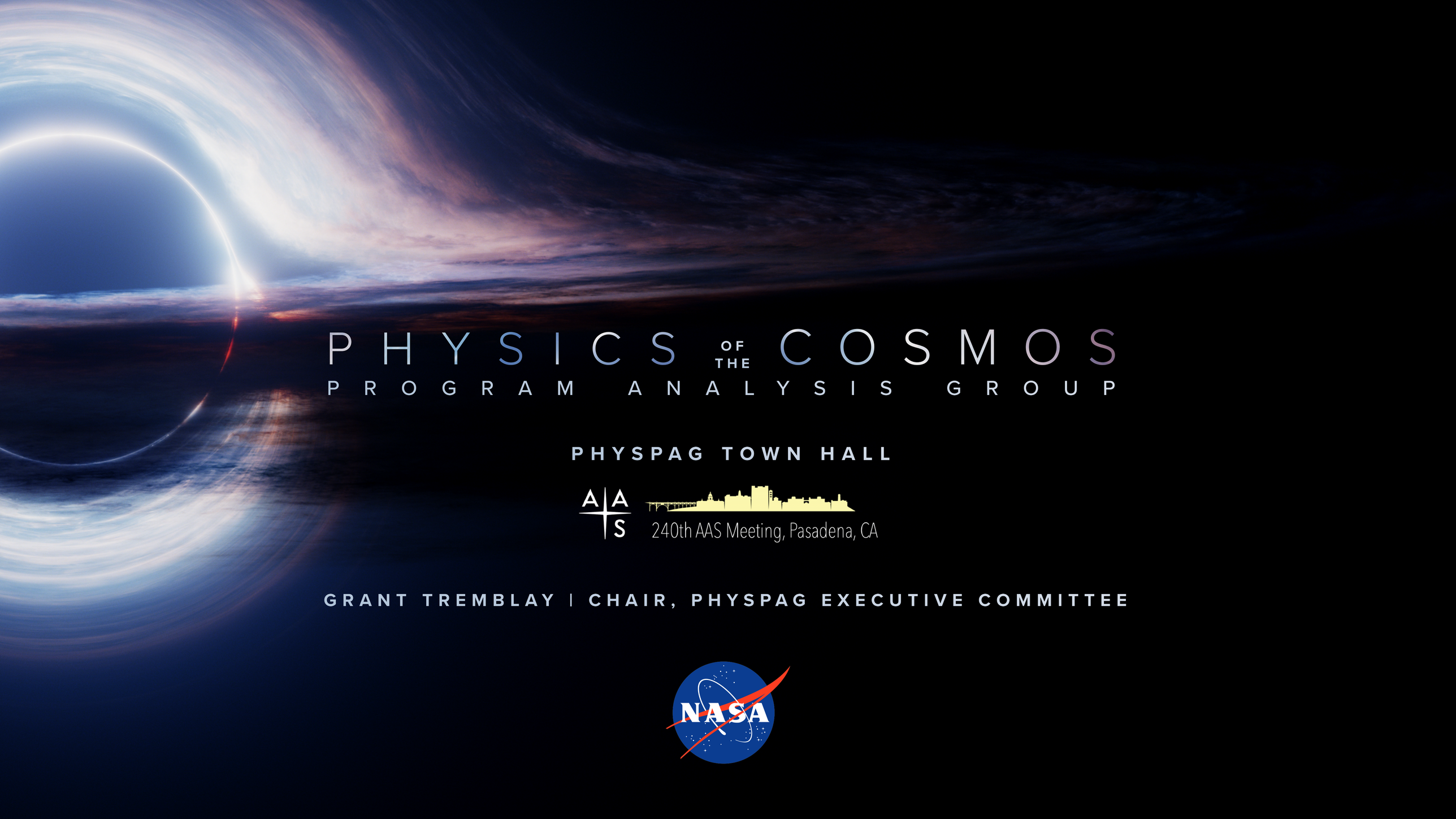

PHYSICS OF THE COSMOS
PROGRAM ANALYSIS GROUP

PHYSPAG TOWN HALL

240th AAS Meeting, Pasadena, CA

GRANT TREMBLAY | CHAIR, PHYSPAG EXECUTIVE COMMITTEE

PHYSICS OF THE COSMOS

PROGRAM ANALYSIS GROUP

The 2022 **PhysPAG Executive Committee**

Chair	Grant **Tremblay**	Smithsonian Astrophysical Observatory
Vice Chair	Justin **Finke**	U.S. Naval Research Laboratory
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New Members!	Eric **Burns**	Louisiana State University
	Kristin **Madsen**	UMBC / NASA Goddard Space Flight Center
	Athina **Meli**	North Carolina Agricultural & Technical State Univ.
	David **Pooley**	Trinity University

PCOS **NASA Colleagues**

PS	Valerie **Connaughton**
DPS	Sanaz **Vahidinia**
CS	Brian **Humensky** New!

