National Aeronautics and Space Administration

NASA

EXPLORE SCIENCE

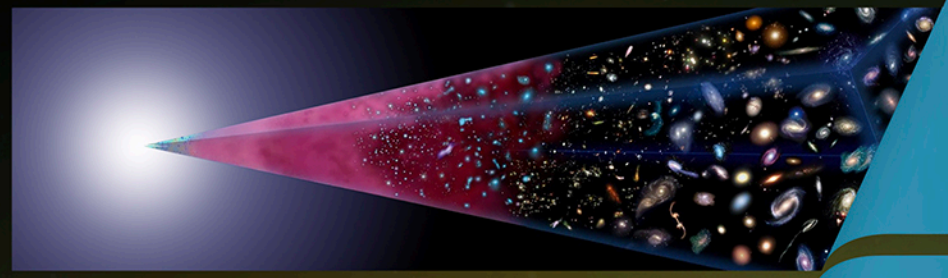
NASA Astrophysics Update

Astronomy and Astrophysics Advisory Committee
National Science Foundation Headquarters
February 25, 2019

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

Why Astrophysics?

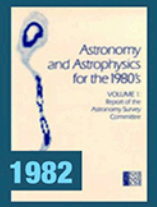


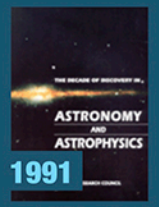
How did our universe begin and evolve?

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

Are we alone?

Enduring National Strategic Drivers





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

NASA Astrophysics Division

ASTROPHYSICS
NASA's Science Mission Directorate

Division Director

Paul Hertz
Astrophysics Division Director

Jeff Volosin
Deputy Astrophysics 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

Joan Centrella
Strategic Planning

Valerie Connaughton
APRA (High Energy)
XRISM

Dan Evans
PCOS Program
APRA (High Energy)

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

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

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Education/Comms
Astrophysics Archives
Astro. Advisory Cmte.

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ExEP Program
ADAP Lead
APRA (Exoplanet Tech.)

Stefan Immler
Astrophysics Research Program Manager
Chandra, Fermi

Patricia Knezek
APRA (UV/Optical)

William Latter
APRA (Lab Astro)
Spitzer, NuSTAR

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

Rita Sambruna
APRA (Fund. Phys.)
SAT (PCOS), ADAP
LISA, NICER

Evan Scannapieco
ATP, TCAN Lead
Swift

Kartik Sheth
APRA (IR/Submm)
SOFIA, JWST

Linda Sparke
Astrophysics Explorers Program

Martin Still
XRP Lead
TESS

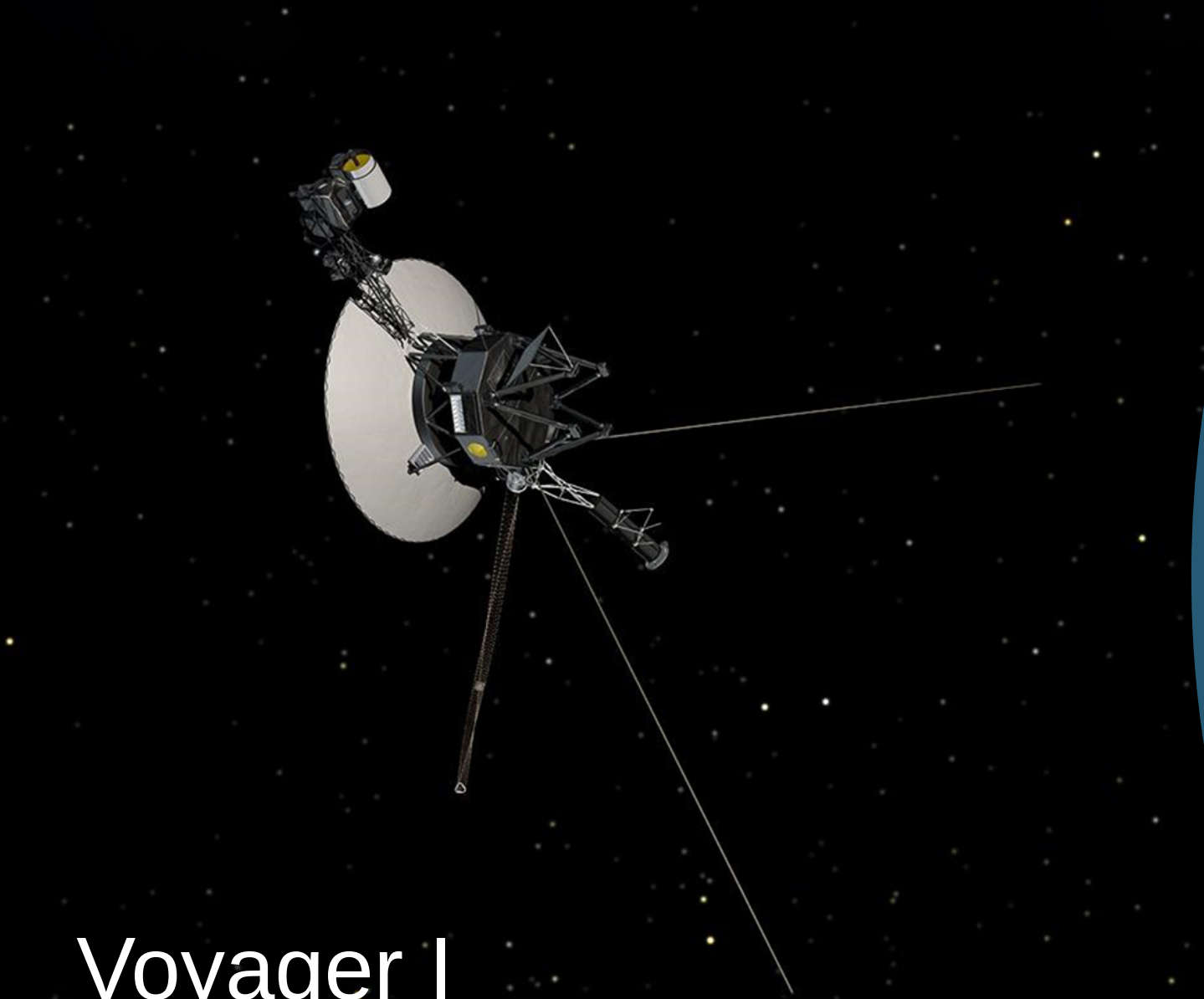
Eric Tollestrup
APRA (IR/Submm)
Euclid, IXPE

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

Outline

- Highlights
  - Science Highlights
  - Impact of the Shutdown
- Program & Budget Update
  - Milestones in 2018 and 2019 (planned)
  - Budget Update
  - R&A Update
- Missions Update
  - Developing Missions
  - Operating Missions
  - Senior Review
- Planning for Astro2020

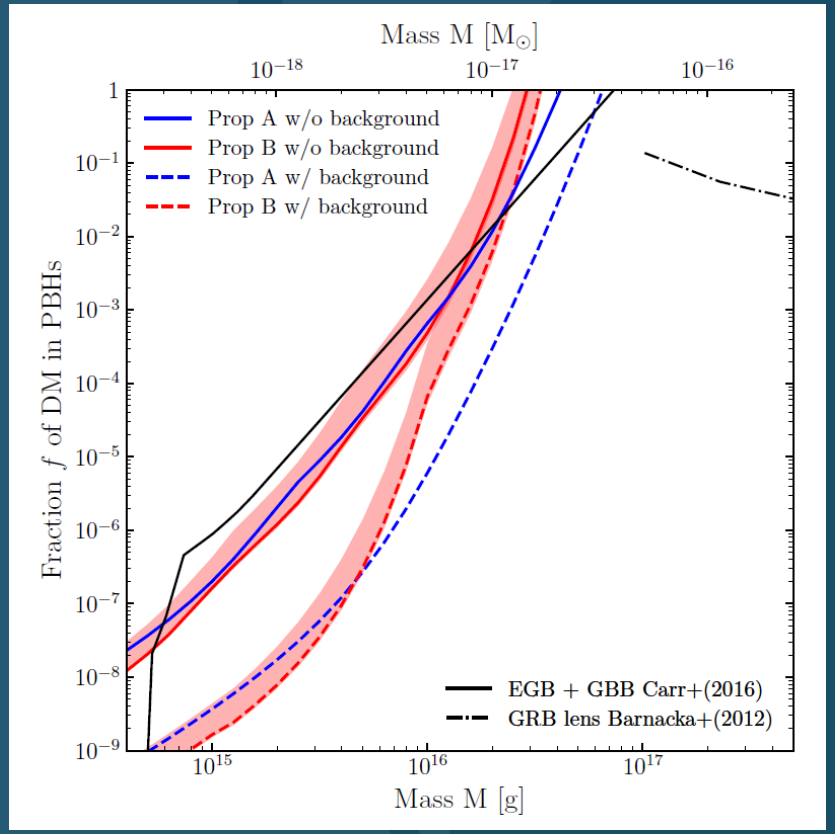
NASA Astrophysics Science Highlights



Voyager I

Boudaud and Cirelli, Voyager 1 e+/e- Further Constrain Primordial Black Holes as Dark Matter, Physical Review Letters, in press, 2019., 2019.

SCIENCE HIGHLIGHT



Jan. 30, 2019 – Previous upper limit (black) and new upper limits in the 10^{16}g mass range (blue and red) observed by Voyager 1

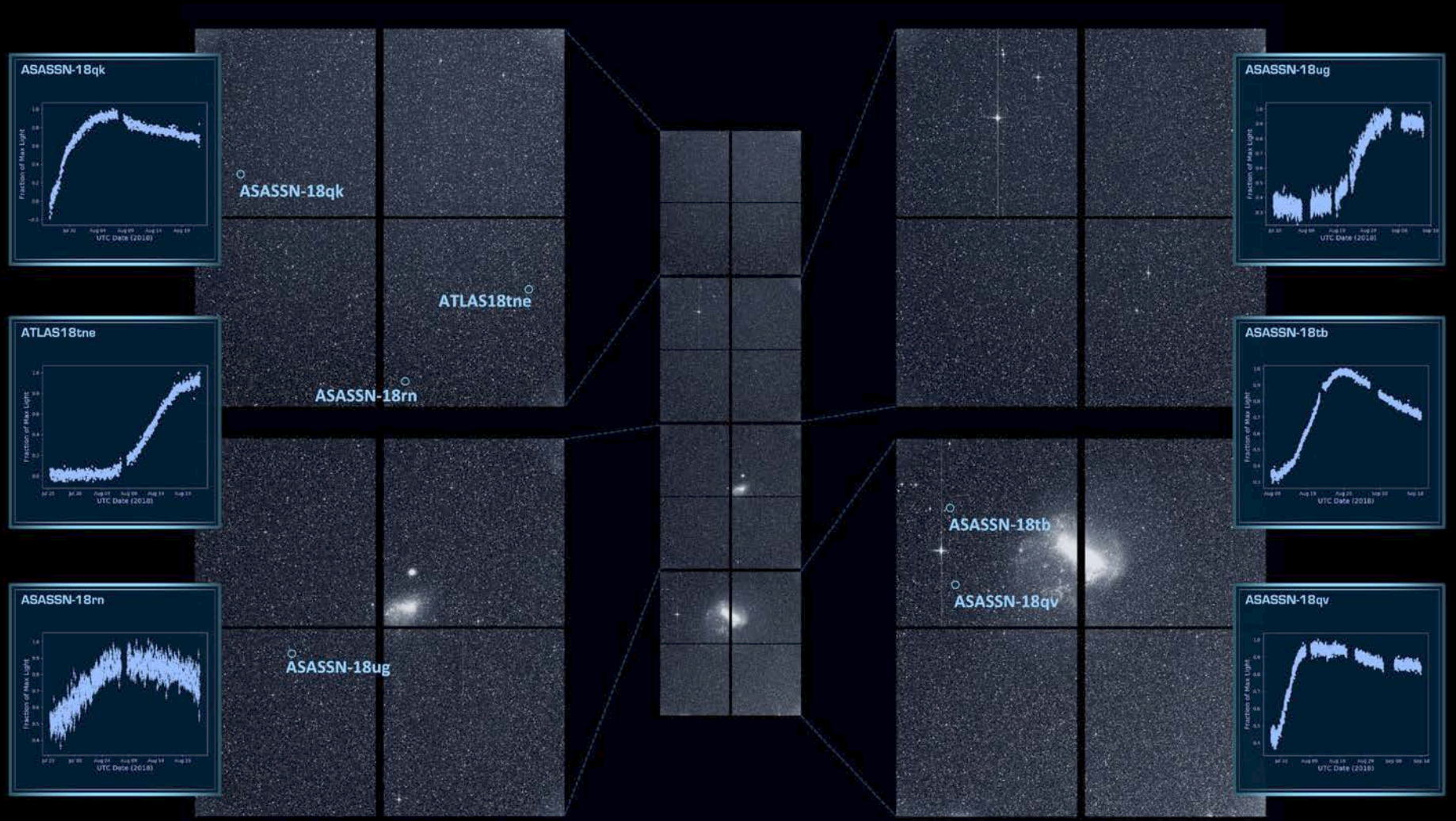
New Horizons

Arrival at Ultima Thule
January 1, 2019

SCIENCE HIGHLIGHT

Jan. 1, 2019 – New Horizons captures image Kuiper Belt object 2014 MU_{69} nicknamed Ultima Thule seven minutes before closest approach

TESS TRANSITING EXOPLANET SURVEY SATELLITE



Early light curves of six supernovae (exploding stars) announced at AAS; data from Sectors 1-5 show numerous asteroids, variable stars of great variety, and even a few comets

Webb

The James Webb Space Telescope

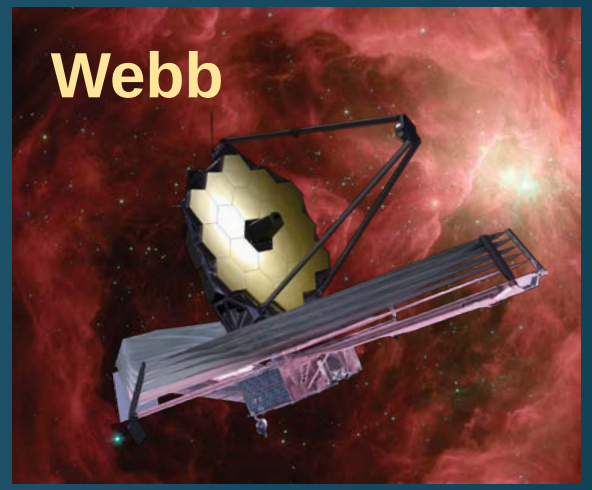
SCIENCE HIGHLIGHT

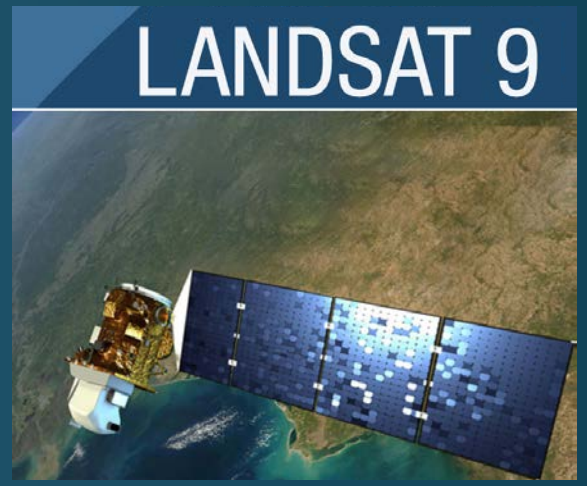
Jan. 29, 2019 – Engineers and technicians in Redondo Beach, Calif., continue critical environmental testing to prepare it for the rigors of launch into space

NASA Astrophysics
Impact from the Shutdown

Summary

- The partial government shutdown impacted all of NASA Science
- We have come back from the 35-day partial government shutdown with a focus on:
  - Supporting Post Docs, Graduate Students, and Contractors
  - Eliminating ambiguity by establishing deadlines and clear paths forward
  - Dealing with impacts to missions in ways that do not affect the rest of research programs
  - Temporarily expediting timelines and modifying processes to complete all planned evaluations and selections within the original timeframe
- We need your help
  - We need the community to actively participate in reviews and be responsive to requests for assistance
  - We are going faster than usual, so please let us know if we make mistakes and be patient as we correct them





Excepted Projects: Examples

- NASA Science had a number of excepted projects or portions of projects, including:
  - All operating missions
  - Flight hardware in environmental testing (e.g., Webb)
  - Critical elements of Lucy, Landsat 9, DART, that otherwise would adversely affect the ability to meet launch windows
  - Antarctic balloon campaign

