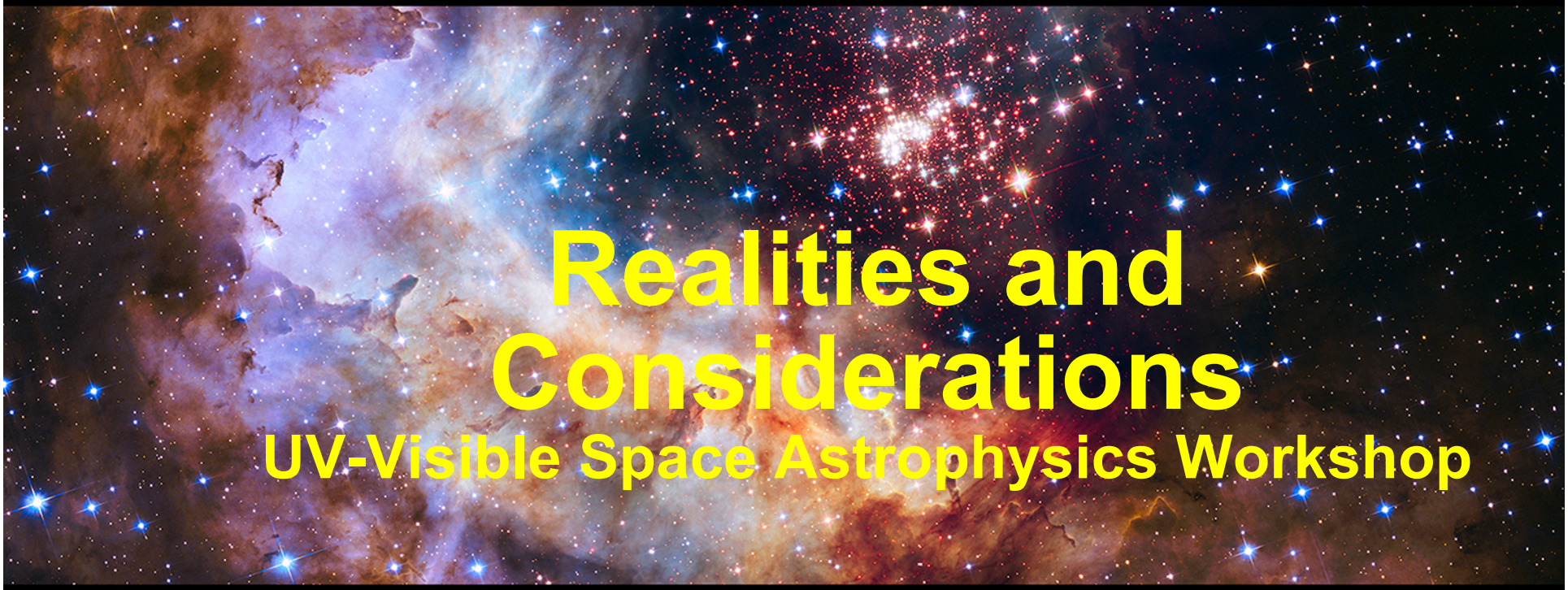
National Aeronautics and Space Administration



