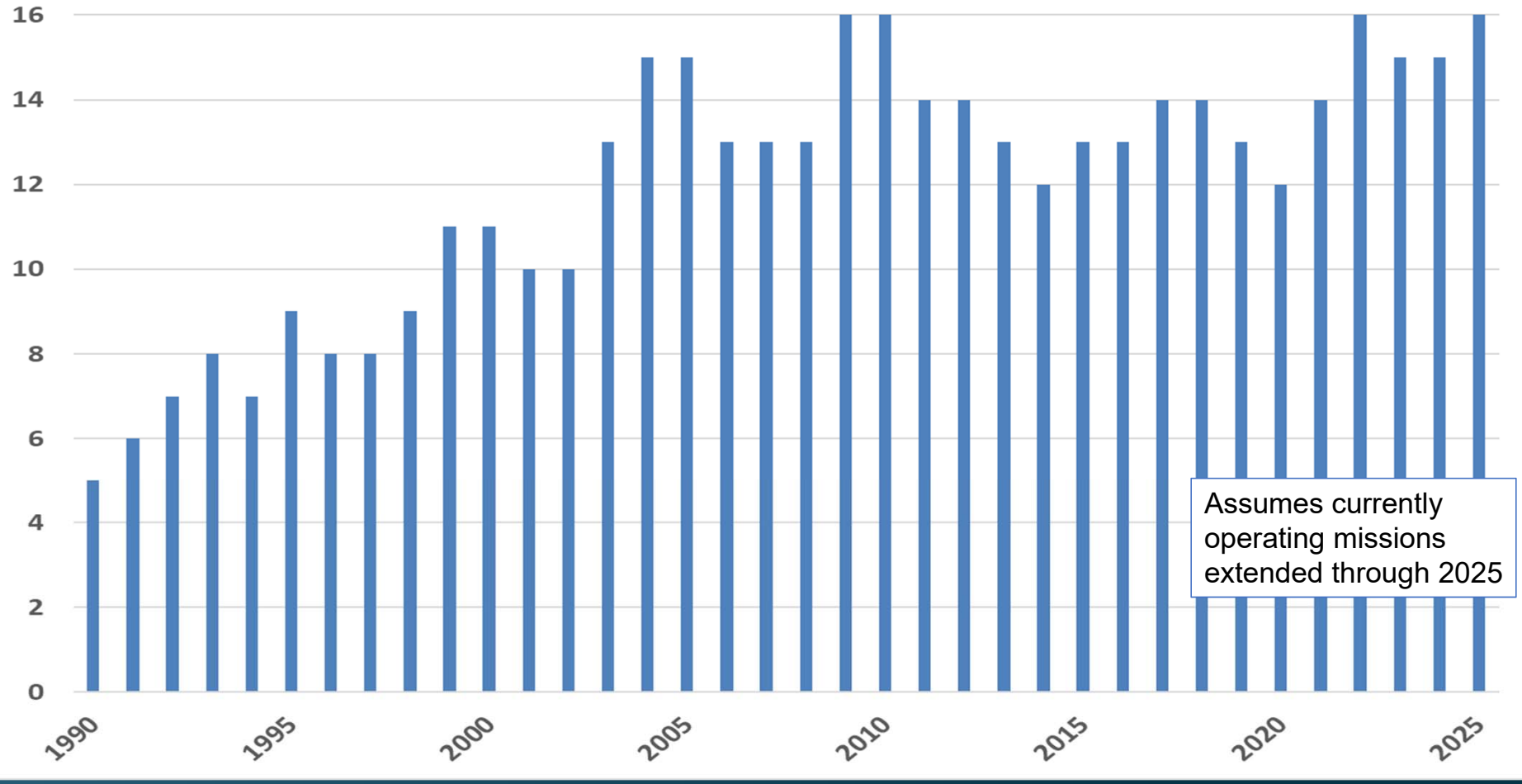
Senior Review 2019

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

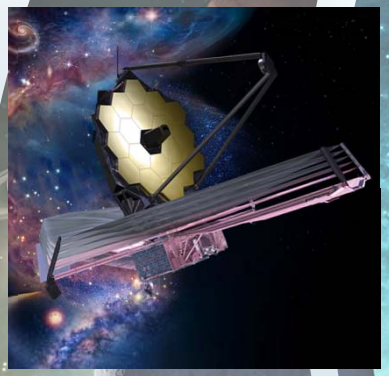
Not in Senior Review: Kepler, SOFIA, Spitzer