Currently Active **Science Interest Groups**

X-ray SIG

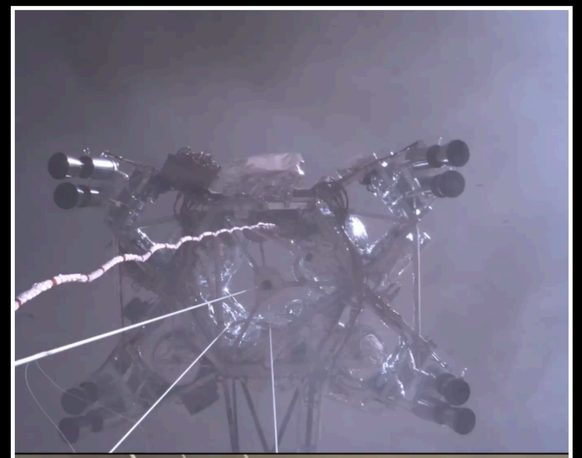
Gravitational Wave SIG

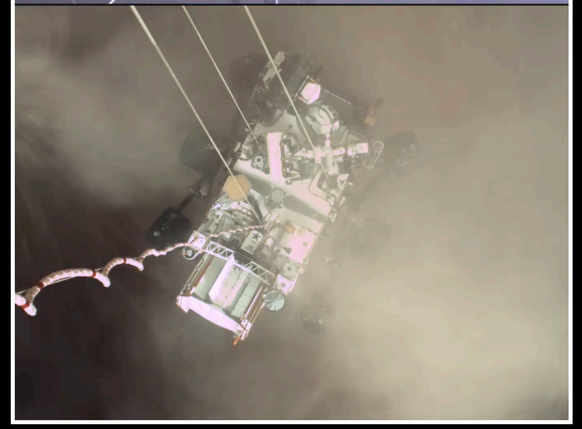
Gamma Ray SIG

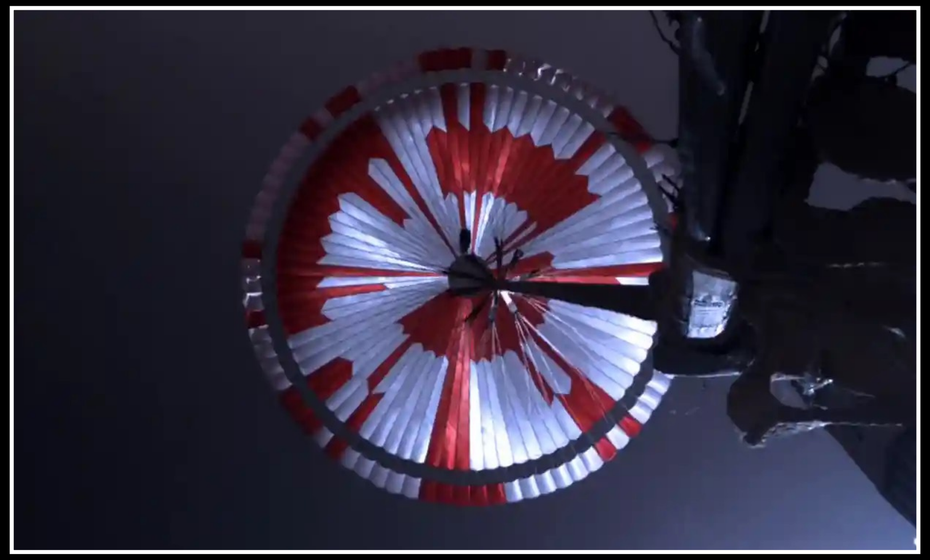
Cosmic Ray SIG

Cosmic Structure SIG

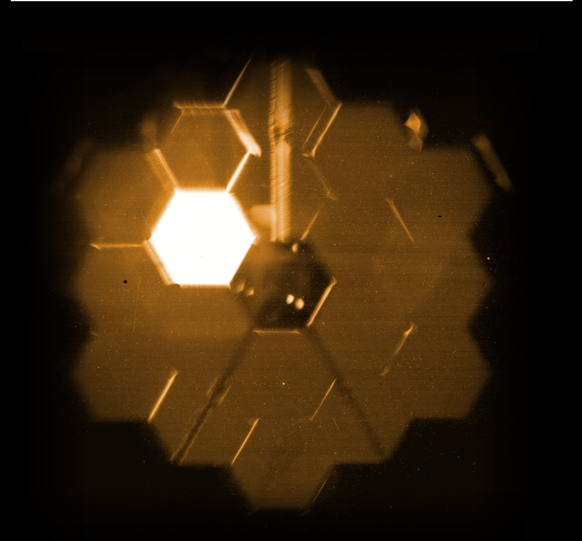
For Sunsetting? **Inflation Probe** SIG

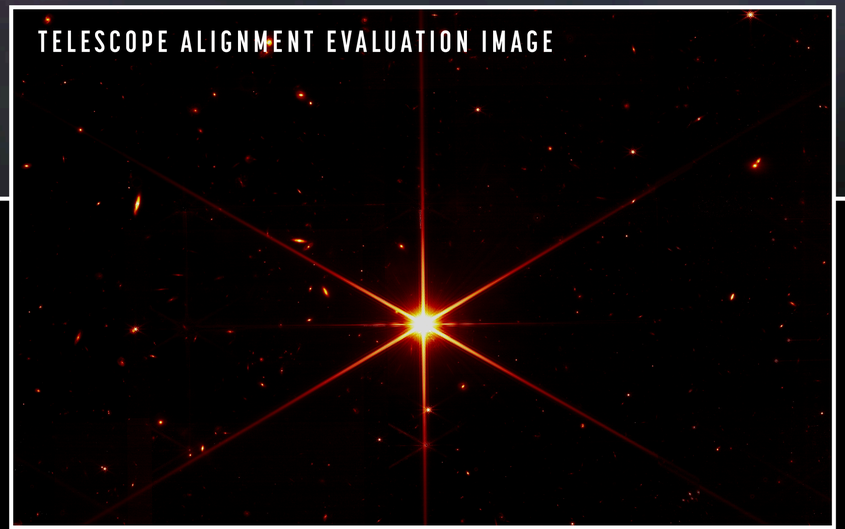






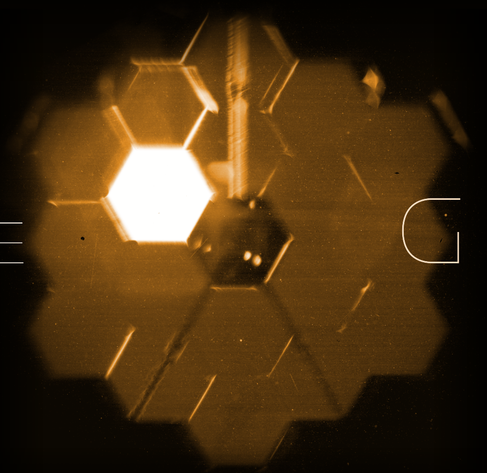

LIVE




TELESCOPE ALIGNMENT EVALUATION IMAGE


ARTEMIS


NASA
LIVE



THE GOLDEN EYE

Astro 2020

Decadal Survey on Astronomy and Astrophysics

The National Academies of | SCIENCES ENGINEERING MEDICINE

The #Astro2020 Steering Committee and NAS Staff. Last face-to-face meeting prior to the Pandemic.

Prof. Fiona Harrison (Caltech)

Prof. Rob Kennicutt (UA / TAMU)

GROUND

S / M / L

SPACE

S / M / L

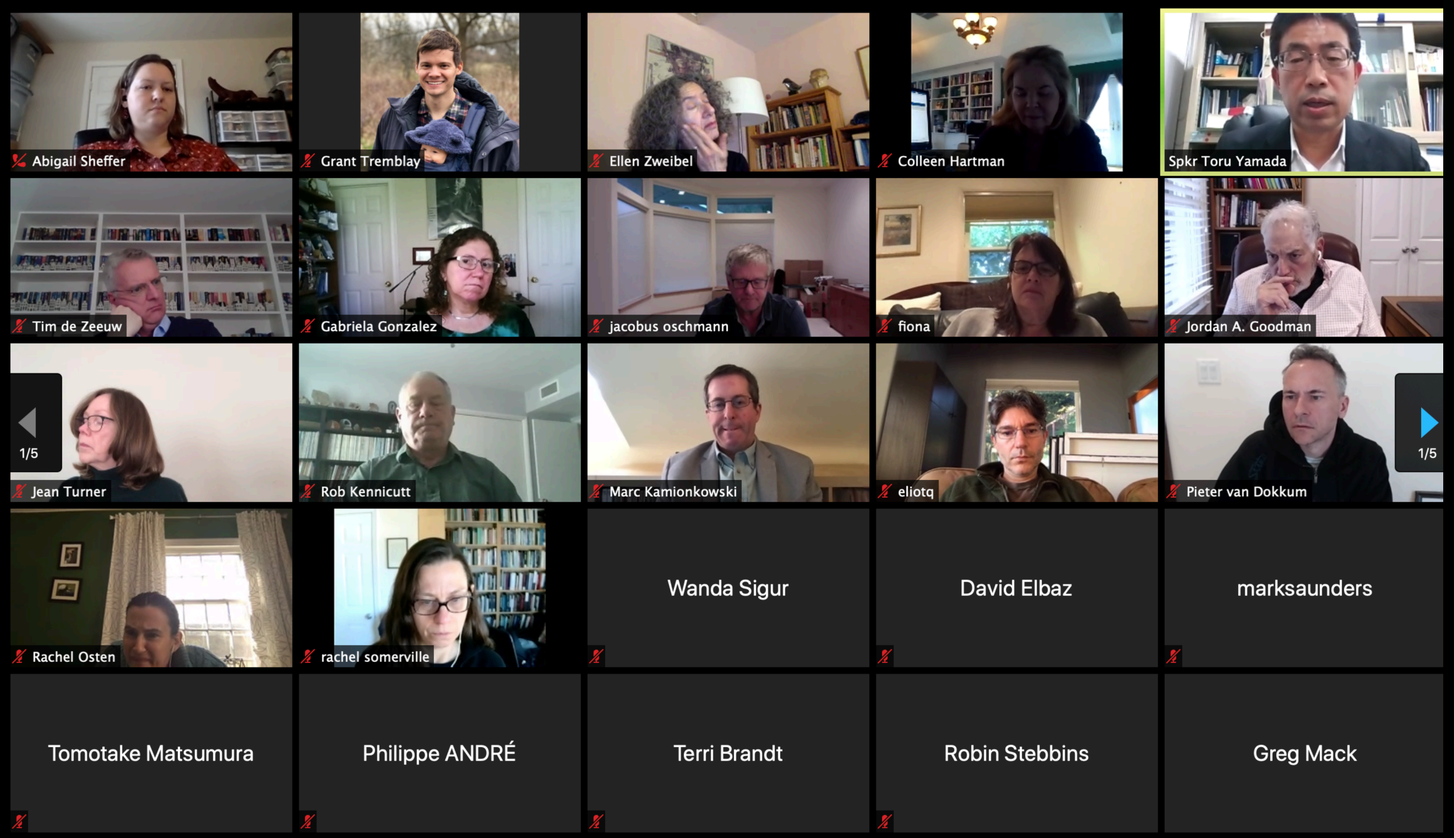
STATE OF THE PROFESSION

ALONG WITH **RESEARCH INFRASTRUCTURE, INT. PARTNERSHIPS,** ETC.

Astro 2020

Decadal Survey on Astronomy and Astrophysics

The National Academies of SCIENCES ENGINEERING MEDICINE



Prof. Fiona Harrison (Caltech)

Prof. Rob Kennicutt (UA / TAMU)

Thank you.