Realities and Considerations

UV-Visible Space Astrophysics Workshop

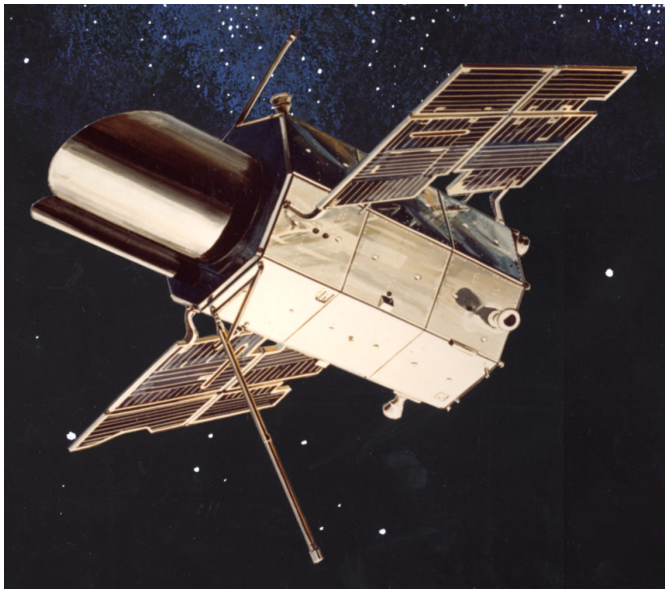
Astrophysics

Mario R. Perez
Astrophysics Division
Science Mission Directorate

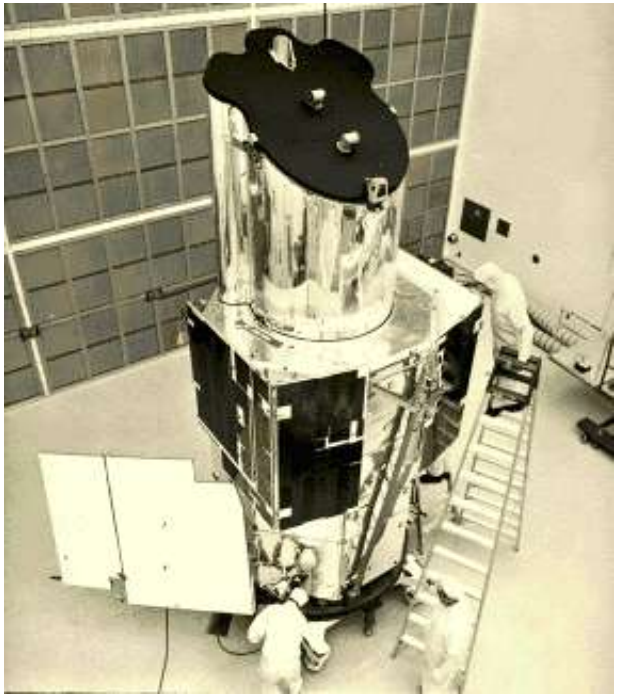
www.nasa.gov

June 25, 2015

Orbiting Astronomical Observatories (OAO)



OAO-2 (1968-1973)
11 UV telescopes



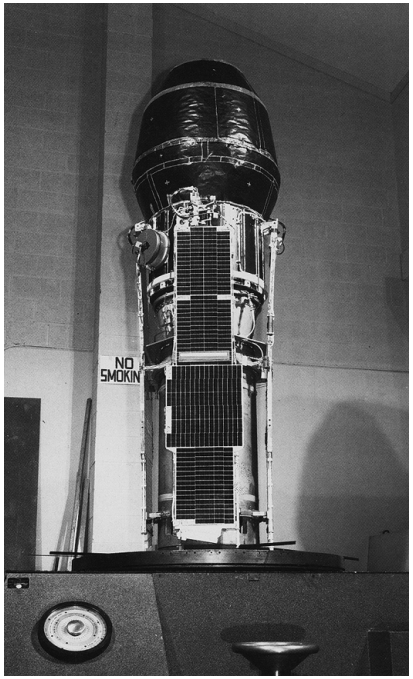
OAO-3 (1972-1981)
Copernicus
1m UV telescope

The Orbiting Astronomical Observatory program set the stage for the development of the Hubble Space Telescope (HST) and other orbiting observatories.

Image Credits: NASA

Small Astronomy Satellites (SAS)

