National Aeronautics and Space Administration

Charts posted at
https://cor.gsfc.nasa.gov/copag/AAS_June2022/AAS2022-Meeting.php
https://exoplanets.nasa.gov/exep/events/375/exopag-26/
https://pcos.gsfc.nasa.gov/physpag/meetings/AAS_June2022/AAS2022-Meeting.php

EXPLORE SOLAR SYSTEM & BEYOND

Joint PAG Meeting

AAS 240th Meeting | June 12, 2022

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@NASAUniverse @NASAExoplanets @NASAWebb

Outline

- The NASA Team: HQ Team / Join the Team / Inclusion, Diversity, Equity, and Accessibility (IDEA)
- Program Updates
  - FY23 Budget Request
  - Missions: Roman / Probe / Explorers / Other Missions / Suborbital
- Implementing the Astro2020 Decadal Survey
- The End
- Backup: FY23 Budget Request Tables

The NASA Team

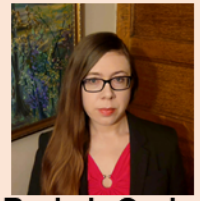
NASA Astrophysics Division

Division Director

Paul Hertz
Astrophysics Division Director

Sandra Cauffman
Astrophysics Division Deputy Director

Program Executives



Rachele Cocks
Dep COSI, Dep Ariel/CASE CubeSats

E. Lucien Cox
SOFIA, GUSTO, XRISM, ExEP

Julie Crooke
GOMAP

Ed Griego
Roman, CGI

Shahid Habib
PCOS/COR, ARIEL, Athena, Euclid, LISA, UltraSat

Janet Letchworth
Operating Missions, Decadal

Mark Sistilli
Explorers Program SPHEREx, COSI Balloons

Cross Cutting

Eric Smith
Chief Scientist Webb Precursor Sci

Vacant

Vacant
Assoc Dir for Flight ASM Program Manager

Mario Perez
Chief Technologist SAT, RTF, ISFM, Swift

Omid Noroozian
Deputy Chief Technologist

Not Pictured

Lisa Wainio
Information Manager, Public Affairs Liaison

Administrative Support

Jennifer Baker
Administrative Assistant

Ingrid Farrell
Program Support Specialist

Kelly Johnson
Administrative Assistant

Sara Schwartzman
Program Support Specialist

Program Scientists

Manuel Bautista

Dominic Benford
Roman, CGI, APRA Lead

Terri Brandt
COSI Dep APRA Dep Pioneers Dep Precursor Sci

Valerie Connaughton
APRA (High Energy) XRISM, UltraSat,XMM, TDAMM, PCOS Program

Antonino Cucchiara

Michael Garcia
APRA (UV/Visible), SmallSats/Pioneers Hubble

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

Hashima Hasan
Education/Comms, Citizen Science, Archives, Advisory Committees, NuSTAR, Keck

Douglas Hudgins
ExEP Program ADAP Lead TESS Dep, ARIEL

Stefan Immler
Astrophysics Research Program Mgr, Chandra, ART-XC

Hannah Jang-Condell
XRP, TESS ExEP, Explorers

Patricia Knezek
Explorers Program Astrophysics Probe SOFIA, Hubble Fellows

William Latter
APRA (Lab Astro) SPHEREx, Fermi

Sangeeta Malhotra
Roman/CGI Dep ATP/TCAN Dep

Roopesh Ojha
Data Lead, NICER, HEC, AI/ML

Joshua Pepper
Deputy TESS, Deputy ADAP, Deputy ExEP

Kartik Sheth
Inclusion Plans Technical assessments

Linda Sparke
2021 MIDEX/MO, Archives, COSI

Eric Tollestrup
APRA (IR/Submm) Euclid, IXPE, COR Program

Sanaz Vahidinia
ATP/TCAN Lead

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

Join the NASA Team at Headquarters

NASA is seeking permanent and visiting Ph.D.-level scientists to serve as Program Scientists in the Astrophysics Division at NASA Headquarters in Washington, DC. With a budget of $1.6 billion annually, the Division is responsible for the nation's space-based astrophysics program.

Talk to any of the NASA HQ staff to learn more.

NASA Program Scientists

- manage scientific research grants programs and the proposal review process;
- serve as the Headquarters science lead for missions;
- implement NASA's response to the 2020 Decadal Survey;
- gain insight into Federal astrophysics policy and programs;
- run scientific programs with multimillion-dollar budgets, and
- contribute to a culture of diversity, equity, and inclusion.

This summer (date TBD), NASA will advertise for program scientists across SMD.

- The ad will be open on USAJobs.gov for <5 days
- Subscribe to USAJobs.gov for an alert
- NASA will advertise through mailing lists (next page) and AAS Job Register

This summer (date TBD), NASA will advertise for astrophysics visiting scientists

- Visiting scientists spend 2-6 years at NASA before returning to their permanent job
- NASA will advertise through mailing lists (next page) and AAS Job Register

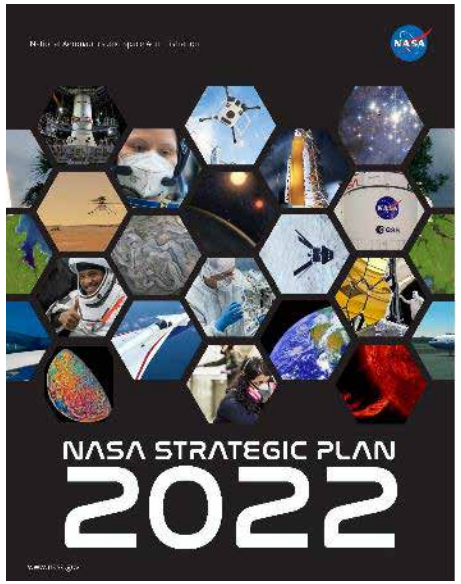
Importance of Inclusion, Diversity, Equity, Accessibility (IDEA)

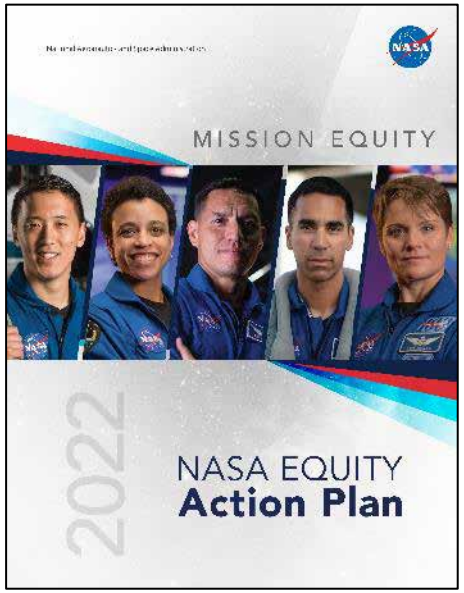
"The panel [on the State of the Profession and Societal Impacts] asserts that fundamentally, the pursuit of science, and scientific excellence, is inseparable from the humans who animate it."

- *Pathways to Discovery in Astronomy and Astrophysics for the 2020s*

NASA is committed to integrating inclusion, diversity, equity, and accessibility (IDEA) into all activities (missions, programs, reviews, internal matters, etc.)

Inclusion & Diversity of Thought





Strategic Objective 4.1: Attract and develop a talented and diverse workforce. Cultivate a diverse, motivated, and highly qualified workforce through modernizing our Human Capital processes and systems, increasing our workforce agility and flexibilities, and implementing a robust Inclusion, Diversity, Equity, and Accessibility (IDEA) approach to ensure systematic and sustainable fairness, impartiality, and equity in our business practices.

NASA is continuing its journey towards equity. To this end, NASA has established four foundational focus areas:

- Increase Integration and Utilization of Contractors and Businesses from Underserved Communities to Expand Equity in NASA's Procurement Process
- Enhance Grants and Cooperative Agreements to Advance Opportunities, Access, and Representation for Underserved Communities
- Leverage Earth Science and Socioeconomic Data to Help Mitigate Environmental Challenges in Underserved Communities
- Advance External Civil Rights Compliance and Expand Access to Limited English Proficient (LEP) Populations within Underserved Communities

Building Excellent NASA Teams Requires Inclusion & Diversity

- IDEA is infused throughout everything we do. It is not a standalone or separate activity.
- Astrophysics has pioneered and piloted IDEA activities that are now adopted across SMD:
  1. Inclusion Plans adopted in ROSES elements across all SMD divisions *
  2. Code of Conduct now adopted for panel reviews across all SMD divisions
  3. Dual Anonymous Peer Reviews adopted across all SMD divisions
  4. Inclusion Criteria in Senior Reviews of Missions adopted across all SMD divisions *
  5. Increasing diversity of reviewers for all panels expected across all SMD divisions
- Other SMD level initiatives:
  7. Collection, evaluation, and publication of demographics of ROSES proposers and awardees *
  8. Regularly report data on proposal submissions and success rates *
  9. SMD Bridge Program funded for better engagement with MSIs *
  10. National Academies study of barriers to inclusion in mission leadership
  11. National Academies study of demographic data required to assess the health of the community *
  12. Regular participation at meetings such as SACNAS and NSBP
  13. PI Launchpad to incubate next generation of diverse leaders for missions *
  14. IDEA criteria being added to Announcements of Opportunity *

* Responsive to an Astro2020 Decadal Survey recommendation

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- Other SMD
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  13. PI Launchpad to incubate next generation of diverse leaders for missions *
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Additional initiatives are being considered for inclusion in the FY24 NASA budget request *

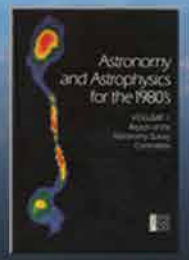
* Responsive to an Astro2020 Decadal Survey recommendation

FY23 President’s Budget Request

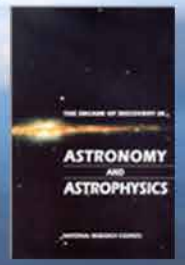
Astrophysics

Decadal Survey Missions

1972
Decadal Survey
Hubble



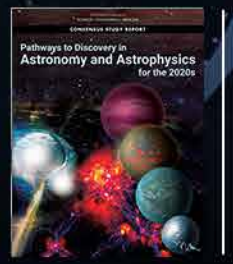
1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer

2001
Decadal Survey
Webb

2010
Decadal Survey
Roman



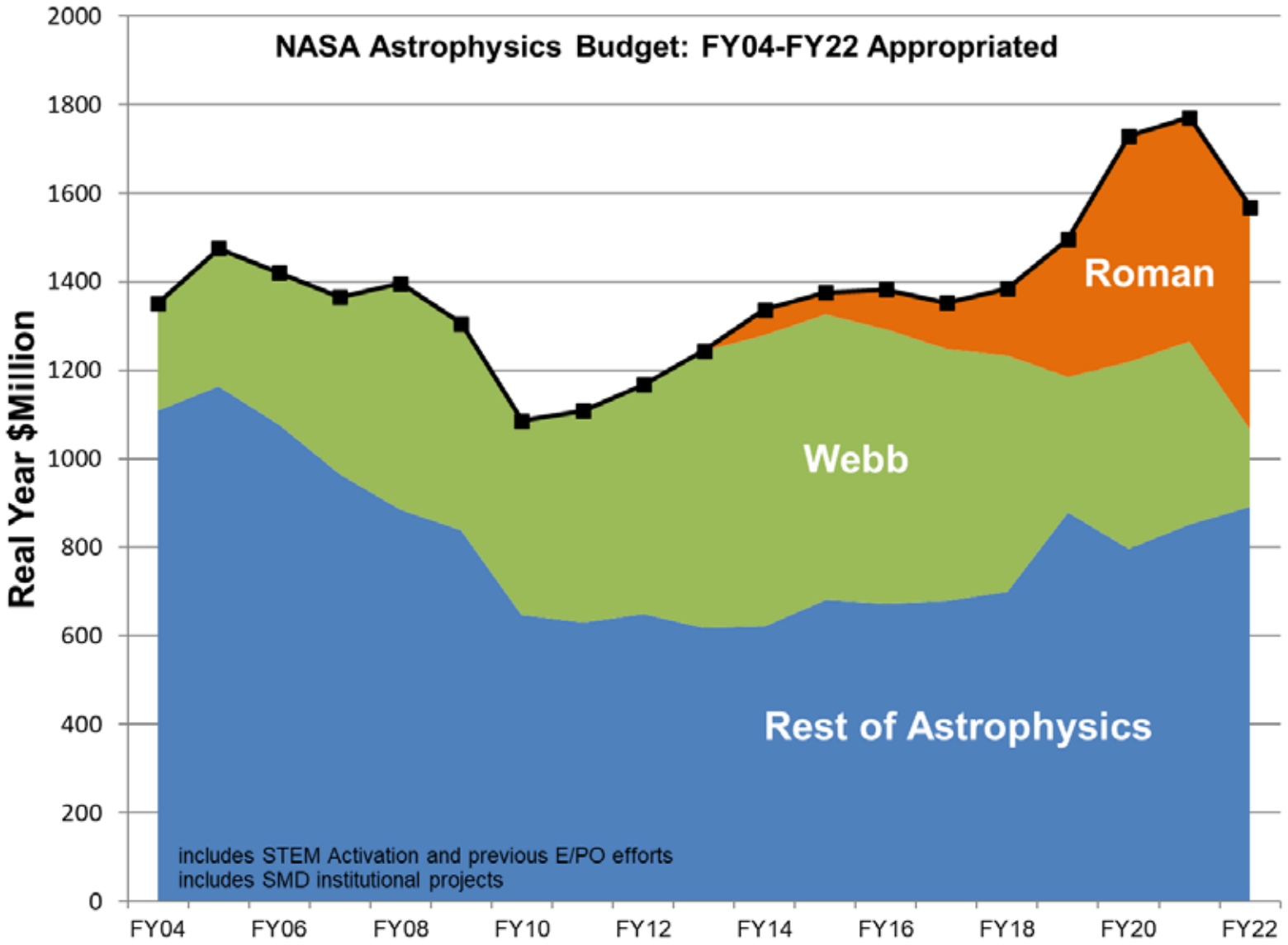
2021
Decadal Survey

We are bound by the budgets that we have

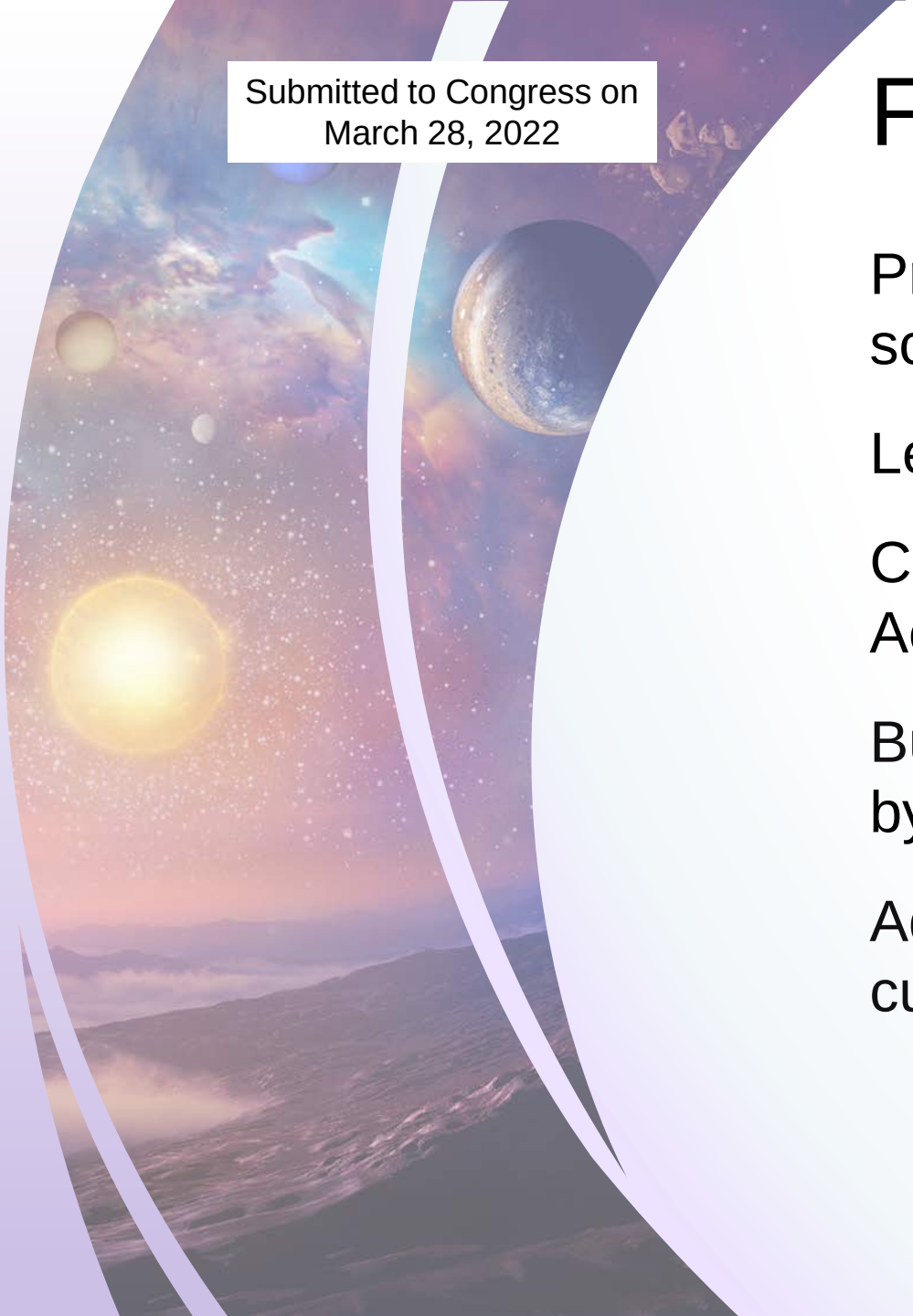
- First budget that is fully informed by the Decadal Survey will be the FY24 budget proposal, which will be formulated by NASA Astrophysics in Spring 2022 and submitted to Congress in February 2023

FY22 Appropriation

Signed into law March 11, 2022



- Astrophysics total (including Webb) at $1.57B, down $7M from the request.
- Webb and Roman appropriated at the request, $175M and $502M respectively.
- SOFIA appropriated at $85M (request was zero).
- Science Activation appropriated $51M, down $5M from the request.
- Explanatory statement says,
  - “The agreement notes all recommendations of Astro2020.”
  - “NASA is expected to include appropriate funding for technology maturation in its fiscal year 2023 budget request to ensure continued Astrophysics mission success.”