In planning its programs, NASA is **obligated by law** to respect the Decadal's recommendations

SEC. 804. IN-SPACE SERVICING. 42 USC 18383.

The Administrator shall continue to take all necessary steps to ensure that provisions are made for in-space or human servicing and repair of all future observatory-class scientific spacecraft intended to be deployed in Earth-orbit or at a Lagrangian point to the extent practicable and appropriate. The Administrator should ensure that agency investments and future capabilities for space technology, robotics, and human space flight take the ability to service and repair these spacecraft into account, where appropriate, and incorporate such capabilities into design and operational plans.

SEC. 805. DECADAL RESULTS. 42 USC 18384.

NASA shall take into account the current decadal surveys from the National Academies' Space Studies Board when submitting the President's budget request to the Congress.

42 U.S.C. § 18384 (2014)

The **most powerful sentences** in Astrophysics spending

The words that gave life to *Hubble*…

1972

ing an expansion of capability for numerical computation;

9. An expanded program of optical space astronomy, including high-resolution imagery and ultraviolet spectroscopy, leading to the launch of a large space telescope at the beginning of the next decade;

10. A large, steerable radio telescope designed to operate efficiently at wavelengths of 1 cm and longer to obtain observations with high angular

…Chandra…

1982

A.

The Committee believes that four major programs are critically important for the rapid and effective progress of astronomical research in the 1980's and is unanimous in recommending the following order of priority:

1. *An Advanced X-Ray Astrophysics Facility* (AXAF) operated as a permanent national observatory in space, to provide x-ray pictures of the Universe comparable in depth and detail with those of the most advanced optical and radio telescopes. Continuing the remarkable development of x-ray technology applied to astronomy during the 1970's, this facility will combine greatly improved angular and spectral resolution with a sensitivity up to one hundred times greater than that of any previous x-ray mission.

…JWST…

2000

TABLE ES.1 Prioritized Initiatives (Combined Ground and Space) and Estimated Federal Costs for the Decade 2000 to 2010[a,b]

Initiative	Cost[c] ($M)
Major Initiatives	
Next Generation Space Telescope (NGST)[d]	1,000
Giant Segmented Mirror Telescope (GSMT)[d]	350
Constellation-X Observatory (Con-X)	800
Expanded Very Large Array (EVLA)[d]	140
Large-aperture Synoptic Survey Telescope (LSST)	170
Terrestrial Planet Finder (TPF)[e]	200
Single Aperture Far Infrared (SAFIR) Observatory[e]	100
Subtotal for major initiatives	2,760

…Roman…

2010

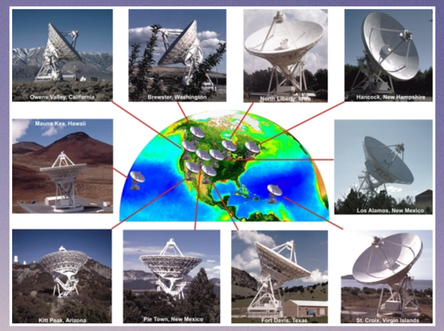
Recommendation	Launch Date[b]	Science	Technical Risk[c]	Appraisal of Costs[a] Total (U.S. Share)	Appraisal of Costs[a] U.S. Share, 2012-2021	Cross-Reference in Chapter 7
1. WFIRST —NASA/DOE collaboration	2020	Dark energy, exoplanets, and infrared survey-science	Medium low	$1.6B	$1.6B	Page 205
2. Augmentation to Explorer	Ongoing	Enable rapid response to science	Low	$463M	$463M	Page 208