SAS-1 (Uhuru)
1970-1973



SAS-2
1972-1973

SAS-3
1975-1979

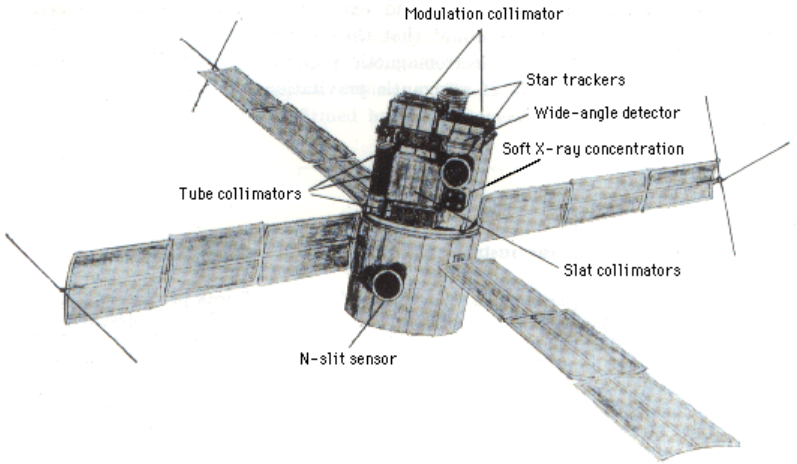
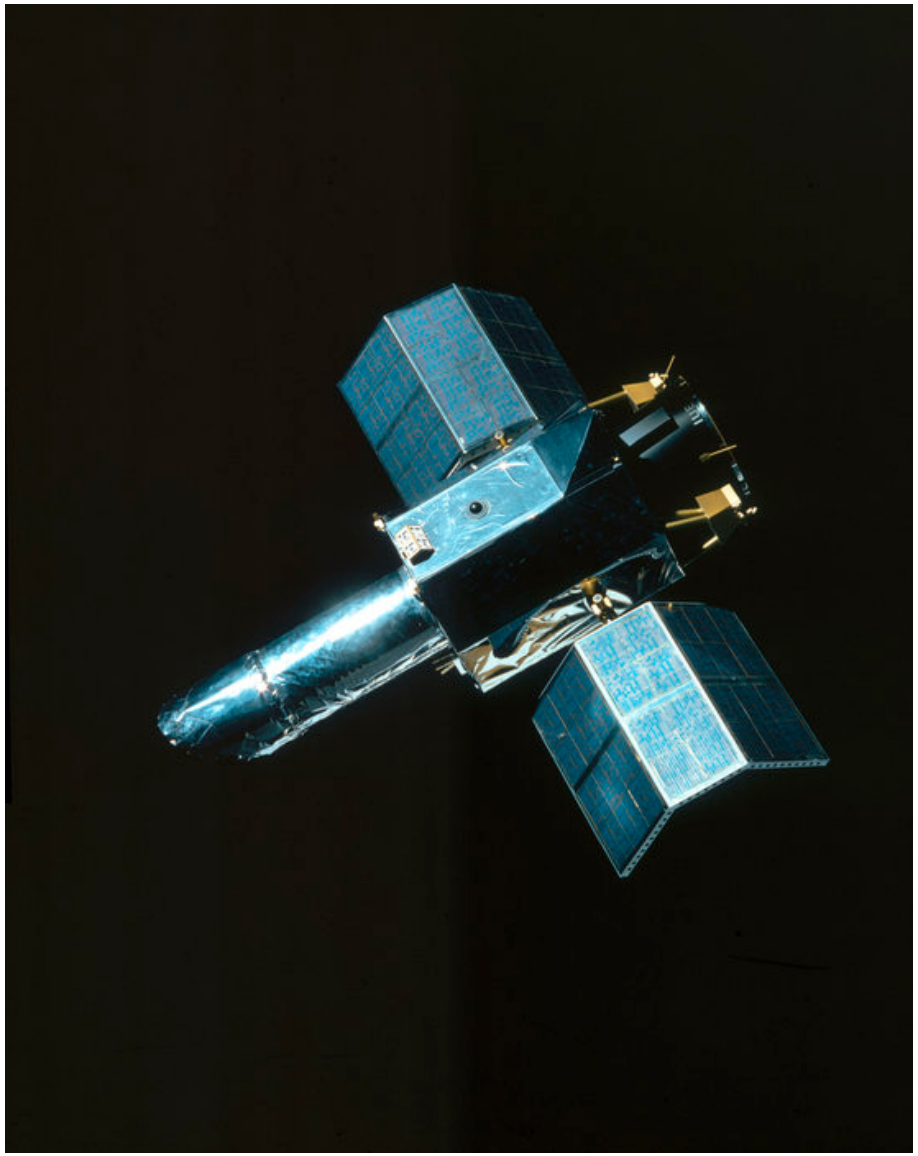


Image Credits: NASA

Small Astronomy Satellites (SAS)