Submitted to Congress on March 28, 2022

FY23 SMD Budget Priorities

Promote US leadership in Earth system science and addressing the climate crisis

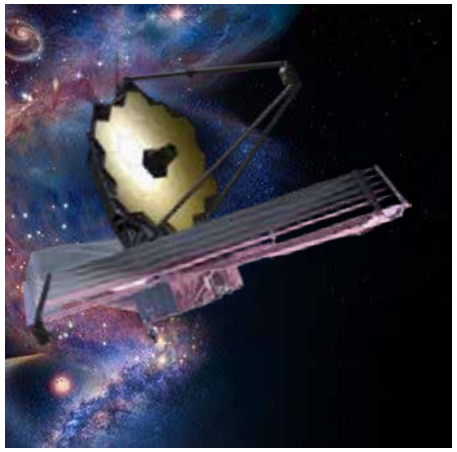
Lead Artemis Science

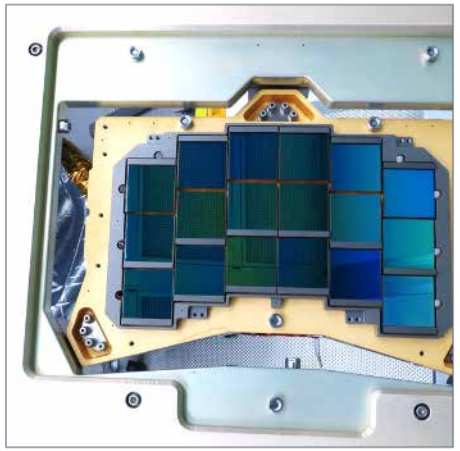
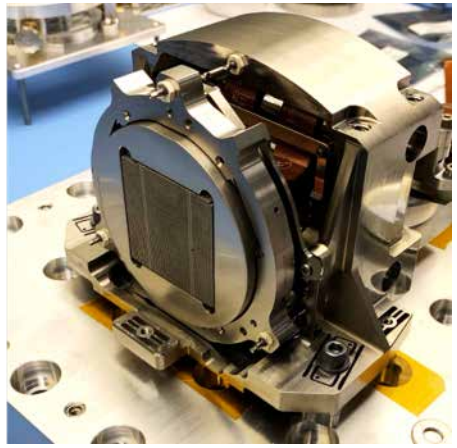
Champion Inclusion, Diversity, Equity and Accessibility

Build a balanced and innovative program driven by the highest national priorities

Advance open science for all by leveraging cutting edge data science techniques

Planned Milestones FY22-23



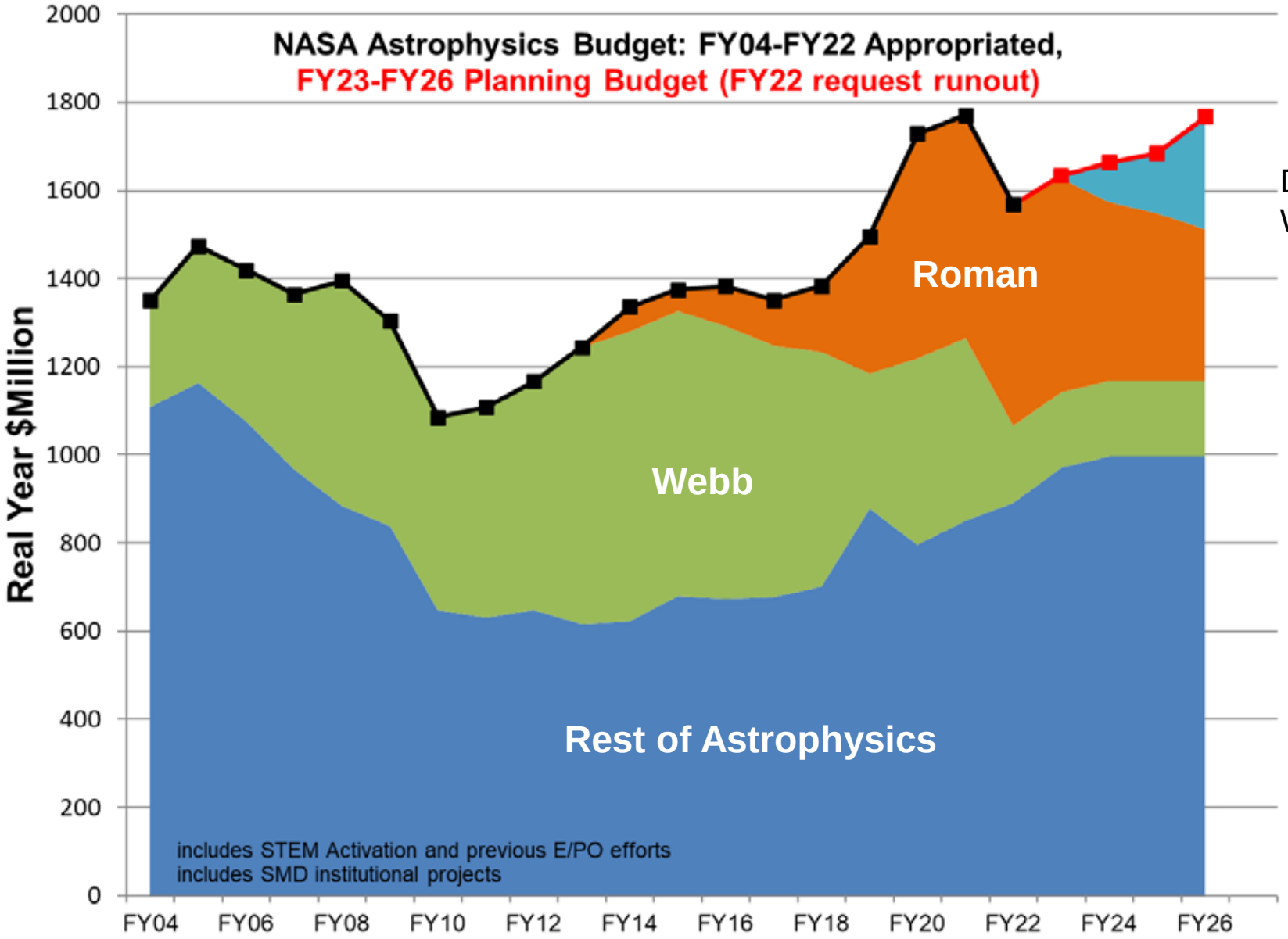



ü Conduct Senior Review of Operating Missions in FY 2022

- Initiate Webb Telescope science in FY 2022
- Conduct sounding rocket campaign in Australia in FY 2022
- Select MIDEX missions for competitive Phase A studies in FY 2022
- Conduct four scientific balloon campaigns in FY 2022 and four campaigns in FY 2023
- Release Astrophysics Probe AO in FY 2023
- Select Webb Cycle 2 science observations in FY 2023
- Begin integration and test of the Roman Space Telescope instruments and telescope in FY 2023
- Initiate precursor science program to advance Astrophysics Decadal Survey priorities in FY 2023
- Participate in launch of JAXA's XRISM mission and ESA's Euclid mission in FY 2023

Last Year

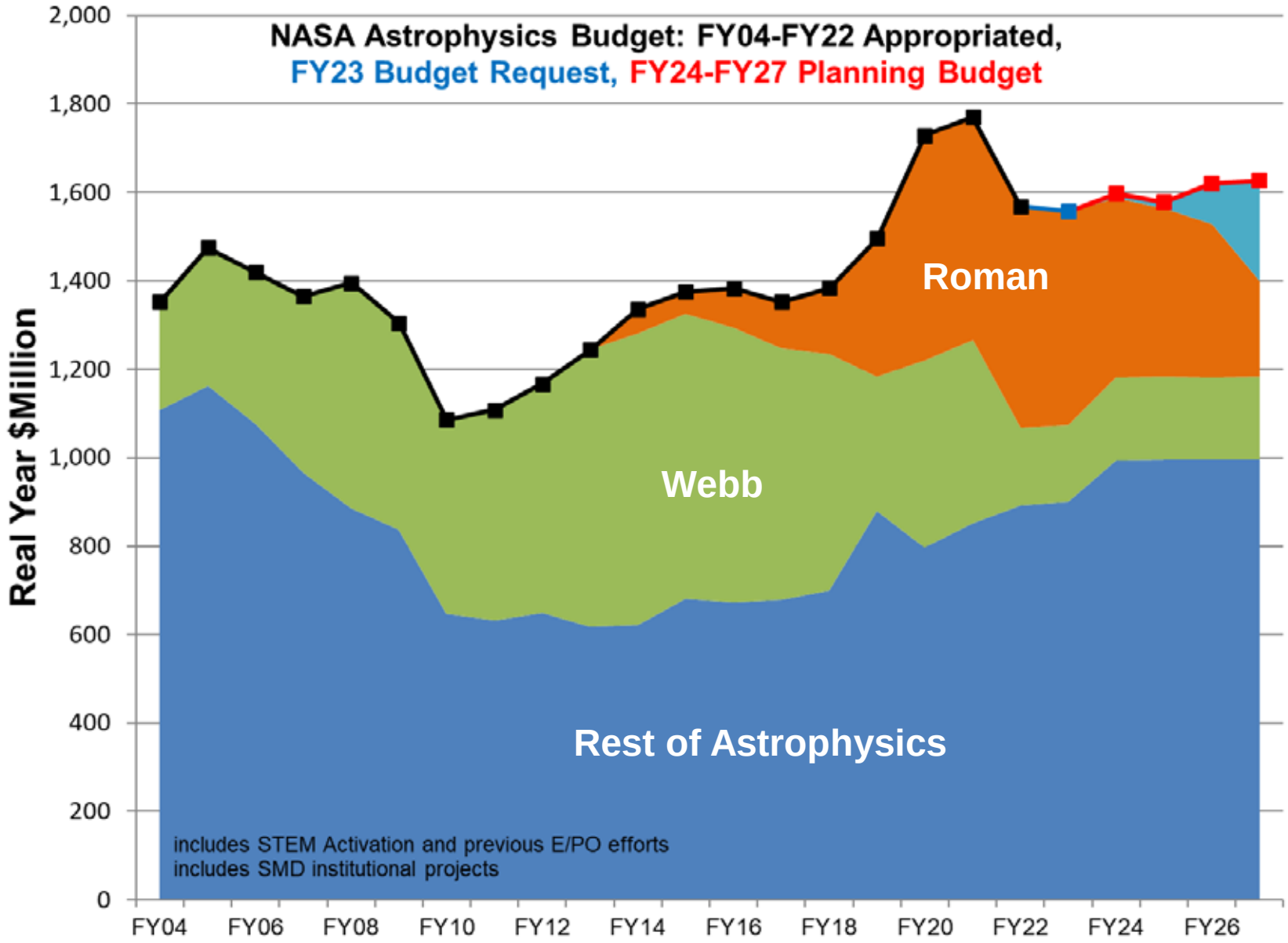
FY22 President's Budget Request



Decadal Survey Wedge

This Year

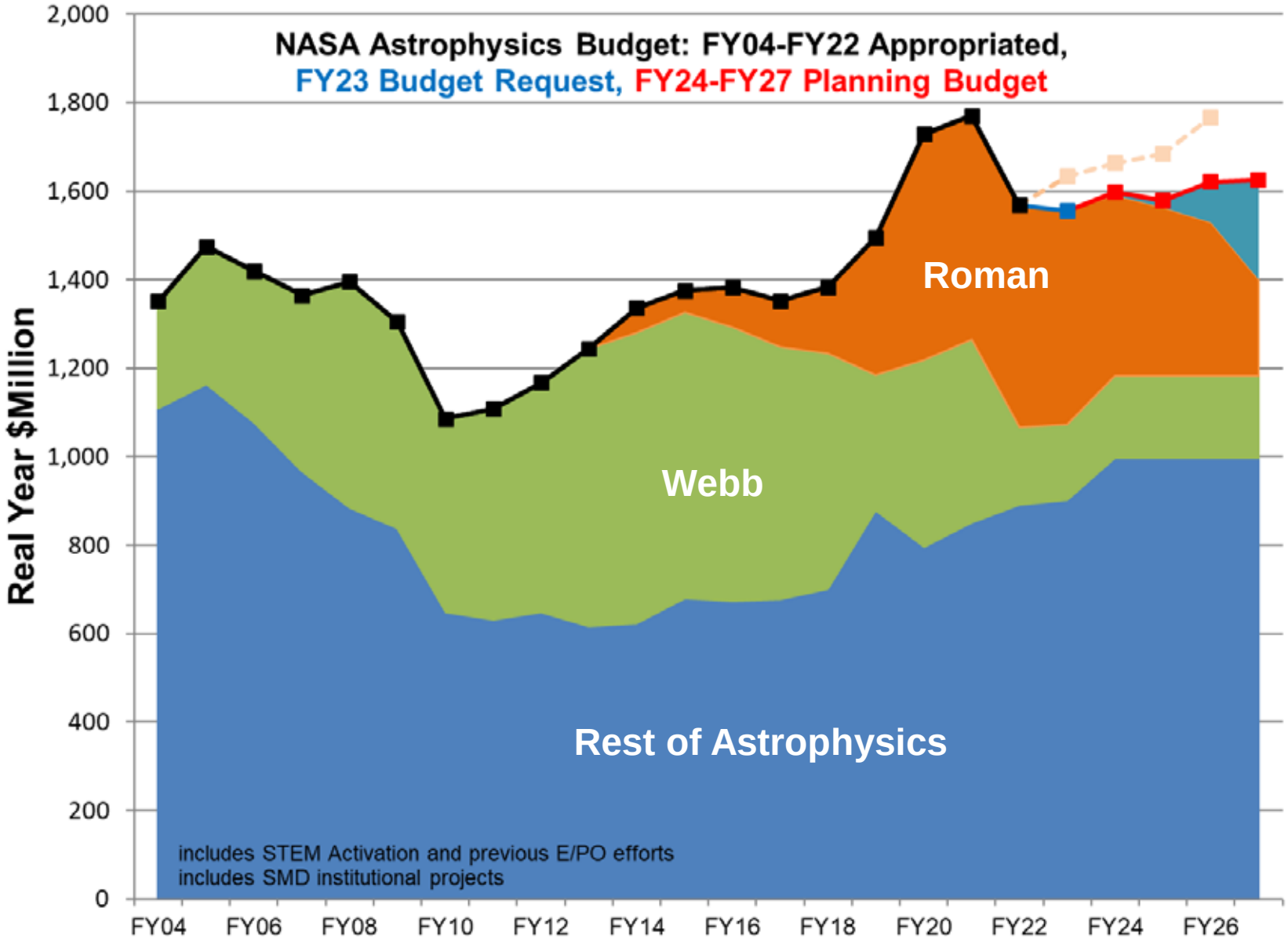
FY23 President's Budget Request



Decadal Survey Wedge

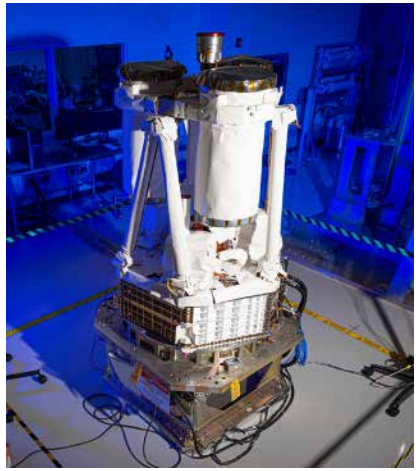
This Year

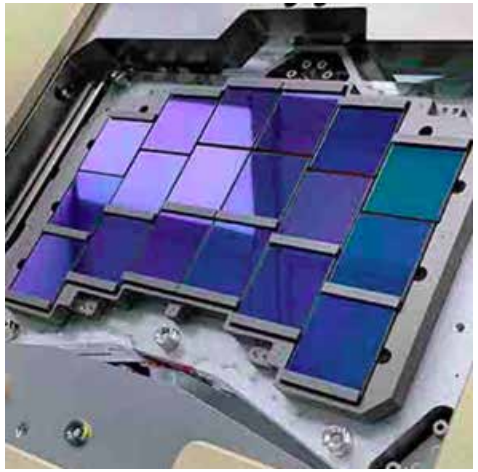
FY23 President's Budget Request



Decadal Survey Wedge

Astrophysics Budget Features





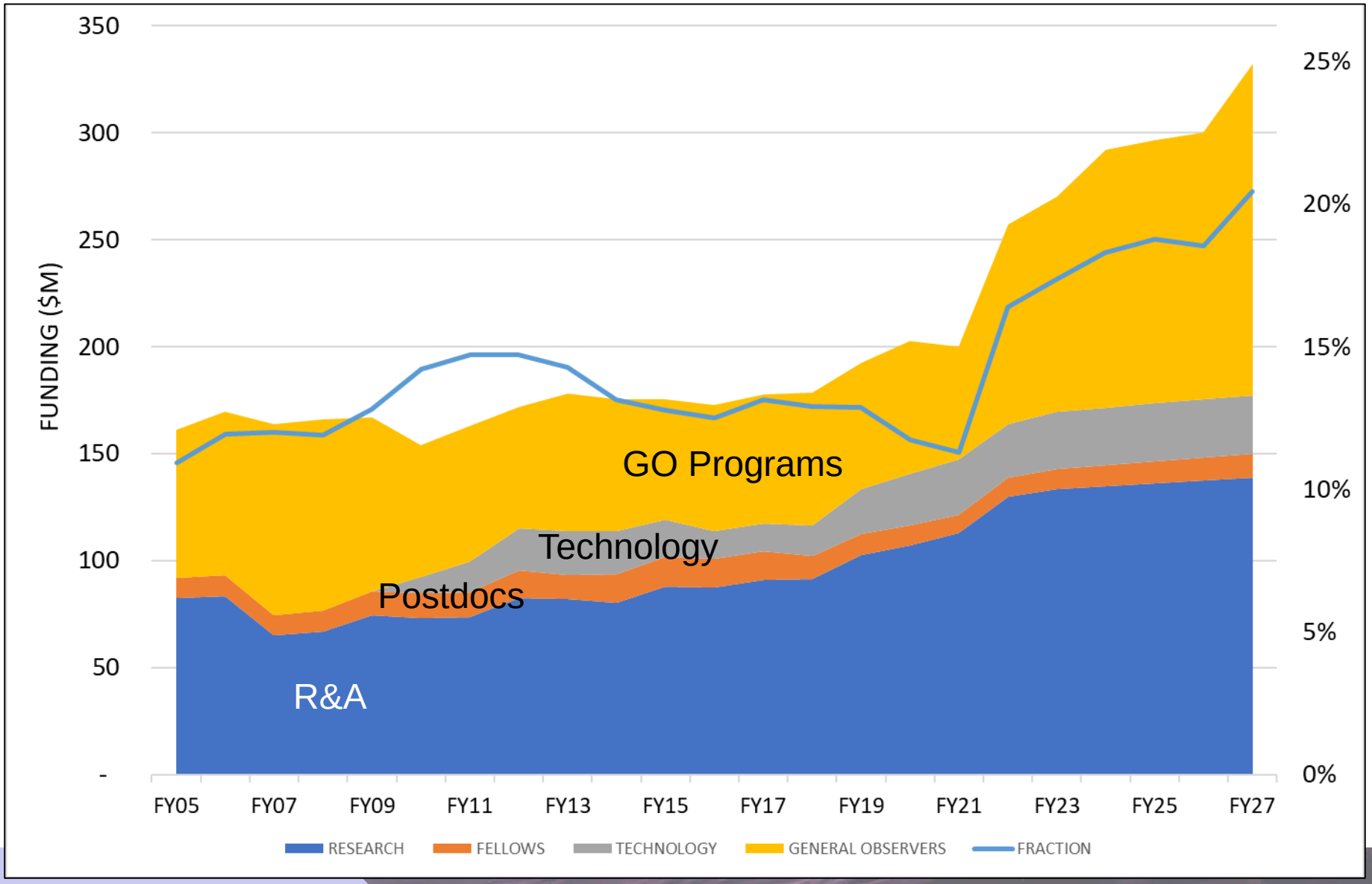
What's Changed since FY22 budget was submitted in 2021

- Additional Webb General Observer funding
- Roman budget adjustments and 7-month delay, consistent with replan due to COVID impacts
- Additional Pioneer selections & increased Pioneers cadence
- Support Great Observatory Precursor Science and Time Domain Astrophysics infrastructure systems for Decadal Survey
- Includes bridge partnerships focused on minority serving institutions and Decadal Survey recommendations for increased inclusion
- SOFIA close out in FY23 per Decadal Survey recommendation
- Extended Phase B for COSI, delayed development for next MIDEX
- Compared to the FY 2022 Budget request, delays a future Astrophysics Probe mission; AO release delayed from January 2023
- Delayed implementation of Decadal Survey recommendations