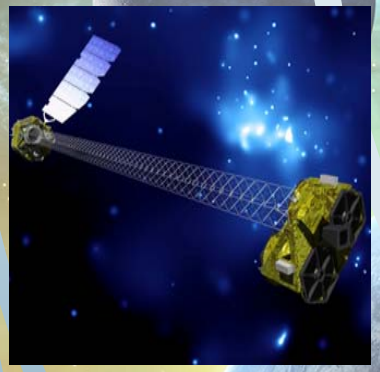
Astrophysics Mission Timeline

Missions operating each year



Budget





FY20 Budget Request

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

Congressional Markup of FY20 Budget Request

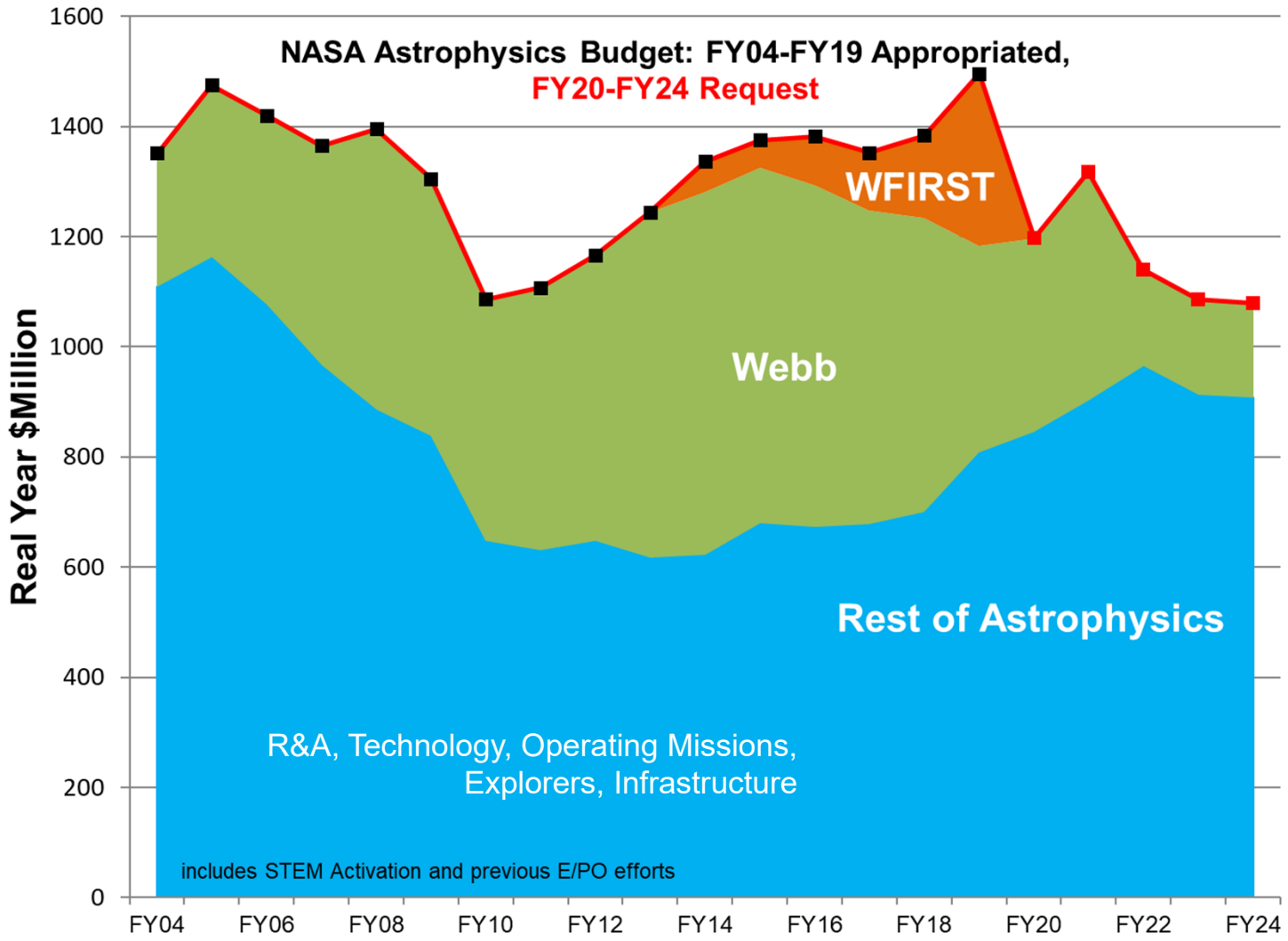
House has marked up NASA's FY20 budget request