Major **Ground-based** outcomes from Astrophysics Decadal Surveys

US ELT
CMB-S4
ngVLA

V L A

V L B A



SOFIA
Stratospheric Observatory for Infrared Astronomy

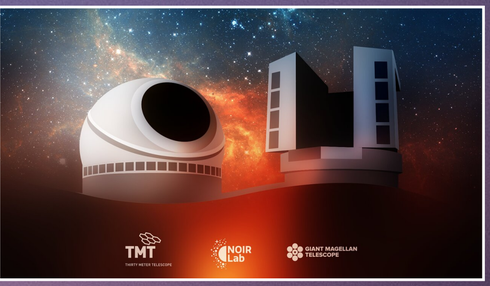
ALMA

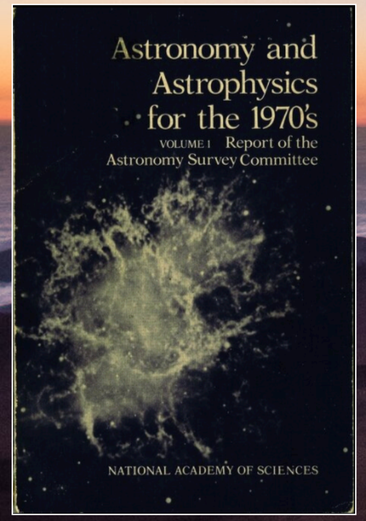
Expanded Very Large Array

30m (GSMT) ranked #1
LSST ranked #4
Re-endorsed ALMA

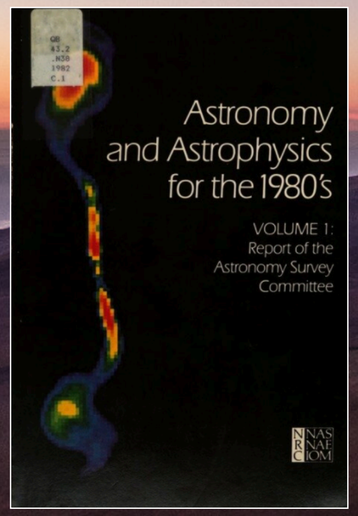
VERA C. RUBIN OBSERVATORY

LSST ranked #1
30m ranked #3

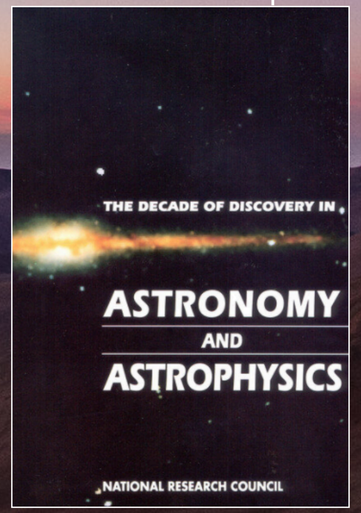




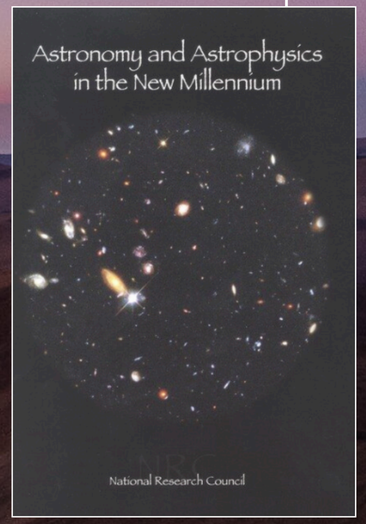
1972



1982

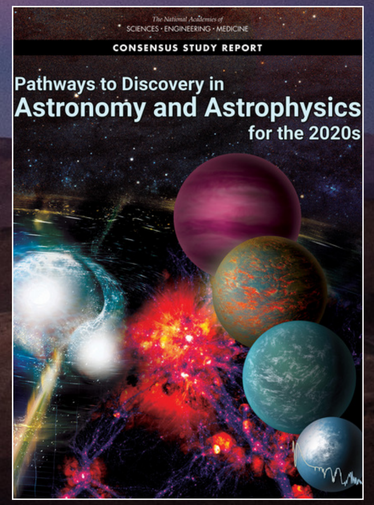


1991



2001

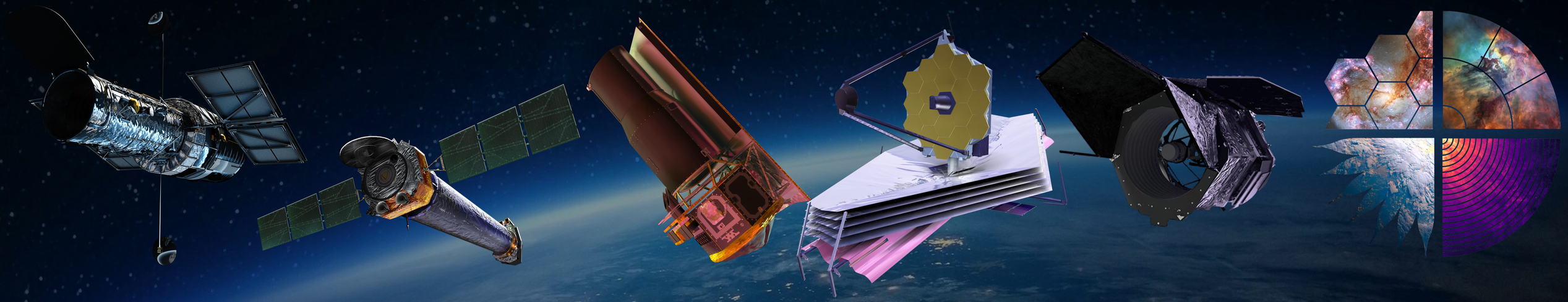
2011

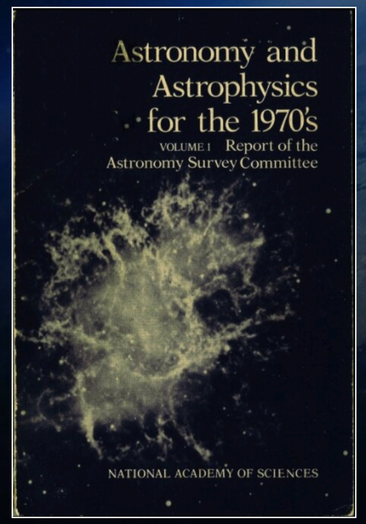


2021

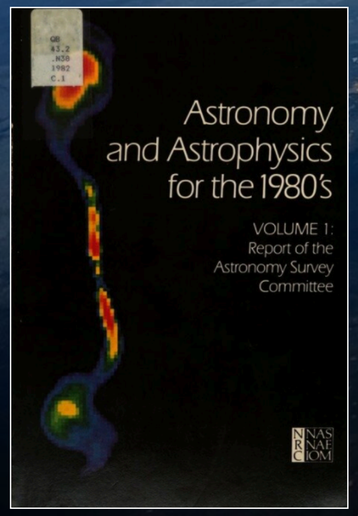
Major **Space-based** outcomes from Astrophysics Decadal Surveys