What's the Same as the runout of the FY22 budget request

- Healthy R&A program
- Development of Astrophysics Explorers GUSTO and SPHEREx
- Development of contributions for JAXA-, ISA-, and ESA-led missions XRISM, ULTRASAT, Euclid, Ariel, Athena, and LISA
- Operating Missions, including Hubble, Chandra, Fermi, TESS, Gehrels Swift, NuSTAR, NICER, per Senior Review

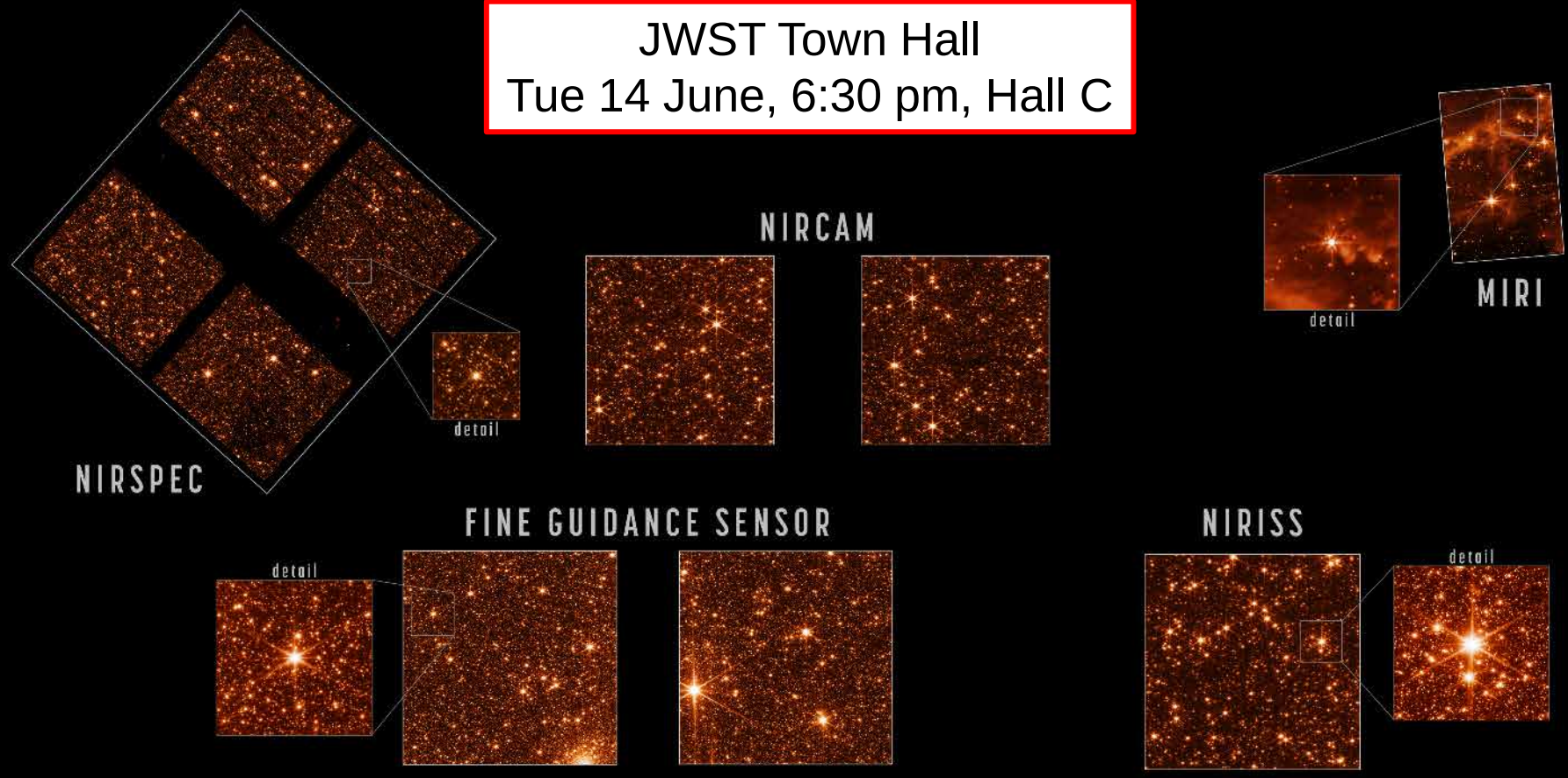
Community Funding / Fraction of Budget



Program Update -- Missions

JWST Optical Performance Better than Requirements!

JWST Town Hall
Tue 14 June, 6:30 pm, Hall C



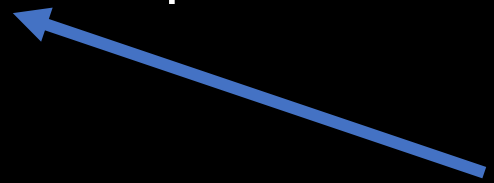
NIRCam (2 micron), NIRSpec (1.1 micron), NIRISS (1.5 micron), and MIRI (7.7 micron)

Commissioning Timeline

The CAST lays out each step of JWST commissioning.
(CAST = Commissioning Activity Sequence Timeline)
There are 730 high-level steps in the timeline.

These are broken down into:

- ~2800 steps for deployments and spacecraft ✓
- ~5400 steps for the telescope ✓
- ~1500 steps for the science instruments



~20 steps left (99% complete)

JWST Town Hall
Tue 14 June, 6:30 pm, Hall C

Webb Cycle 1 Long Range Plan

The Cycle 1 Long Range Plans (LRP) was released to the public the week of 18-April-2022.
It is a dynamic plan that will change with execution times as run, spacecraft anomalies, ToO's, etc.

LRP Cycle 1 Dates: 27-June-2023 to 2-July-2023

Category	Total Time [hrs]	Total Planned Time [hrs] (%)
GO	6090.1[1]	5749.7 (94%
GTO	3774.0[2]	3667 (98%
ERS[3]	529.5	529.5 (100%
Cal	659.6	659.6 (100%
Total	11023.2	10491.0 (95%)

[1]Includes 200.5 hrs of ToO's which do not get planned until activation
[2]Includes 5.2 hrs of ToO's which do not get planned until activation
[3]Bulk of ERS programs are schedule in the first 5 months of Cycle 1

https://www.stsci.edu/contents/news/jwst/2022/schedule-for-cycle-1-science-operations-released

Data courtesy N. Reid, STScI

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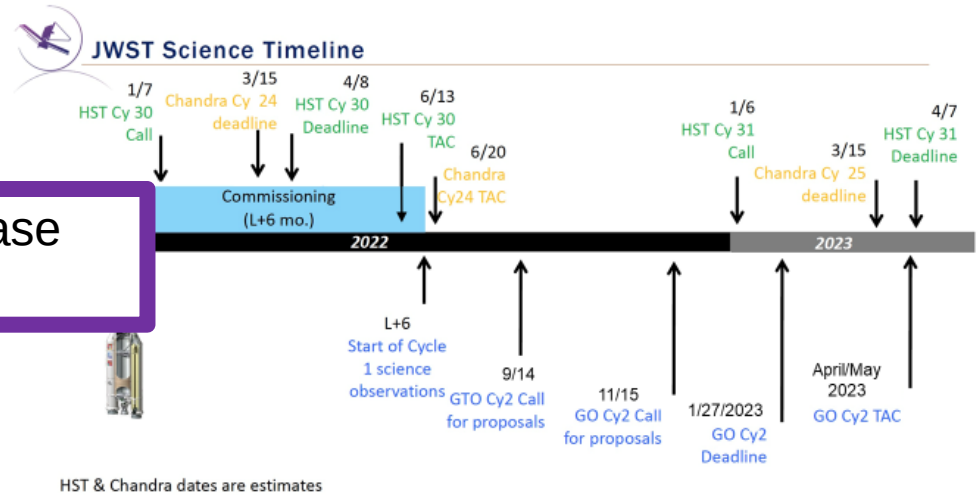
First Image Release
July 12, 2022

Science Timeline



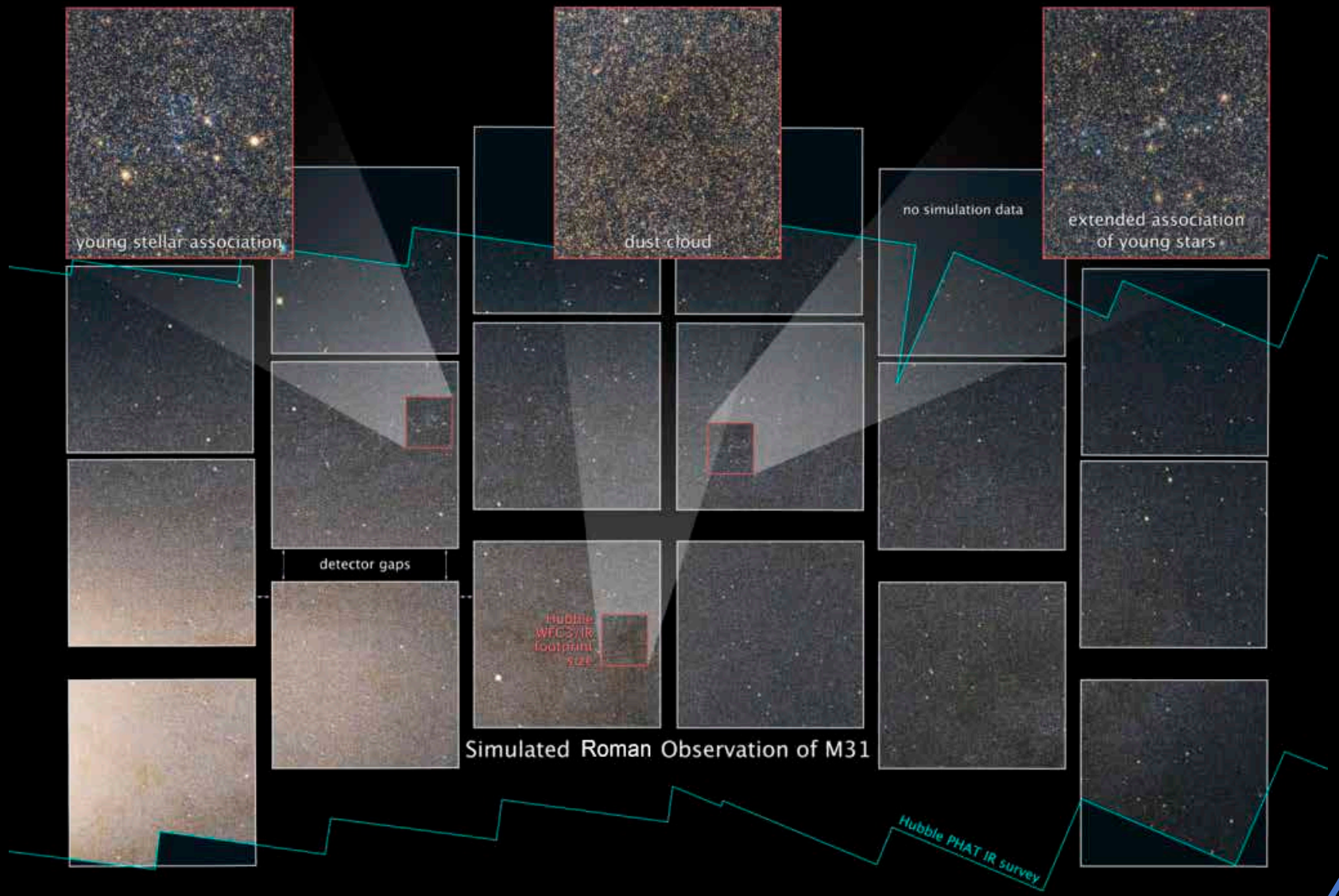
HST & Chandra dates are estimates

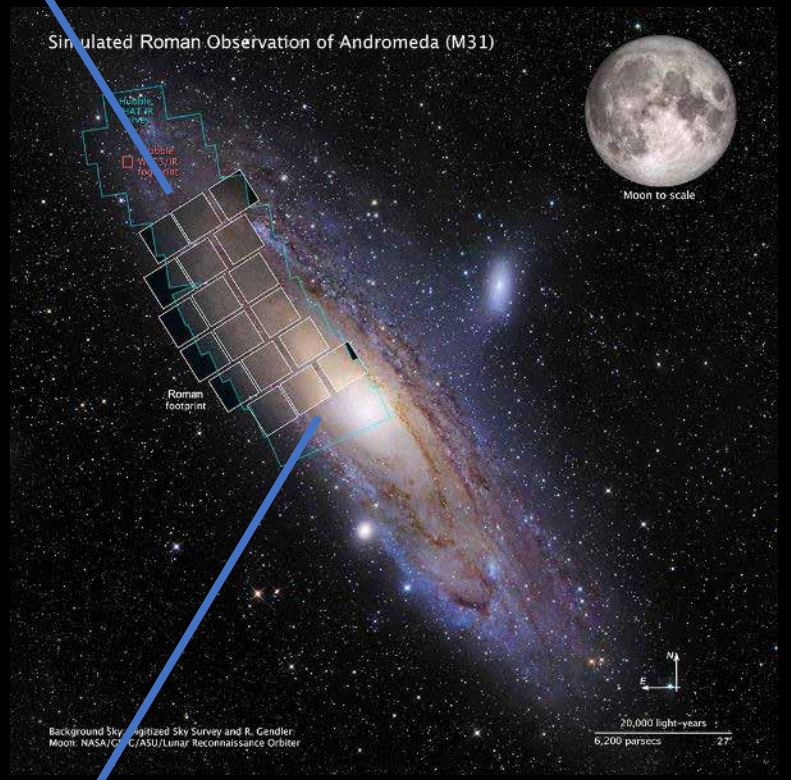
18

Keep up with JWST online
JWST homepage — nasa.gov/webb
JWST Blog — blogs.nasa.gov/webb
Where is JWST — jwst.nasa.gov/content/webbLaunch/whereIsWebb.html

Twitter: @NASAWebb, @JWSTObserver
Facebook: nasawebb
YouTube: NASAWebbTelescope
Flickr: nasawebbtelescope
Instagram: nasawebb

NANCY GRACE ROMAN SPACE TELESCOPE





The Wide Field Instrument with its 300 Mpix infrared camera provides Hubble's resolution and sensitivity over 200× larger FOV – *flagship-level survey capability*

https://roman.gsfc.nasa.gov/

NANCY GRACE ROMAN SPACE TELESCOPE

All major flight hardware procurements complete; substantial flight hardware completed – Heritage Telescope completion expected late 2022. Transitioning to assembly & test: Coronagraph late 2022; Wide Field Instrument early 2023; Spacecraft late 2023. Launch Vehicle selection imminent.

NASA launch commitment date remains May 2027.

NASA has asked the CAA to conduct a non-advocate review of the Roman Space Telescope science program and observing plan, as per Astro2020.

Opportunities for participation in Roman Space Telescope research and support are offered in ROSES-2021; draft solicitation Draft ROSES solicitation released; final expected in ~1 mo.

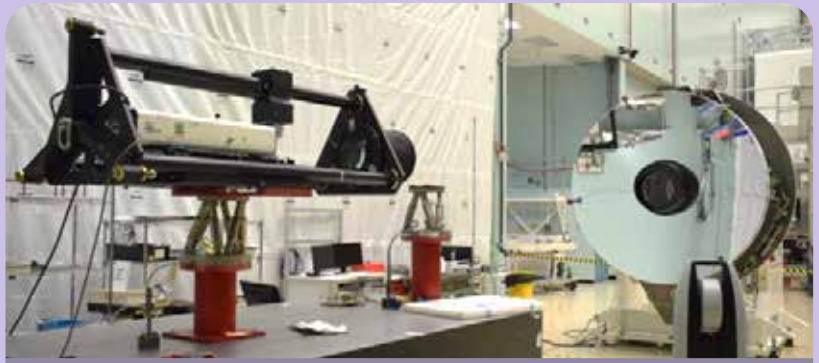
Roman Town Hall at AAS (Thu 12:45pm Ballroom D), plus varied Hyperwall talks scheduled every day!

https://roman.gsfc.nasa.gov/

Optical Telescope Assembly Hardware

Tertiary Optical Mirror Assembly

Secondary Mirror Support Tube

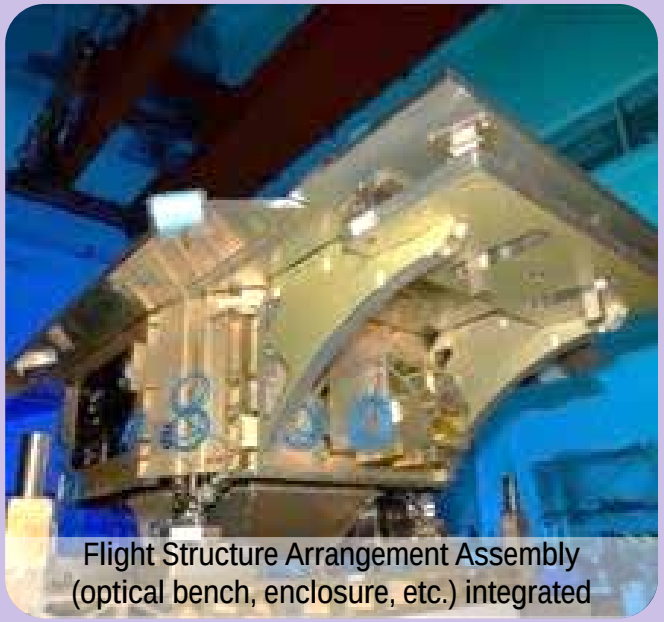


Primary Mirror horizontal optical test

Forward Metering Shell w/thermal control hardware installed

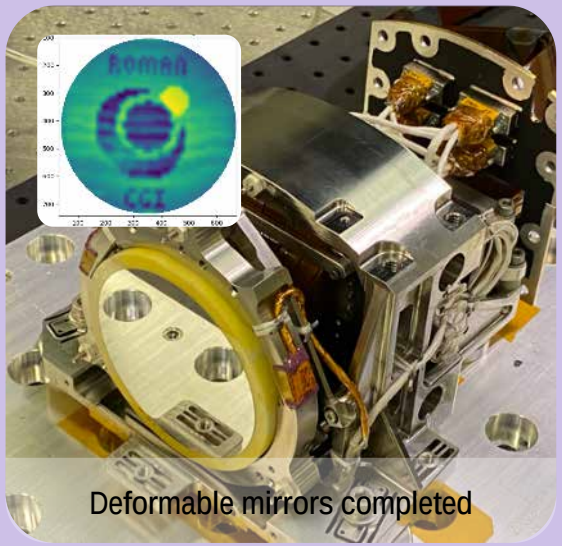
Wide Field Instrument Hardware

Flight Element Wheel Assembly completed; done thermal vac test

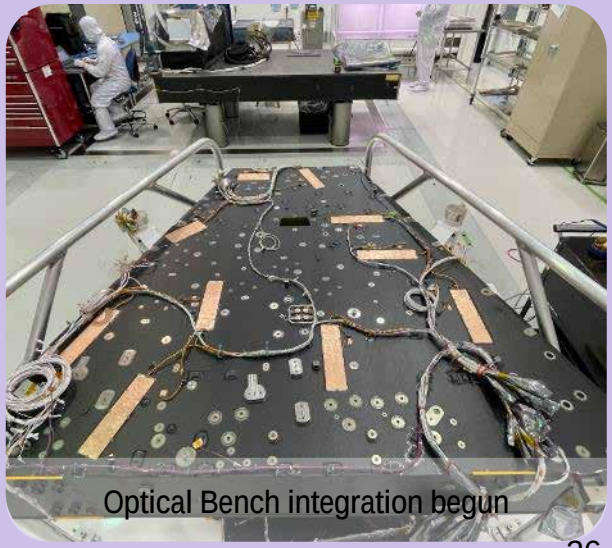


Flight Structure Arrangement Assembly (optical bench, enclosure, etc.) integrated

Coronagraph Instrument Technology Demonstration Hardware



Deformable mirrors completed



Optical Bench integration begun

Visit the NASA booth to play the console version of our new Roman video game!