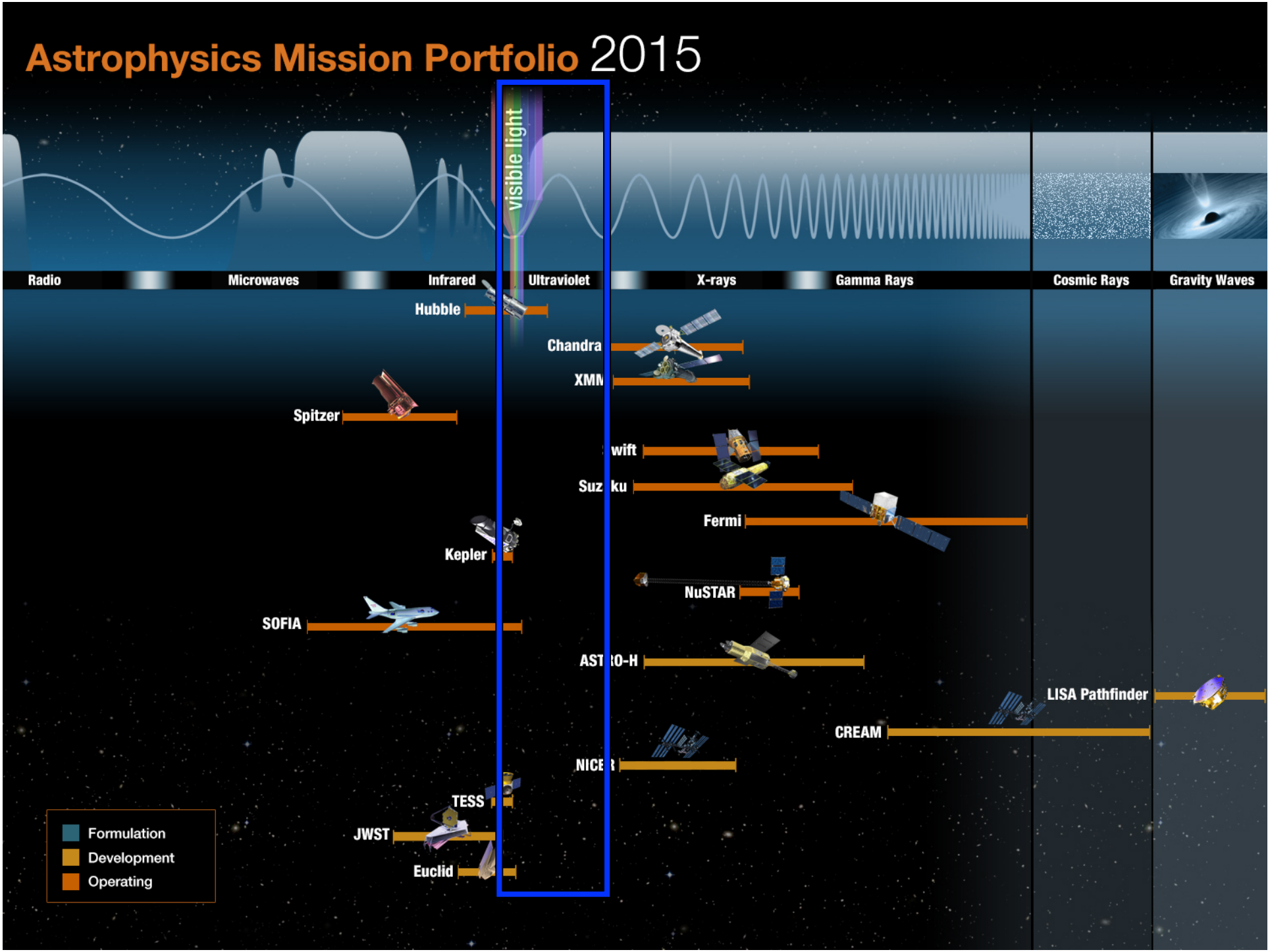
SAS-D
International Ultraviolet Explorer (IUE)
1978-1996

- 45 cm mirror
- Low- and High-dispersion spectrographs
- FES camera
- Observed more than 10,000 objects

Image Credit: NASA

UV Science at NASA

- NASA has been involved directly or indirectly in many UV missions:
  - **Legacy:** ANS, TD-1, Copernicus, IUE, Astro I/II (UIT, WUPPE, HUT), MSX
  - **Large Observatory:** HST (FOC, WPFC2, FOS, STIS, GHRS, ACS, COS)
  - **Explorer Series:** EUVE, FUSE, GALEX and limited capabilities: XMM and Swift


Astrophysics Mission Portfolio 2015
visible light
Radio
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Rays
Cosmic Rays
Gravity Waves
Hubble
Chandra
XMM
Spitzer
wift
Suz ku
Fermi
Kepler
NuSTAR
SOFIA
AST O-H
LISA Pathfinder
CREAM
NICE
TESS
JWST
Euclid
Formulation
Development
Operating

Decadal Survey 2010

Main Report Table ES.1	Main Report Page 7-26	Panel Reports Page 6-36	Panel Reports Fig. 6.17-19
Definition of a future UV-optical space capability. Technology development benefiting a future UV telescope to study hot gas between galaxies, ISM, and exoplanets **$40M for decade**	Key advances could be made with a telescope with a 4-m diameter aperture with large FOV ad fitted with high-efficiency UV and optical cameras/ spectrographs operating at shorter wavelengths than HST	The panel views this is a unique opportunity that requires a ***dedicated technology development program.*** Because it believes that a UV optical telescope is a particularly strong candidate for a new stars in the 2021-2030 decade……	UV Detectors, Large Focal Plane Array UV and Optical Detectors, Wave Front Sensing and Control, Coatings, Occulters, Deployable Mirrors Mirror and Optical Technologies, UV coatings, Nulling Interferometry

The Future of Astronomy – September 2014

Biosignatures, big data, international scientific collaborations, examine exoplanets, search for life…

Superficially, dark energy and inflation do seem to have some similarities," says Fermilab's Dan Hooper. Scientists say that the universe is expanding at an accelerated rate today because of something called dark energy and that for a fraction of a second shortly after the Big Bang, the universe expanded at a tremendously accelerated rate during the inflation epoch. ***Might dark energy be a contemporary version of what physicists call the inflaton field, which they suspect drove inflation? "***

Astrophysics (1990 – now)