HUBBLE *CHANDRA* *SPITZER* *JWST* *ROMAN*

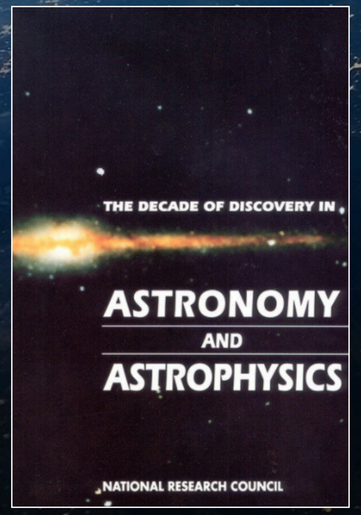




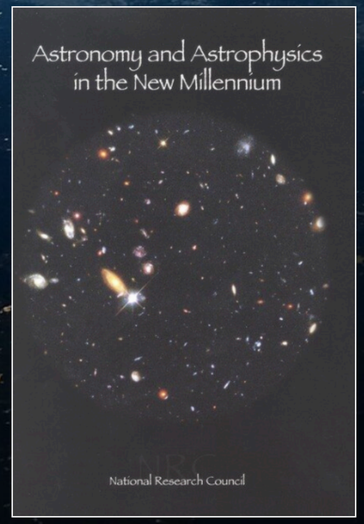
1972



1982

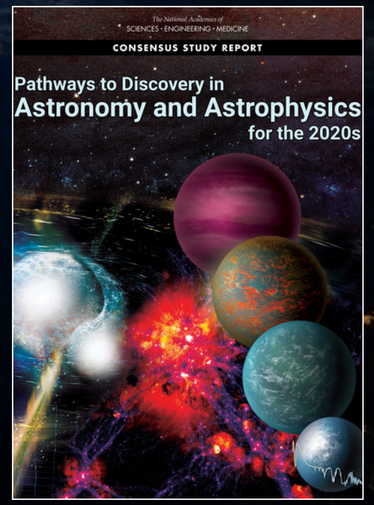


1991



2001

2011



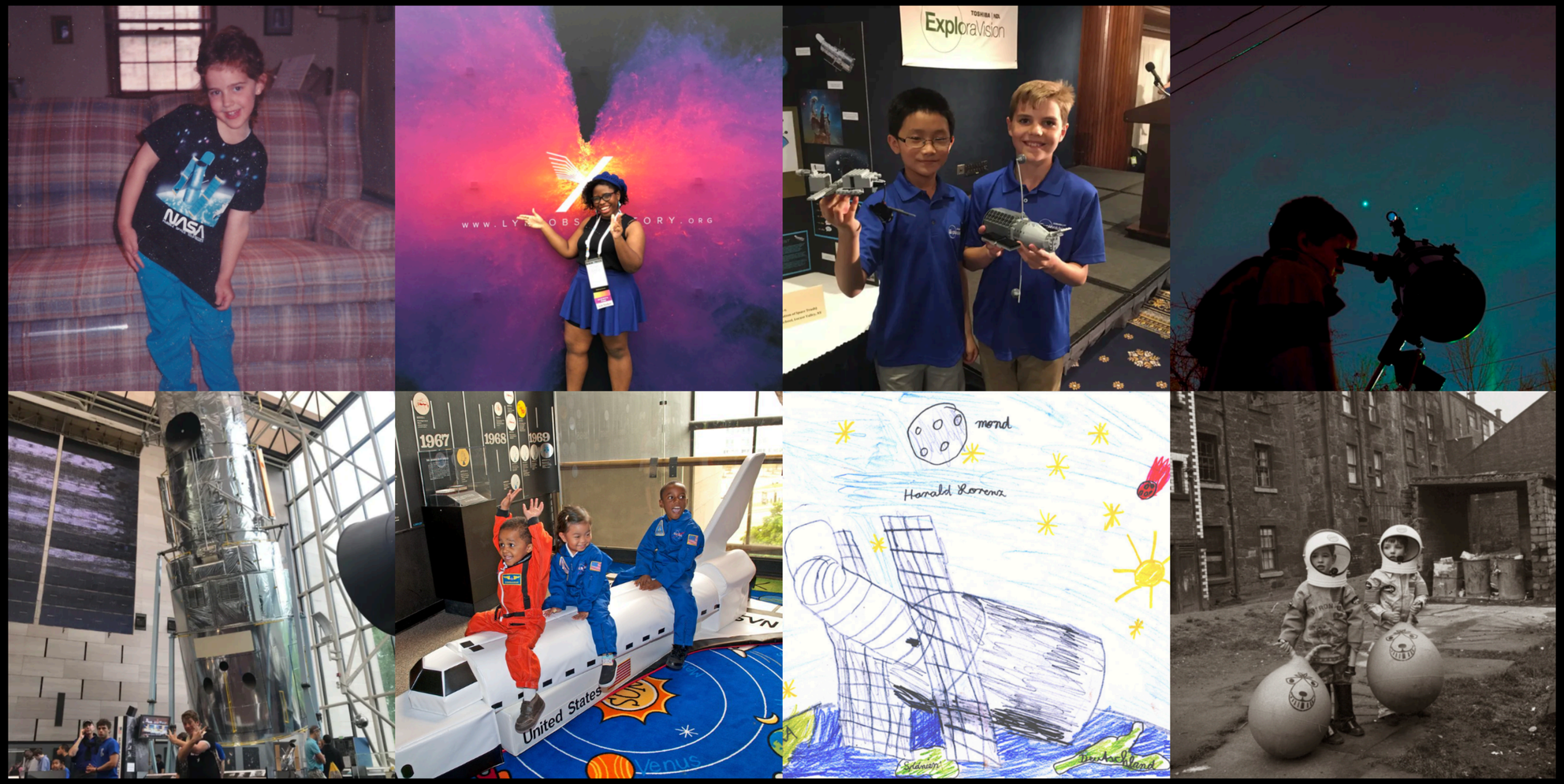
2021

Astro2020 State of the Profession Prioritizations

TABLE S.1 Foundations of the Profession

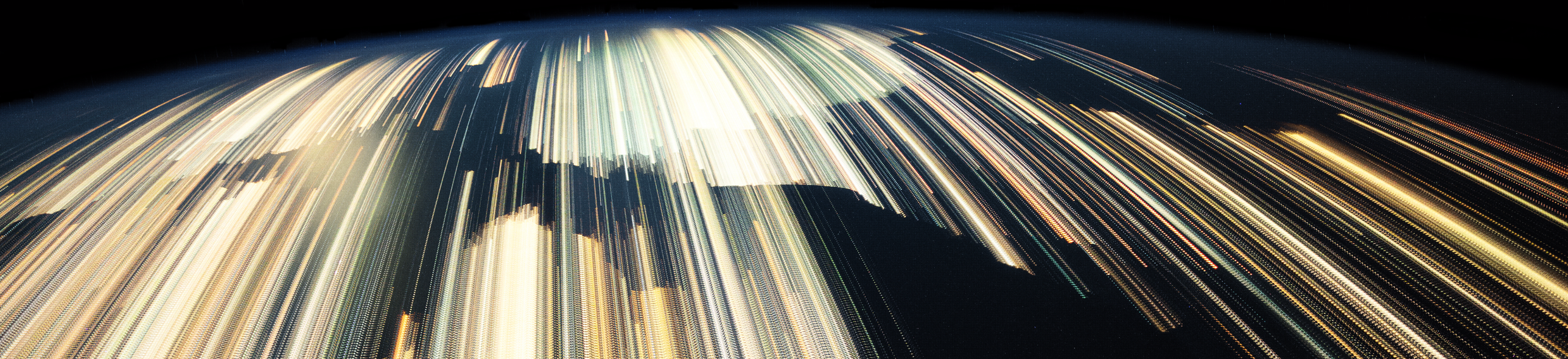
Recommendation Topic	Agency	Per Year Budget *Increases Relative to FY2019 Agency Budget Allocations (FY2020$)*	Cross-Reference in Chapter 3
Faculty diversity, and early-career faculty awards	NSF NASA DOE	(augmentation of) **$2.5M:** $1M NSF; $1M NASA; $0.5M DOE	p. 3-14
Workforce development/diversity, bridge programs and minority serving institutions partnerships	NSF NASA	(augmentation of) **$4.5M:** $1.5M NSF; $3M NASA	p. 3-22
Undergraduate and graduate "traineeship" funding	NSF NASA DOE	(augmentation of) **$3M:** $1M NSF; $1M NASA; $1M DOE	p. 3-23
Independent postdoc fellowships	NSF NASA	(augmentation of) **$1M:** $0.5M NSF; $0.5M NASA	p. 3-23
Treat discrimination and harassment as professional misconduct	NSF NASA DOE	N/A	p. 3-27
Collecting, evaluating, and reporting demographic data and indicators pertaining to equitable outcomes	NSF NASA	(augmentation of) **$1M** Split NSF/NASA	p. 3-29

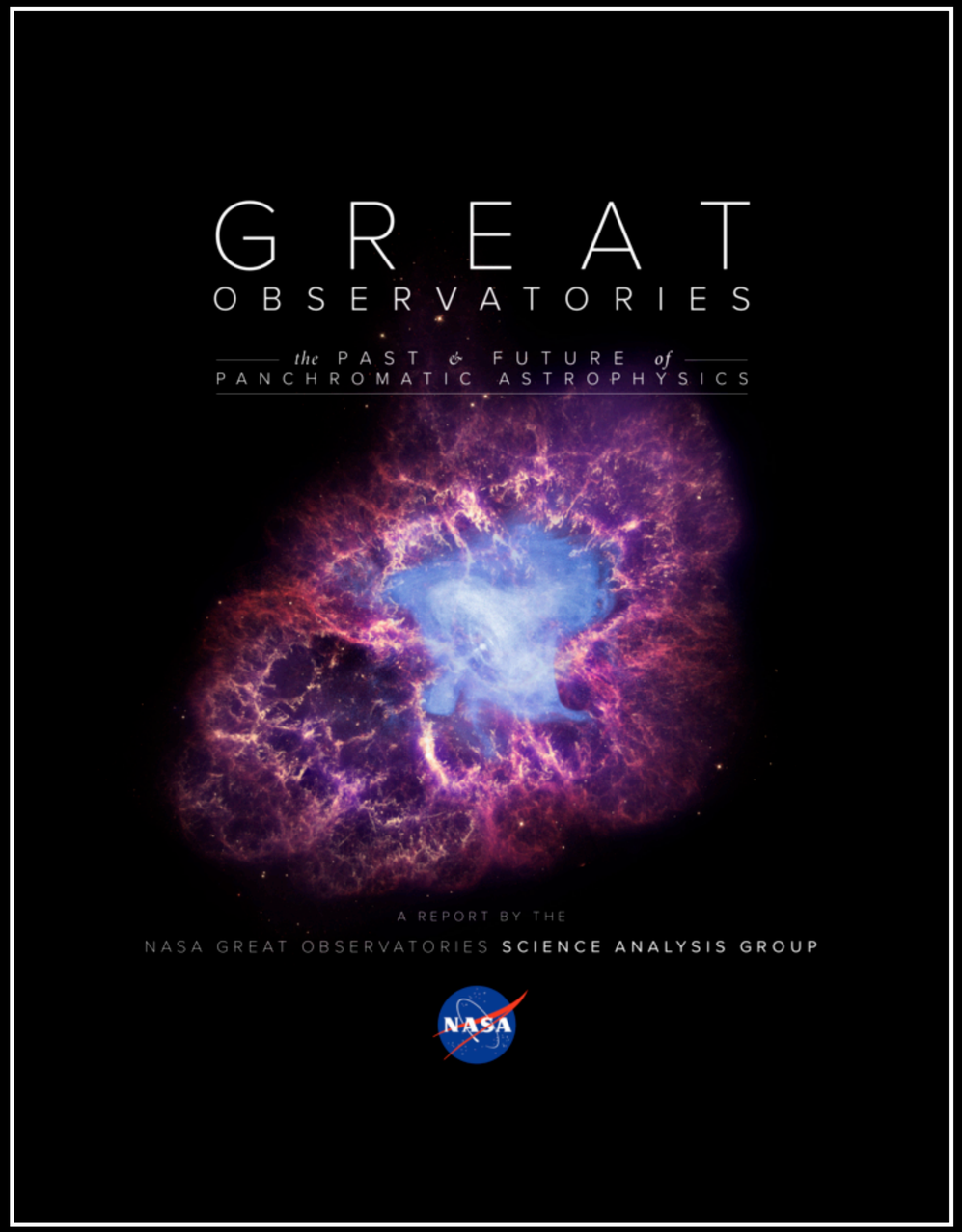
“Discovery is inseparable from the humans who animate it.”



Read Appendix N of Astro2020

The 2020 Decadal Survey *in* Astronomy & Astrophysics has placed pursuit of a new constellation of *GREAT OBSERVATORIES* as the top national priority for the future of space astrophysics.





The NASA *GREAT OBSERVATORIES* **Science Analysis Group Report**, heavily cited by Astro2020, provides an account of how these four missions changed our country, the world, and our understanding of everything beyond it.