Or go to:
https://roman.gsfc.nasa.gov/game

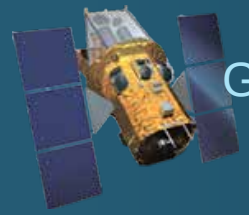
Roman Proposal Opportunities

- Roman will support core community surveys and GO investigations.
  - This is not a call for either kind of observing proposals.
  - Core community surveys will be defined by an open community process run by STScI and IPAC
- Nancy Grace Roman Space Telescope Research and Support Opportunities is being solicited as part of ROSES-2022. Draft posted; final call in ~month, proposals due ~90 days after.
- Open to small teams, large teams, or individuals. Seeking early career researchers; theorists, observers, data analysts. Opportunity for researchers at smaller institutions to participate on a major NASA mission.
- Proposal categories are:
  - Wide Field Instrument Science – Science teams to to prepare for Wide Field Instrument surveys.
  - Project Infrastructure Teams – Teams work with science centers to develop tools & capabilities.
  - Coronagraph Community Participation Program – Investigators work with Coronagraph instrument team to plan and execute tech demo observations.

Roman Solicitation Hyperwall
Wednesday 5:40pm NASA booth

Roman Space Telescope Town Hall
Thursday 12:45pm Ballroom D

Astrophysics Explorers Program



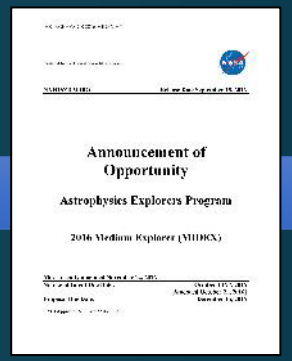
Gehrels
Swift

NuSTAR

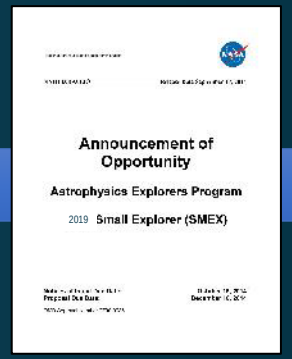
4 AOs per decade

MIDEX
2011

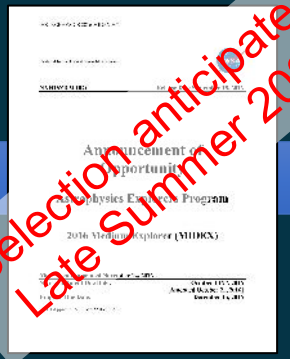
SMEX
2014



MIDEX
2016



SMEX
2019



Selection anticipated
Late Summer 2022

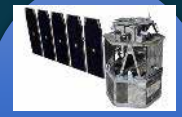
MIDEX
2021

Small and
Mid-Size
Missions

TESS

IXPE

SPHEREx

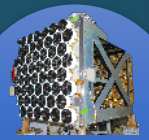


COSI

Directed
2013

Euclid

Missions of
Opportunity

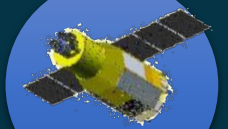


NICER

GUSTO

ARIEL

Directed
2017



XRISM

Astrophysics Probe

NASA is drafting an AO for a PI-led Astrophysics Probe

A Community Announcement laying out the primary parameters of the upcoming Astrophysics Probe AO was released on Jan 11, 2022

A second Community Announcement laying with two updates was released on May 19, 2022

- The target date for the final Probe AO was revised to July 2023
- Due to European Space Agency (ESA) consideration of whether the Athena mission will be substantially replanned, it was no longer practical to require proposed X-ray probes to "complement ESA's Athena Observatory." This requirement was therefore removed. Astrophysics will now accept proposals for:
  - A far-infrared imaging and/or spectroscopy mission
  - An X-ray probe

Community announcements and FAQ at https://explorers.larc.nasa.gov/2023APPROBE/

Release of draft AO:	July 2022 (target)
Release of final AO:	July 2023 (target)
Proposals due:	NET 90 days after AO release

Astrophysics Missions in Development

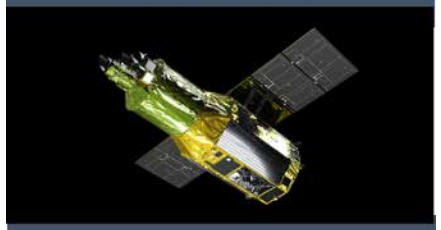
IXPE 2021
NASA Mission

Imaging X-ray Polarimetry Explorer

Webb 2021
NASA Mission

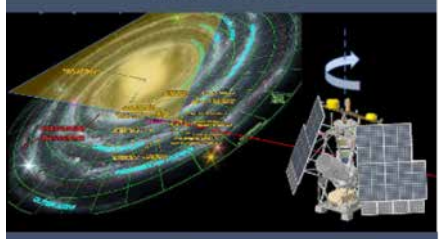
James Webb Space Telescope

XRISM 2023
JAXA-led Mission



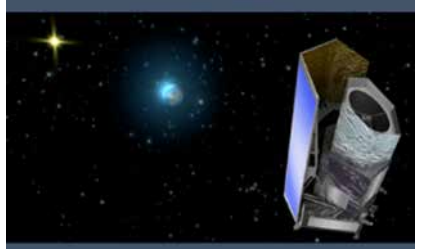
NASA is supplying the SXS Detectors, ADRs, and SXTs

GUSTO 2023
NASA Mission



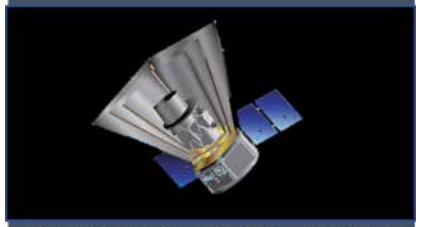
Galactic/ Extragalactic ULDB Spectroscopic Terahertz Observatory

Euclid 2023
ESA-led Mission



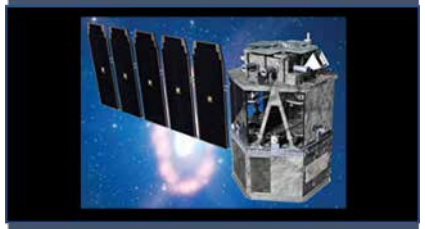
NASA is supplying the NISP Sensor Chip System (SCS)

SPHEREx 2025
NASA Mission



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

COSI 2025
NASA Mission



Compton Spectrometer and Imager

Roman 2027
NASA Mission

Nancy Grace Roman Space Telescope

MIDEX/MO 2028
NASA Missions

Medium-class Explorer Explorer Mission of Opportunity

ARIEL 2029
ESA-led Mission

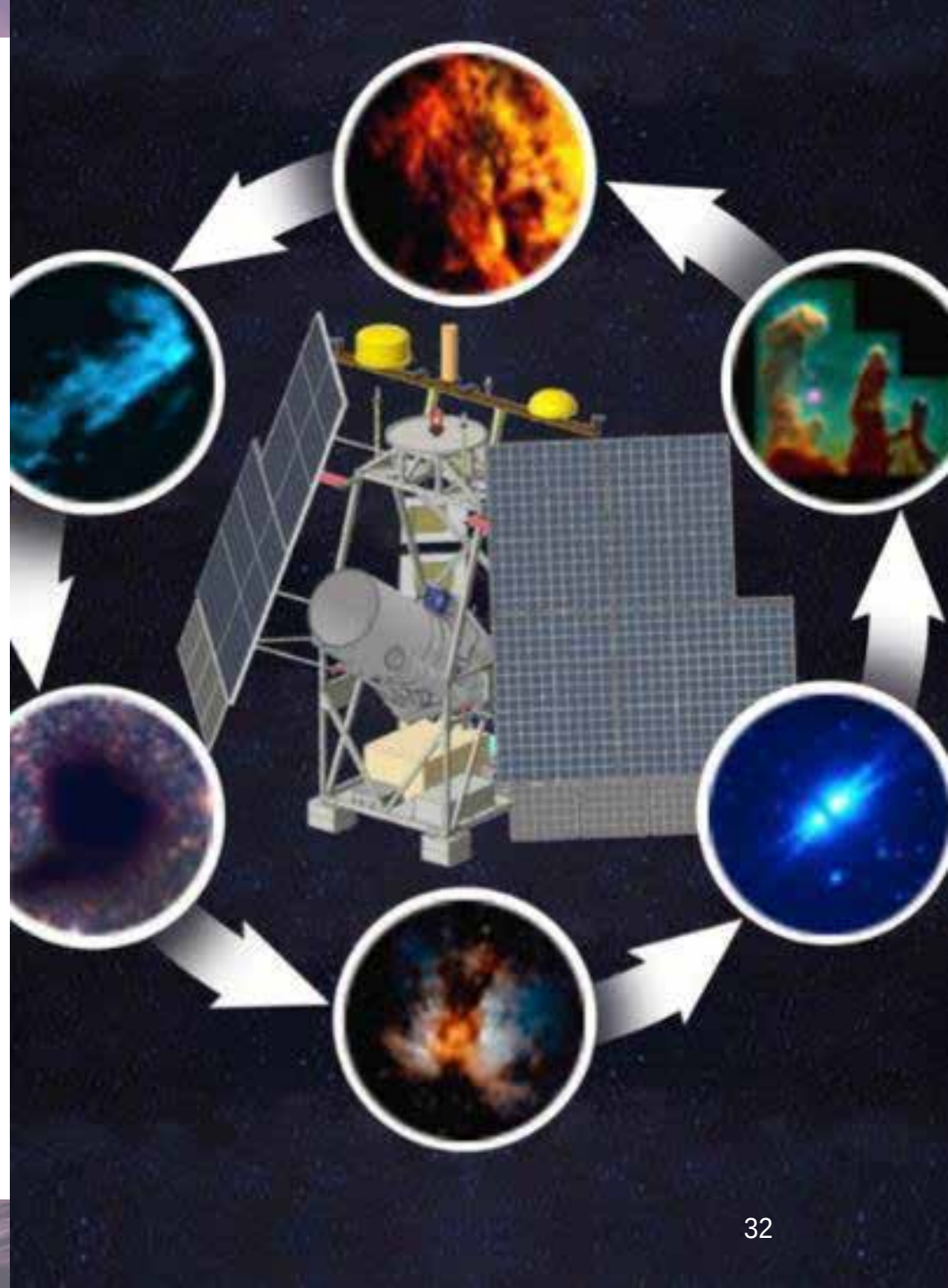
NASA is supplying the CASE fine guidance instrument

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

Does not include Pioneers or CubeSats

GUSTO

- GUSTO removed from the 2022/2023 NASA Antarctica Long Duration Balloon (LDB) Campaign due to a launch readiness schedule breach
- The NASA conducted a Continuation/Termination Review on May 19, 2022, to assess the GUSTO Projects' replan proposal to receive a one-year extension to the 2023/2024 NASA Antarctica LDB Campaign
  - Decision: The GUSTO Project was approved for an extension provided critical launch readiness milestones are met:
  - 1) complete the GUSTO payload and meet the success criteria for an instrument TVAC Pre-Ship Review in early August 2022;
  - 2) conduct the instrument TVAC test and pass the instrument TVAC Review based on criteria set by the GUSTO SRB/IRT in August 2022; failure to meet and pass these milestones will result in mission termination



XRISM

X-ray Imaging and Spectroscopy Mission

- JAXA, NASA, and ESA partnership
  - XRISM will investigate the X-ray sky using high-resolution spectroscopy and imaging
- NASA *Resolve* and JAXA *Xtend* instruments are integrated with the spacecraft in Japan at NEC
- NASA X-Ray Mirror Assemblies delivered to Japan for optical alignment prior to final integration to the spacecraft in Fall 2022
- Functional tests in 2022 to prepare for JAXA launch in Spring 2023
- XRISM Guest Scientist program for broader US participation in Performance Verification phase through ROSES-22 – proposals due July 21

Photo ©JAXA/NEC

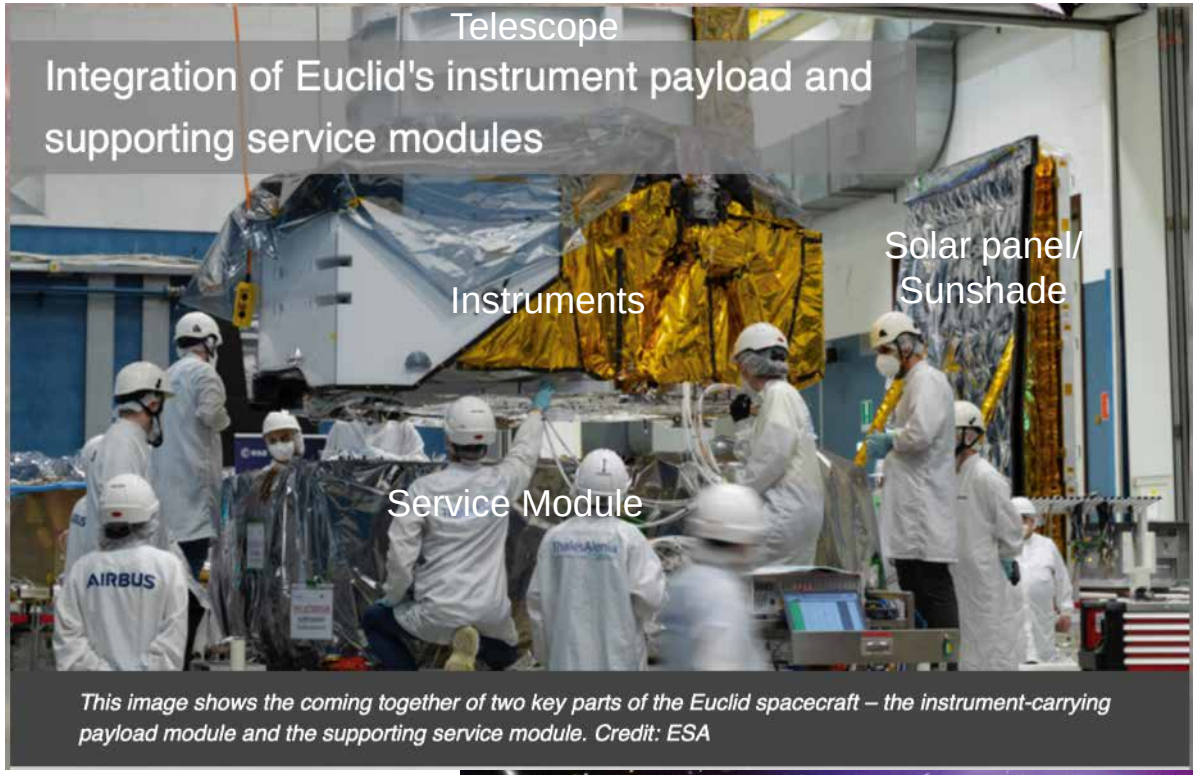
Euclid

ESA and NASA partnership

- Euclid will study the nature of Dark Energy, Dark Matter, and General Theory of Relativity

NASA's contribution:

- Sensor Chip System for the Near Infrared Spectrometer Photometer instrument
- Euclid NASA Science Center at IPAC
- Over 70 US Science Team members



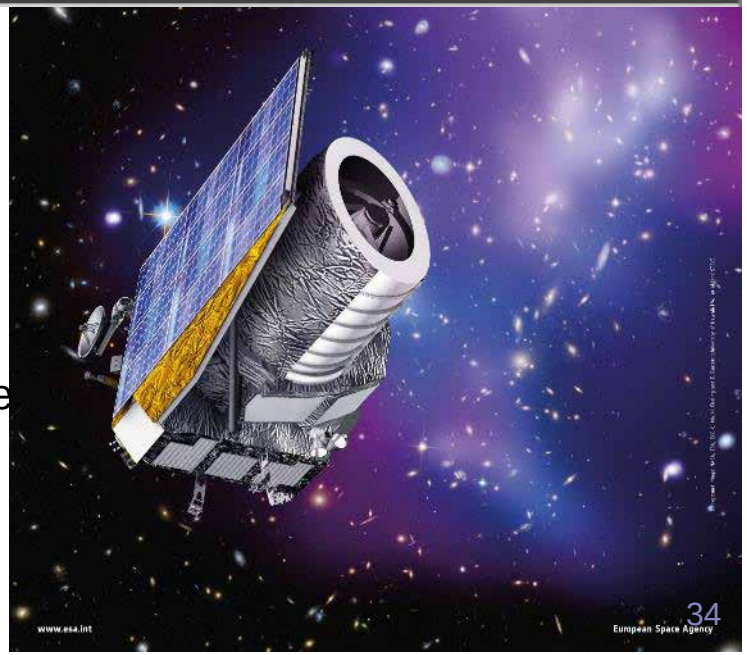
This image shows the coming together of two key parts of the Euclid spacecraft – the instrument-carrying payload module and the supporting service module. Credit: ESA

NASA Status:

- NASA hardware successfully delivered and integrated into NISP
- IPAC science ground segment software deliveries on track
- Three NASA science teams continue science preparation

ESA Status

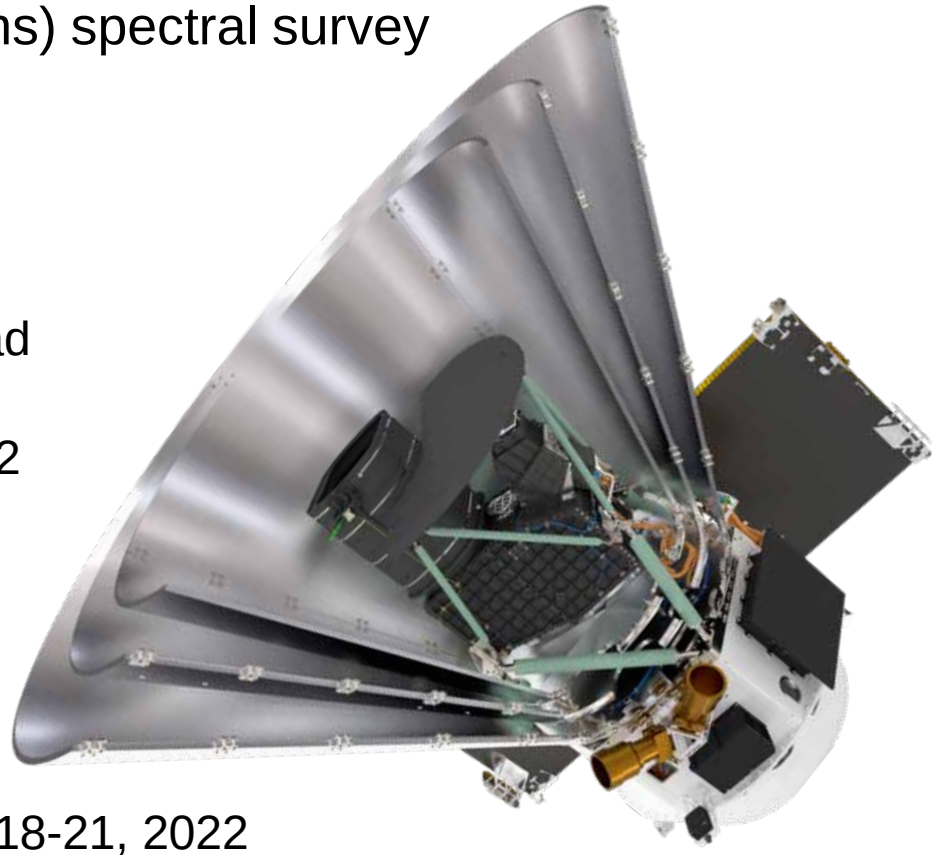
- Instrument-carrying payload module and service module successfully integrated in March 2022 at Thales-Alenia, Italy.
- Additional I&T activities (e.g., solar panels/sunshade) planned through June 2022.
- Launch delays expected
  - Was early-2023 on a Soyuz ST2-1b; Russian cooperation suspended
  - ESA moving towards an Ariane-6 launch with TBD launch date