- 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 Appropriations Subcommittee and Committee scheduled to mark up NASA's budget on September 24 and 26, respectively

Congressional Markup of FY20 Budget

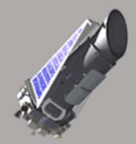
($M)	Request	House	Senate	Comment
Webb	352.6	352.6		Supports replan
WFIRST	0	510.7		Includes $65M for CGI
SOFIA	73.0	85.2		
Rest of Astrophysics	772.8	771.8		$1M (0.1%) reduction
Total	1,197.4	1,720.3		


NASA Astrophysics Budget: FY04-FY19 Appropriated,
FY20-FY24 Request
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
FY04
FY06
FY08
FY10
FY12
FY14
FY16
FY18
FY20
FY22
FY24
WFIRST
Webb
Rest of Astrophysics
R&A, Technology, Operating Missions,
Explorers, Infrastructure
includes STEM Activation and previous E/PO efforts

Supporting the Decadal Survey

Medium Mission Concepts (Probes)

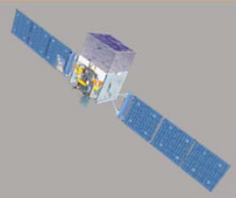
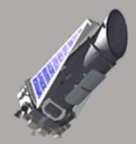
Probes are strategic missions that have had a strong impact on astrophysics, either through a focused investigation or as a broadly-capable observatory

COBE 11/89	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	Rossi X-ray Timing Explorer	Gravity Probe B The Relativity Mission	Fermi Gamma-ray Space Telescope	Kepler Space Telescope

2016 Oct	Endorsement by Astrophysics Subcommittee of plan for Probe Concept Studies
2017 Mar	Selection of 10 proposals for NASA-funded probe concept studies
2018 Jan	Presentation to community at AAS special session
2019 Mar	Submission of final reports to NASA
2019 Apr-Aug	Independent review of reports by NASA
2019 Sep	Submission of final reports with NASA findings to Astro2020

Medium Mission Concepts (Probes)

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

COBE 11/89	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	Rossi X-ray Timing Explorer	Gravity Probe B The Relativity Mission	Fermi Gamma-ray Space Telescope	Kepler Space Telescope

Options for 2020 Decadal Survey

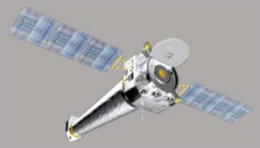
- Do not recommend a medium mission in Astro2020
- Recommend specific probe(s) as medium-size strategic missions
- Recommend several specific science concepts for an AO (New Frontiers)
- Recommend an unconstrained AO (Super-Explorer)

Large Mission Concepts (Flagships)

Flagships drive science

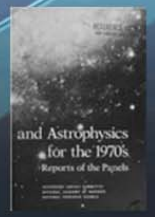
Flagships drive US capabilities and contribute to US leadership

Flagships drive NASA budget and create stakeholder support

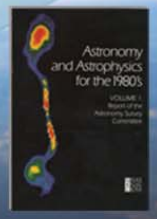
Hubble 04/90	Compton 05/91	Chandra 09/99	Spitzer 8/03	Webb 2021	WFIRST Mid 2020s
NASA Great Observatory	NASA Great Observatory	NASA Great Observatory	NASA Great Observatory	NASA Mission	NASA Mission
					