READ THE REPORT NOW AT

WWW.GREATOBSERVATORIES.ORG

GREAT OBSERVATORIES

the PAST & FUTURE *of* PANCHROMATIC ASTROPHYSICS

a report commissioned by the

COSMIC ORIGINS, PHYSICS *of the* COSMOS, *and* EXOPLANET EXPLORATION
PROGRAM ANALYSIS GROUPS

for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NOVEMBER 2020

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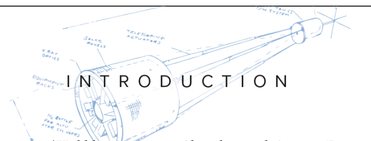


INTRODUCTION

NASA's Great Observatories (*Hubble*, *Compton*, *Chandra*, and *Spitzer*, Fig. 1-1) have opened up the electromagnetic spectrum from space, providing sustained access to wavelengths not visible, or greatly compromised, from the ground due to Earth's atmosphere. The first, *Hubble*, was launched in 1990, and two of the four (*Hubble* and *Chandra*) are still operating today. Each of these observatories delivered large gains in sensitivity, angular resolution, mapping speed and/or spectral coverage. Together, they have provided the scientific community with a flexible and powerful suite of telescopes capable of addressing broad scientific questions, and reacting to a rapidly changing scientific landscape. Through regular peer-reviewed proposal calls open to the community, this has become a central feature of modern astrophysics, where objects are now routinely observed across the electromagnetic spectrum from the ground and space. It has also become the basis upon which multiple generations of students and post-doctoral scholars have built their careers. However, the concept of the Great Observatories was not an inevitable outcome of a system where communities vied and competed for a share of the limited resources available for new missions.

the GREAT OBSERVATORIES

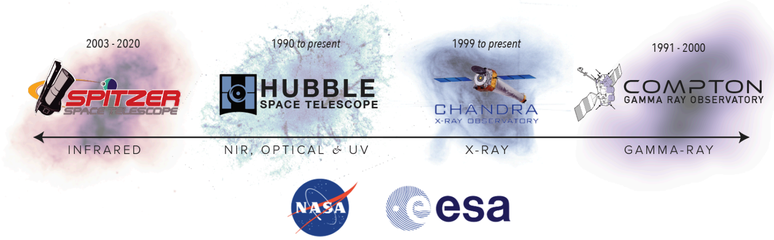


Fig. 1—1. The Great Observatories. *Spitzer, Hubble, Chandra, and Compton, arranged according to the part of the electromagnetic spectrum they observe.*

The concept of the Great Observatories took shape in the late 1970s as scientists and NASA administrators recognized that fundamental strides in astrophysics required access to the entire electromagnetic spectrum, well beyond what could be accessed from the ground, and any single space observatory could deliver. The article "*The Number of Class A Phenomenon Characterizing the Universe*" (Harwit, 1975) served as inspiration first for Frank Martin and later Charlie Pellerin, who succeeded Martin as Astrophysics Division director in 1983 and initiated the study of the Great Observatory concept. By that time, *Hubble* and *Compton* were already approved, and the key issue was how to get support and funding for *AXAF* and *SIRTF* (later *Chandra* and *Spitzer*; both highly ranked by the 1980 Decadal review), which would open up the X-ray and Infrared windows, respectively, so that they could be launched and be operational well before the *HST* and *CGRO* missions were over. The Astrophysics Council, formulated by Pellerin in 1985 and chaired by Harwit, was charged with sketching out a total astrophysics program that would require all four observatories.

read it now at

GREATOBSERVATORIES.ORG

DRAFT | APPROVAL PENDING

THE GREAT OBSERVATORIES

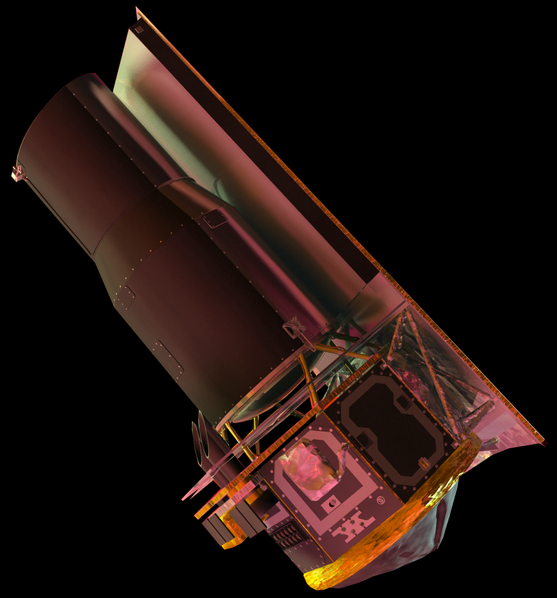
CHANDRA X-RAY OBSERVATORY

1999 *to present*

HUBBLE SPACE TELESCOPE

1990 *to present*

SPITZER SPACE TELESCOPE



2003 — 2020

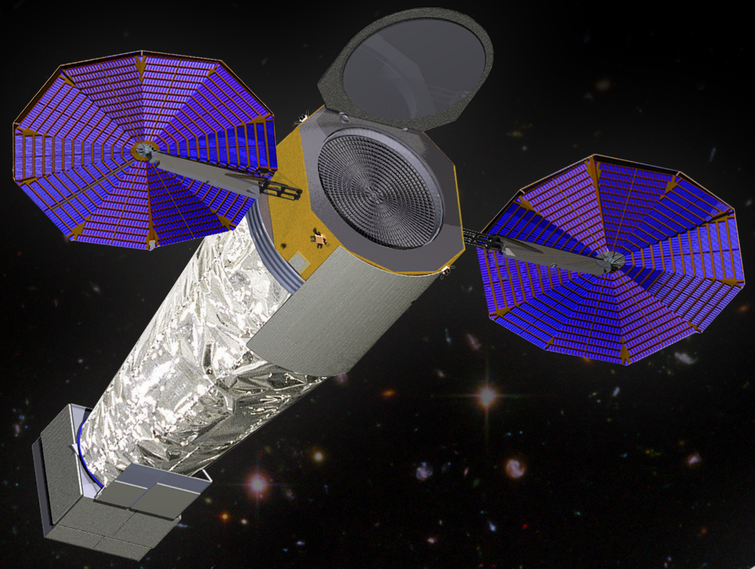
X-RAY | UV / OPTICAL / INFRARED | MID INFRARED

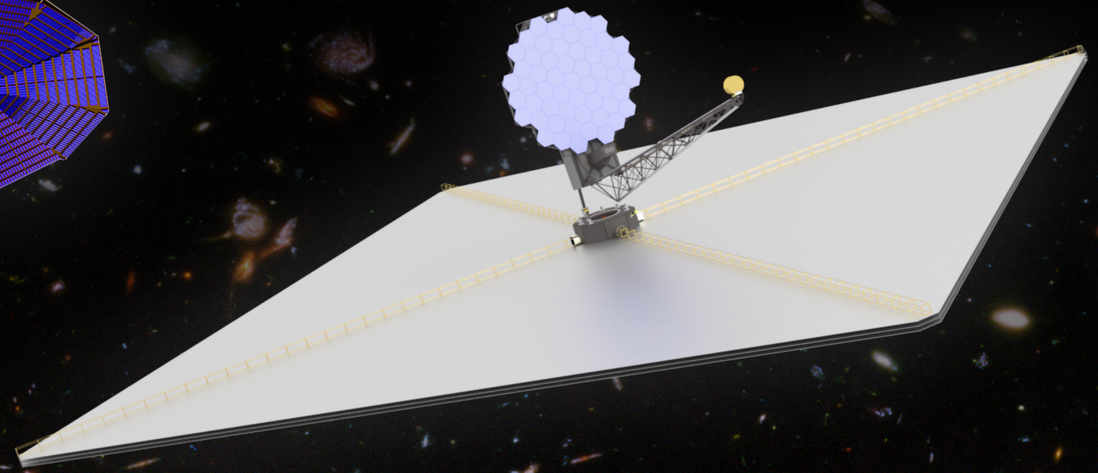
NOT SHOWN TO EMPHASIZE SYMMETRY (BUT STILL A WONDERFUL MISSION!)