Overall Impacts

Missions

- Non-excepted and some excepted missions' near-term milestones may be somewhat delayed; however, there are no significant changes to any launch readiness dates
- Increased costs due to ramp-down and ramp-up of operations, contract modifications, etc.
- Extended formulation and delayed life cycle reviews and key decision points

Research programs

- Due dates of proposals were shifted, with the vast majority shifted to no earlier than March 29, 2019
- Reviews of proposals and grants were suspended and must be rescheduled
- Processing and payment of funded grants were suspended temporarily
- Spring 2019 balloon campaign in New Zealand cancelled

Impact to Research Program

- Our intent is to fund the entire research program and return to previous schedules as quickly as possible
- Consistent with our communication during the shutdown, proposals will be due no earlier than March 29, 2019 except in the following cases:
  - TESS Guest Observer
  - Fermi Guest Observer
  - Lunar Surface Instrument & Technology Payloads
- Publication of ROSES 2019 delayed to ~March 2019
- Some solicitations originally planned for ROSES 2019 will be issued as amendments to ROSES 2018, including Astrophysics Data Analysis Program (ADAP)
- FINESST proposal due date has been moved to March 11, 2019, in order to make it more likely that funding for new awards will reach universities before the start of the academic year
- NESSF renewal proposals will remain due March 15, 2019

Research Program: Next Steps

- Reviews of proposals are now being rescheduled
- We need help in three areas, otherwise we cannot be successful
  - Reschedule reviews – volunteer and make yourself available
  - Accelerate reviews to catch up – support NASA Science Program Officials by accommodating compressed review schedules
  - Add surge capabilities in our teams – support NASA Program Officials when they request help

Thanks for your consideration and help!
Without you, we may have a gap in some programs

Impact to Astrophysics Announcements of Opportunity

- Principles are to go as fast as feasible, while maintaining fairness between all communities, and manageable work-flow for all stakeholders

Astrophysics Medium Explorers (MIDEX) 2016 and Missions of Opportunity Down-Selection

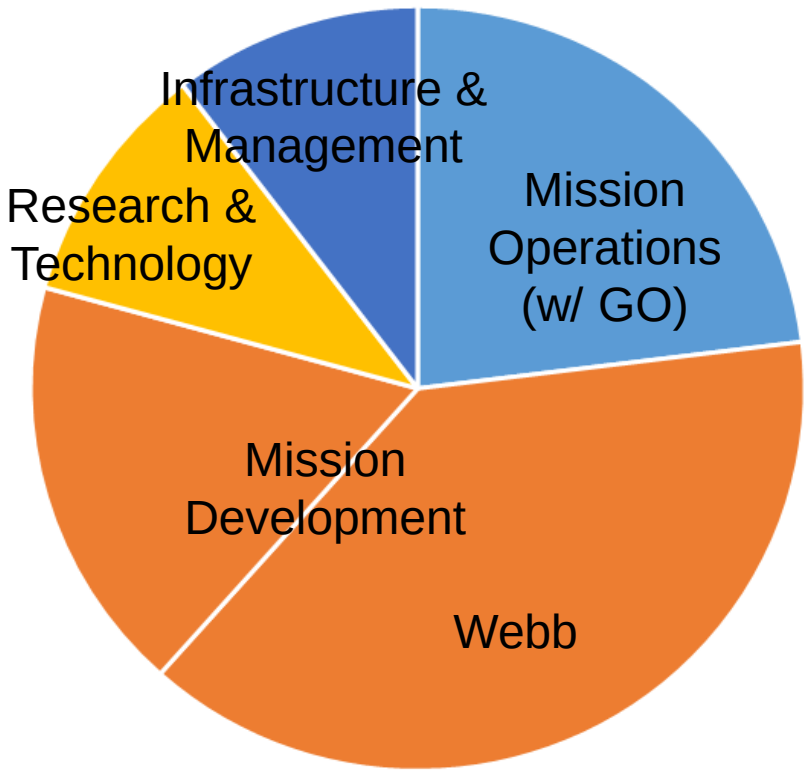
- All evaluations and reviews and site visits have been completed
- Step-2 down-selection announcements are targeted for February/March 2019

Astrophysics Small Explorers (SMEX) 2019 and Missions of Opportunity

- Draft AOs were released before shutdown
- Final AO releases are scheduled for March/April 2019
- Rescheduled Step-1 proposal due date of August 1, 2019

NASA Astrophysics Program and Budget Update

NASA's Astrophysics Program



FY 2018 Budget: $1.38B

Strategic Missions

- Flagships and probes led by NASA
- Contributions to partner-led missions

PI-led (competed) Missions

- Explorers missions (small and medium)
- Contributions to partner-led missions

Supporting Research and Technology

- Research and Analysis
- Technology development
- Suborbital payloads (balloons, sounding rockets)
- CubeSats and ISS-attached investigations

Infrastructure and Management

- Data archives
- Balloon Program
- Mission studies

Astrophysics Strategic Planning

To be updated in 2018
(per GPRAMA)

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

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

Milestones 2019 (Planned)

Jan/Feb 2019	MIDEX / MO downselect announ
Feb 2019	GUSTO passes Confirm e C
Mar/Apr 2019	SMEX / MO A
Apr 2019	SOF
May 201	
	pt Studies completed, submitted to
	bb Observatory integration begins
	Delivery of XRISM Resolve instrument flight hardware to JAXA
Oct 2019	WFIRST passes Preliminary Design Review
Dec 2019	Delivery of final Euclid flight hardware to ESA (NLT)

Full impact of 5 week shutdown has not been determined

Milestones 2019 (Planned)

Feb/Mar 2019	MIDEX / MO downselect announced
Mar 2019	GUSTO passes Confirmation Review, enters Phase C
Mar/Apr 2019	SMEX / MO AO released
May 2019	SOFIA reviews completed
Jun 2019	Senior Review completed
Sep 2019	Webb Observatory integration begins
Sep/Oct 2019	Large Mission Concept Studies completed, submitted to Decadal Survey
Oct 2019	Delivery of XRISM Resolve instrument flight hardware to JAXA
Oct/Nov 2019	WFIRST passes Preliminary Design Review
Dec 2019	Delivery of final Euclid flight hardware to ESA (NLT)

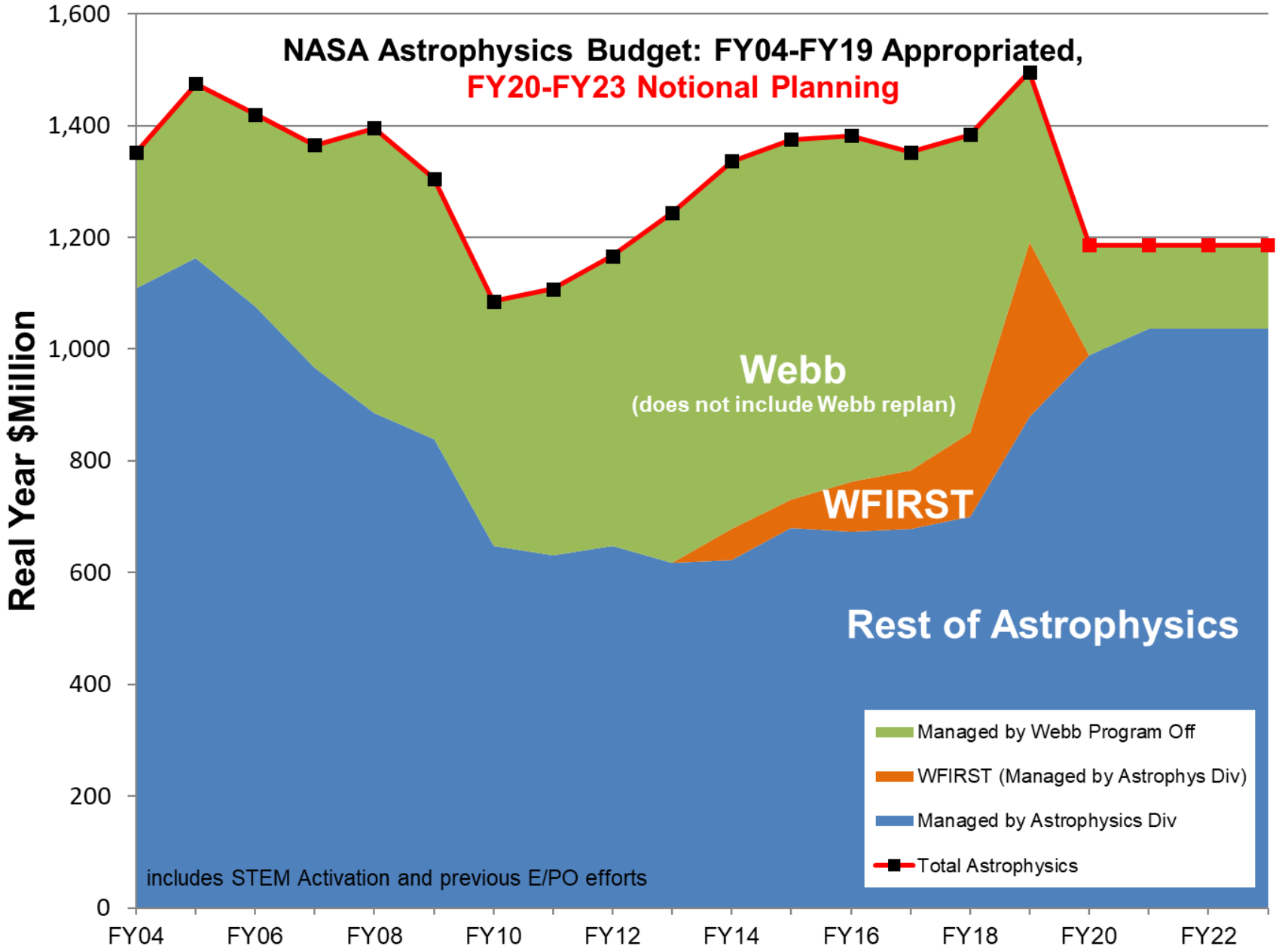
Astrophysics Budget Overview

The FY19 appropriation provides an increased level of funding for NASA Astrophysics

- Total appropriated funding for FY19 (Astrophysics including Webb) is ~$1.496B, a 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
  - NASA's plans for accommodating Webb's increased budget requirements will be submitted as part of the FY20 budget request
- WFIRST funded at $312M, proposed termination not supported by Congressional appropriation
  - Appropriated amount is $60M less than FY19 budget planned at KDP-B
- Hubble and SOFIA received appropriations above requested levels
- R&A and Science Activation specified at requested levels
- Spending on starshade technology and life detection technology is required
  - Spending on technosignatures is not required; nonetheless, Exoplanet Research Program will be clarified to make clear that technosignature research proposals are permitted

Astrophysics Budget – FY19 Appropriations

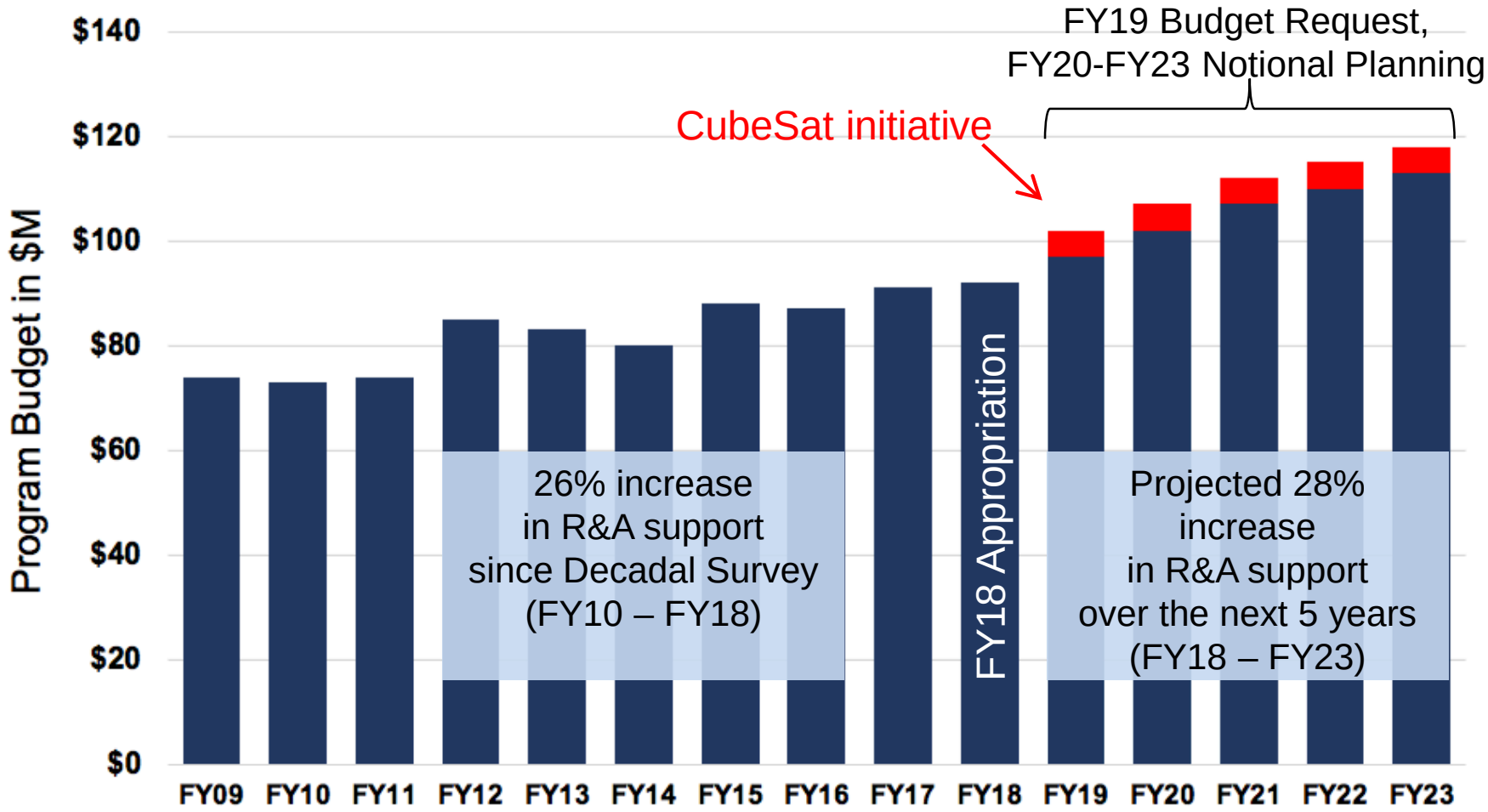
($M)	Administration Request	Final Appropriation	Comments
Astrophysics (w/ Webb)	1,185.4	1,496.2	
Webb	304.6	304.6	Reauthorize @ $8.8B
Hubble	78.3	98.3	
SOFIA	74.6	85.2	No Senior Review
WFIRST	0.0	312.2	$3.2B cost cap, launch in 2025
R&A	83.4	83.4	
Science Activation	44.6	45.0	
Technosignatures			Not directed, allowed in XRP
Search for Life Technology	>10.0	10.0	
Starshade Technology	7.3	10.0	
Rest of Astrophysics	592.6	557.5	Reduce $35.1M (-6%)


NASA Astrophysics Budget: FY04-FY19 Appropriated,
FY20-FY23 Notional Planning
Real Year $Million
1,600
1,400
1,200
1,000
800
600
400
200
0
FY04
FY06
FY08
FY10
FY12
FY14
FY16
FY18
FY20
FY22
Webb
(does not include Webb replan)
WFIRST
Rest of Astrophysics
includes STEM Activation and previous E/PO efforts
Managed by Webb Program Off
WFIRST (Managed by Astrophys Div)
Managed by Astrophysics Div
Total Astrophysics