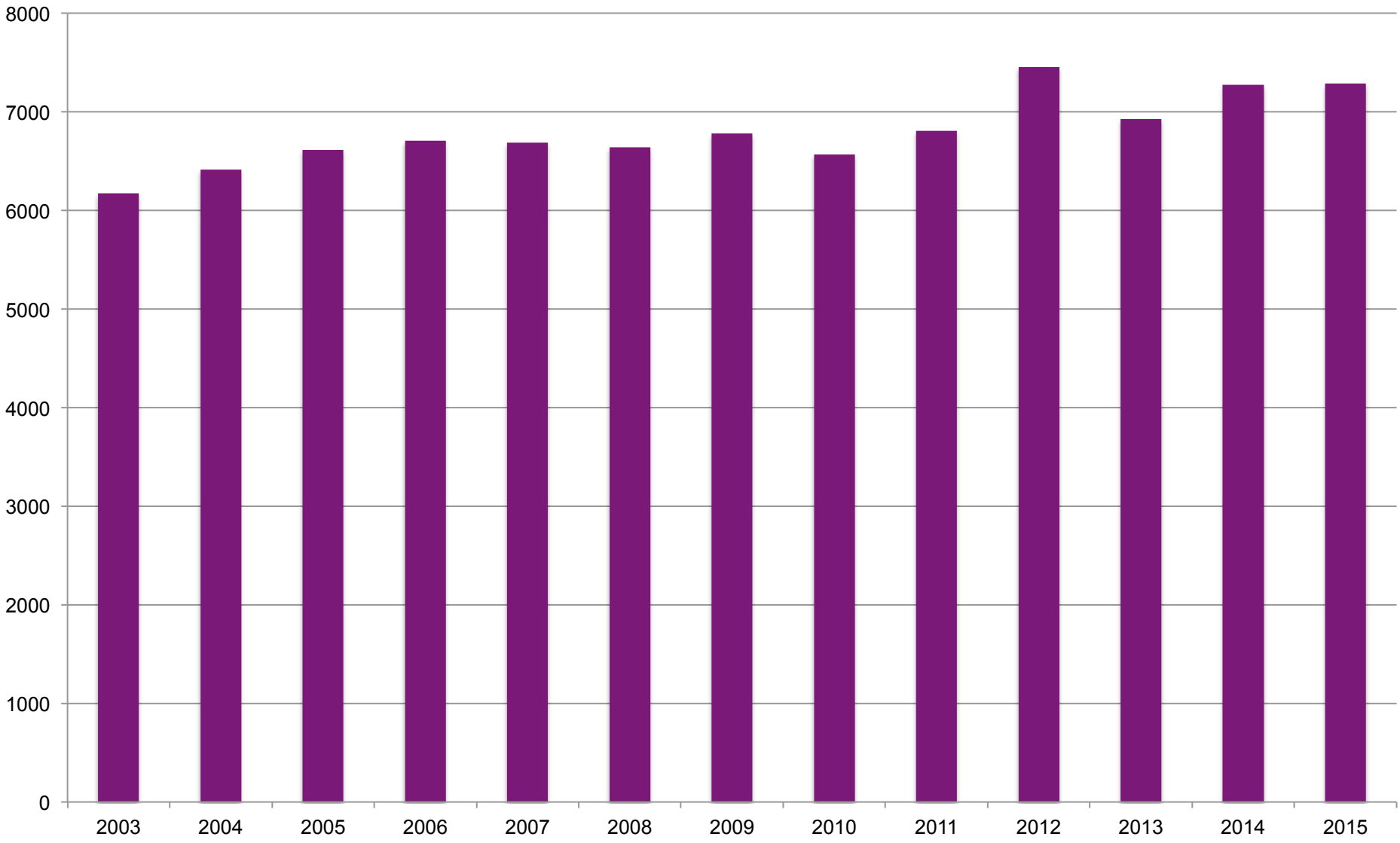
- **Community Growth**
  - Sustainability

- **Great Observatories Era:**
  - All four missions **(Hubble - 25, Chandra - 16, Spitzer -12, CGRO - 9**)
  - Named fellowships (**2015 - Sagan: 6, Hubble: 17, Einstein: 14**) => ~ 90+ fellows!
    - **Roman Technology Fellowship (2**)
  - Data archives (MAST, ADS, IPAC/NED/NExScI, HEASARC)

- ***Increasing system throughput is the single most important and cost-effective way to increase science productivity at UV wavelengths.***
  (from White Paper to Astro Decadal 2010, by Sembach et al. 2009)

- **Science Case for Mission *Concepts:***
  - ***RFI for UV/Vis science – 34 submissions – 2012 (Scowen et al. 2013, Experimental Astronomy)***
  - Articulating & Formulating
  - Communicating
  - Marketing and Selling