SPHEREx

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

NASA's first all-sky near-infrared (0.75microns – 5 microns) spectral survey



Status:

- Development of flight detectors completed
- KASI (Korea Astronomy and Space Science Institute) payload thermal test chamber delivered to Caltech May 31, 2022
- Payload thermal subsystem delivery planned for August 2022
- Flight telescope delivery planned for February 2023
- Photon shield payload thermal subsystem is in vendor procurement process, with flight hardware delivery planned for July 2023

Critical Design Review (CDR) successfully completed January 18-21, 2022

Systems Integration Review (SIR) planned for December 2023

Current Agency launch readiness date is April 2025

Compton Spectrometer and Imager (COSI)

PI: John Tomsick, University of California, Berkeley

COSI is Compton imaging spectrometer with cryogenic Ge detectors for 0.1-5 MeV gamma-rays

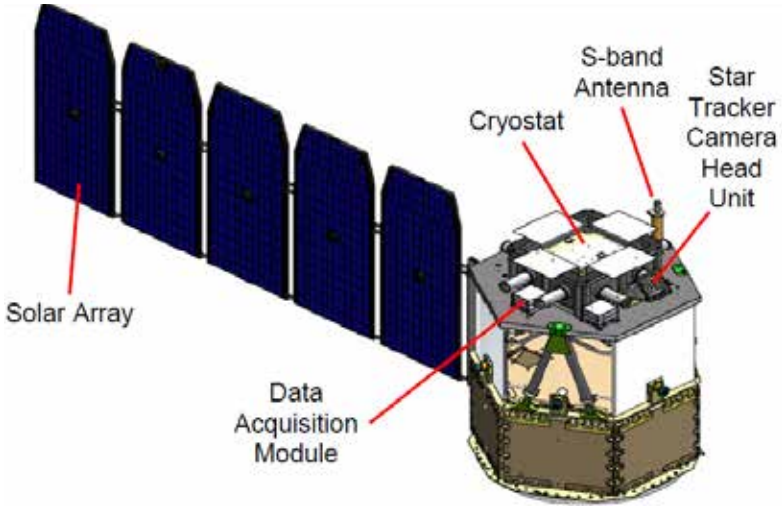
COSI will provide an understanding of the positron excess; map ^{26}Al (half-life 60yr) to study element formation; make the first map of ^{60}Fe (half-life 2.6Myr, only source is core-collapsed SN) to trace past core collapse supernovae; and discover new young supernovae in ^{44}Ti (half-life 0.7Myr).

COSI will gain insight into extreme environments with polarization, such as accreting black holes (AGN and Galactic) and γ-ray bursts (GRBs).

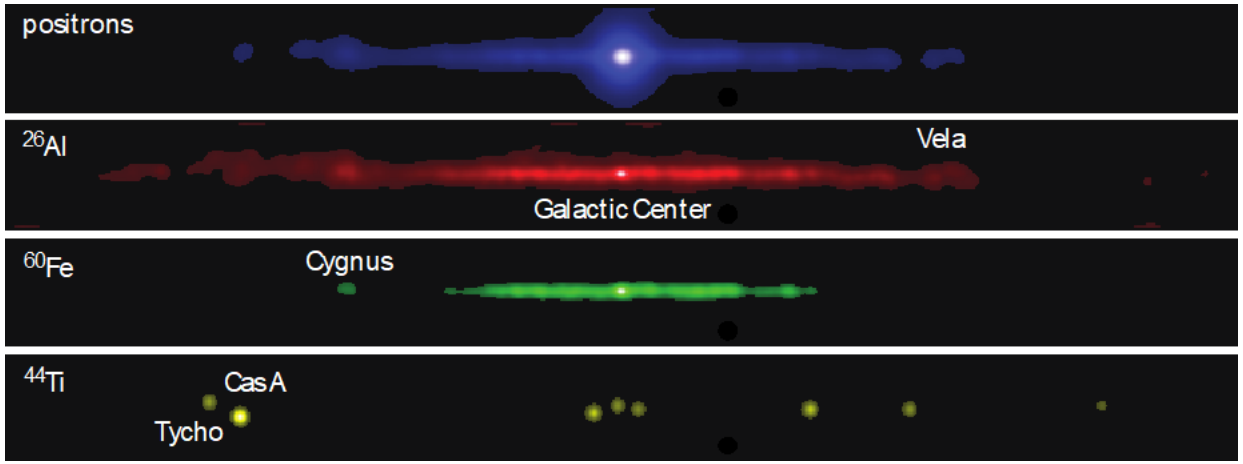
COSI will localize the γ-ray counterparts to GW events (short GRBs) and detect high-energy neutrino counterparts.

System Requirements Review (SRR) currently planned for October 2022.

Launch Readiness Date: Under review.



Simulated Radioactive Milky Way



ARIEL

Atmospheric Remote-sensing Infrared Exoplanet Large survey

ESA and NASA partnership

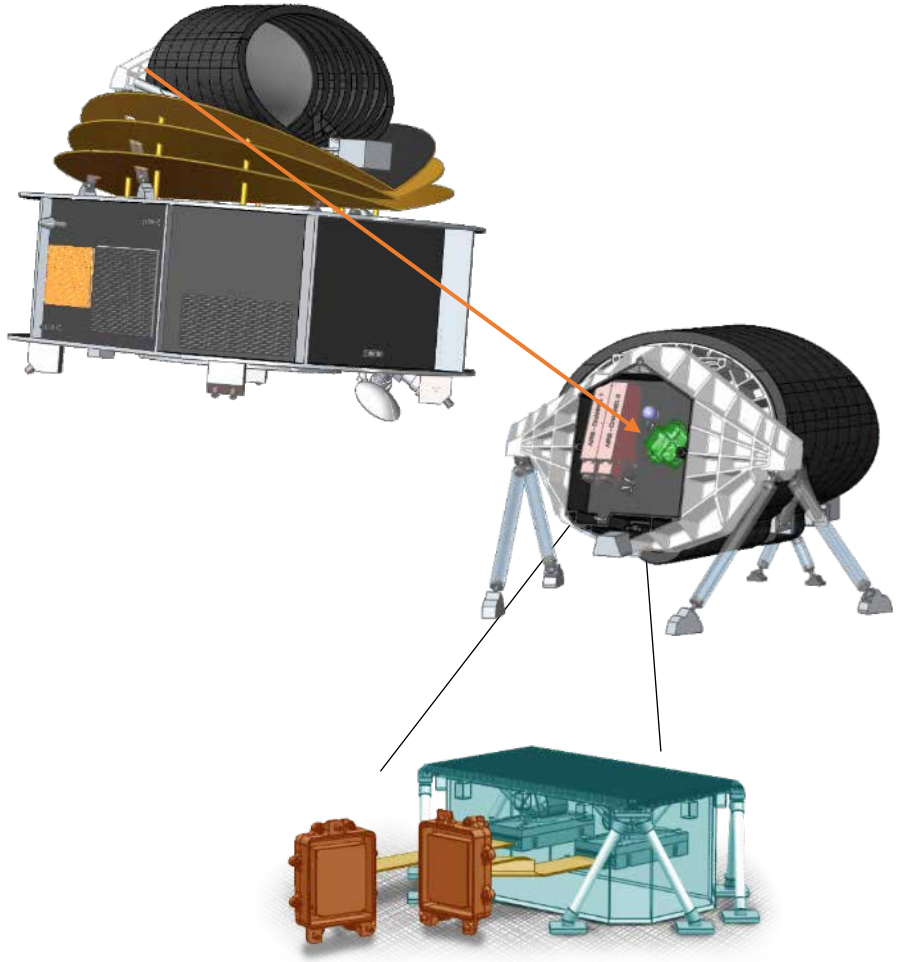
- Observe ~1000 exoplanets
- Survey and characterize exoplanet atmospheres

NASA contribution (CASE) includes detectors and cold front-end electronics, packaging, thermal management, and cryoflex cables for ARIEL Fine Guidance System

Provides US participation in science team, mission survey design, and scientific discoveries

STATUS:

- MOU draft is under State Dept review
- Summer 2022 – NASA Preliminary Design Review
- ~ Oct 2022 – NASA Confirmation
- Fall 2023 – NASA Critical Design Review
- Hardware deliveries late 2024 to 2025
- Launch ~2029



CASE
Contribution to ARIEL Spectroscopy of Exoplanets

ATHENA

Advanced Telescope for High Energy Astrophysics

ESA and NASA partnership

- ATHENA will map hot gas structures and determining their physical properties, search for supermassive black holes in the Hot and Energetic Universe

NASA contributions:

- X-IFU Focal Plane Array (GSFC, NIST-Boulder, LLNL, Stanford, UMBC, UC-Boulder)
- Use of NASA Testing Facilities (MSFC XRCF facility for mirror calibration)
- Vibration Isolation System
- WFI VERITAS ASIC Design and WFI Background Analysis Model
- US Athena Science Center
- Science Grant Program for US Co-Is and Guest Observers

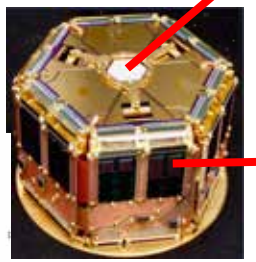
STATUS:

- NASA transitioned from ATHENA study phase to ATHENA project on September 30, 2021. GSFC is the implementing Center
- ESA mission adoption review currently scheduled for June 2024
- Per ESA independent study, mirror will not meet 5'' resolution requirement
- ESA presented the study results to the Science Program Committee on June 9, 2022, for further direction
- SPC decided on a replan with a design-to-cost constraint

x 120

Vibration Isolation System

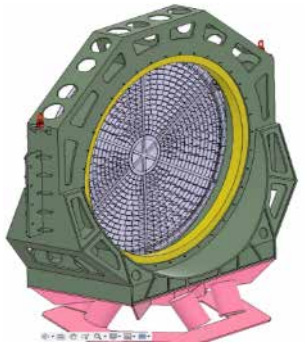
Focal Plane Array



Sensor Assembly

Readout

X-IFU Focal Plane Array



XRCF Mirror Assembly

LISA

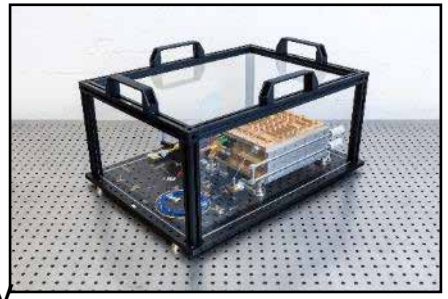
Laser Interferometer Space Antenna

ESA and NASA partnership

- LISA will observe the universe in the millihertz gravitational wave band, detecting tens of thousands of sources ranging from white dwarf binaries in the Milky Way to massive black hole mergers at high redshift.

NASA contributions

- Interferometric Telescopes (GSFC, L3 Harris)
- Laser Systems (GSFC)
- Charge Management Device (U. Florida, Fibertek)
- TBD contributions to data analysis & science (concept study initiated)
- NASA in pre-Phase A Study and technology development managed by Physics of the Cosmos Program Office at GSFC. Systems engineering & science support from JPL & MSFC.

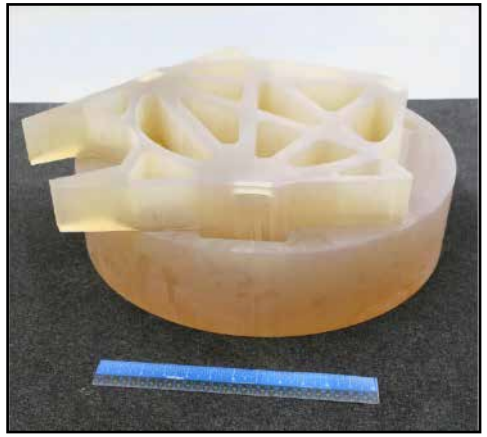


TRL4 laser brassboard

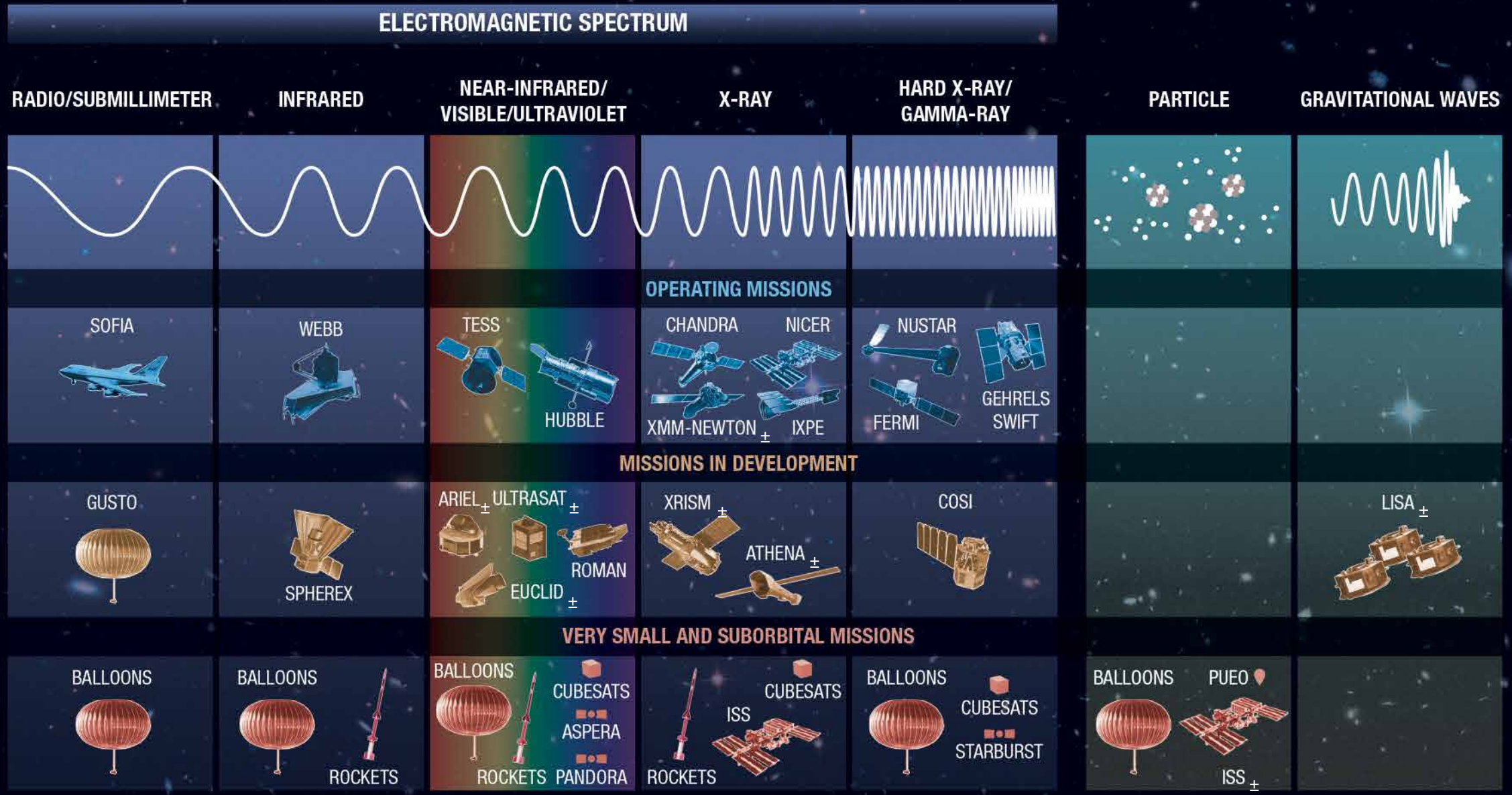
TRL5 Charge Management Unit

STATUS

- ESA development in phase B1
- NASA TRL 4/5 laser shipped in 2021 to ESA designated lab (CSEM) Switzerland for performance testing
- Charge Management Device TRL 6 unit under development
- Telescope Engineering model under development at L3Harris
- September 2023 –



Primary mirror blank for EDU telescope



5 balloon payloads
2 sounding rocket payloads

2 Pioneers smallsats
6 balloon payloads
2 rocket payloads
3 cubesats

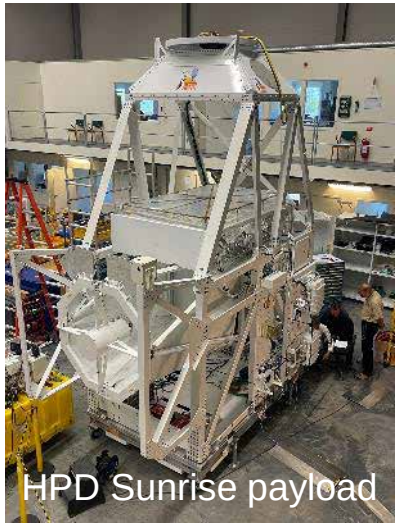
1 Pioneers smallsat
4 balloon payloads
4 sounding rocket payloads
2 cubesats 1 ISS experiment

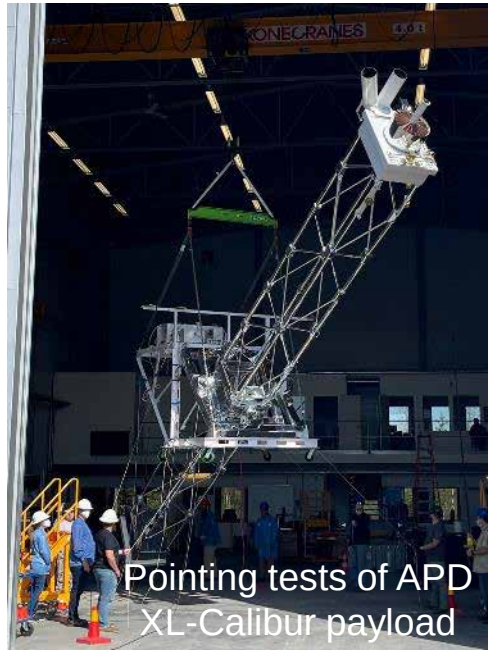
1 Pioneers balloon
4 balloon payloads
1 ISS experiment

March 2022

± Partner-led mission

Balloon Program


HPD Sunrise payload


Pointing tests of APD XL-Calibur payload

Campaigns cancelled due to COVID-19: Spring 2020 (New Zealand), Summer 2020 (Palestine TX), Fall 2020 (Ft Sumner NM), Winter 2020 (Antarctica), Spring 2021 (New Zealand), and Winter 2021 (Antarctica).

Successfully demonstrated Return to Flight using COVID-safe procedures with Spring and Fall **Ft Sumner NM** campaigns in 2021 launching 10 missions with 4 piggy-backs.

Wanaka, New Zealand super-pressure balloon campaign (Mar-May) was one test. Launch attempt resulted in an abort due to an anomaly in non-NASA ground support equipment, ARB ongoing. For FY23 two science missions planned for Wanaka.

Sweden Campaign is ongoing with two science payloads: Sunrise (heliophysics) and XL-Calibur (astrophysics) plus a 60 MCF qualification test flight. First Launch expected for Mid June.