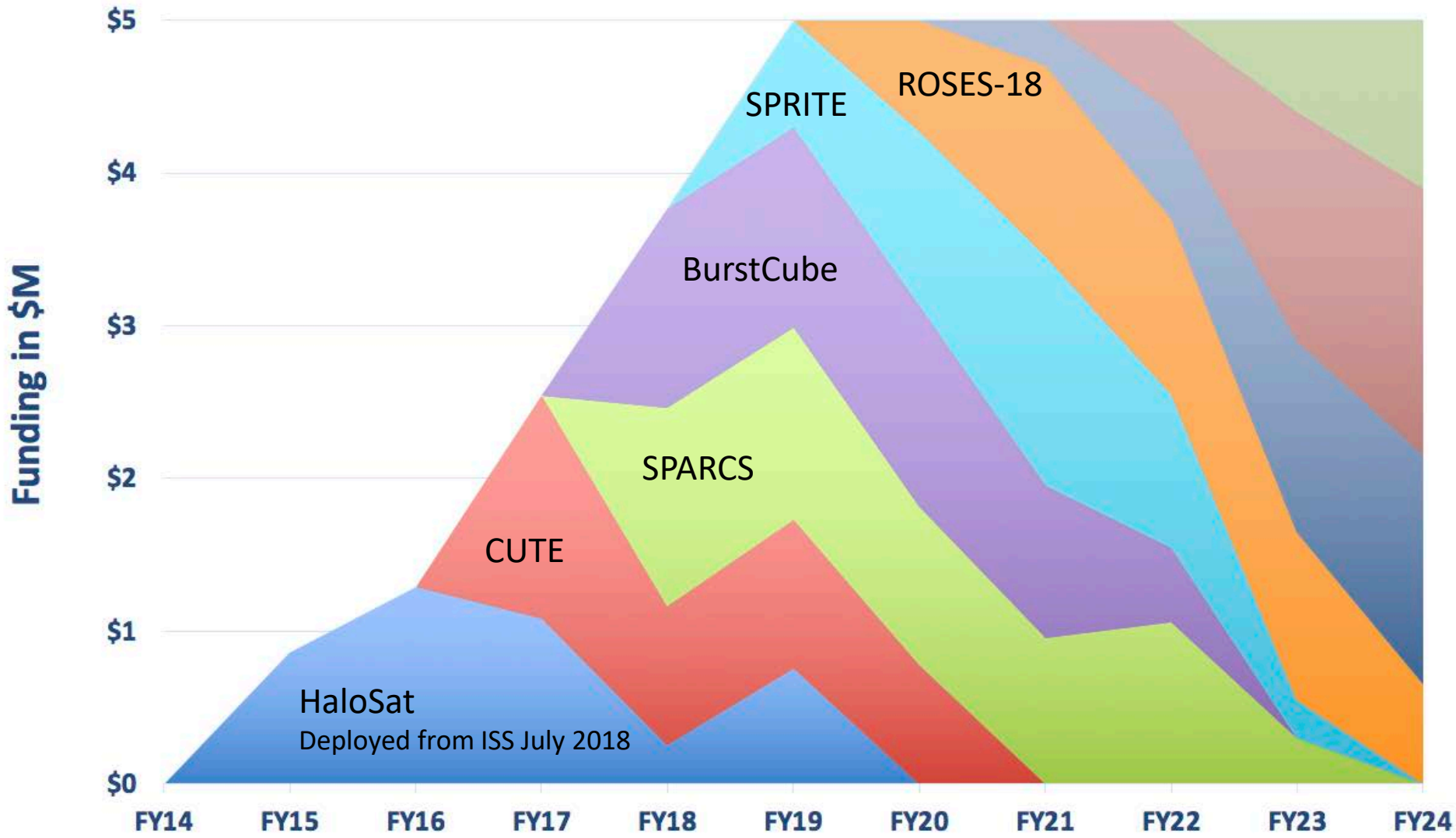
NASA Astrophysics Research and Analysis Update

Growth in R&A Funding ($M)

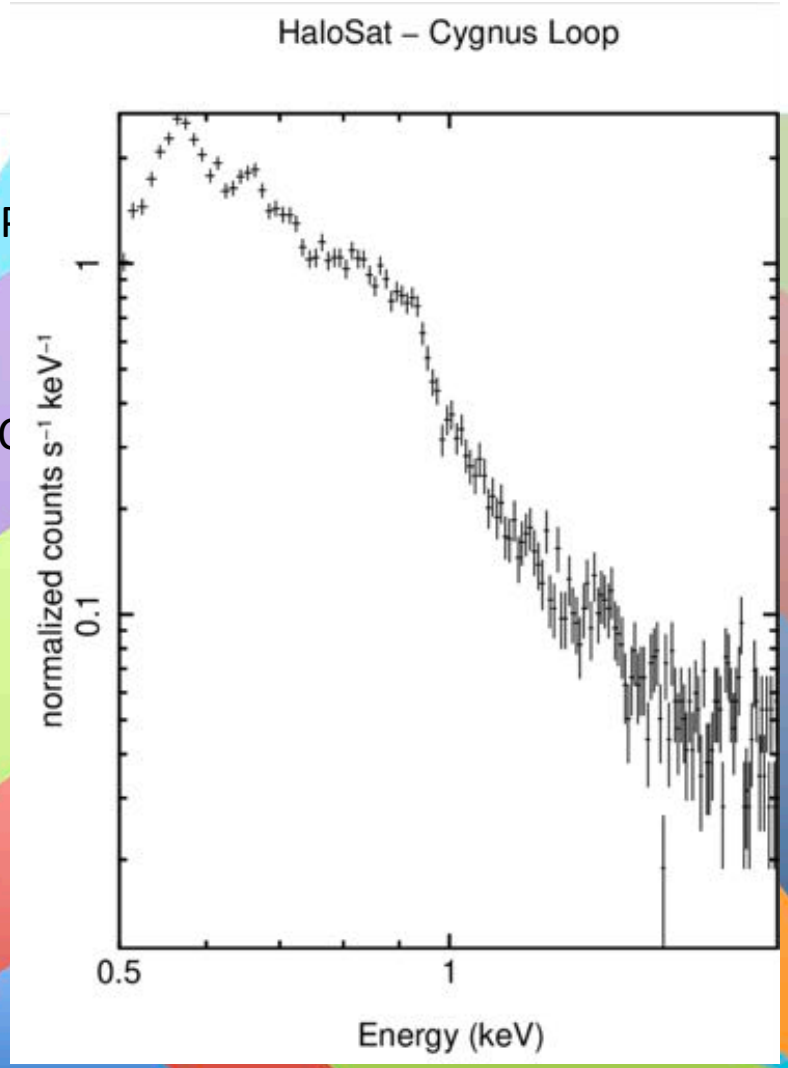
Program	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23
R&A	$74	$73	$74	$85	$83	$80	$88	$87	$91	$92	$97	$102	$107	$110	$113
CubeSat											$5	$5	$5	$5	$5
Total	$74	$73	$74	$85	$83	$80	$88	$87	$91	$92	$102	$107	$112	$115	$118



CubeSat Cadence



CubeSat Cadence



HaloSat
Deployed from ISS July 2018

$5
$0
FY14 FY15 FY16 FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24

Launch:

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

Astrophysics Science SmallSat Studies

NASA selected 9 Astrophysics Science SmallSat Studies in 2018. These studies will report out at a special session of the June 2019 AAS meeting in St. Louis

A second SmallSat Studies solicitation is planned for ROSES-2019

NASA is considering holding a workshop later this year focused on technologies and commercial partners in advance of this solicitation

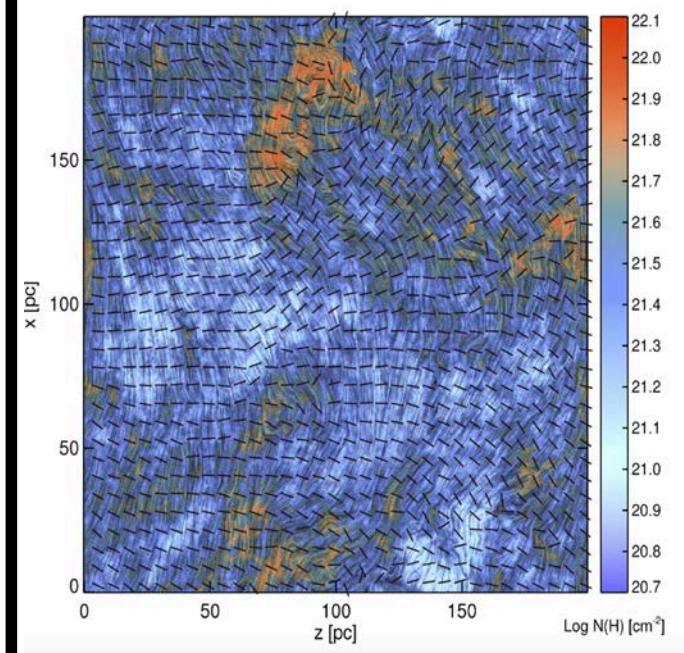
The 2017 Astrophysics SmallSats RFI for science and technology ideas highlighted enabling and enhancing technologies including

- Power Systems
- Cryo-coolers
- Formation flying
- Accurate pointing / communications
- Advanced detectors and mirrors
- Detectors

Theoretical and Computational Astrophysics Networks (TCAN)

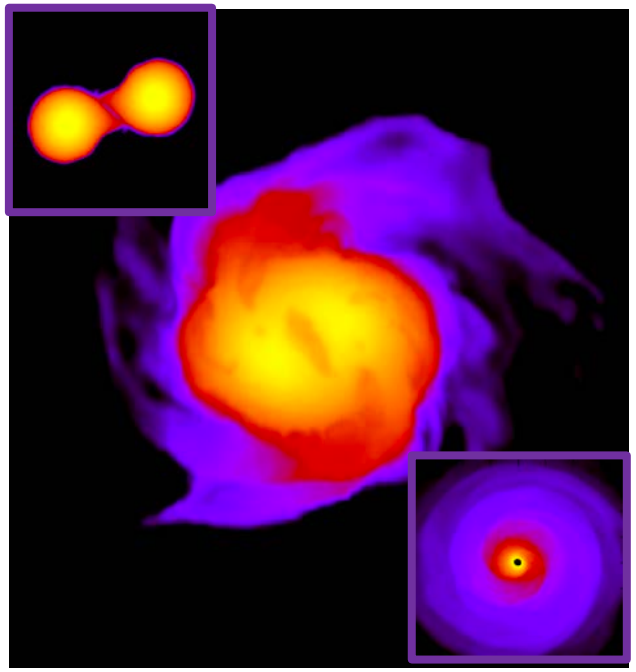
- Supports collaborative cross-institutional networks in theory and computation.
- Previous call for proposals was in 2012 with NSF. NASA issued a second call for proposals in 2017. $1.5M allocation, selections made on June 19, 2018
- 32 proposals received, 3 proposals selected, selection rate 9%.

Modeling Polarized Galactic Background for Cosmic Microwave Background Missions



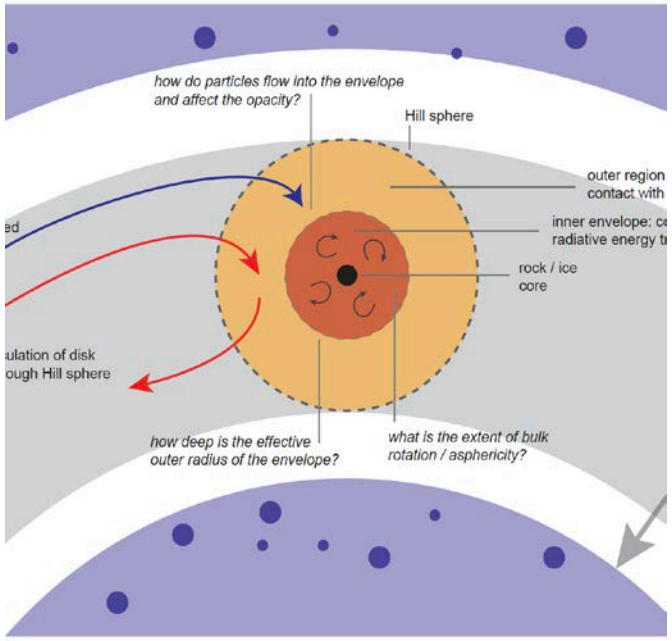
J. Borrill (UCB)
Princeton, UCSD, Wisconsin

Advancing Computational Methods of the Dynamics of Ejection, Accretion, Winds & Jets in Neutron Star Mergers



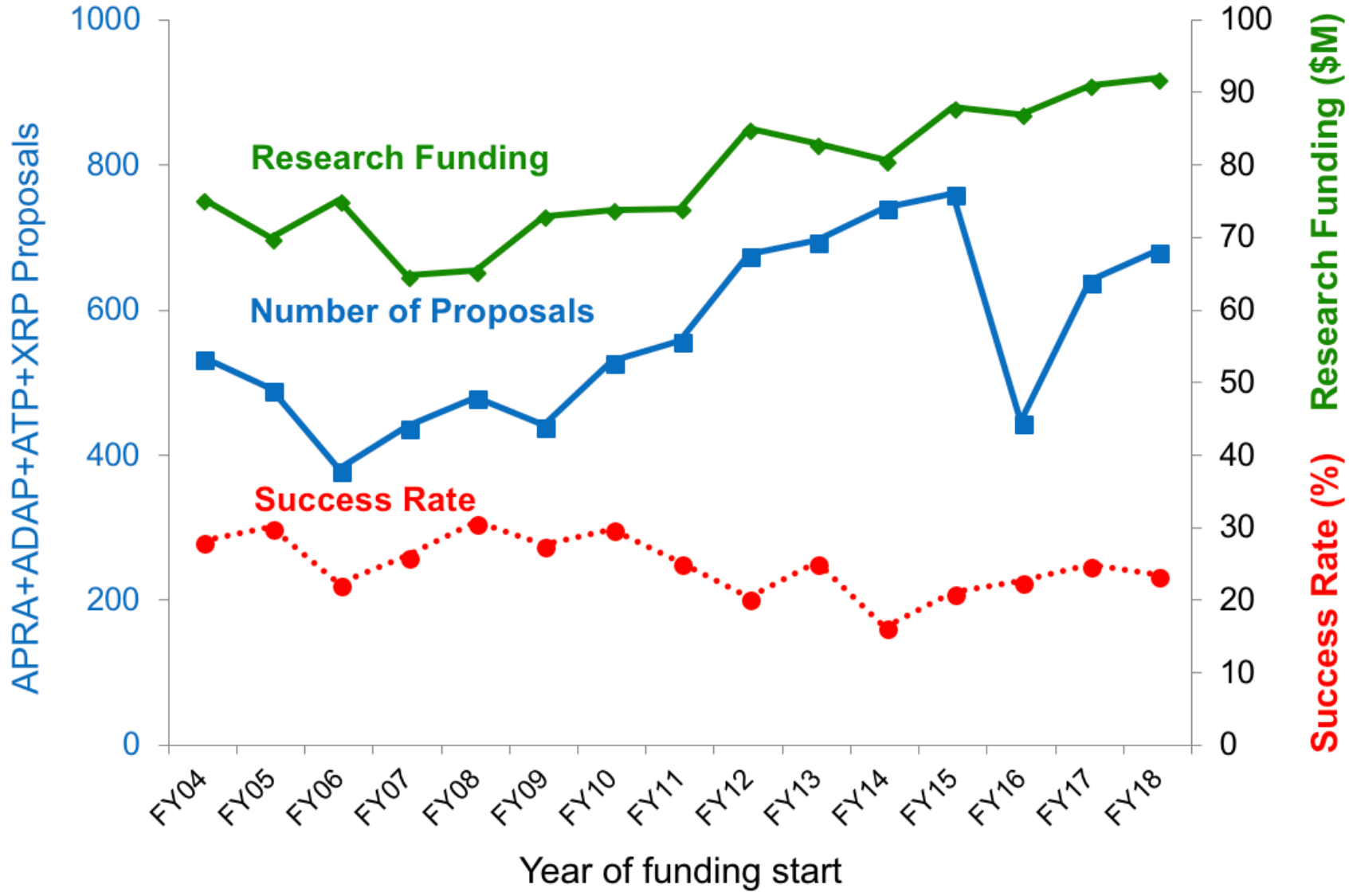
P. Armitage (Colorado)
Arizona, UNLV

Origin of the Giant Planet Dichotomy: Multi-Scale Modeling of Planetary Envelope Accretion