AAS Members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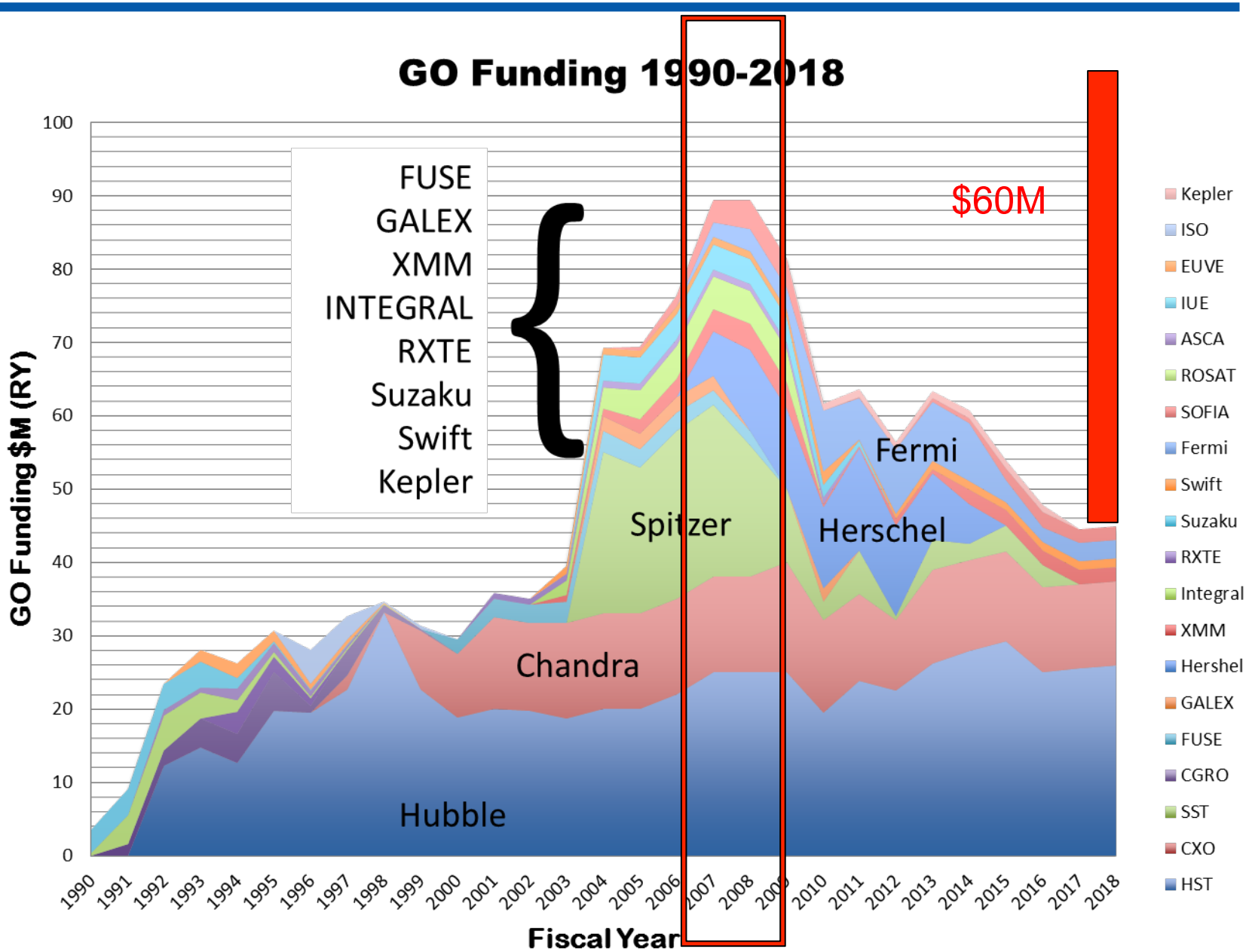
2015

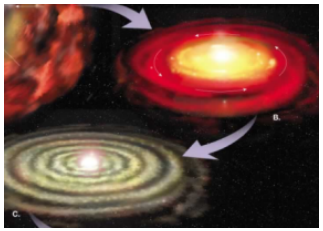
Astrophysics Division

GO Funding



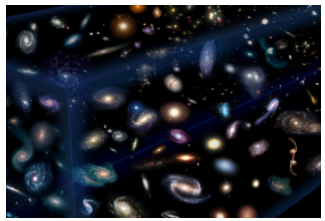
Strategic Astrophysics Technology (SAT)

- Introduced in 2009, the ***Strategic Astrophysics Technology (SAT)*** Program was established to support the maturation of mid-range Technology Readiness Level (TRL) technologies developed and tested in the laboratory (TRL ≥ 3) to a point where they can be incorporated into flight missions with an acceptable level of risk (TRL ~ 5-6).