Hubble Space Telescope	Compton Gamma Ray Observatory	Chandra X-ray Observatory	Spitzer Space Telescope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

Astrophysics

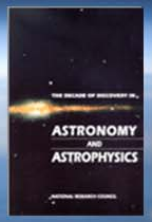
Decadal Survey Missions



1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra

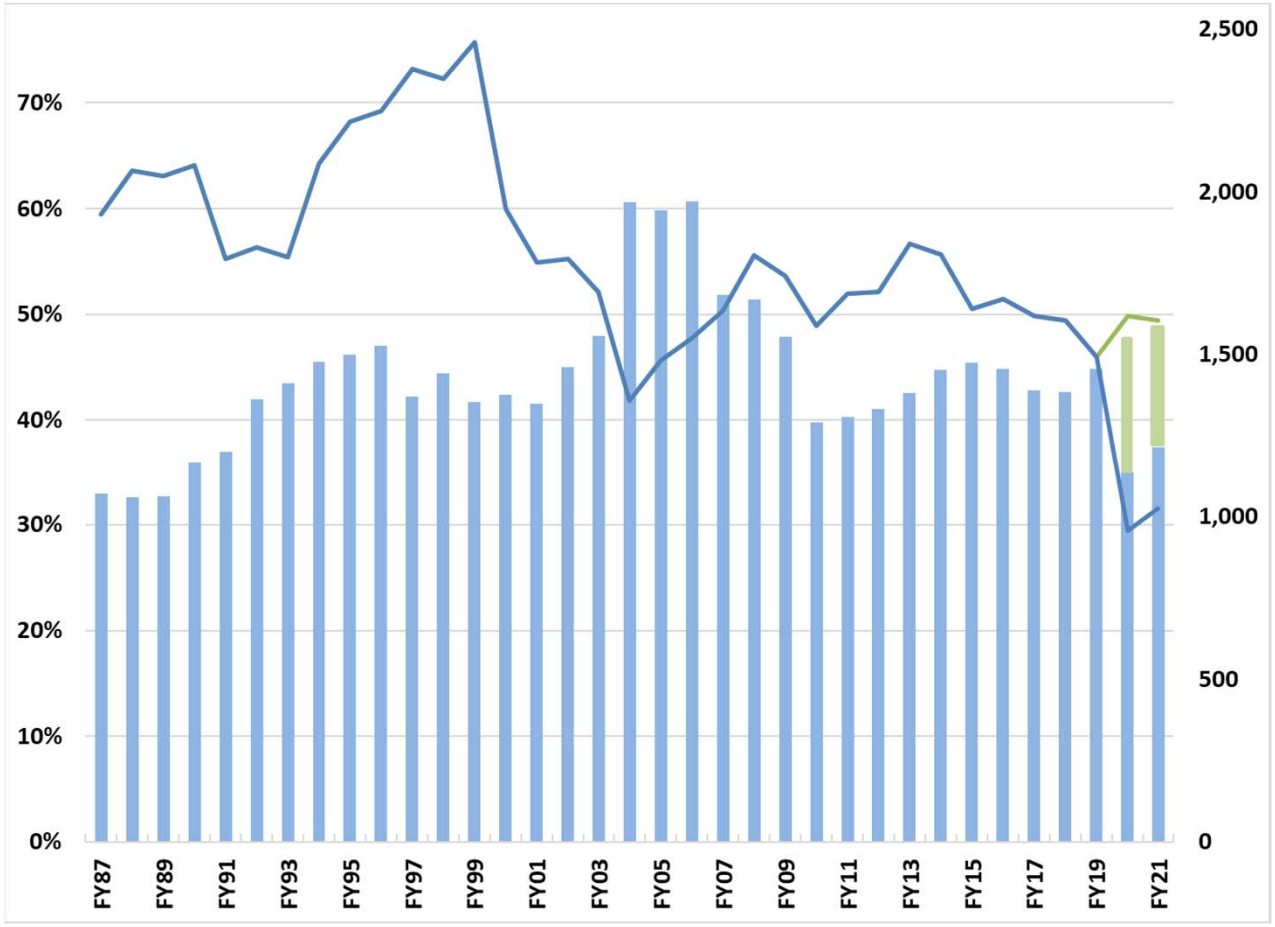


1991
Decadal Survey
Spitzer

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST

Flagship Fraction of Astrophysics Budget

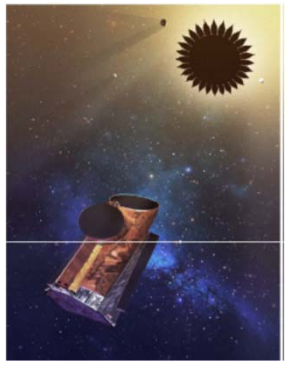


All dollars inflated to FY18$.
Development only, no ops.