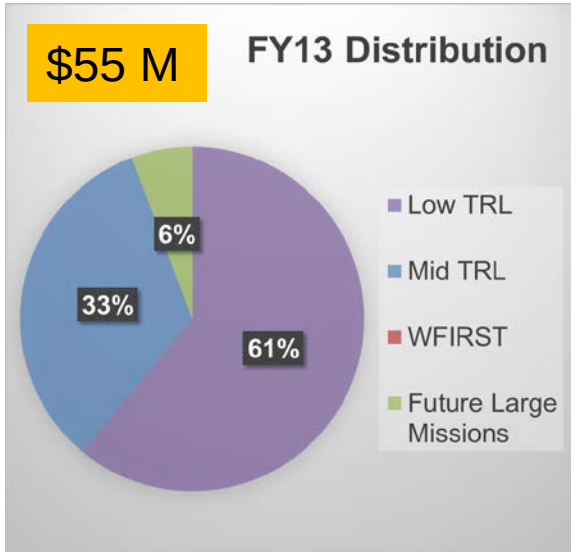
M. Campanelli (RIT)
GSFC, JHU, WVU

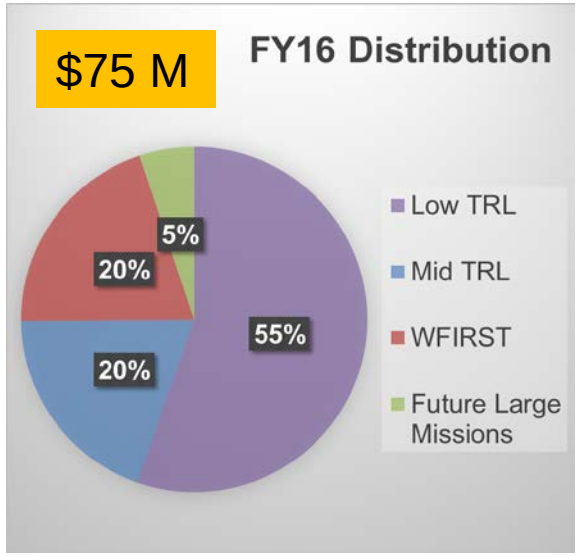
Proposal Pressure

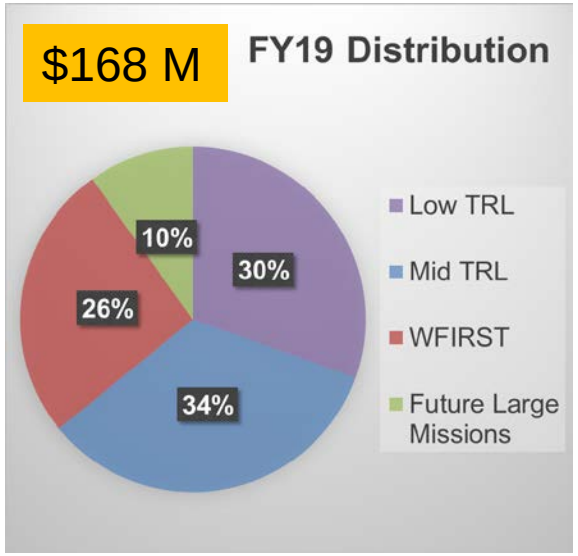


Astrophysics Technology Investment FY13-FY19

- 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
  - Mid TRL: SAT, Athena, LISA, X-ray Mirrors, Detectors
  - WFIRST: Detectors, Coronagraph
  - Future Missions: Ultrastable Telescope, Starshade, Next Gen Coronagraph







Preparing for the 2020 Decadal Survey Technology Development

HabEx

- 12 of 13 technologies being addressed

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

- 13 of 14 technologies being addressed
- 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

- 5 of 5 gaps being addressed
- 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

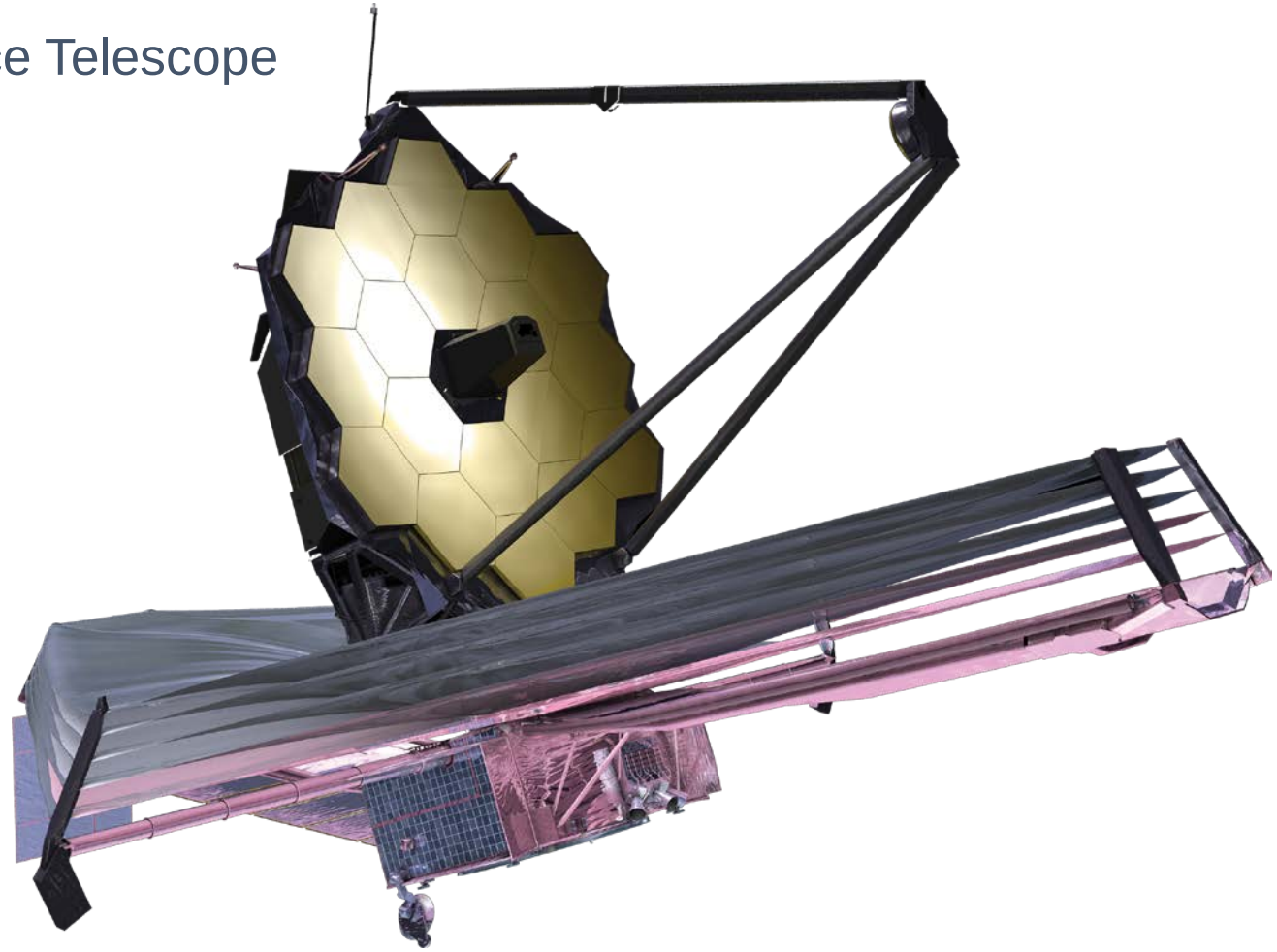
- 3 of 6 technologies being addressed
- Far IR Detectors, Cryogenic Readouts for Far IR Detectors, Warm readout electronics for large format Far IR detectors, Mid IR detectors, Sub-Kelvin Coolers, 4.5 K cryocoolers

– Purple: Technologies being advanced through SAT or directed development,
– **Bold**: Technologies being advanced by LISA, WFIRST, or ATHENA
– Additional gaps being addressed through APRA but not tallied here

NASA Astrophysics Developing Missions Update

Webb

The James Webb Space Telescope



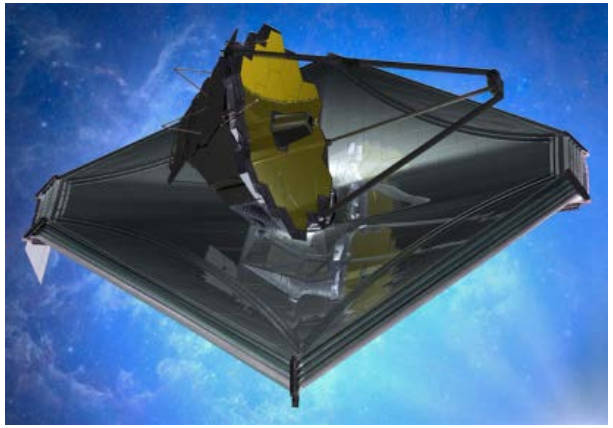
James Webb Space Telescope (JWST)

2018 Accomplishments

- Repaired Spacecraft Element (SCE) sunshield membrane cover assemblies after finding loose fasteners during acoustic testing
- Mission rebaselined for March 2021 launch
- Re-installed repaired sunshield membrane cover assemblies
- Completed SCE acoustic testing
- Conducted numerous mission rehearsals at the mission operation center (STScI)

2019 Plans

- Completed SCE vibration testing (Feb 2019)
- Complete SCE thermal vacuum testing
- Conduct post test deployment of sunshield
- Integrate the Science Payload to the SCE, forming the Observatory
- Begin testing the Observatory
- Additional mission rehearsals at STScI



Large Infrared Space Observatory
Top priority of 2000 Decadal Survey
Science themes: First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life
Mission: 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield
Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph
Operations: 2021 launch for a 5-year prime mission
Partners: ESA, CSA

JWST Hardware Progress

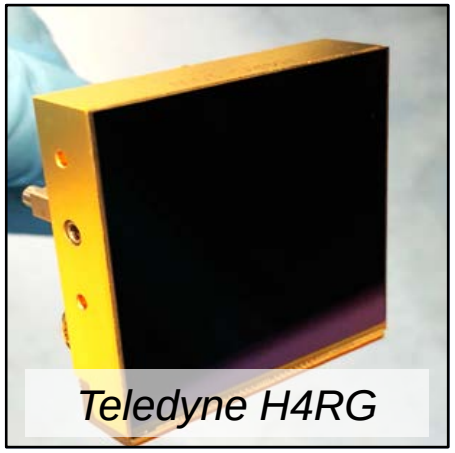
The two components of Webb, the science payload (left) and SCE (right) in the cleanroom at Northrop Grumman. The SCE is in its launch configuration with a telescope simulator (silver structure). It is being lifted for transport to environmental testing.

Wide-Field Infrared Survey Telescope

WFIRST Status

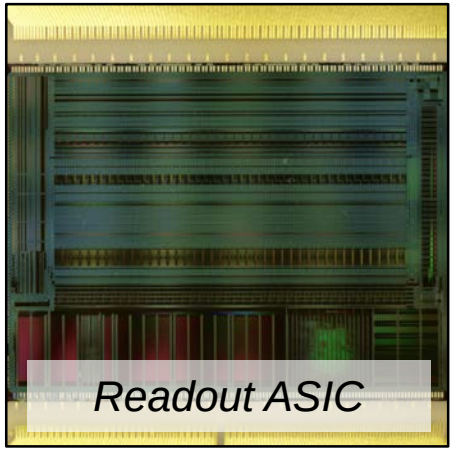
- **NASA continuing work on WFIRST as planned**
  - Work continues under recently approved FY19 appropriation; appropriation enacted in February 2019 includes $312M for WFIRST
  - WFIRST remains on the plan approved at the beginning of Phase B: SMD cost is $3.2B, launch is in late 2025
  - Formal cost 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 Preliminary Design Review and Confirmation