The Fall **Fort Sumner, NM Campaign**, with launch window opening in Aug, has 9 missions plus 7 piggy-backs on the manifest.

The **Antarctica 2022/2023** long-duration balloon campaign has two science missions: SPIDER (astrophysics) and AESOP-lite (heliophysics) on the manifest. Due to delays in meeting payload milestones, the GUSTO mission slipped to the 2023/2024 manifest.

Australia Sounding Rocket Campaign

XQC (X-ray Quantum Calorimeter Experiment)

PI – D McCammon / Univ. Wisconsin (ELA) **2022-06-26**

The purpose of this mission is to measure the spectrum of the diffuse X-ray emission from the interstellar medium over the energy range 0.07 to 1 keV.

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

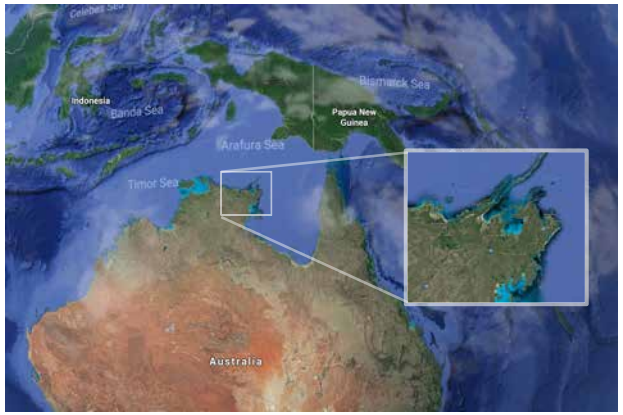
PI - K. France / Univ. Colorado (ELA) **2022-07-04**

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.

DEUCE (Dual-channel Extreme Ultraviolet Continuum Experiment)

PI – I. Fleming / Univ. of Colorado (ELA) **2022-07-12**

Technology development for future UV missions, physics of re-ionization from B stars at extreme UV.

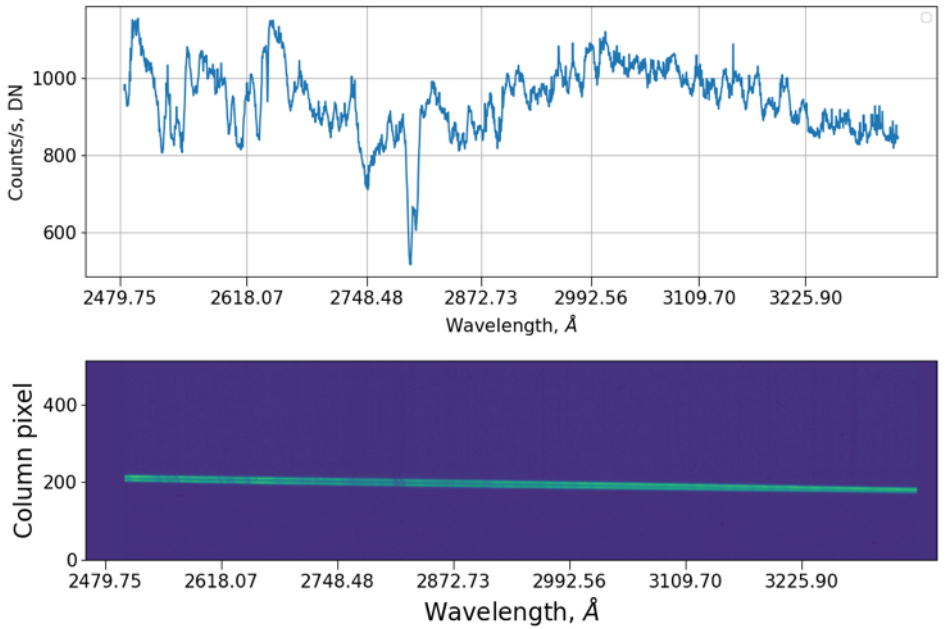


Equatorial Launch Australia (ELA) is a commercial launch site near Arnhem, Northern Territory Launches planned for Jun/Jul 2022.

Images from the RSPO Site set-up travel in Oct 2021.

Colorado Ultraviolet Transit Experiment (CUTE) In Science Operation

- CUTE is a 6U cubesat with an NUV (255 – 330nm) telescope and spectrograph to study transiting planets around bright stars
- Launched September 27, 2021, as a secondary payload on the LANDSAT-9 mission. Spacecraft tracked and communications established within 2 days in coordination with amateur satellite community



- Completed spacecraft and instrument commissioning in February 2022. Science operations underway now (*completing 6 transit observations of first Early Release Science target now*).
- Science mission scheduled to complete in December 2022.

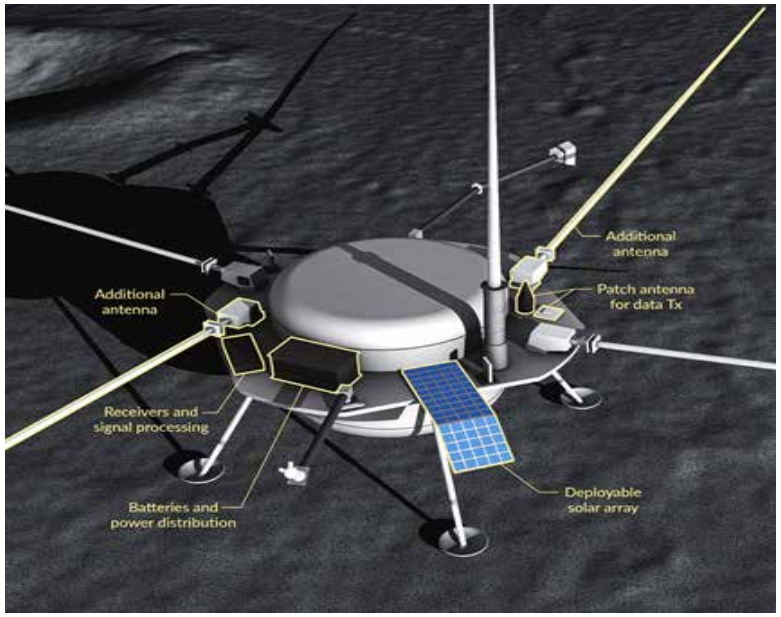
Left: Flux calibration spectrum from CUTE (K. France/University of Colorado)
Right: CUTE on secondary payload adapter

LANDSAT-9 launch
Sept 27, 2021

LuSEE Night

LuSEE Night Details

Lead Developer Org:	**U. California at Berkeley**
LuSEE Payload PI:	**Stuart Bale**
Payload & Science Team:	**DOE Lab under UCB/Bale**
Lunar Landing Location:	**Lunar Farside**
Payload Mass:	**90 kg (including ~50 kg batteries)**
Launch Schedule:	**Landing on lunar surface in Q1 CY25 to coincide with giant planets below lunar horizon**



NASA/DOE Partnership

NASA Scope

- Baseline LuSEE instrument provision
- Systems, mechanical, thermal engineering; Flight qualification; Instrument integration and testing
- Mission operations

DOE Scope

- Added instrumentation design and development
- Leadership of DOE Scientific Team, theory studies, data planning, processing and analysis
- Night survival batteries, solar array for recharging

Science Theme: Dark Ages Science

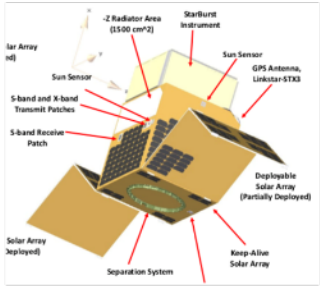
- Pathfinder mission to understand the moon's radio environment & potentially make the first-ever measurement of the Dark Ages
- Capability to measure the radio environment and observe the long-wavelength radio signal through the lunar night
- Place the most sensitive constraints on the Dark Ages signal to date
- Aligned with the DOE High Energy Physics "P5" Science Drivers - Cosmic Acceleration and Dark Matter - as well as the recommendation for small projects
- Astro2020 "Discovery Area" with great potential

Astrophysics Pioneers

- A new class of small missions solicited annually in ROSES. Includes SmallSats, CubeSats >6U, major balloon payloads, modest ISS attached payloads, and cis-lunar payloads (via CLPS); $20M maximum PI cost cap
- Fills in the gap between existing ROSES investigations (<$10M for APRA) and existing Explorers MO investigations (~$35M for SmallSats)

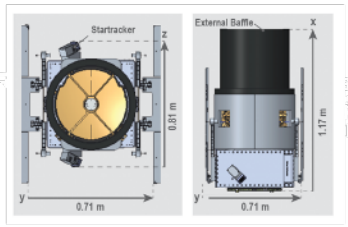
Astrophysics Pioneers – Cycle 1 Selections

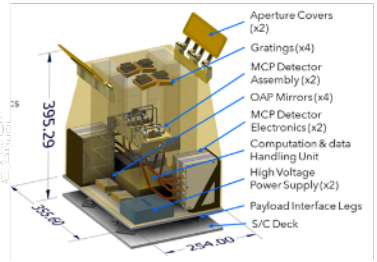
PUEO: A Long-duration Balloon-borne Instrument for Particle Astrophysics at the Highest Energies (PI Abigail Vieregg, U. Chicago) APPROVED for DEVELOPMENT



StarBurst: Gamma-ray ASM, Simultaneous detection of NS/NS mergers with LIGO (PI Daniel Kocevski, NASA MSFC) APPROVED for DEVELOPMENT

Pandora: Multiwavelength Characterization of Exoplanets and their Host Stars (PI Elisa Quintana, NASA GSFC) APPROVED for DEVELOPMENT





Aspera: IGM Inflow/outflow from galaxies via OVI 10^5K emission line imaging (PI Carlos Vargas, U. Arizona) APPROVED for DEVELOPMENT

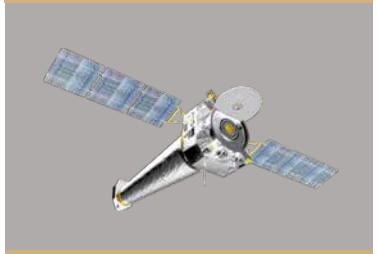
- ROSES-2020, 24 Proposals, 4 selected, all 4 passed gate review!
- ROSES-2021, 18 proposals received, review completed, selections soon
- ROSES-2022 proposals due March 16, 2023

Astrophysics Missions in Operations

Hubble 4/90
NASA Strategic Mission

Hubble Space Telescope

Chandra 7/99
NASA Strategic Mission



Chandra X-ray Observatory

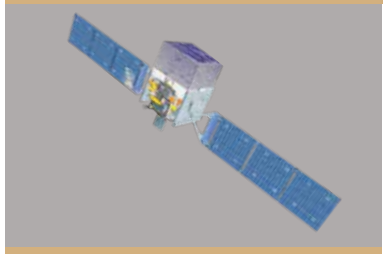
XMM-Newton 12/99
ESA-led Mission

X-ray Multi Mirror - Newton

Gehrels Swift 11/04
NASA MIDEX Mission

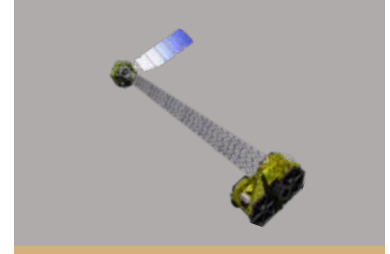
Neil Gehrels Swift Gamma-ray Burst Explorer

Fermi 6/08
NASA Strategic Mission



Fermi Gamma-ray Space Telescope

NuSTAR 6/12
NASA SMEX Mission



Nuclear Spectroscopic Telescope Array

SOFIA 5/14
NASA Strategic Mission

Stratospheric Observatory for Infrared Astronomy

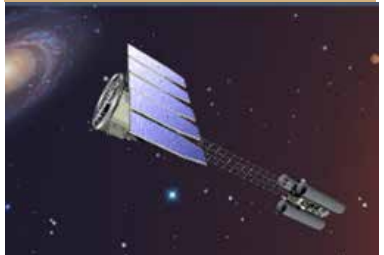
ISS-NICER 6/17
NASA Explorers Miss. of Oppty

Neutron Star Interior Composition Explorer

TESS 4/18
NASA MIDEX Mission

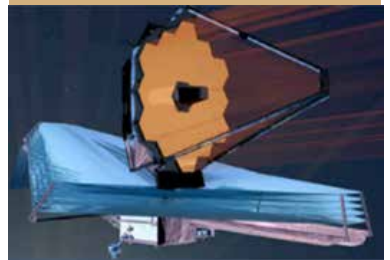
Transiting Exoplanet Survey Satellite

IXPE 12/21
NASA SMEX Mission



Imaging X-ray Polarimetry Explorer

Webb 12/21
NASA Strategic Mission



James Webb Space Telescope

Balloon Program
Four Campaigns per Year

Managed by the Astrophysics Division

Astrophysics Missions in Operations

Hubble 4/90
NASA Strategic Mission

Hubble Space Telescope

Chandra 7/99
NASA Strategic Mission

Chandra X-ray Observatory

XMM-Newton 12/99
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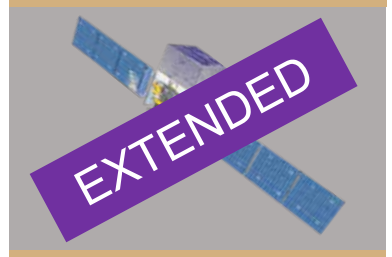

Fermi Gamma-ray Space Telescope

NuSTAR 6/12
NASA SMEX Mission

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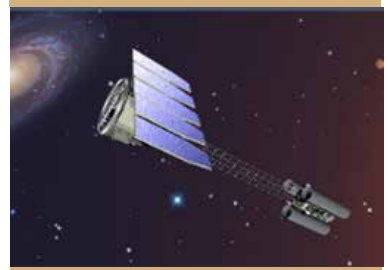
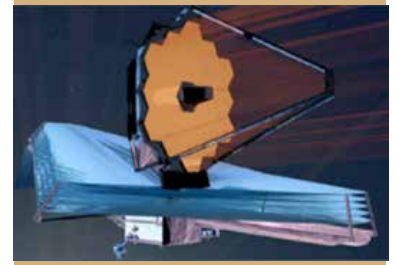


Imaging X-ray Polarimetry Explorer

Webb 12/21
NASA Strategic Mission



James Webb Space Telescope

Balloon Program
Four Campaigns per Year

Managed by the Astrophysics Division

Imaging X-ray Polarimetry Explorer (IXPE)

Launched Dec 9

Boom deployed Dec 15

Science started Jan 10

Special Session on IXPE Initial Results
Tuesday 14 June, 8:30 am in Con Rm 101

- Positive, statistically significant detections of polarization!
  - CAS-A, 4U 0142, Mrk 501, Crab and Vela pulsar wind nebulae, Her X-1
  - Discovery papers to Nature, Science, and the Astrophysical Journal are in progress and/or have been submitted

SOFIA

SOFIA Town Hall
June 15 at 6:30pm
in Ballroom C

The Decadal Survey recommended NASA end the SOFIA mission after its current mission extension.

On April 28, NASA and DLR (the German Space Agency) jointly announced that they will conclude the SOFIA mission, after a successful eight years of science.

SOFIA will finish out its scheduled operations for the 2022 fiscal year, followed by an orderly shutdown.

During FY 2022, SOFIA will carry out a full program of science operations including multiple deployments to the southern hemisphere.

During FY 2022, SOFIA will prioritize completing legacy surveys to establish an enduring archive of data for community use. Over 80% of Cycle 9 selected investigations will be completed; some selected proposals will not get conducted due to scheduling conflicts.

Airborne Astronomy Ambassadors (AAA), the SOFIA teachers-in-flight program, will continue to operate during FY 2022.

Proposals for Cycle 10 (FY 2023) were received earlier this year; no selections will be made from the Cycle 10 proposals.

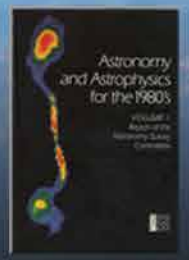
The SOFIA project has been directed to develop a project closeout plan for FY 2023.

Implementing the 2020 Decadal Survey

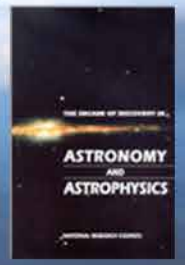
Astrophysics

Decadal Survey Missions

1972
Decadal Survey
Hubble



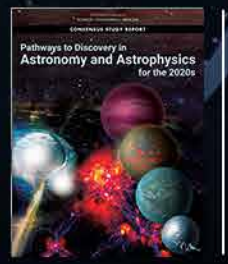
1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer

2001
Decadal Survey
Webb

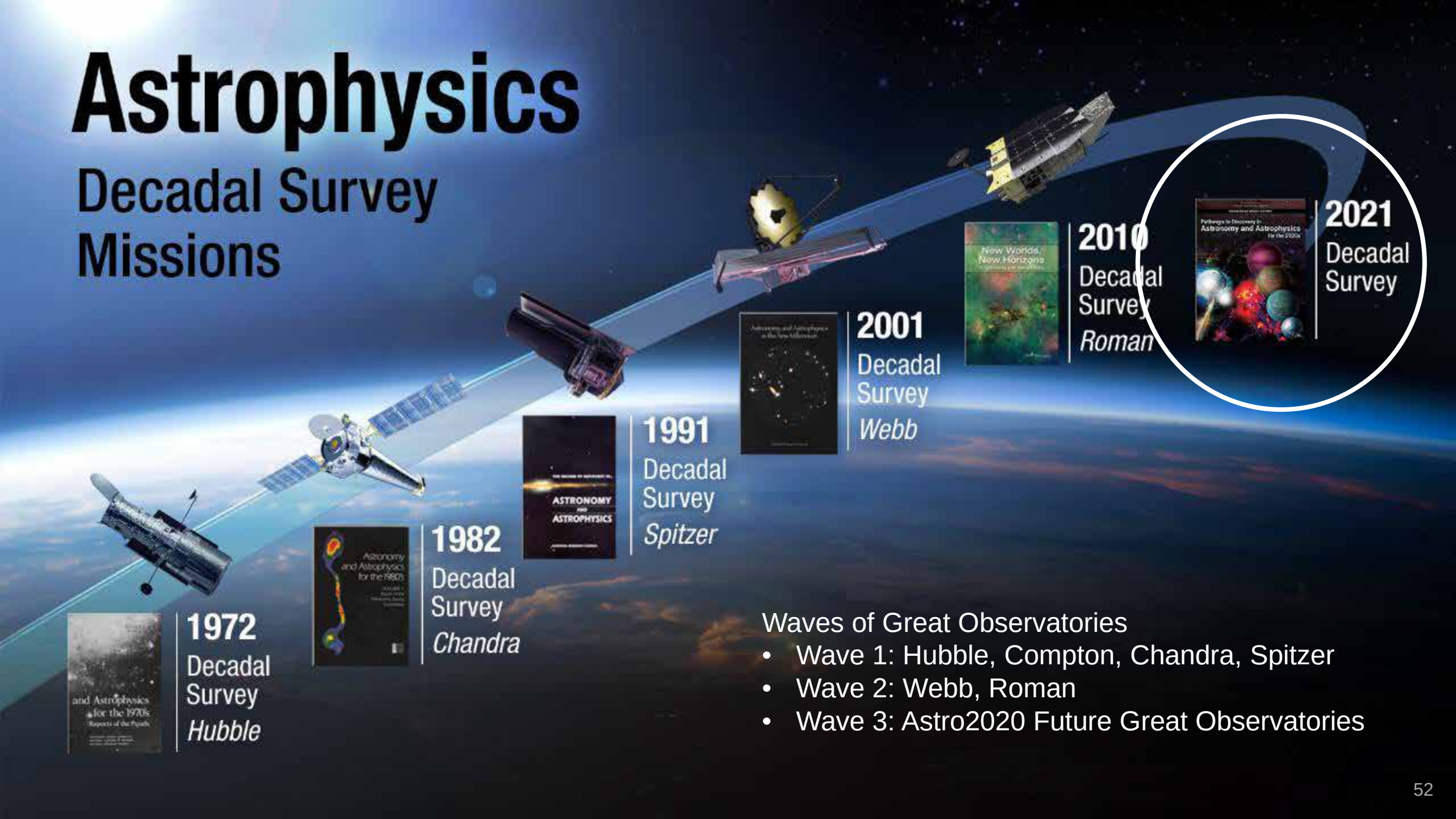
2010
Decadal Survey
Roman



2021
Decadal Survey

Astrophysics

Decadal Survey Missions



Waves of Great Observatories

- Wave 1: Hubble, Compton, Chandra, Spitzer
- Wave 2: Webb, Roman
- Wave 3: Astro2020 Future Great Observatories