How did we get here? ➔ *Cosmic Origins Program (COR)*
– GSFC Program Office

Are we alone? ➔ *Exoplanet Exploration Program (EXEP)*
– JPL Program Office



How does the universe work? ➔ *Physics of the Cosmos (PCOS)*
– GSFC Program Office

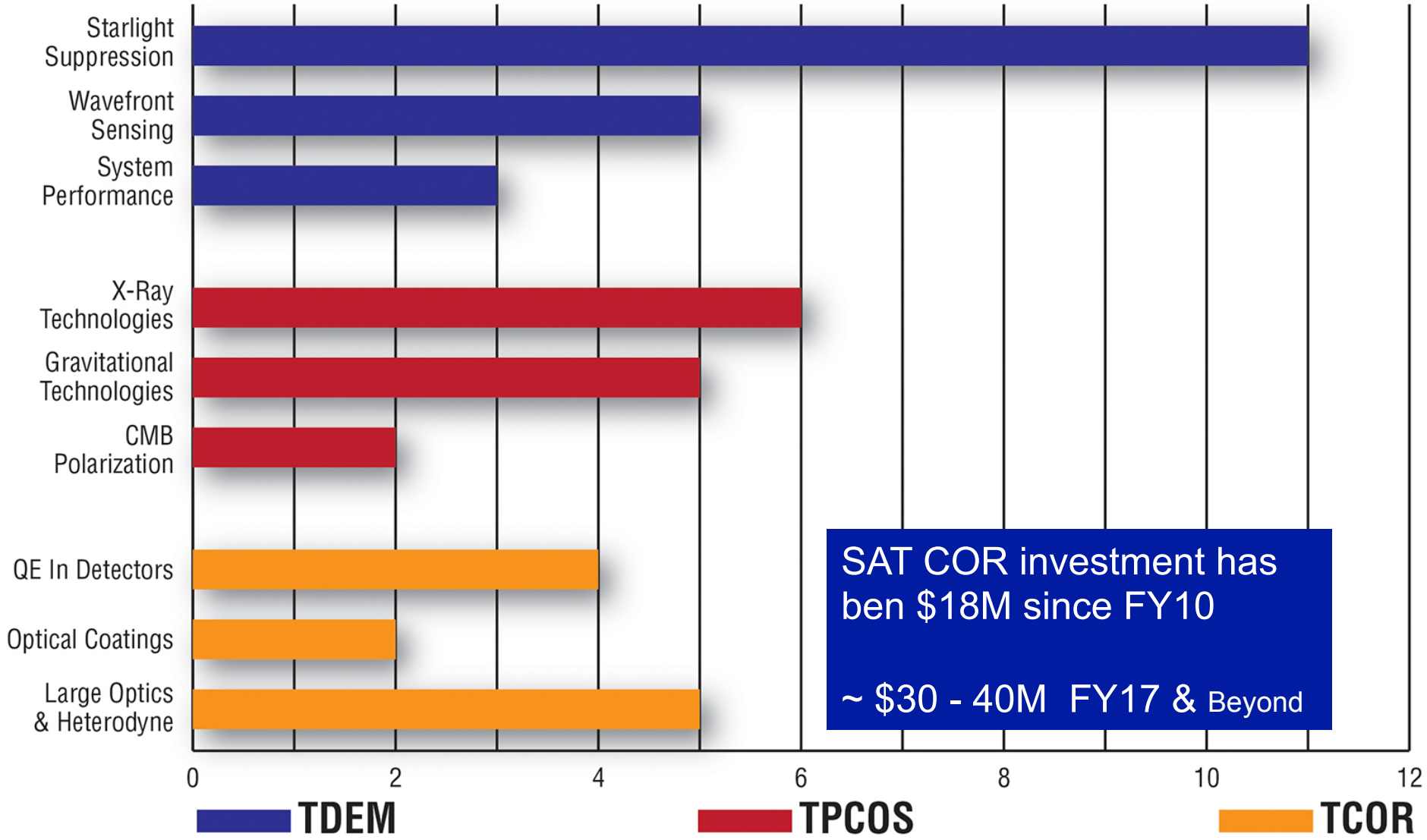
Why Technology Maturation?

- The need for technology maturation is imposed by the entrance requirements for proposing flight missions (TRL ~ 5-6).