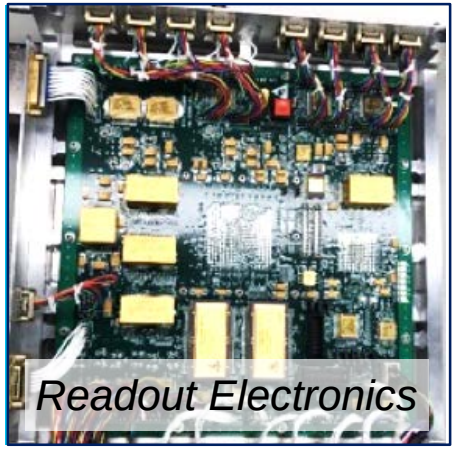
WFIRST Progress

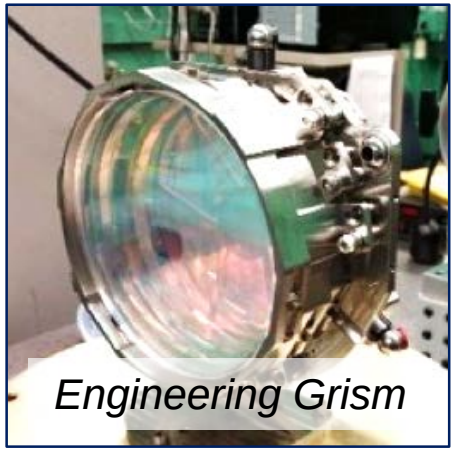

Teledyne H4RG

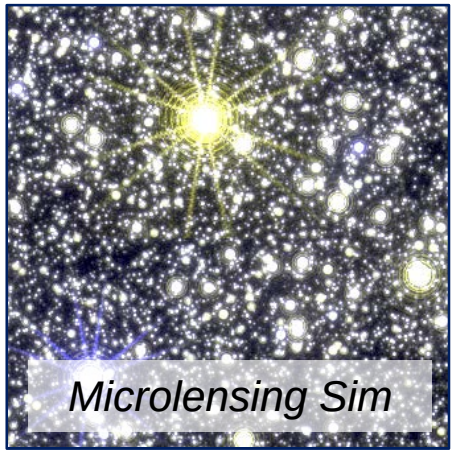

Detector First Light

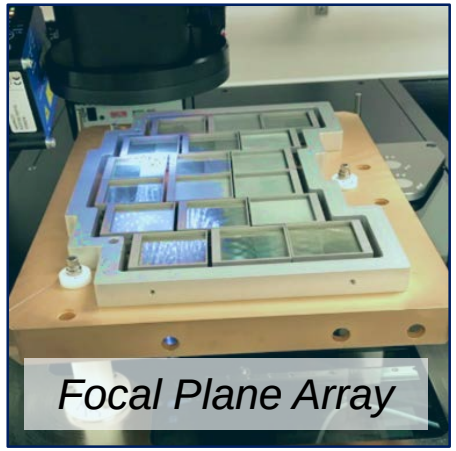
Wide Field Instrument


Readout ASIC

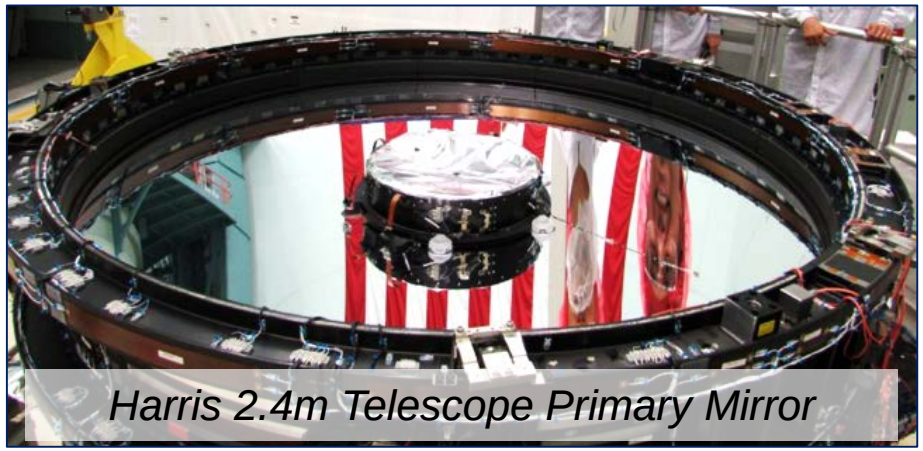

Readout Electronics


Engineering Grism


Microlensing Sim


Focal Plane Array

WFIRST Progress

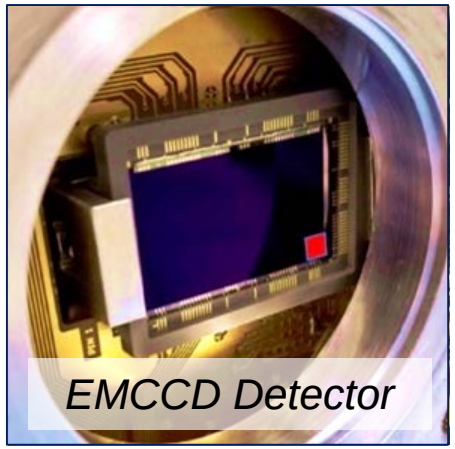

Harris 2.4m Telescope Primary Mirror

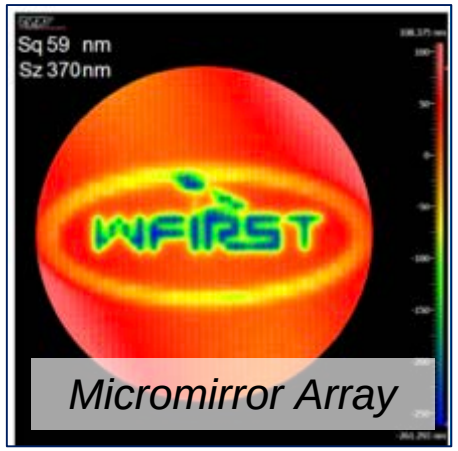
Telescope

Coronagraph Technology Demonstration Instrument

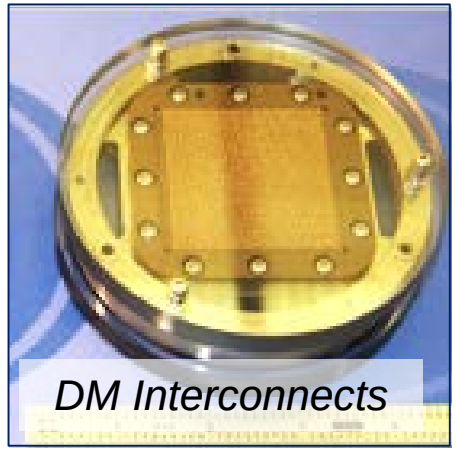

Mirror Figuring


Telescope Contract

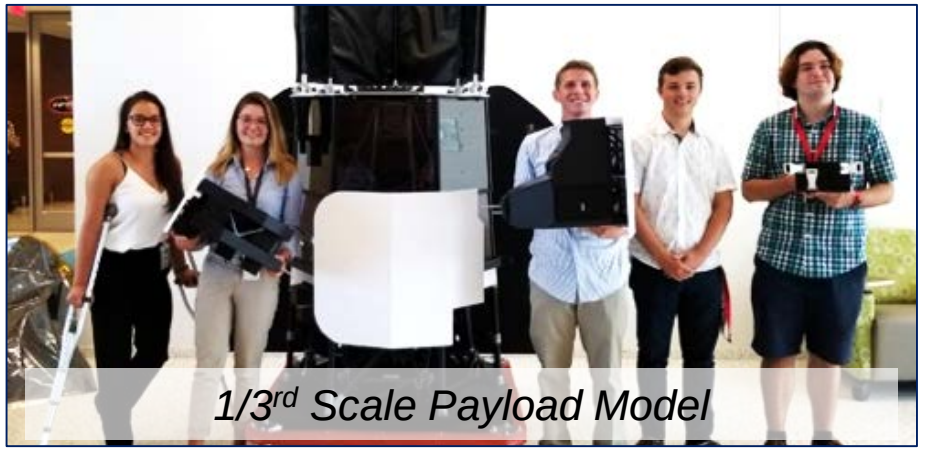

EMCCD Detector



Micromirror Array


DM Interconnects

WFIRST Progress

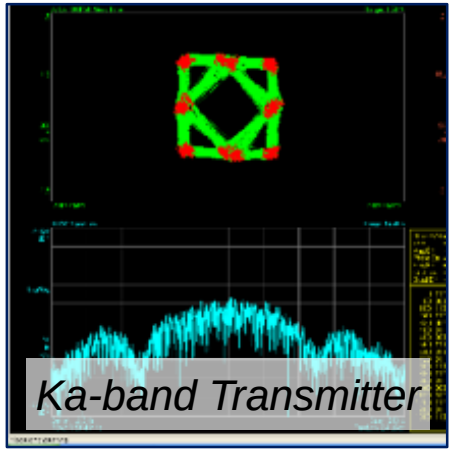

1/3rd Scale Payload Model

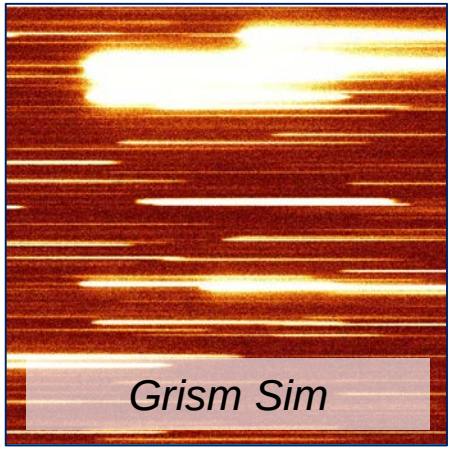
Spacecraft/Observatory

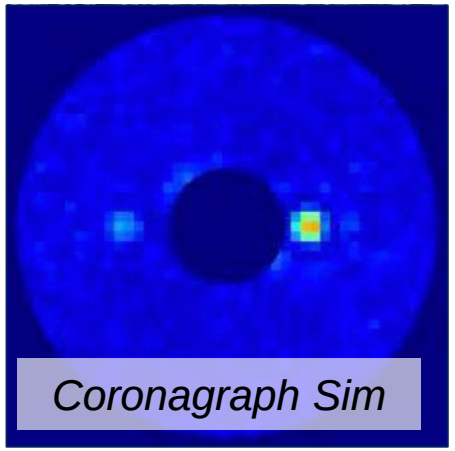
Science Preparation


Structural Tubing

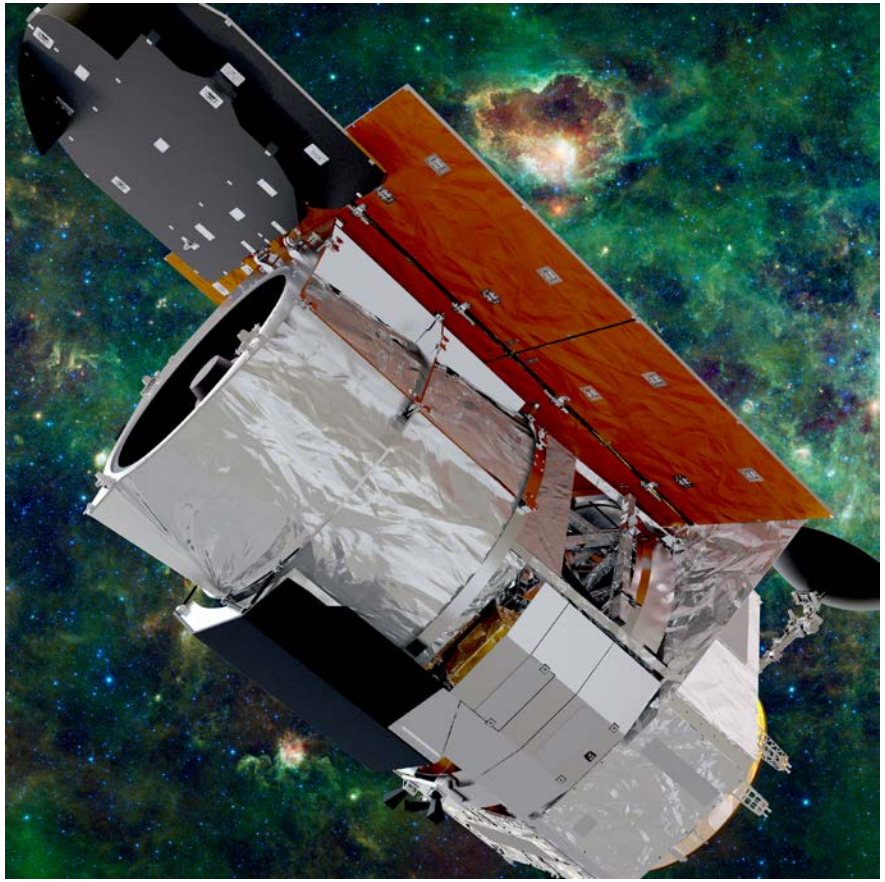

Flight Recorder


Ka-band Transmitter


Grism Sim


Coronagraph Sim

WFIRST Future



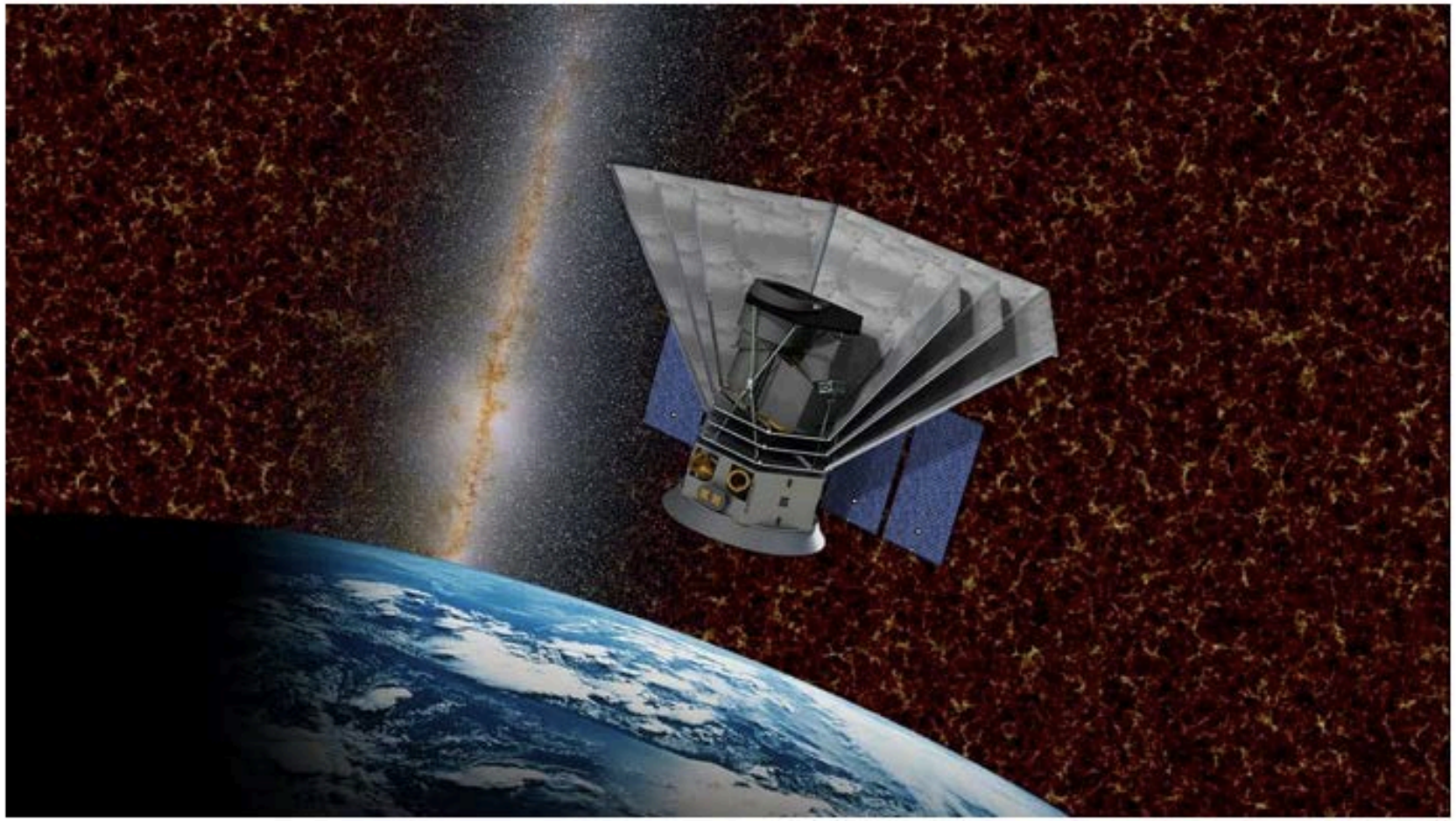
- WFIRST included in final FY19 appropriation
- Core survey science teams anticipated to be selected in 2021 by open competition
- All mission elements making excellent technical progress; expecting to go through Preliminary Design Reviews mid-2019
- Mission being prepared for review to enter Implementation phase in ~1yr

Impact of 5 week shutdown has not been determined

MIDEX Selection Announcement

February 13, 2019
RELEASE 19-005

NASA Selects New Mission to Explore Origins of Universe



NASA's Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) mission is targeted to launch in 2023. SPHEREx will help astronomers understand both how our universe evolved and how common are the ingredients for life in our galaxy's planetary systems.
Credits: Caltech

2019 Explorers AOs: SMEX and Missions of Opportunity

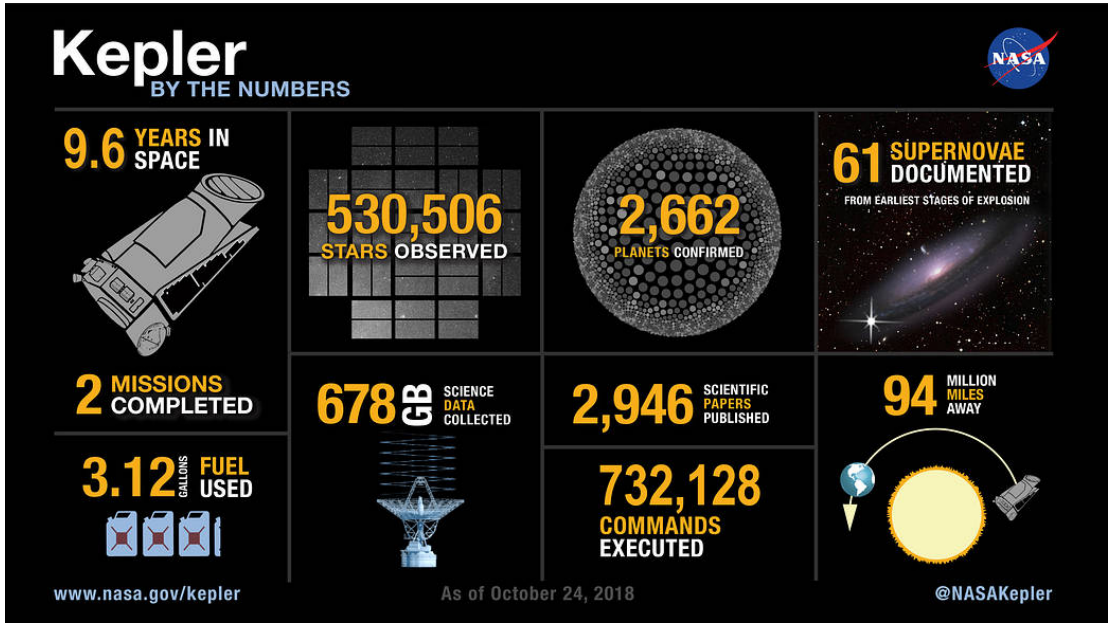
- Next Astrophysics Explorers AO will be issued in March/April 2019 with proposals due August 1, 2019
- Small Explorers (SMEX) missions
  - PI-managed Cost Cap: $145M (FY20$) excluding launch
  - NASA-provided launch options include a dedicated small launcher, or rideshare on ESPA or ESPA Grande to low Earth orbit, geostationary transfer orbit, and cislunar space.
  - PI-provided alternative access to space will not be permitted
- Missions of Opportunity
  - PI-managed Cost Cap: $75M (FY20$) for: Partner MOs, Small Complete Missions
  - PI-managed Cost Cap: $35M (FY20$) for: SmallSat MOs, CubeSat MOs, no balloons
- Draft AOs posted November 6, 2018; FAQs posted December 2018 and more to come
- https://explorers.larc.nasa.gov/2019APSMEX/

NASA Astrophysics Operating Missions Update

Kepler End of Mission – Oct 30, 2018

Top Science Discoveries

- **Planets outnumber stars** - Kepler has proven there are more planets than stars in our galaxy — and knowing that revolutionizes our understanding of our place in the cosmos.
- **Small planets are common** - Kepler has shown us our galaxy is teeming with terrestrial-size worlds, and many of them may be similar to Earth in size and distance from their parent stars. The most recent analysis of Kepler's discoveries concludes that 20 to 50 percent of the stars in the sky are likely to have small, possibly rocky planets that are in the habitable zones of their stars where liquid water could pool on the surface. We still have much to learn about whether any of them could host life.
- **Planets are diverse** - Kepler has discovered a diversity of planet types, opening our eyes to new possibilities. The most common size of planet Kepler found doesn't exist in our solar system — a world between the size of Earth and Neptune — and we have much to learn about these planets.
- **Planetary systems are diverse too** - While our own inner solar system has four planets, Kepler found systems with considerably more planets — up to eight — orbiting close to their parent stars. The existence of these compact systems raises questions about how planetary systems form: Are these planets "born" close to their parent star, or do they form farther out and migrate in?
- **New insights revealed about stars** - Kepler observed more than a half million stars over the course of its nine years in operation. In particular, Kepler has captured the beginning stages of exploding stars, called supernovae, with unprecedented precision, giving us new knowledge into how these stellar explosions begin.