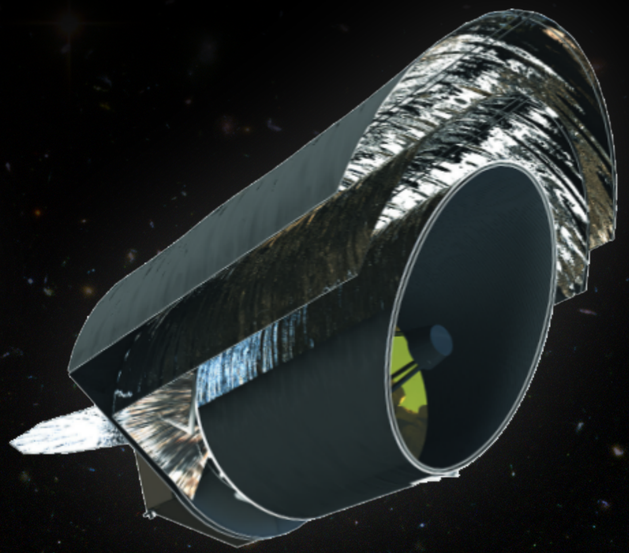
COMPTON GAMMA RAY OBSERVATORY

1991 — 2000

THE NEW GREAT OBSERVATORIES





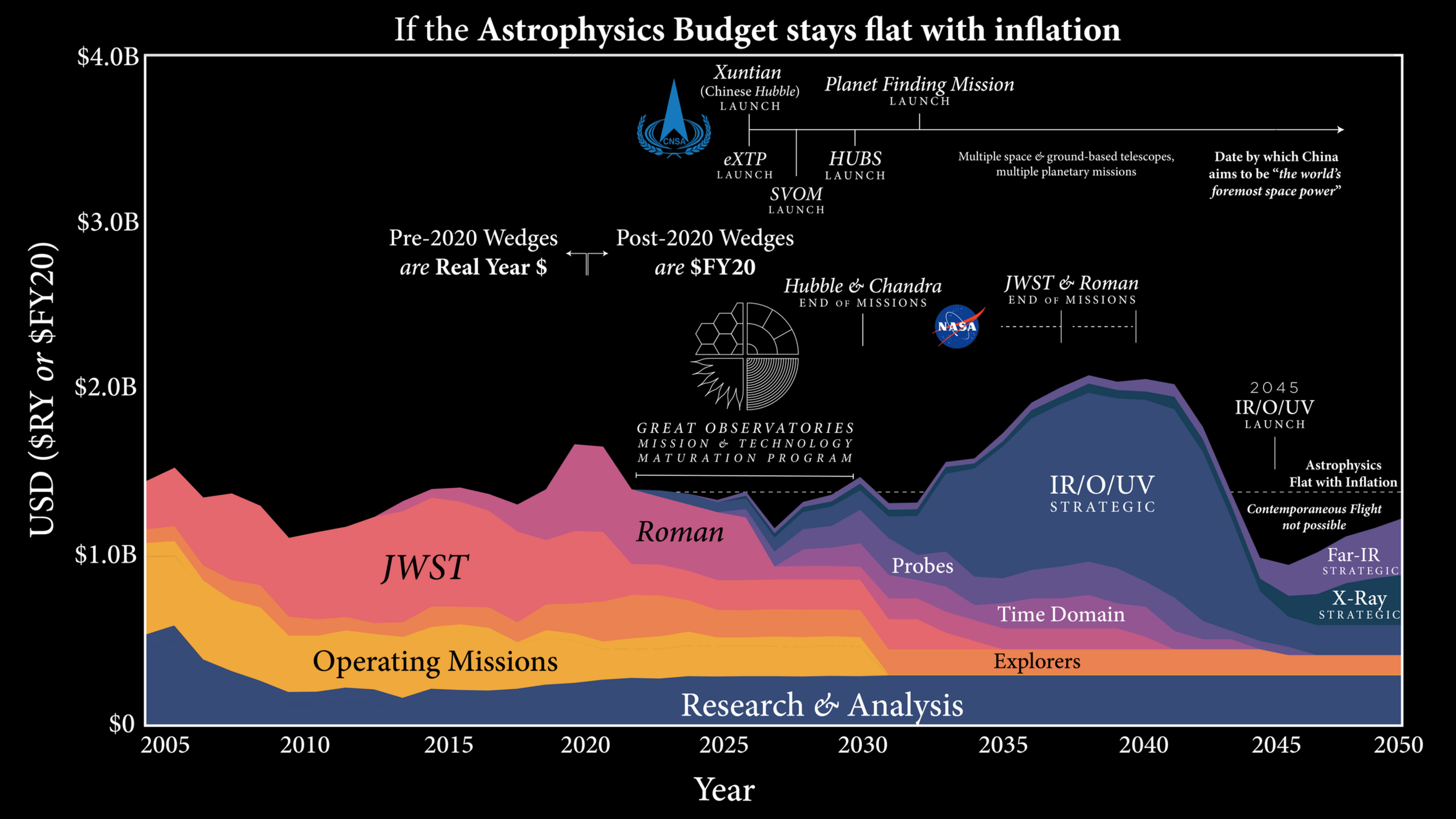


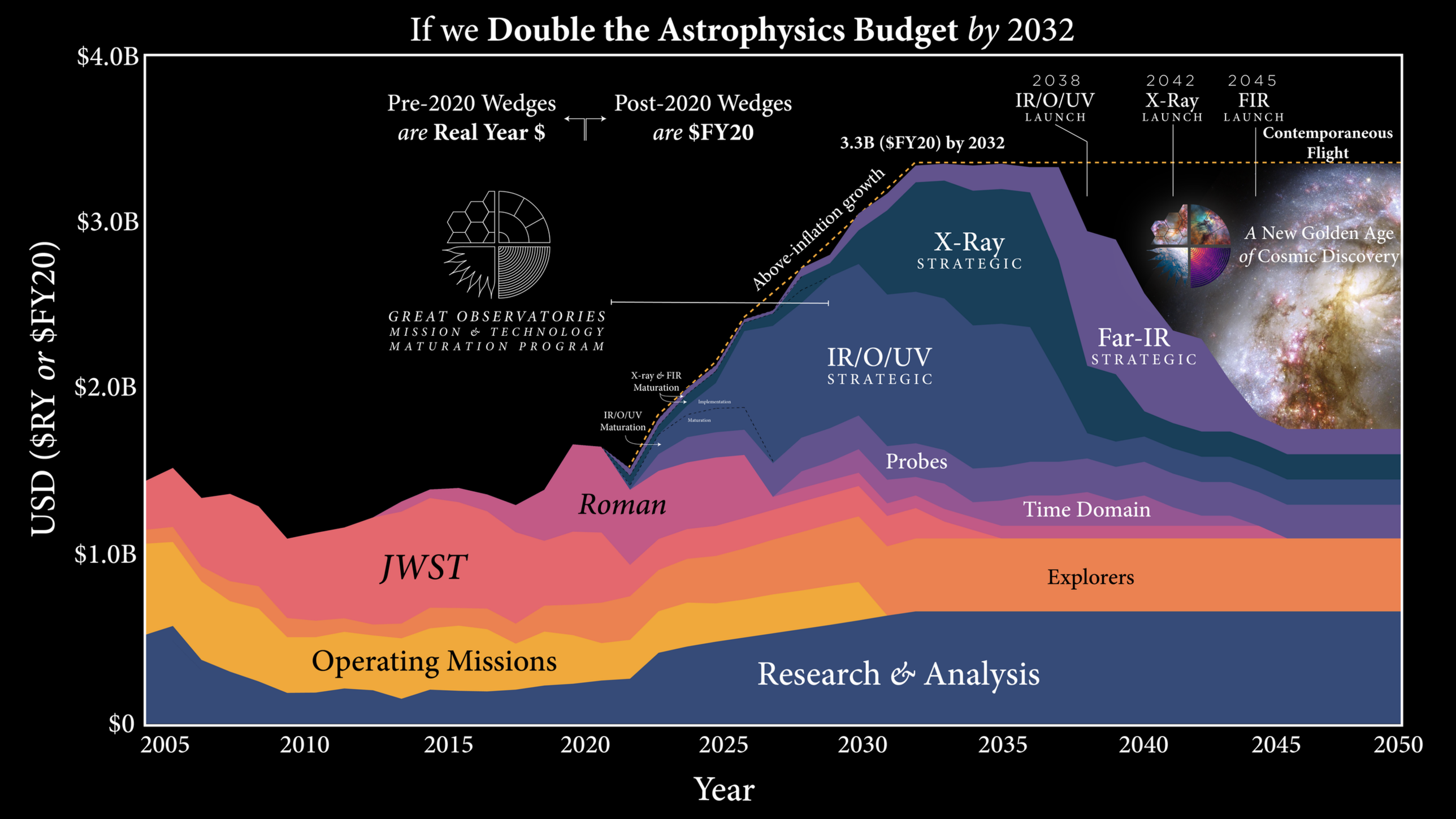
X-RAY

UV / OPTICAL / INFRARED

FAR INFRARED

ALL ARCHITECHTURES NOTIONAL


If the Astrophysics Budget stays flat with inflation
$4.0B
$3.0B
$2.0B
$1.0B
$0
USD ($RY or $FY20)
Xuntian
(Chinese Hubble)
LAUNCH
Planet Finding Mission
LAUNCH
eXTP
LAUNCH
SVOM
LAUNCH
HUBS
LAUNCH
Multiple space & ground-based telescopes, multiple planetary missions
Date by which China aims to be "the world's foremost space power"
Pre-2020 Wedges are Real Year $
Post-2020 Wedges are $FY20
Hubble & Chandra
END OF MISSIONS
JWST & Roman
END OF MISSIONS
GREAT OBSERVATORIES MISSION & TECHNOLOGY MATURATION PROGRAM
2045
IR/O/UV
LAUNCH
Astrophysics Flat with Inflation
Contemporaneous Flight not possible
IR/O/UV
STRATEGIC
JWST
Roman
Probes
Time Domain
Explorers
Operating Missions
Research & Analysis
Far-IR
STRATEGIC
X-Ray
STRATEGIC
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year