Decadal Survey Implementation Update

Page	Recommendation	NASA Actions
3-22	IDEA workforce	SMD bridge program appropriated for FY22
3-23	Postdoc fellowships	Independent review conducted of NASA Hubble Fellowship Program to improve inclusion and diversity
3-29	Proposal demographics	National Academies study on the "Foundation for Assessing the Health and Vitality of the NASA Science Mission Directorate's Research Communities" underway
3-30	IDEA evaluation criteria	Inclusion plans required in 8 astrophysics ROSES elements
5-12	SOFIA	SOFIA will conclude its mission by September 30, 2022
6-8	Balloon program review	APAC task force approved at March APAC meeting
7-11	Great observatories program	Precursor science workshops in April and August 2022
7-19	Time domain program	Time domain workshop planned for August 2022
7-20	Astrophysics probes	AO announced for mid 2023
7-35	Roman science program review	CAA working group is conducting a non-advocate review

Decadal Survey Implementation Update

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7-19	Tim… domain program	Time domain workshop planned for August 2022
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Additional initiatives are being considered for inclusion in the FY24 NASA budget request

Time Domain & Multi-Messenger Initiative

Operating Missions

- Hubble
- Chandra
- Gehrels Swift
- Fermi
- CALET (w/ JAXA)
- AMS (DOE mission)
- NICER
- TESS

Missions in Development

- BurstCube (cubesat)
- BlackCat (cubesat)
- PUEO (balloon payload)
- StarBurst (Pioneer)
- UltraSat (w/ ISA)
- COSI (SMEX)
- Roman

Future Missions under study or being proposed

- THESEUS (w/ ESA)
- Proposed CubeSat
- Proposed Pioneer
- Proposed Mission of Opportunity
- Proposed MIDEX
- Future Probe

Time Domain & Multi-Messenger Initiative

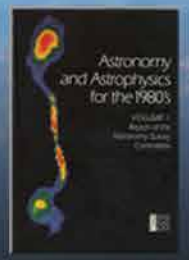
Actions are being developed to address Time Domain Astrophysics and Multi Messenger (TDAMM) recommendations of the 2020 Decadal Survey

- Operating NASA missions continue to make significant contributions to TDAMM and NASA expects future missions to pursue this science:
  - NASA is making investments in infrastructure – transient alerts, data archives, communications, software – which are essential to maximize scientific return; funding for these investments is included in the FY23 budget request.
  - Responding to transient astrophysical phenomena involves multiple ground- and space-based assets and NASA is studying efficiencies in how to deploy its fleet
  - Astro 2020 urges TDAMM be addressed across agencies and NASA is standing up interagency and international working groups to address this coordination
- TDAMM will be an initiative with extensive interagency and international cooperation, shaped using broad community input
  - Prioritizing the science NASA should address. Community workshop this 22-24 August 2022: https://pcos.gsfc.nasa.gov/TDAMM/
  - Partner-led TDAMM missions with NASA contributions
  - NASA missions with international partner contributions

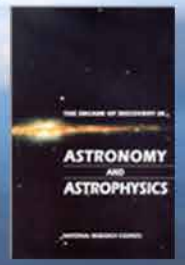
Astrophysics

Decadal Survey Missions

1972 Decadal Survey *Hubble*



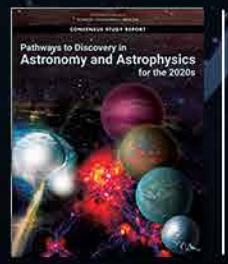
1982 Decadal Survey *Chandra*



1991 Decadal Survey *Spitzer*

2001 Decadal Survey *Webb*

2010 Decadal Survey *Roman*



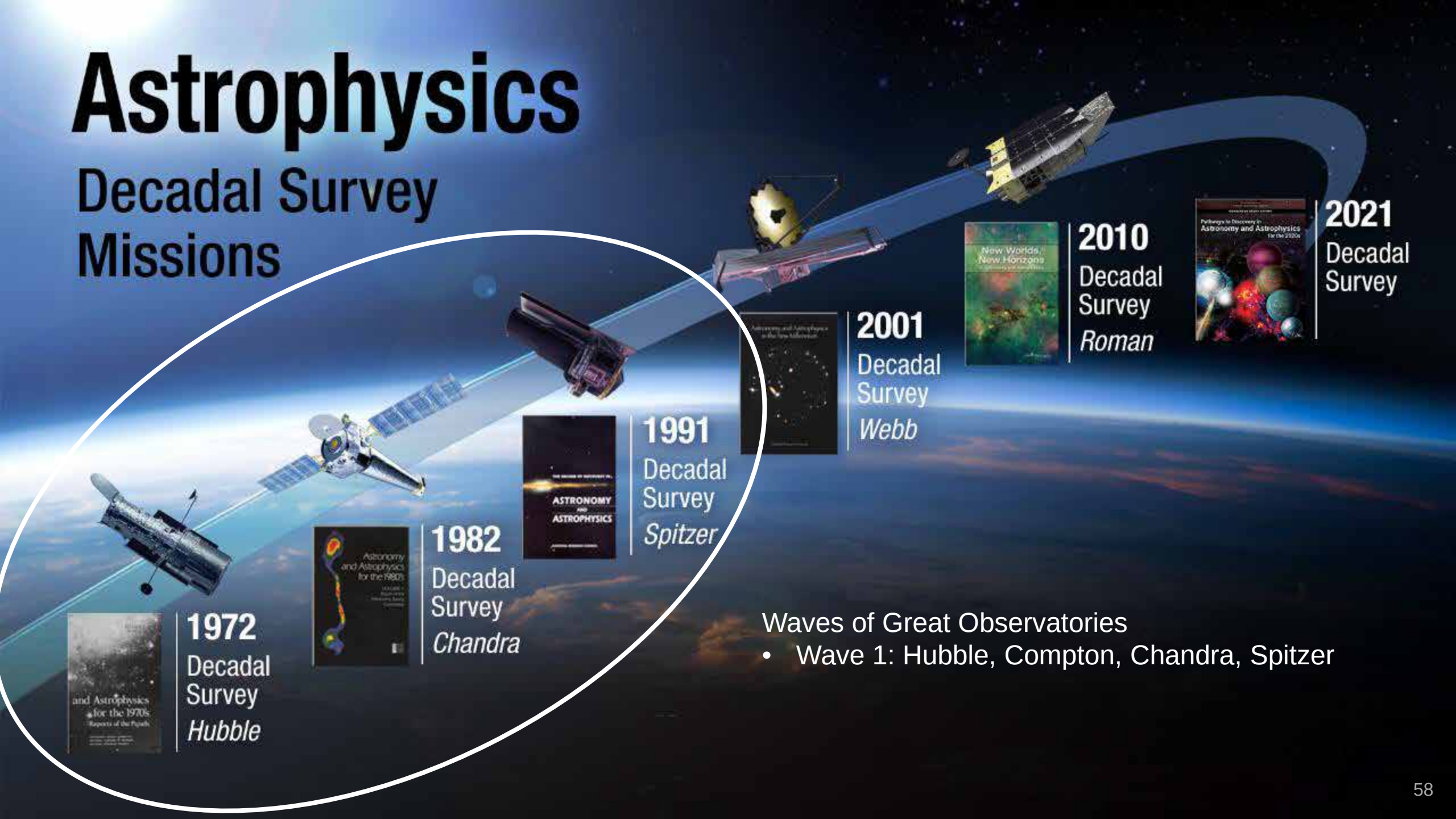
2021 Decadal Survey

We are bound by the budgets that we have

- First budget that is fully informed by the Decadal Survey will be the FY24 budget proposal, which will be formulated by NASA Astrophysics in Spring 2022 and submitted to Congress in February 2023

Astrophysics

Decadal Survey Missions

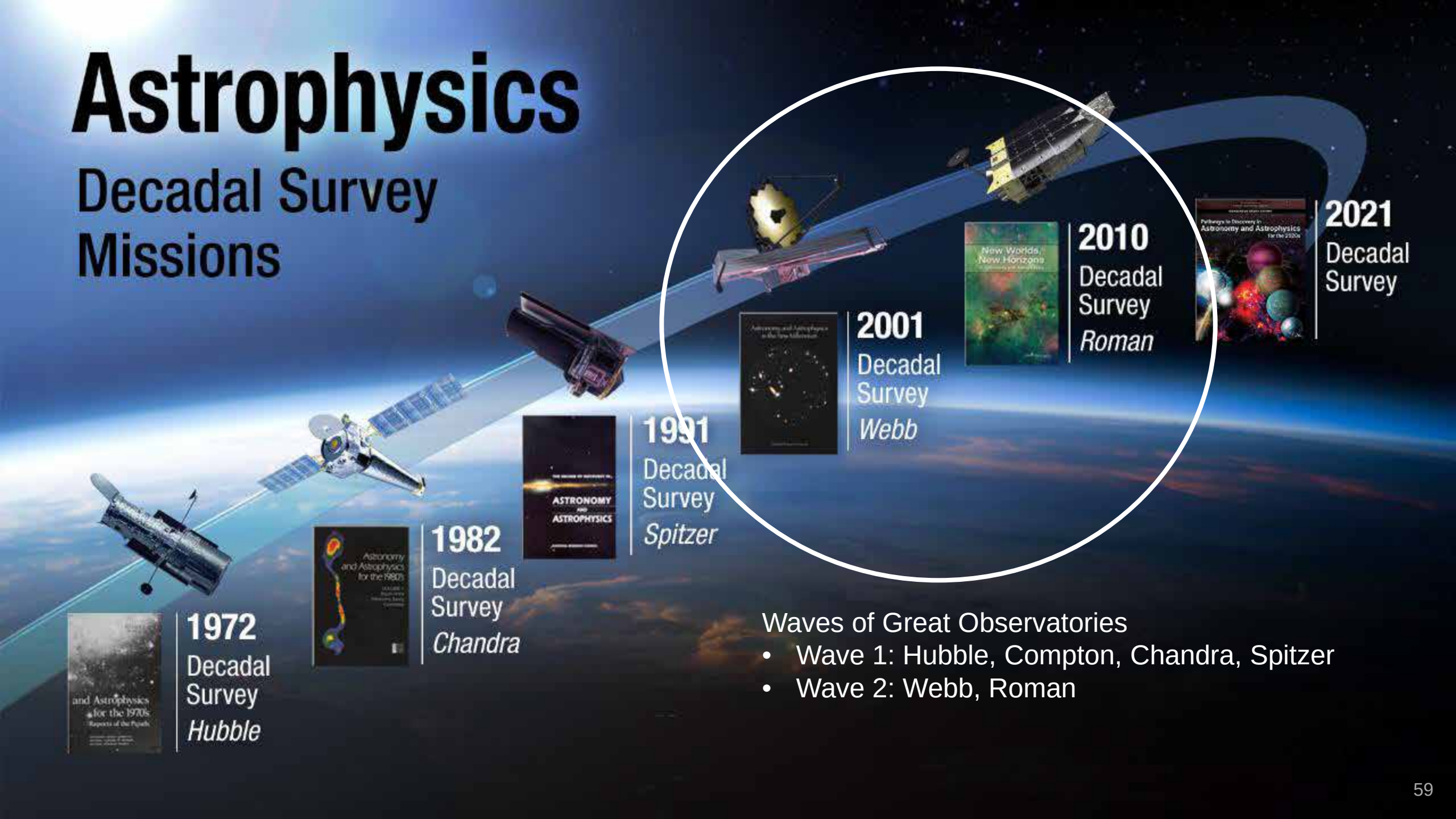


Waves of Great Observatories

- Wave 1: Hubble, Compton, Chandra, Spitzer

Astrophysics

Decadal Survey Missions



Waves of Great Observatories

- Wave 1: Hubble, Compton, Chandra, Spitzer
- Wave 2: Webb, Roman

Future Great Observatories

Large observatories are a critical component of NASA's astrophysics portfolio

- The Decadal Survey recommends a compelling, feasible, timely portfolio of future great observatories that is part of a balanced Astrophysics program

Today NASA's priority is ensuring mission success for Webb and Roman

- Webb completed telescope commissioning; science instrument commissioning is progressing well; preparations are underway for science to commence in July 2022.
- Roman is progressing well in Mission Phase C "Final Design and Fabrication" and is on track for a mid-2027 launch

Now is not the time to start a Future Great Observatory; now is the time to prepare

NASA will take a deliberate, multi-stage planning and strategy approach to the next large observatory mission

- Stage 1 – Begin the Decadal Survey recommended "Great Observatories Maturation Program". Focus on enabling science and technology; begin Stage 1 now
- Stage 2 – Conduct Analysis of Alternatives (AoA) and science / technology / architecture trades; begin Stage 2 in a few years (driven by planning and budget availability)
- Stage 3 – Pre-formulation and decision to start the next Great Observatory; begin after Stage 2 AoA complete (Decadal Survey estimates 6 years for Stages 2 and 3)

STAGE 1 ACTIVITIES

Science	Workshops - compile metrics and science gaps	Update ROSES Call	Determine efforts beyond ROSES	ROSES Selected	Science Gaps Identified for 3 Great Observatories	Begin Precursor Science Funded activities
				SCIENTIFIC ASSESSMENT →		
Science Evaluation	Stand up Team	Develop initial Metrics	Develop input parameters	Sensitivity study of key parameters	Iterate with SST and TST	Update sensitivity study with new parameters
				TECHNOLOGY DEVELOPMENT →		
Technology	Stand up Team	ID Tech Gaps	Develop high level Tech Dev plans	ID tech studies. Trades & study groups	ID long lead tech investments	Begin tech studies

Note: This is not a timeline; some activities within each lane occur in parallel
There is cross-communication and cross-participation between activities in different rows
ROSES call for presursor science investigations anticipated for January 2023

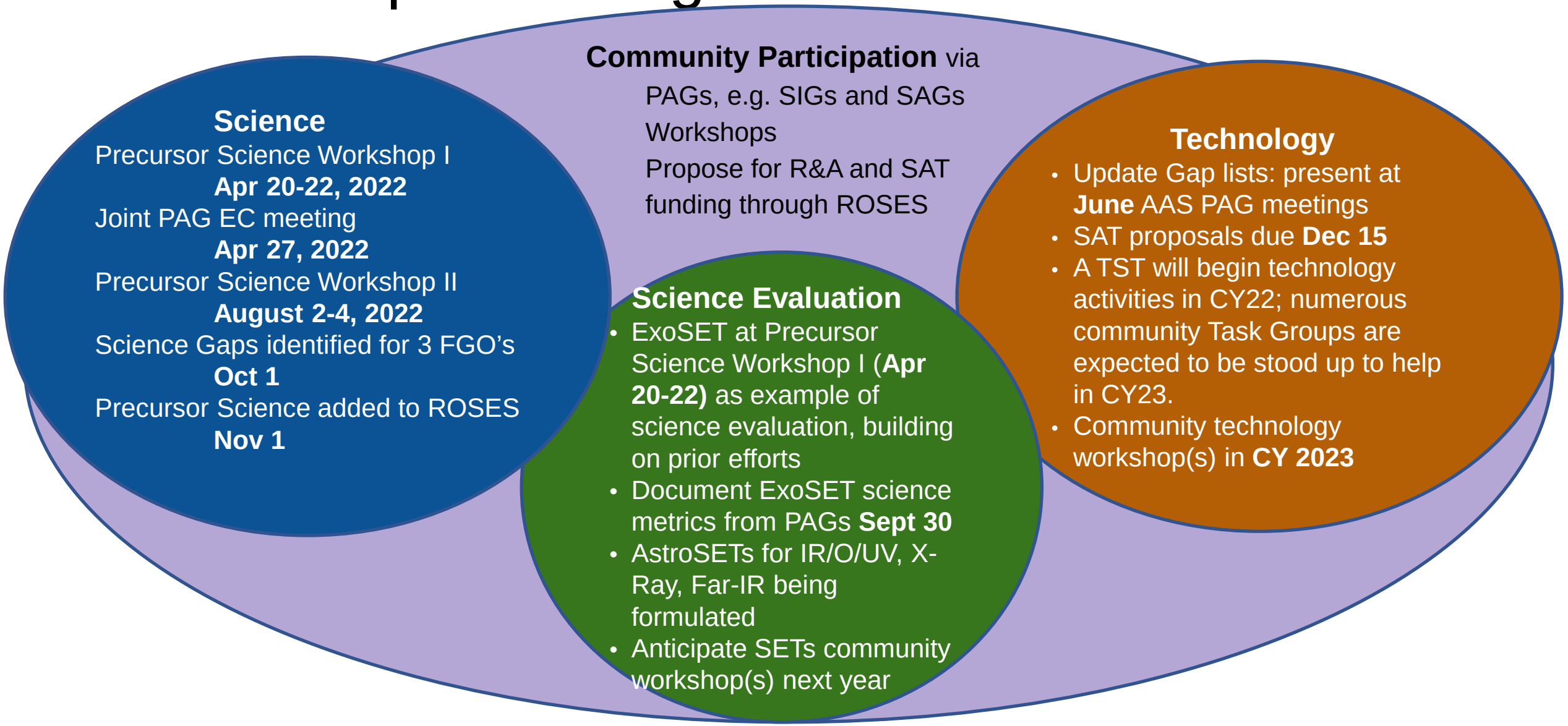
Technology Report and Gaps List

The COR, ExEP, and PCOS Program Offices just completed a new technology gap prioritization cycle, informed by the Astro2020 Decadal Survey

The outcome of this exercise is a new joint Astrophysics Technology Gap List, which divides the 57 Astrophysics technology gaps into five priority tiers

- This gap list and updates on the current state of Astrophysics technology development and infusions are presented in the 2022 Astrophysics Biennial Technology Report (ABTR), now available through the Program Office technology webpage

Next Steps for Stage 1



Large Mission Study

SMD Large Missions Study Implementation Plan

No.	Large Missions Study Recommendation	Disposition	Large Missions Study Implementation Plan
1	*Pre-Phase A Team Composition*	Accept	Staffing will be based on needed skill sets and expertise (not based on availability of personnel). An Agency-wide search shall be conducted, followed by a nationwide search, if needed
2	*Pre-Phase A Architecture Trades and Descope Options*	Accept	Program Office will conduct independent assessment of Pre-Phase A architecture trades and descope options for evaluation at KDP-A. Implementation effective immediately.
3	*System Maturity Assessment*	Accept w/Follow-Up	Further action is required. A team, sponsored by the SMD DAA/P and led by the SMD Chief Engineer, will be formed for further investigation.
4	*Technology Integration into Complex Systems*	Partially Accept	Mandate increased scrutiny of technology maturity at reviews and KDPs. Implementation effective immediately. Further action is required - A strategic approach will be developed by the SMD Chief Technologist to identify technology needs and funding sources for technology development.
5	*Analytical Tools*	Partially Accept	Large strategic missions will incorporate common tool sets, when possible, and establish an agreed margin and risk philosophy with partners and providers early in the life cycle.
6	*Cost and Schedule Estimation*	Accept	Life cycle cost estimates shall be communicated in terms of bins for Pre-Phase A and ranges for Phases A and B to set external expectations. Implementation effective immediately.
7	*Standing Review Boards (SRBs)*	Accept	The SMD policy of convening the SRBs prior to MCR, and when required, convening of the Independent Review Boards (IRBs), has already been implemented. Initiating SRB kickoff meetings.
8	*Instrument Selection Process*	Partially Accept w/Follow-Up	Further action is required. A team led by the SMD Deputy AA for Research will be established. Modification of SMD policy may be required.
9	*SMD Capabilities*	Accept	Program Offices of large missions will be adequately staffed early in pre-formulation in order to perform programmatic assessments and oversight. Implementation effective immediately.
10	*Center Capabilities*	Accept	SMD and Centers have ownership and accountability of large strategic missions and will work closely to identify and solve problems. Implementation effective immediately.