SOFIA

Stratospheric Observatory for Infrared Astronomy

- SOFIA's 5-year prime mission will be completed at the end of FY19
- At the end of a prime mission, NASA usually assesses the science performance, management of a program and proposed future science to decide on an extension of the program through a Senior Review Process, as required by the NASA Authorization Act of 2005
- The Explanatory Statement accompanying the FY2018 Consolidated Appropriations Act, however, forbade NASA from placing SOFIA in the 2019 Senior Review
- Given that the program has finished 5 years of operations, the time is appropriate to review 2 aspects of the SOFIA Project:
  - SOFIA's maintenance and operations paradigm (late 2018)
  - SOFIA's science progress and science prospects (early 2019)
- The reviews will not consider closeout or cancellation of SOFIA

SOFIA was grounded during the shutdown

SOFIA Operations & Maintenance Efficiency Review

The objective of the SOMER is to establish a baseline for comparison between the current SOFIA operations and maintenance model with alternative SOFIA aircraft operations and maintenance models with the goal of achieving a substantially greater number of flights and/or reducing overall program cost.

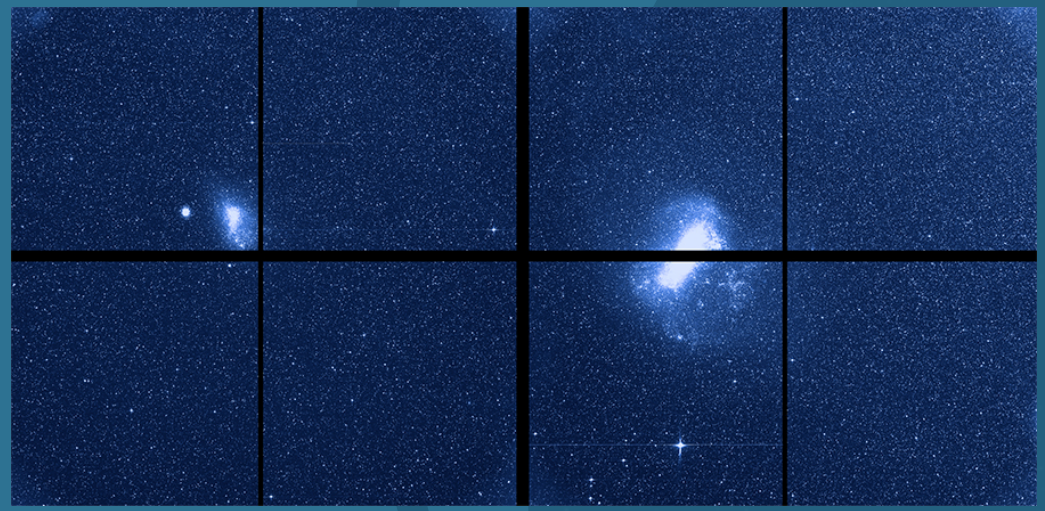
SOFIA Five Year Flagship Mission Review

- The objectives of the S5YFMR is to:
  - Evaluate SOFIA's continuing relevance to the Agency's Strategic Plan
  - Assess SOFIA's performance with respect to expectations established in the SOFIA Project Plan
  - Assess the scientific merits of expected returns from SOFIA during FY20-22 and FY23-25
  - Assess the cost efficiency, particularly the science value per dollar, data availability and usability, value of data for archival / legacy purpose, and vitality of SOFIA's operations center
- The S5YFMR panel consists of senior members from the astrophysics community, as well as mission operations experts

TESS

TRANSITING EXOPLANET SURVEY SATELLITE

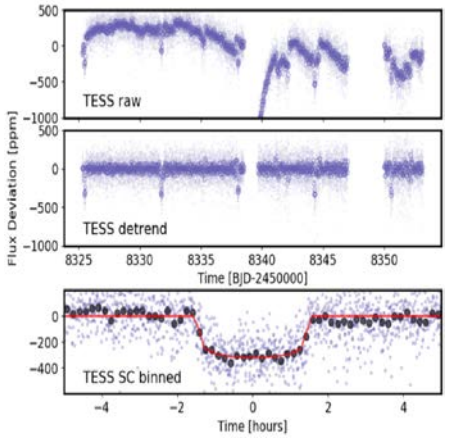
SCIENCE HIGHLIGHT

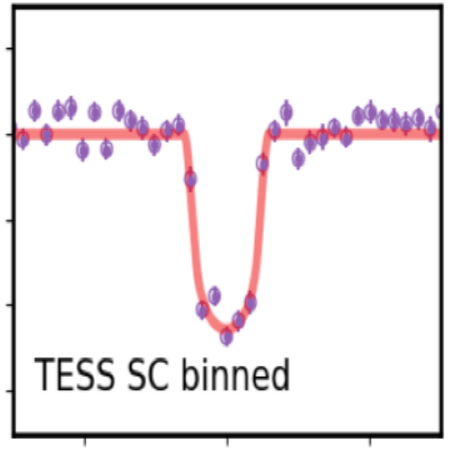


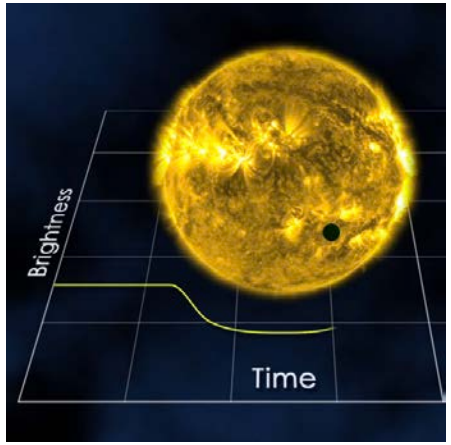
TESS's wide field-of-view cameras are surveying our galactic neighborhood for transiting exoplanets.

TESS survey is ongoing

π Men c: 2R_E planet, V=5.7 host star (Huang et al. 2018 arxiv.org/abs/1809.05967)







LHS 3844 b: 1.3R_E planet, 15 pc away (Vanderspek et al. 2018 arxiv.org/abs/1809.07242)

- TESS sky survey is 25% complete, with data having been downloaded for 7 of the 26 sectors planned for the two year primary mission.
- TESS data from Sectors 1-5 is now public at MAST, including more than 300 TESS Objects of Interest (TOIs) which exhibit transit-like behavior.

  http://archive.stsci.edu/tess/

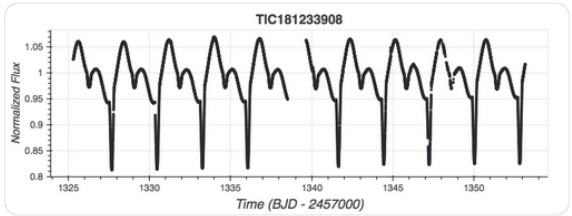
  https://archive.stsci.edu/prepds/tess-data-alerts/
- First 5 TESS planets were announced in January at AAS. Since then, at least 4 additional multi-planet systems have been established from the first three survey sectors.
- Ground-based radial velocity measurements to establish planet masses are in progress for more than 20 additional TESS small planet candidates.
- 38 selected GI investigations are underway

  https://heasarc.gsfc.nasa.gov/docs/tess

TESS Roulette

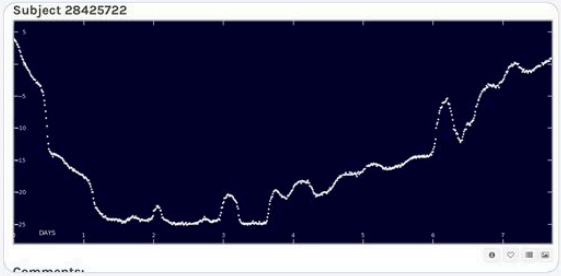
Shout out to Megan Bedell, Ben Montet, and Adina Feinstein!

David Rodriguez @Strakul · Dec 10
I won big with lucky TIC 181233908 at the TESS.casino!! #TESSroulette
Though, seriously: what type of system has this kind of light curve? Some kind of trinary system eclipsing?



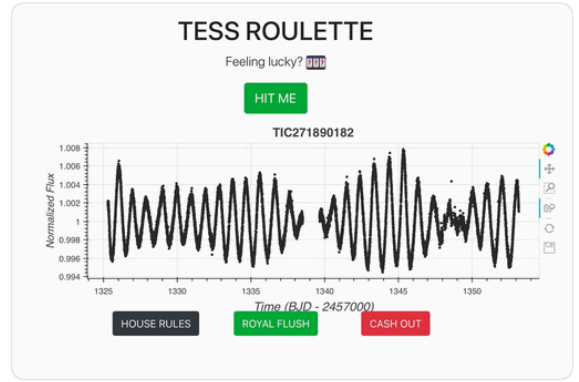
1 7

Eric Agol @AgolEric · Dec 9
Any ideas what is happening with this star? #TESSroulette #tessyay @mattkenworthy @EricMamajek @tsboyajian @Astro_Wright @twitspek @aussiastronomer



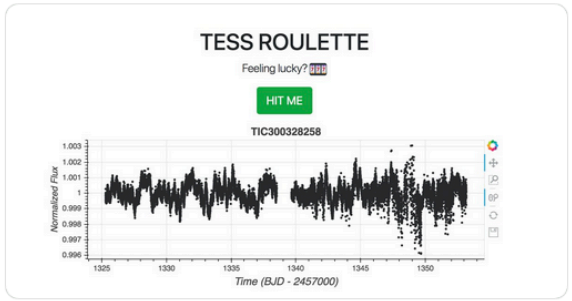
2 3 27

JJ Hermes @jotajotahermes · Dec 7
Woot, check out this chemically peculiar star proposed by Ernst Paunzen in the new @NASA_TESS data! This is like the real-life version of the AM album cover from the @ArcticMonkeys! Awesome tool by @meg_bedell, @benmontet, and @afeinstein20: tess.casino #TESSroulette



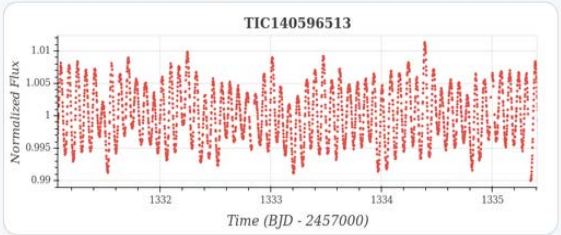
1 1 22

NASA_TESS Retweeted
Megan Bedell @meg_bedell · Dec 7
want to play with some @NASA_TESS lightcurves but not sure where to start? take a spin at the tess.casino! made with love by me, @benmontet, and @afeinstein20 #TESSyay #TESSroulette



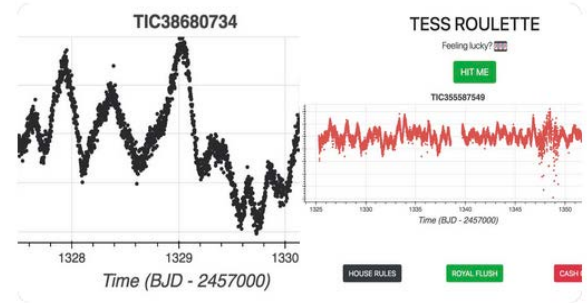
12 46 132

Kevin Hardegree-Ullman @kevinkhu · Dec 8
Stars like TIC 140596513 at the TESS.casino make me want to add periodogram functionality... #TESSroulette



1 1 2

Vivien Parmentier @V_Parmentier · Dec 7
This Tess casino is a lot of fun ! tess.casino/index.html #TESSroulette

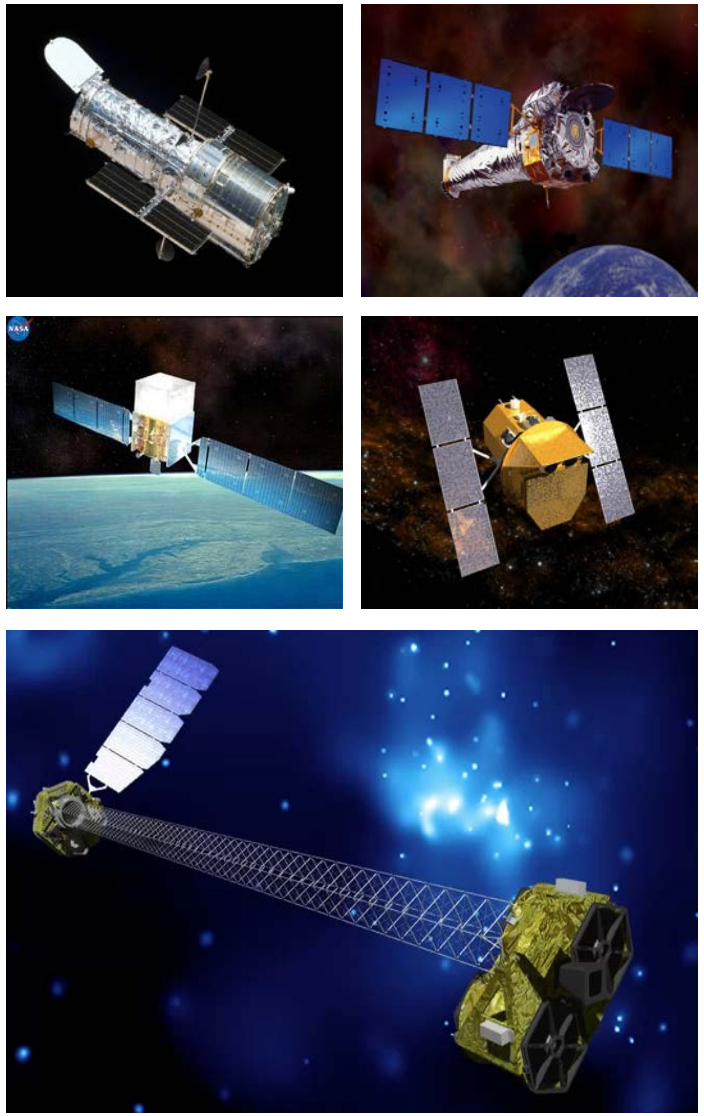


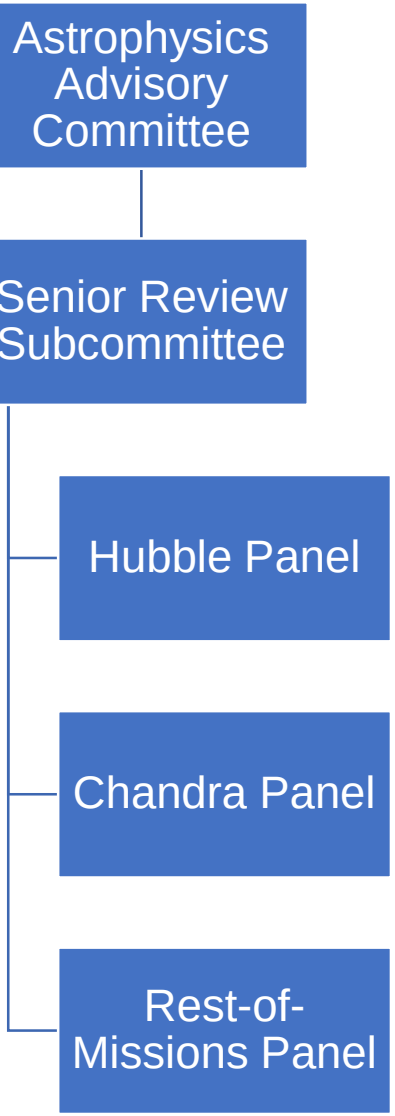
2

http://tess.casino/

Senior Review Paradigm

- NASA conducts regular reviews of its operating science missions in order to assess their continued science productivity and whether their operations should be continued through approval of a mission extension
  - The NASA Authorization Act of 2005 (P.L. 109-155) states that “The Administrator shall carry out biennial reviews within each of the Science divisions to assess the cost and benefits of extending the date of the termination of data collection for those missions that have exceeded their planned mission life time.” The NASA Transition Authorization Act of 2017 (P.L. 115-10) modified the cadence to be triennial reviews
- These reviews of operating missions are NASA’s highest form of peer review, as the subject is not a single science investigation, or even a single space mission, but rather a portfolio of operating missions
  - The reviews of operating missions are referred to as senior reviews, in recognition of the high level of the peer review