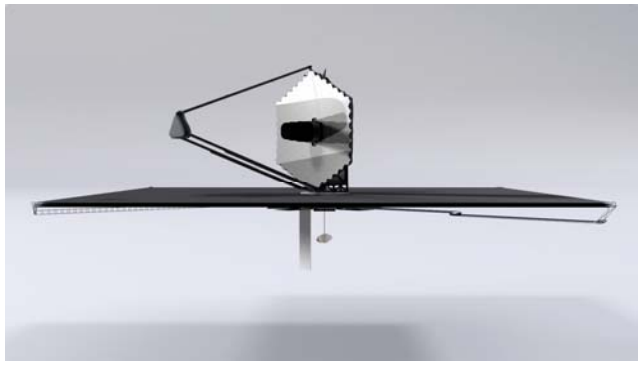
- Large mission fraction (left scale)
- Inflation adjusted Astrophysics budget (right scale)
- Current planning budget (without WFIRST beyond FY19)
- What if WFIRST is funded as needed on top of FY20 President's Budget Request?

Large Mission Concepts

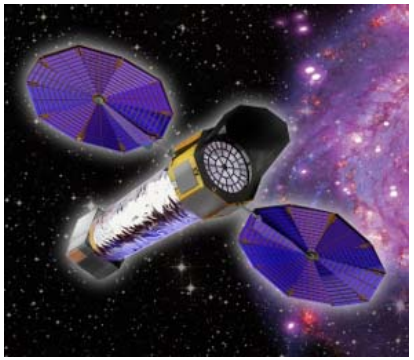
"NASA should ensure that robust mission studies that allow for trade-offs (including science, risk, cost, performance, and schedule) on potential large strategic missions are conducted prior to the start of a decadal survey. These trade-offs should inform, but not limit, what the decadal surveys can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