If we Double the Astrophysics Budget by 2032
$4.0B
$3.0B
$2.0B
$1.0B
$0
USD ($RY or $FY20)
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
Pre-2020 Wedges are Real Year $
Post-2020 Wedges are $FY20
GREAT OBSERVATORIES MISSION & TECHNOLOGY MATURATION PROGRAM
3.3B ($FY20) by 2032
Above-inflation growth
2038 IR/O/UV LAUNCH
2042 X-Ray LAUNCH
2045 FIR LAUNCH
Contemporaneous Flight
A New Golden Age of Cosmic Discovery
X-ray & FIR Maturation
IR/O/UV Maturation
Implementation
Maturation
X-Ray STRATEGIC
IR/O/UV STRATEGIC
Far-IR STRATEGIC
Probes
Time Domain
Explorers
Research & Analysis
Operating Missions
JWST
Roman

A PITCH TO THE APAC

THE NEW GREAT OBSERVATORIES
SCIENCE ANALYSIS GROUP

THE NEW GREAT OBSERVATORIES
SCIENCE ANALYSIS GROUP

A proposed **Joint-PAG SAG** in response to Astro2020

Inclusive and open. We want a broad, diverse subset of the community to participate

In some ways, this is a “sequel” to SAG-10 in the wake of Astro2020’s
Great Observatories Mission & Technology Maturation Program Recommendation

THE NEW GREAT OBSERVATORIES SCIENCE ANALYSIS GROUP

PROPOSED CHARTER (KEY POINTS)

1. Identify key questions left unanswered by today's space astronomy missions, building on the SAG-10 report

2. Synthesize notional science cases for a future fleet of New Great Observatories, specifically those recommended to enter Astro2020's Maturation Program (i.e. IR/O/UV, X-ray, FIR)

3. Identify important questions not raised by Astro2020 (or the four Large Mission Study Reports) that can be addressed by multi-wavelength observations.

4. Identify science gaps that might be close should these observatories enjoy contemporaneous flight

TIME DOMAIN & MULTI-MESSENGER

SCIENCE ANALYSIS GROUP

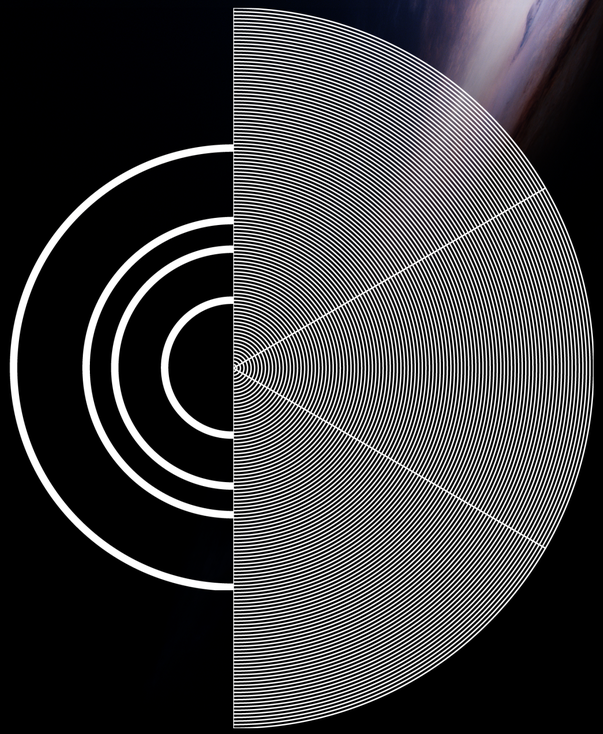
DRAFT LANGUAGE FOR CHARTER

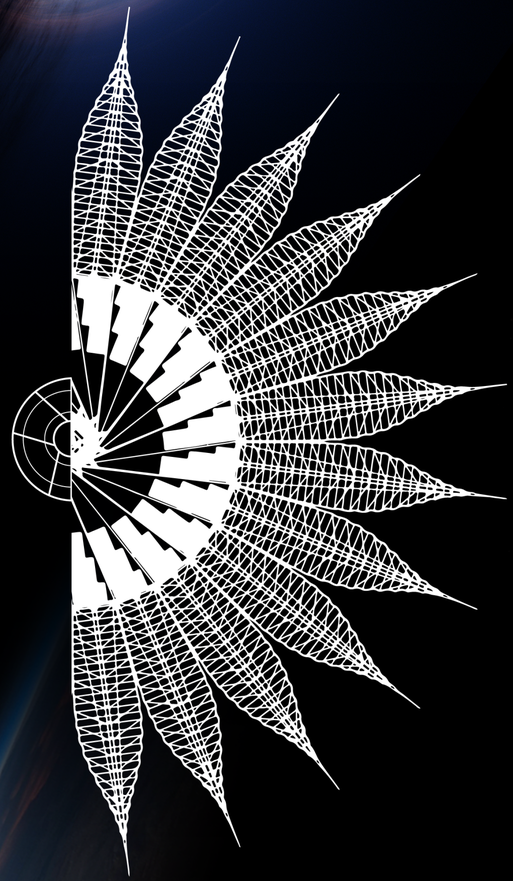
1. Are existing NASA community funding mechanisms meeting the needs of TDAMM science? Are studies quantifying projections for future missions supported through current means? If gaps are identified, what scientific or technical advances are limited by these gaps? (**Abridged)**

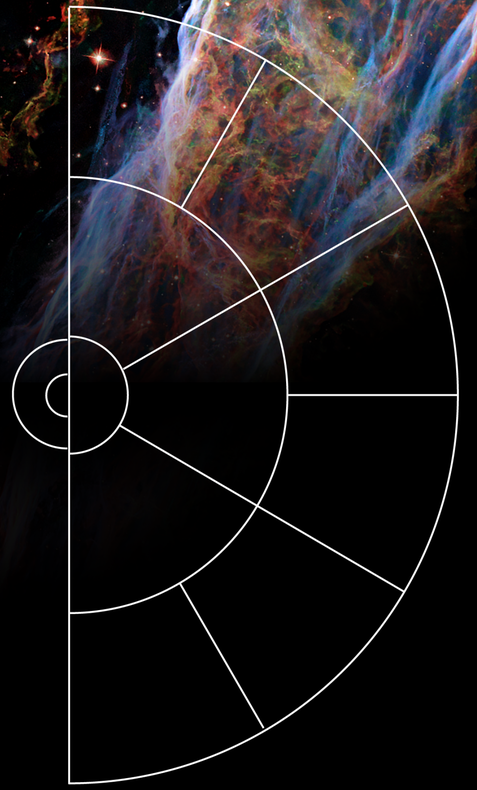
2. Are event alert mechanisms being supported and built (by NASA or even NSF w.r.t. Rubin) sufficient for coordination between future ground and space facilities? What gaps exist?

3. What are key space-based wavelengths for multi messenger astronomy? What are the key capabilities necessary across wavelength ranges? What types of mission and mission scales, within Astro2020's recommended funding envelope, could accomplish these science requirements?

YOUR PAGS ARE READY







PhysPAG, ExoPAG, and COPAG are **energized and ready to work** in the wake of Astro2020

We are ready to help with, e.g. **Analyses of Alternatives** that must be commissioned.
We can explore questions like:

How do decadal recommendations differ from input recommendations of large mission concepts?

Have any of the goals or science objectives put forth in the recommended mission's study been modified by the Decadal Survey?

Have any of the technologies or methods in the recommended mission's study been modified by the Decadal Survey?

Are the mission goals separable in a way such that some of the science could be achieved quicker or more cheaply by multiple missions?

Are there mission technologies or concepts of operation that could be simplified or significantly changed with better knowledge of some aspect of astronomy or astrophysics before any mission study were to start?

What alternative methods exist for achieving any of the mission goals?