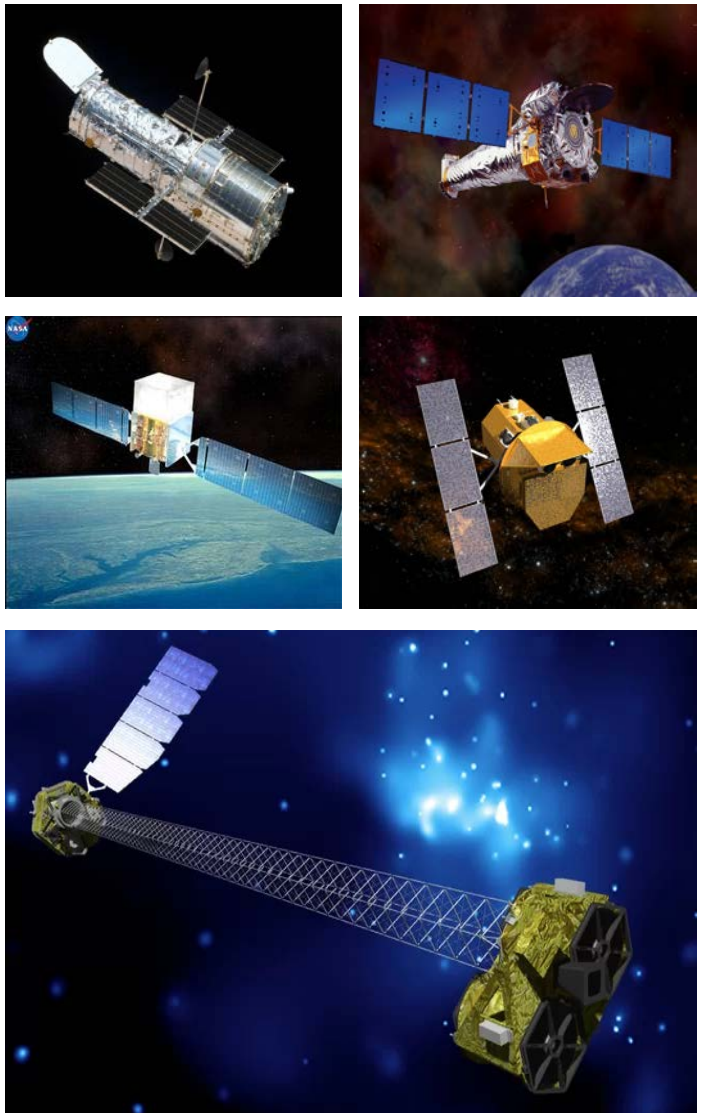




Senior Review 2019

- 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



Senior Review 2019 Schedule

2018:

- ✓ APAC approves Terms of Reference for the Senior Review Subcommittee
- ✓ Establish Senior Review Subcommittee
- ✓ Draft call for proposals issued
- ✓ Final call for proposals issued

2019:

- Appointment of subcommittee members compliant with FACA
- Senior Review proposals due Mar 15
- Rest-of-missions, Chandra, & Hubble panels meet Apr 29 – May 24
- Reports from Rest-of-missions, Chandra, and Hubble panels due to Senior Review Subcommittee
- Senior Review Subcommittee meets
- Senior Review Subcommittee reports to APAC
- APAC delivers formal recommendations to NASA
- NASA responds to Senior Review and provides direction to projects

NASA Astrophysics Preparation for 2020 Decadal Survey

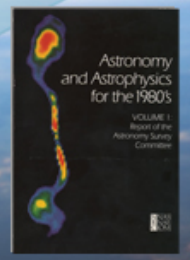
Decadal Survey Planning

- 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

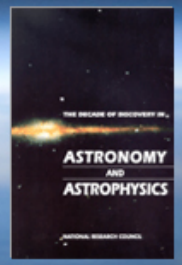
Astrophysics

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

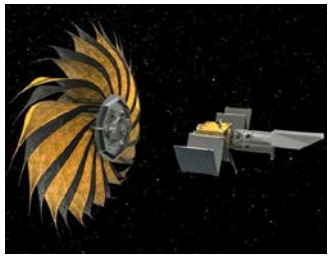
2001
Decadal Survey
JWST

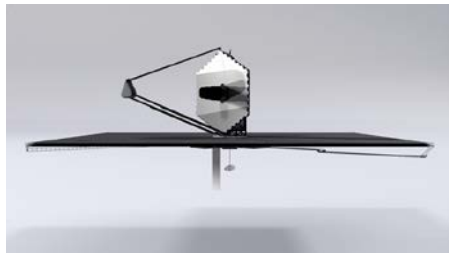
2010
Decadal Survey
WFIRST

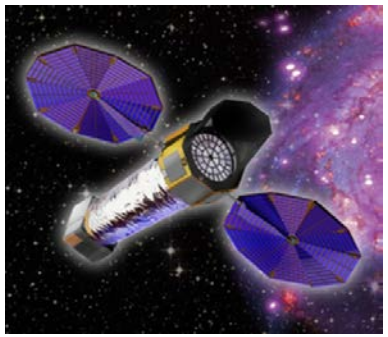
Decadal Survey Planning

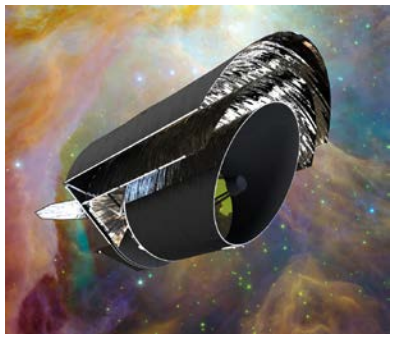
- NASA has initiated studies for large (Flagship) and medium (Probe) size mission concepts to inform the 2020 Decadal Survey Committee in an organized and coherent way
- Primary purpose is to provide the Decadal Survey Committee with several well-defined mission concepts to inform their deliberations

Large Mission Concepts









- Habitable Exoplanet Imaging Mission (HabEx)
  - STDT Co-Chairs: Scott Gaudi (OSU) & Sara Seager (MIT)
  - https://www.jpl.nasa.gov/habex/
- Large UV/Optical/IR Surveyor (LUVOIR)
  - STDT Co-Chairs: Debra Fischer (Yale) & Brad Peterson (OSU)
  - https://asd.gsfc.nasa.gov/luvoir/
- Lynx X-ray Observatory
  - STDT Co-Chairs: Feryal Ozel (ASU) & Alexey Vikhlinin (SAO)
  - https://wwwastro.msfc.nasa.gov/lynx/
- Origins Space Telescope (OST)
  - STDT Co-Chairs: Asantha Cooray (UC Irvine) & Margaret Meixner (STScI)
  - https://asd.gsfc.nasa.gov/firs/
  - https://origins.ipac.caltech.edu/

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

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

Decadal Survey Preparation

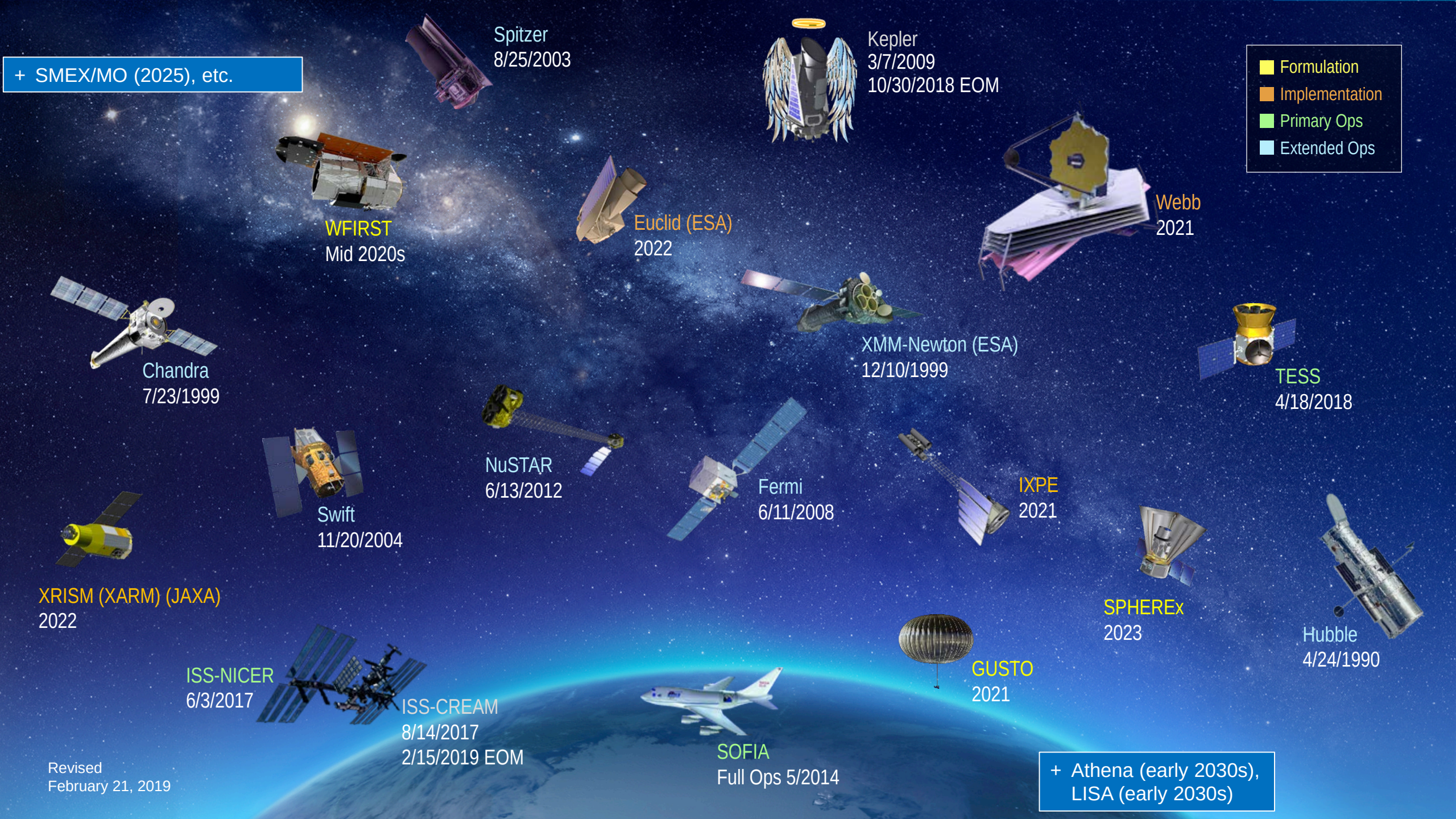
NASA is:

- ✓ Sponsoring 4 community-based Science and Technology Definition Teams (STDTs) to partner with a NASA Center-based engineering team and study large (strategic) mission concept studies selected from the NASA Astrophysics 30-year Visionary Roadmap, a community-based report, and the 2010 Decadal Survey
- ✓ Supporting 10 PI-led Study Teams for Probe-size mission concept studies, selected competitively
- ✓ Supporting several other planning activities / studies / white papers including:
  - Balloon Program Roadmap
  - Evolution of NASA Data Centers
  - In-Space Servicing/In-Space Assembly
- ✓ Investing in next-generation technologies, including ultrastable telescope technology, starshades, coronagraphs, x-ray mirrors, detectors, etc.

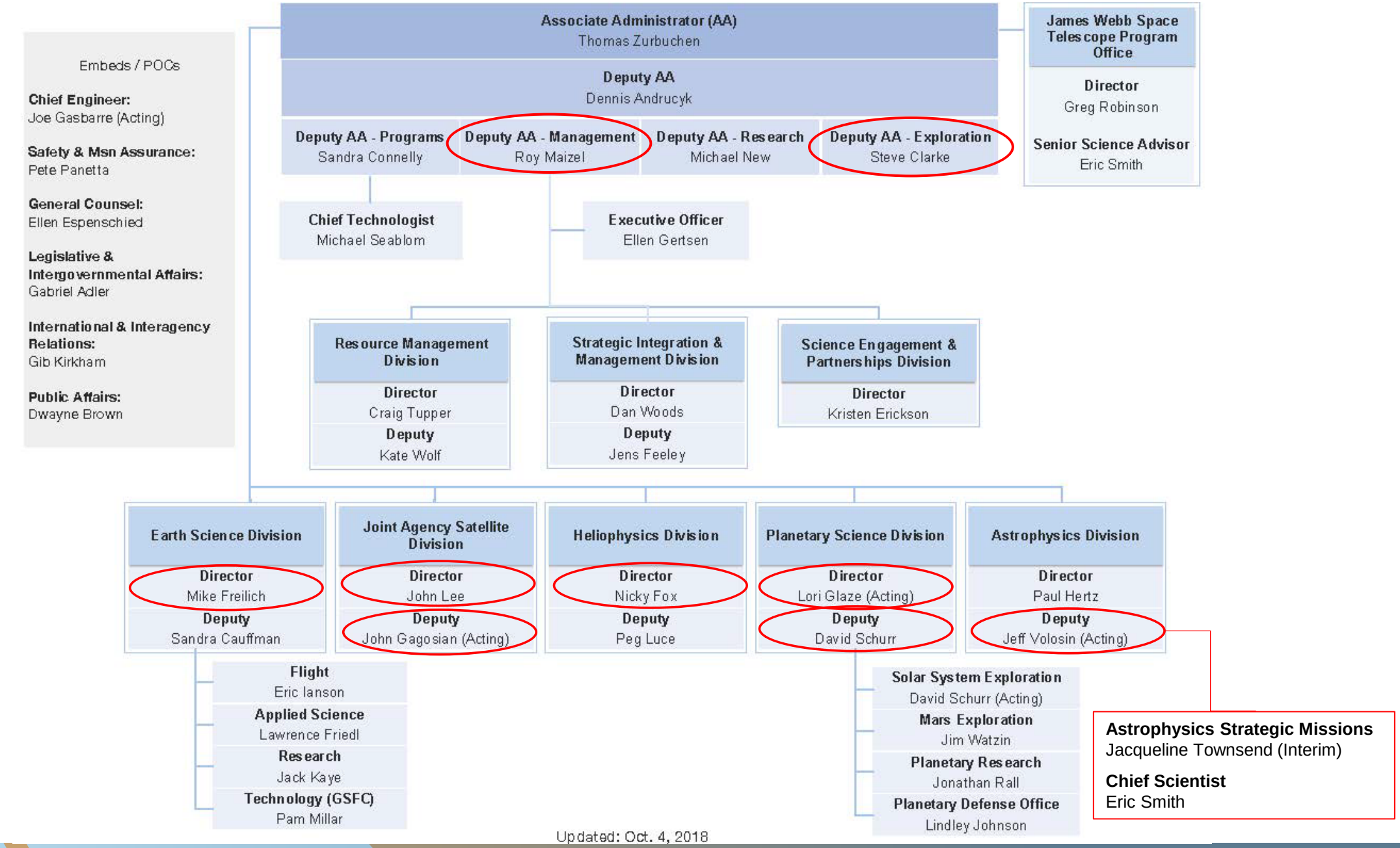
https://science.nasa.gov/astrophysics/2020-decadal-survey-planning

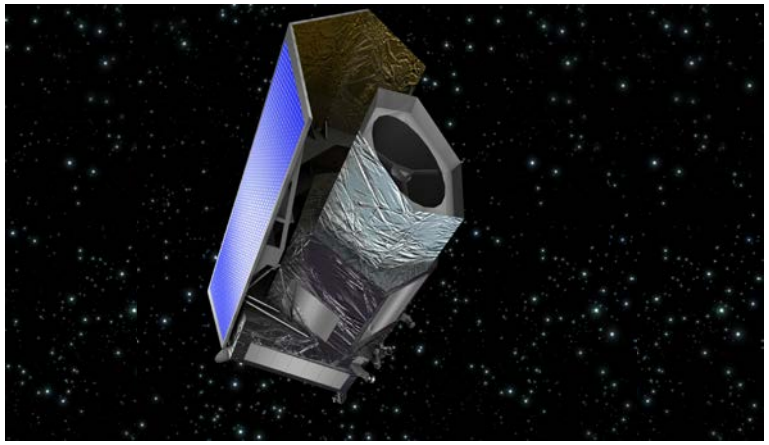

APOLLO
50
NEXT GIANT LEAP

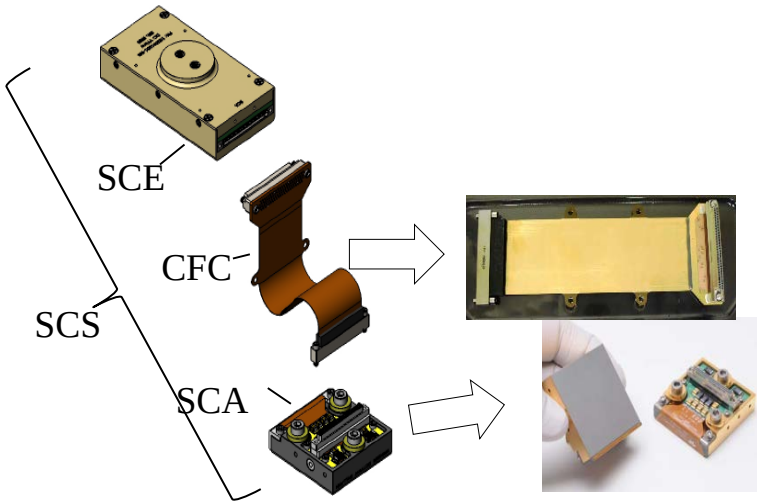
BACKUP


+ SMEX/MO (2025), etc.
Spitzer
8/25/2003
Kepler
3/7/2009
10/30/2018 EOM
Formulation
Implementation
Primary Ops
Extended Ops
WFIRST
Mid 2020s
Euclid (ESA)
2022
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 (XARM) (JAXA)
2022
SPHEREx
2023
Hubble
4/24/1990
ISS-NICER
6/3/2017
ISS-CREAM
8/14/2017
2/15/2019 EOM
GUSTO
2021
SOFIA
Full Ops 5/2014
Revised
February 21, 2019
+ Athena (early 2030s),
LISA (early 2030s)