The SMD Large Missions Implementation Plan will require an intentional shift in how we approach the development of our missions

https://science.nasa.gov/about-us/large-mission-study

October 2019 – October 2020

Large Mission Study

SMD Large Missions Study Implementation Plan

No.	Large Missions Study Recommendation	Disposition	Large Missions Study Implementation Plan
1	*Pre-Phase A Team Composition*	Accept	Staffing will be based on needed skill sets and expertise (not based on availability of personnel). An Agency-wide search shall be conducted, followed by a nationwide search, if needed
2	*Pre-Phase A Architecture Trades and Descope Options*	Accept	Program Office will conduct independent assessment of Pre-Phase A architecture trades and descope options for evaluation at KDP-A. Implementation effective immediately.
3	*System Maturity Assessment*	Accept w/Follow-Up	Further action is required. A team, sponsored by the SMD DAA/P and led by the SMD Chief Engineer, will be formed for further investigation.
4	*Technology Integration into Complex Systems*	Partially Accept	Mandate increased scrutiny of technology maturity at reviews and KDPs. Implementation effective immediately. Further action is required - A strategic approach will be developed by the SMD Chief Technologist to identify technology needs and funding sources for technology development.
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https://science.nasa.gov/about-us/large-mission-study
October 2019 – October 2020

★ Astro2020 recommendations for the Great Observatories Mission and Technology Maturation Program (aka GOMAP)

Great Observatories Mission and Technology Maturation Program (GOMAP)

Objectives

- GOMAP will co-develop and mature the science, mission architecture, and technologies for Astro2020's NASA flagships
- Engage stakeholders and leverage the entire multi-sector community: industry, academia, NASA centers, other agencies, and international partners
    - Support trade studies, technology development, integrated modelling, and other feedback via openly competed procurements
    - Host open, hybrid workshops with published outcomes
    - Majority (>80%) of funding will be competed
- Intentionally seek out, build upon, and leverage the IDEA community to enable an inclusive culture and broad participation by all as the missions evolve
    - Adopt affirmative codes of conduct
- Engage community groups in all mission phases for developing science requirements and priorities; thereafter, prevent science-scope creep
    - Continually engage new science community members as the activities evolve
- Communicate broadly to community for transparency and confidence in the process

The End

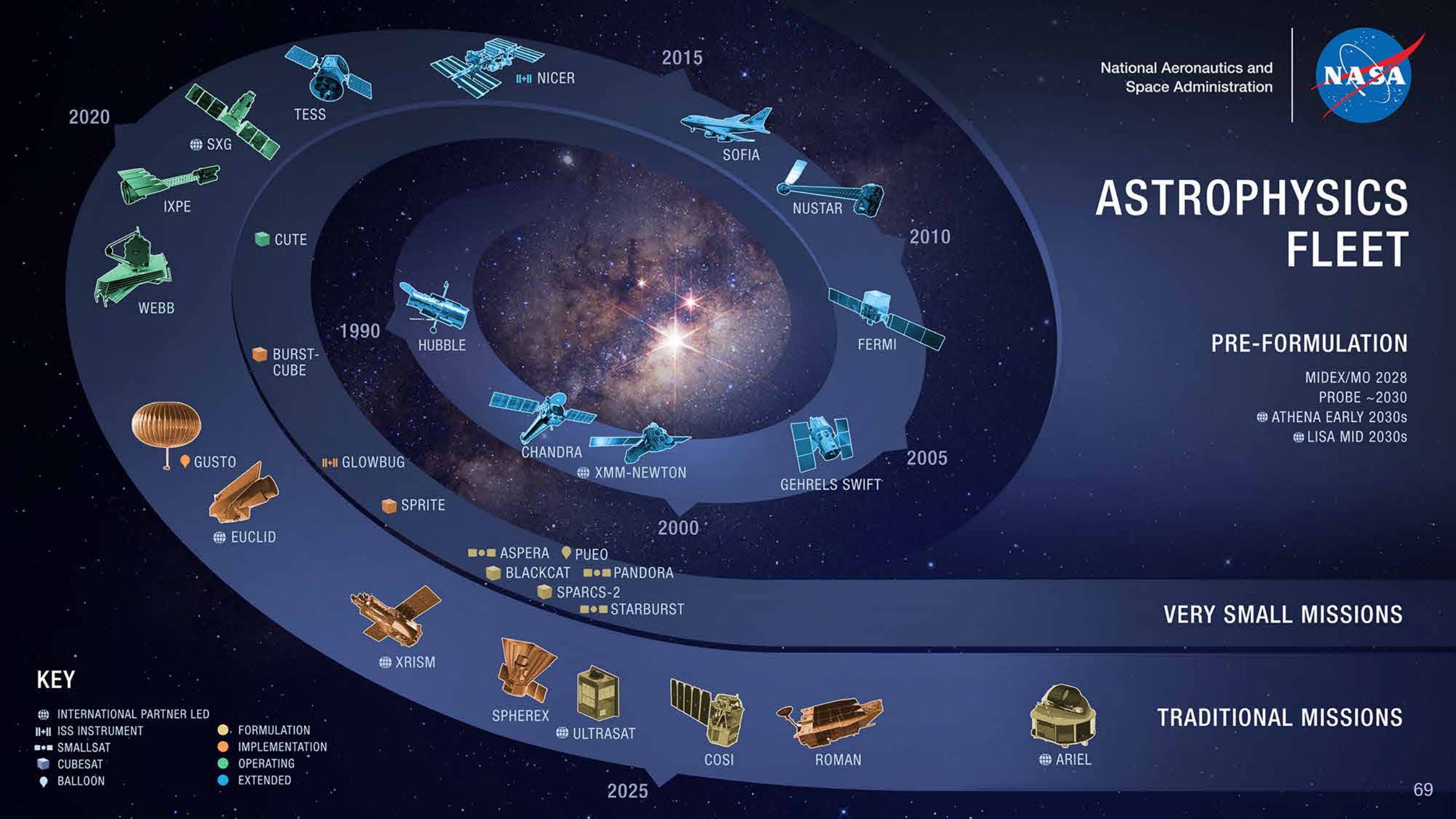
What's next for Astrophysics?

I will be stepping down this summer after more than 10 years as Director of Astrophysics (the best job at NASA)

- This is my last Joint PAG plenary address
- Ten years makes me the longest serving Director of Astrophysics in the history of NASA
- Once the new Director of Astrophysics is in place, I will move to the SMD Front Office as Senior Advisor to the SMD Associate Administrator

Applications are in and the review is underway to identify the person who will lead NASA astrophysics in the upcoming era of

increasing inclusion and diversity,
growing R&A,
Webb science,
Roman development,
exoplanet characterization,
time domain and multi-messenger astrophysics,
dark energy and dark matter,
first Astrophysics Probe,
more Explorers / Pioneers / cubesats,
future great observatories,
and realizing Decadal Survey priorities


National Aeronautics and Space Administration
NASA
ASTROPHYSICS FLEET
PRE-FORMULATION
MIDEX/MO 2028
PROBE ~2030
ATHENA EARLY 2030s
LISA MID 2030s
2020
2015
2010
2005
2000
1990
2025
TESS
NICER
SXG
SOFIA
IXPE
NUSTAR
CUTE
WEBB
HUBBLE
FERMI
BURST-CUBE
CHANDRA
XMM-NEWTON
GEHRELS SWIFT
GUSTO
GLOWBUG
SPRITE
EUCLID
ASPERA
PUEO
BLACKCAT
PANDORA
SPARCS-2
STARBURST
VERY SMALL MISSIONS
XRISM
SPHEREX
ULTRASAT
COSI
ROMAN
ARIEL
TRADITIONAL MISSIONS
KEY
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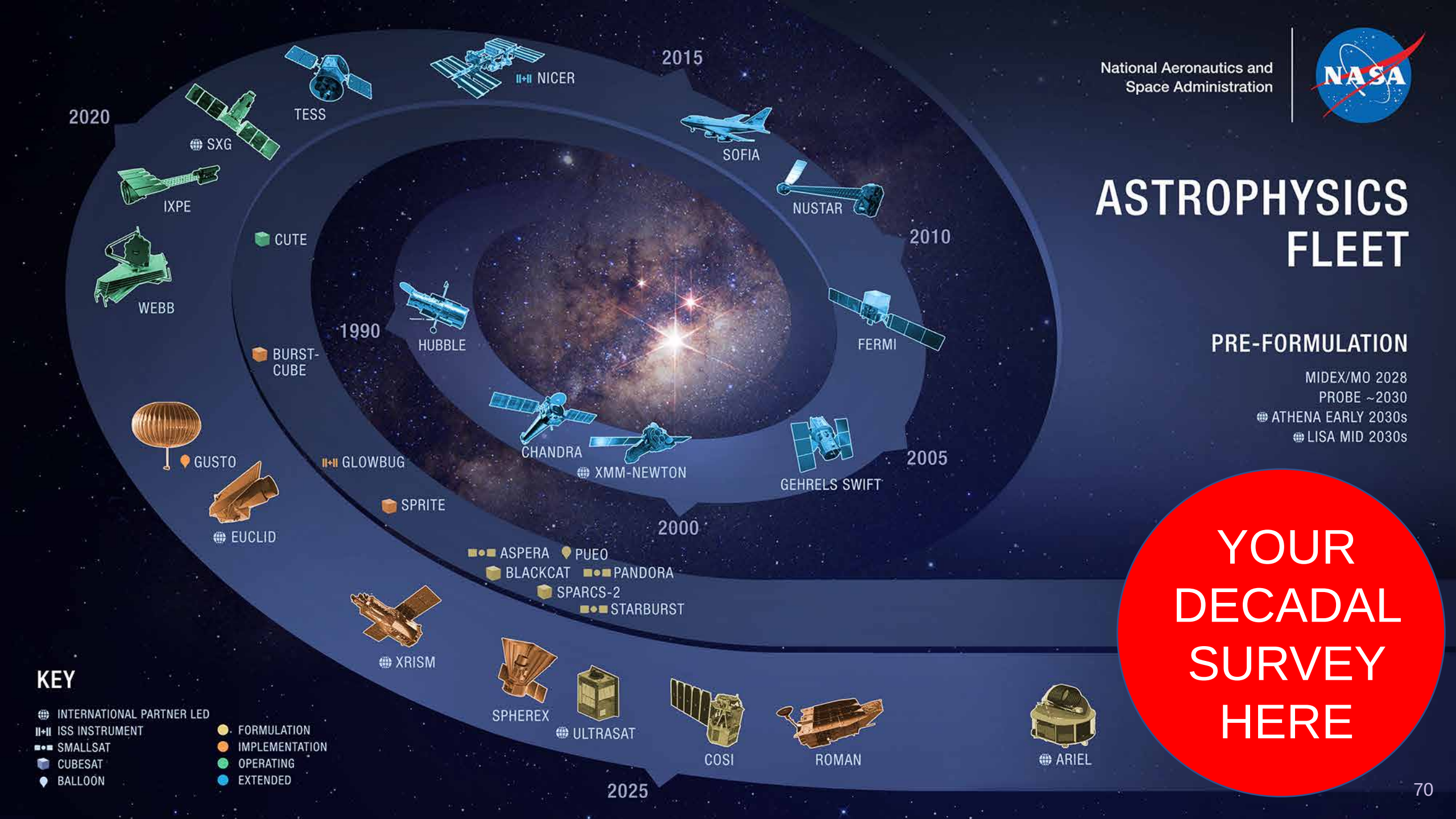
ISS INSTRUMENT
SMALLSAT
CUBESAT
BALLOON
FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED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EXTENDED
YOUR DECADAL SURVEY HERE

BACKUP

Astrophysics Science Program Content ($M)

	Actual	Enacted	Request	Out-Years			
	FY21	FY22	FY23	FY24	FY25	FY26	FY27
Astrophysics	**$1,770.9**	**$1,568.9**	**$1,556.0**	**$1,597.0**	**$1,578.5**	**$1,620.5**	**$1,625.6**
Astrophysics Research	$249.3		$329.8	$350.8	$345.5	$348.4	$350.1
Astrophysics Research and Analysis	*$91.1*		*$111.0*	*$113.0*	*$114.1*	*$115.2*	*$116.4*
Balloon Project	*$44.8*		*$45.7*	*$46.3*	*$46.3*	*$46.3*	*$46.3*
Science Activation	*$45.6*		*$55.6*	*$55.6*	*$55.6*	*$55.6*	*$55.6*
Other Missions and Data Analysis (research and management)	*$67.8*		*$117.6*	*$135.9*	*$129.5*	*$131.2*	*$131.9*
Astrophysics Directed R&T	$0.0		$0.0	$9.0	$0.0	$0.0	$0.0
Contract Administration, Audit & QA Svcs	$17.7		$17.3	$19.6	$19.6	$19.6	$19.6
Astrophysics Senior Review	$0.0		$48.3	$52.5	$53.1	$53.7	$54.1
Astrophysics Data Program	$21.6		$23.6	$23.8	$24.0	$24.3	$24.5
Astrophysics Data Curation and Archival	$28.5		$28.4	$31.0	$32.7	$33.7	$33.7
Cosmic Origins	$618.5		$298.5	$316.5	$316.3	$316.6	$316.6
James Webb Space Telescope	*$414.7*		*$172.5*	*$187.0*	*$187.0*	*$187.0*	*$187.0*
Webb Science	$1.2		$51.0	$60.0	$60.0	$60.0	$60.0
James Webb Space Telescope	$413.5		$121.5	$127.0	$127.0	$127.0	$127.0
Hubble Space Telescope (HST)	*$93.3*		*$93.3*	*$98.3*	*$98.3*	*$98.3*	*$98.3*
Other Missions and Data Analysis	*$110.5*		*$32.7*	*$31.2*	*$31.0*	*$31.3*	*$31.3*

Astrophysics Science Program Content ($M)

	Actual	Enacted	Request	Out-Years			
	FY21	FY22	FY23	FY24	FY25	FY26	FY27
Cosmic Origins	$618.5		$298.5	$316.5	$316.3	$316.6	$316.6
(development/formulation/technology)							
Cosmic Origins SR&T	$18.3		$13.9	$21.4	$21.4	$21.4	$21.4
Cosmic Origins Future Missions	$1.2		$2.1	$3.0	$3.0	$3.0	$3.0
(operating)							
Stratospheric Observ for Infrared Astron	$85.2		$10.0	$0.0	$0.0	$0.0	$0.0
(research and management)							
Astrophysics Strategic Mission Prog Mgmt	$5.8		$6.8	$6.9	$6.7	$6.9	$7.0
Physics of the Cosmos	$146.4		$159.9	$188.1	$182.4	$182.2	$177.6
Other Missions and Data Analysis	*$146.4*		*$159.9*	*$188.1*	*$182.4*	*$182.2*	*$177.6*
(development/formulation/technology)							
Physics of the Cosmos SR&T	$45.6		$75.2	$101.1	$98.6	$98.4	$94.1
Euclid	$7.7		$9.9	$10.3	$9.9	$9.7	$9.1
Physics of the Cosmos Future Missions	$0.1		$1.3	$3.0	$3.0	$3.0	$3.0
(operating)							
Fermi Gamma-ray Space Telescope	$15.9		$0.0	$0.0	$0.0	$0.0	$0.0
Chandra X-Ray Observatory	$66.8		$64.0	$64.0	$64.0	$64.0	$64.0
XMM	$4.0		$0.0	$0.0	$0.0	$0.0	$0.0
(research and management)							
PCOS/COR Technology Office Management	$6.2		$9.4	$9.8	$6.9	$7.2	$7.4

Astrophysics Science Program Content ($M)

	Actual FY21	Enacted FY22	Request FY23	Out-Years FY24	FY25	FY26	FY27
Exoplanet Exploration	$552.4		$522.2	$450.2	$423.0	$388.4	$258.0
Nancy Grace Roman Space Telescope	*$505.2*		*$482.2*	*$407.3*	*$380.0*	*$345.7*	*$216.6*
Other Missions and Data Analysis (development/formulation/technology)	*$47.2*		*$40.0*	*$42.9*	*$43.0*	*$42.7*	*$41.4*
Exoplanet Exploration SR&T	$32.2		$23.3	$23.9	$24.1	$23.7	$22.4
Exoplanet Exploration Future Missions	$0.0		$1.3	$3.0	$10.5	$10.5	$10.5
(operating)							
Keck Operations	$7.5		$7.5	$7.4	$0.0	$0.0	$0.0
(research and management)							
Exoplanet Exploration Technoloy Off Mgmt	$7.5		$7.8	$8.6	$8.5	$8.5	$8.6
Astrophysics Explorer	$204.4		$245.6	$291.4	$311.3	$385.0	$523.2
SPHEREx	*$68.5*		*$78.7*	*$75.0*	*$24.0*	*$6.0*	*$0.1*
Other Missions and Data Analysis (development/formulation/technology)	*$135.8*		*$166.9*	*$216.4*	*$287.3*	*$379.0*	*$523.1*
X-Ray Imaging and Spectroscopy Mission	$16.8		$36.2	$28.3	$16.9	$14.1	$2.0
Contribution to Ariel Spectroscopy of Ex	$18.0		$10.3	$8.9	$4.0	$2.2	$2.9
Pioneers	$0.0		$23.4	$23.8	$32.1	$35.0	$40.2
Compton Spectrometer and Imager	$0.0		$51.3	$87.4	$71.0	$28.4	$5.3
Astrophysics Explorer Future Missions	$5.2		$23.9	$53.9	$155.0	$284.8	$460.7

Astrophysics Science Program Content ($M)

	Actual	Enacted	Request	Out-Years			
	FY21	FY22	FY23	FY24	FY25	FY26	FY27
Astrophysics Explorer Cont.	$204.4		$245.6	$291.4	$311.3	$385.0	$523.2
(operating)							
Neutron Star Interior Composition Explor	$4.8		$0.0	$0.0	$0.0	$0.0	$0.0
Transiting Exoplanet Survey Satellite	$15.2		$0.0	$0.0	$0.0	$0.0	$0.0
Imaging X-Ray Polarimetry Explorer	$38.8		$6.9	$0.7	$0.0	$0.0	$0.0
Galactic/Extragalactic ULDB Spectroscopi	$8.8		$1.0	$0.0	$0.0	$0.0	$0.0
Neil Gehrels Swift Observatory	$6.4		$0.0	$0.0	$0.0	$0.0	$0.0
Nuclear Spectroscopic Telescope Array	$8.6		$0.0	$0.0	$0.0	$0.0	$0.0
(research and management)							
Astrophysics Explorer Program Management	$13.3		$14.0	$13.5	$8.2	$14.5	$12.1