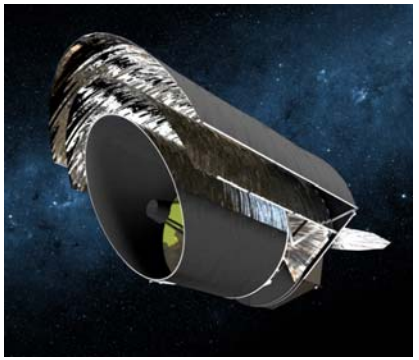
HabEx



LUVOIR

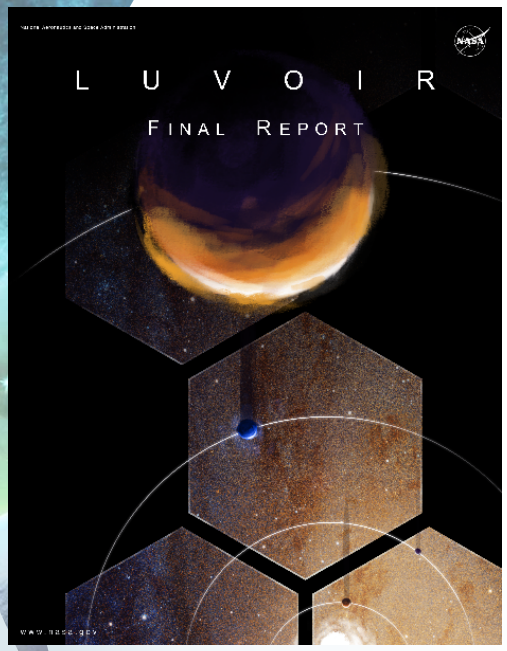


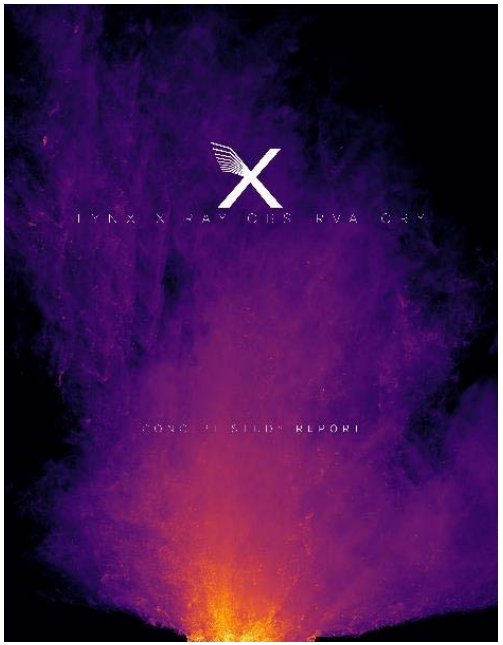
Lynx



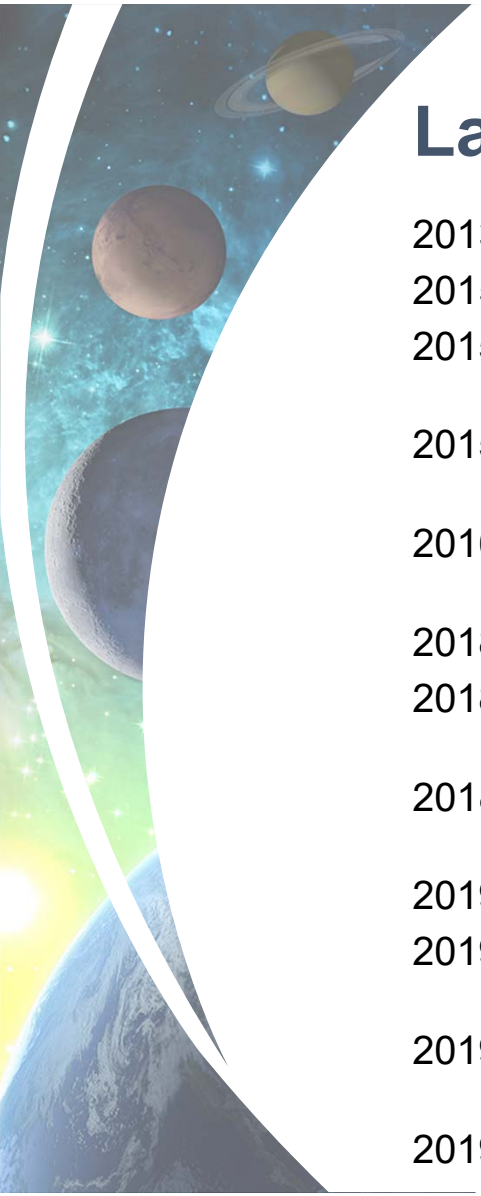
Origins

Large Mission Concept Studies





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



Large Mission Concepts

2013	30-year Visionary Roadmap: *Enduring Quests, Daring Visions*
2015 Jan-Oct	Community-based process to identify large mission concepts
2015 Oct	Endorsement by Astrophysics Subcommittee of four large mission concepts
2015 Nov-Dec	Initiation of Community-based STDTs; members appointed in 2016 Apr after an open call for nominations
2016 – 2020	Technology investments to support four large mission concepts, in addition to supporting Astro2010 priorities
2018 Jan	Presentation to community at AAS special session
2018 Aug	Committee on Astronomy and Astrophysics report on NASA's preparations for Astro2020
2018 Aug	Interim reports (https://science.nasa.gov/astrophysics/2020-decadal-survey-planning)
2019 Jan	Presentation to community at AAS special session
2019 Aug 23	Final reports (https://science.nasa.gov/astrophysics/2020-decadal-survey-planning)
2019 Sep	Independent assessment of reports by NASA's Large Mission Concepts Independent Assessment Team
2019 Oct	Submission of NASA Letter to Astro2020

Decadal Survey Goal

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

Carpe Posterum


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