SMD Organization Chart







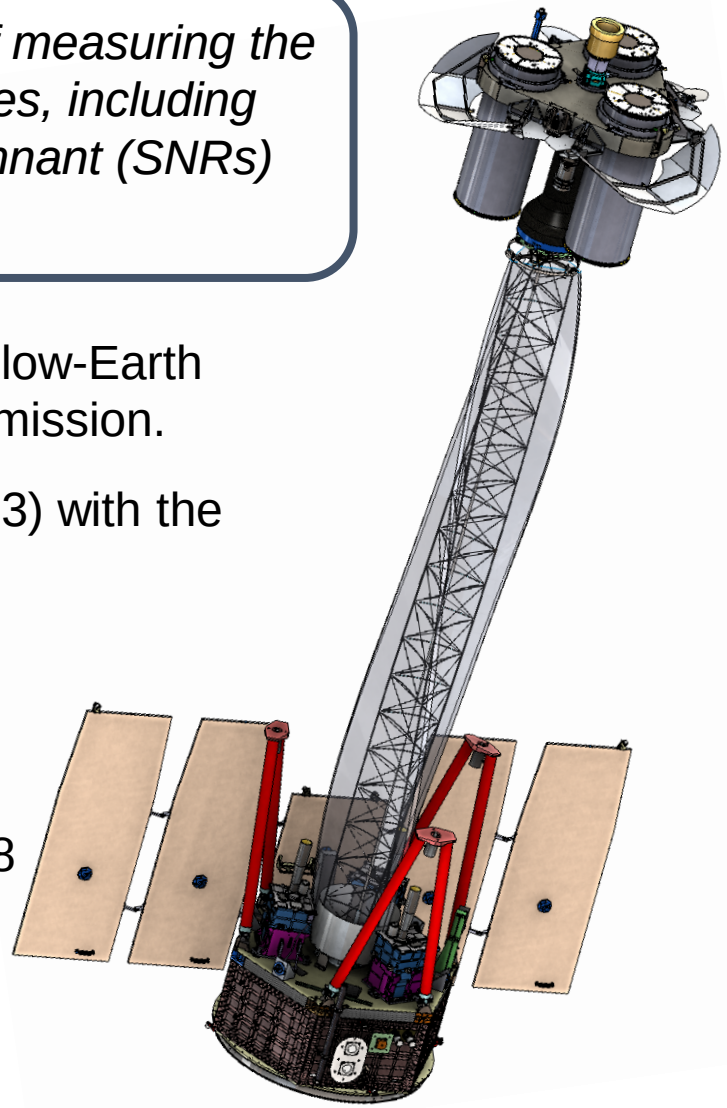
Sensor Chip Assembly (SCA)
Cryo-Flexi Cable (CFC)
Sensor Chip Electronics (SCE)

Euclid

- ESA-led dark energy mission with NASA contributions
- Launch date ~ June 2022
- NASA providing
  - 20 Characterized NIR Sensor Chip Systems
  - ~70 U.S. members of Euclid Consortium
  - Euclid NASA Science Center at IPAC
- NASA delivered 20 detectors and cryo-flex cables to ESA for the Near Infrared Spectrometer Photometer (NISP) instrument
  - Detectors presently integrated in the NISP focal plane and under characterization testing in Europe
- NASA is now manufacturing and testing the redesigned sensor chip electronics (readout boards)
  - 8 SCEs delivered to ESA in February 2019
  - Remaining 12 SCEs will be delivered to ESA by end of 2019

Imaging X-ray Polarimetry Explorer (IXPE)

NASA's first imaging X-ray polarimetry mission capable of measuring the X-ray polarization of a significant number of cosmic sources, including neutron star binaries, black hole binaries, Supernova Remnant (SNRs) and Active Galactic Nuclei (AGN).



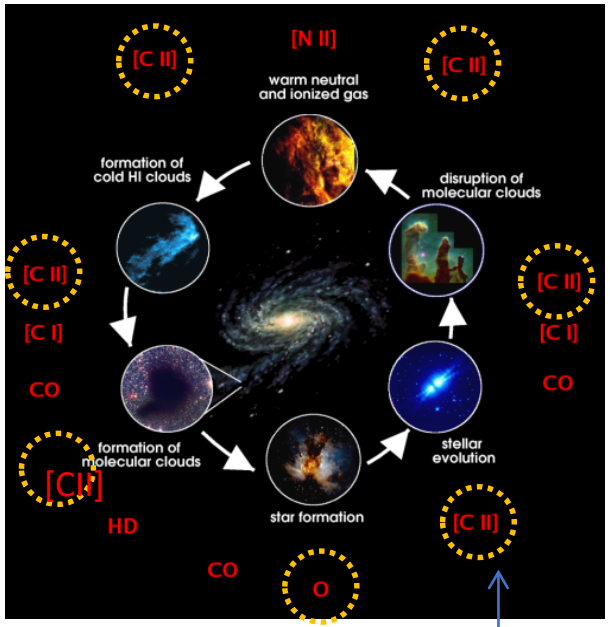
IXPE will be a 3-axis stabilized observatory launched into low-Earth equatorial orbit in April 2021 for a 2-year primary science mission.

IXPE is a small Explorer-class mission (class D, category 3) with the PI/Project Office at MSFC.

Milestones

- ✓ Mission Preliminary Design Review (PDR): June 2018
- ✓ Mission Confirmation Review (KDP-C): November 2018
- Mission Critical Design Review (CDR): May 2019
- Launch: April 2021

GUSTO Suborbital Explorer (MO)



GUSTO Lines

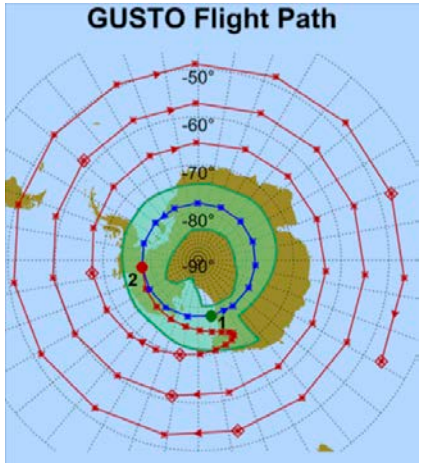
Brightest line in the *FIR over cosmic times.*

GUSTO surveys will provide Milky Way and Large Magellanic Cloud (LMC) templates from which star formation can be understood throughout cosmic time.

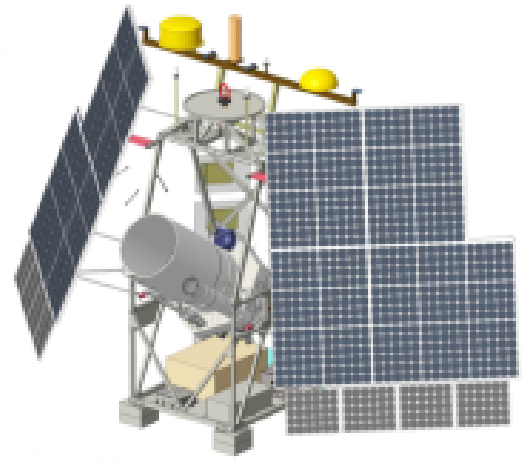
~300 dedicated SOFIA flights would be required to equal the GUSTO survey

- 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

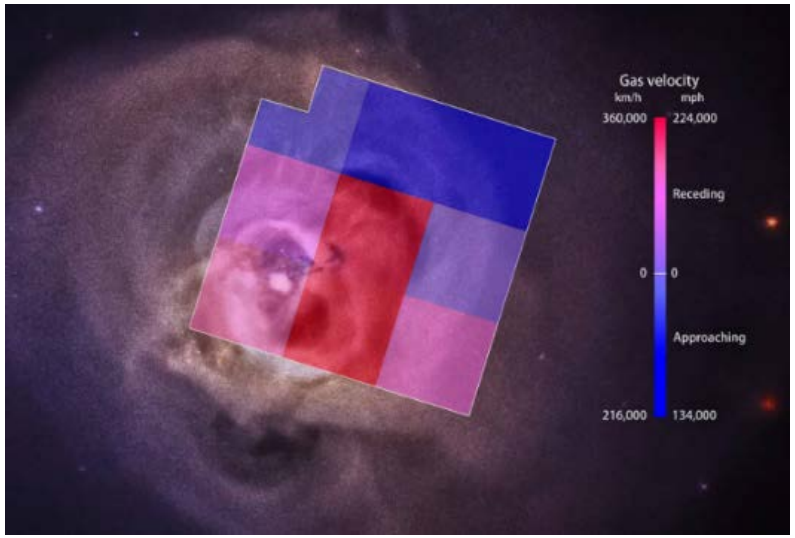
- **Milestones:**
  - ✓ Mission PDR: Nov 2018
    KDP-C: Mar 2019
    Launch: Dec 2021

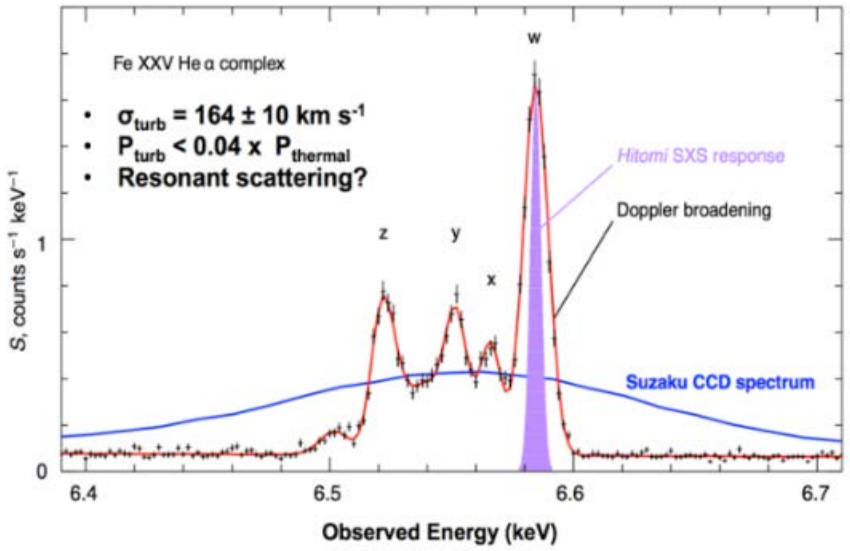


Flight strategy, Launch Dec 2021 from McMurdo on a superpressure balloon and allow payload to leave the continent. Instrument recovery preferred but optional. Target survey duration 75 days, acceptable base-line 20 days, cryogenic for 100 days.



GUSTO Payload



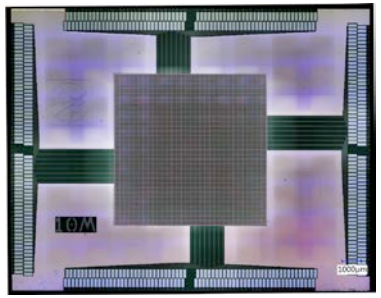


Launch readiness date: January 2022

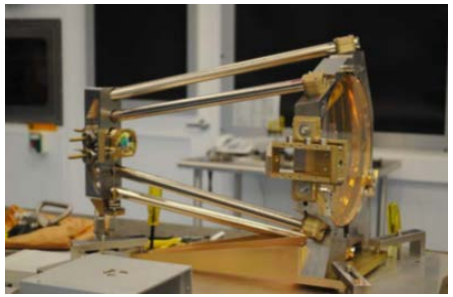
X-ray Imaging and Spectroscopy Mission (XRISM)

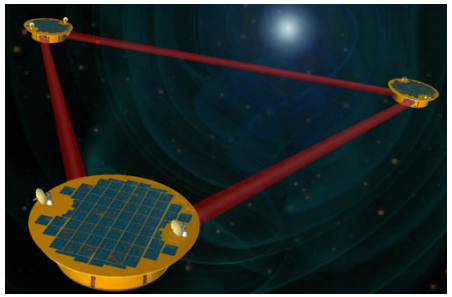
- XRISM (formerly XARM) is the successor to ASTRO-H/Hitomi.
- Mission will include an X-ray microcalorimeter and an X-ray imager
- NASA will provide same hardware contribution as for Hitomi: X-ray microcalorimeter and X-ray mirrors
- XRISM project at NASA is now in Phase C, nearing the completion of the hardware build and preparing for test. The project is on plan for the pre-ship review on Oct 2019
- The JAXA XRISM project initiation was held on July 1, 2018 and the project is currently in Phase B. The mission PDR is Mar 2019
- NASA project team engaged with JAXA at the instrument and mission level.
- U.S. Community Involvement
  - U.S. Participating Scientists on XRISM Science Team were selected in the Spring 2018. First XRISM science team meeting held in Nara, Japan, May 19-20, 2018. XRISM North American science team meeting held in Maryland, Sep 17-18, 2018
  - U.S. Scientists on Guaranteed Time Observing (GTO) Target Teams: to be selected approx. 1 year before launch
  - General Observing (GO) Program: Open to U.S. scientists starting 6-9 months after launch

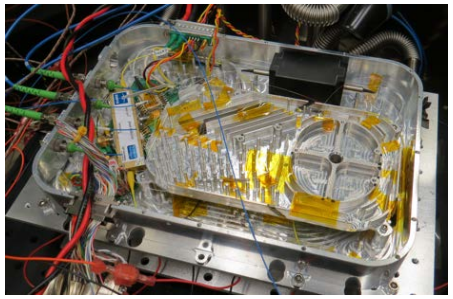
Advanced Telescope for High-Energy Astrophysics (Athena)

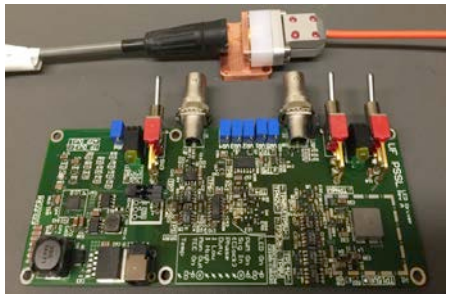


- ESA-led X-ray mission with NASA contributions; Launch date 2031
- NASA providing hardware, plus a U.S. GO program and a U.S. data center. Currently studying the following potential contributions:
  - X-ray Integral Field Unit (X-IFU) m-calorimeter main sensory array (GSFC)
  - Wide Field Imager (WFI) ASIC design, heat pipes & radiators, Science Products Module (SPM) (Penn State & GSFC)
  - Soft-Ride system (GSFC)
  - X-ray and Cryogenic Facility (XRCF) for possible calibration (MSFC)
- Athena Study Office (“proto-project”) at GSFC is responsible for managing technology investments and science contributions. US scientists Co-Is on instrument teams, represented on Athena Science Study Team, and Science Working Groups









Laser Interferometer Space Antenna (LISA)

- ESA-led gravitational wave mission with NASA contributions; Launch date ~ 2030s
- NASA providing hardware to the payload. Currently funding 5 technologies as potential contributions:
  - Telescope (GSFC)
  - Laser (GSFC)
  - Microthrusters (JPL)
  - Phasemeter (JPL)
  - Charge Management System (Univ. Florida)
- LISA Study Office (“proto-project”) at GSFC is responsible for managing technology investments and science contributions. US scientists deeply involved in Science Working Teams as part of the LISA Consortium