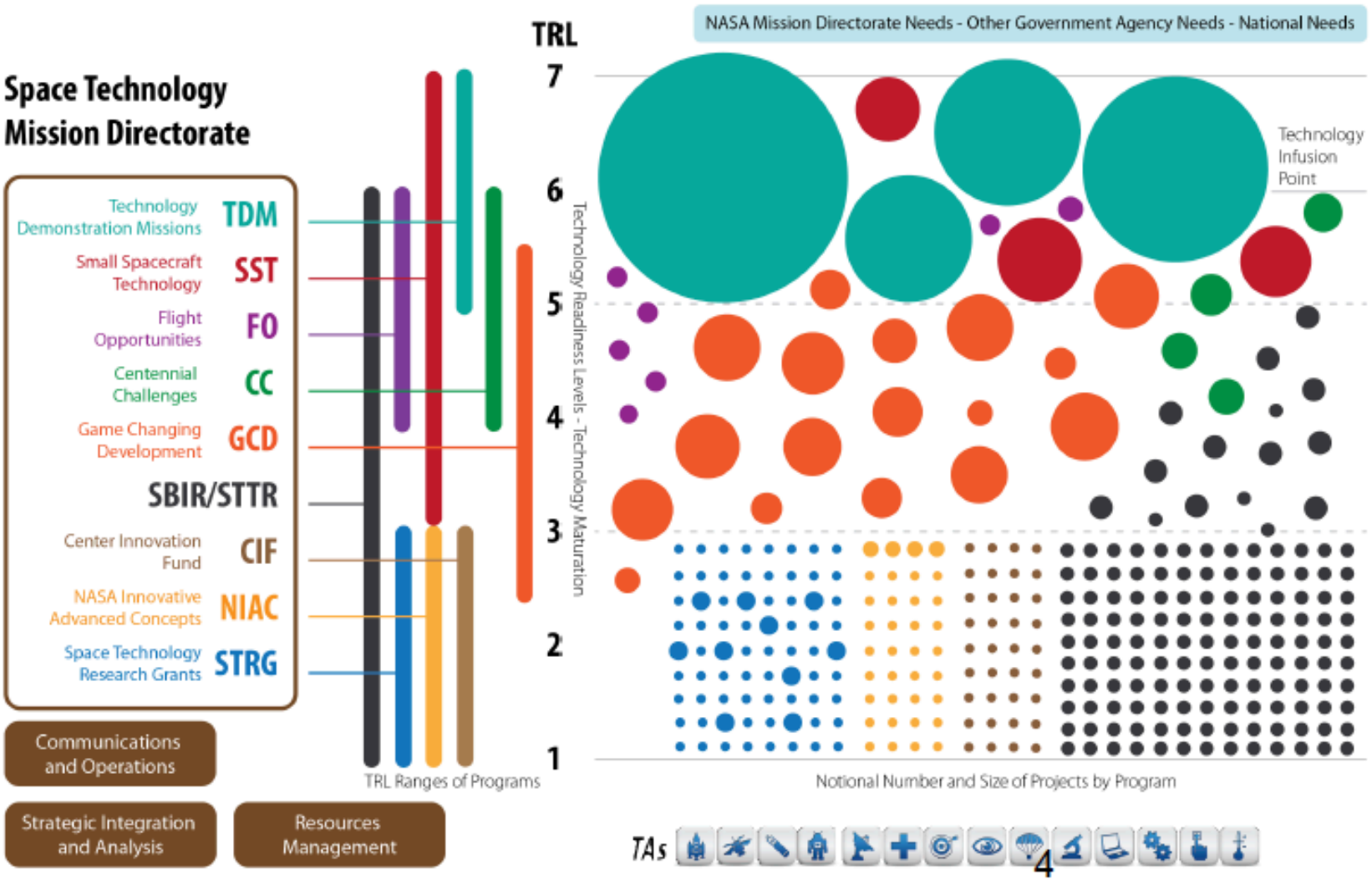
- The impact of ***"technology maturity and design stability,... can lessen cost and schedule risks"*** *(US Government Accountability Office report on 21 large NASA projects for a combined life-cycle cost in excess of $43B).*

- There are many programs about technology inception, but few on technology maturation because they are ***more expensive, specific and laborious.***

SAT Selected Proposals in Themes (2014)



Space Technology Portfolio



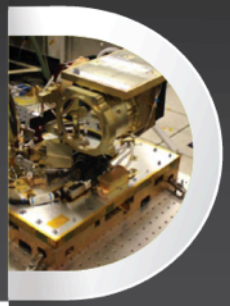
4

Astrophysics and Heliophysics Workshop

Space Technology Portfolio

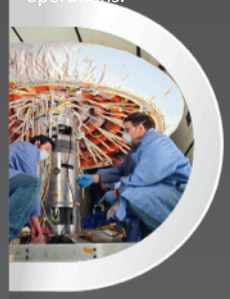
Transformative & Crosscutting Technology Breakthroughs

Technology Demonstration Missions (TDM)
bridges the gap between early proof-of-concept tests and the final infusion of cost-effective, revolutionary technologies into successful NASA, government and commercial space missions.



Small Spacecraft Technology Program (SSTP)
develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.

Game Changing Development (GCD)
seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's broad array of future space missions.

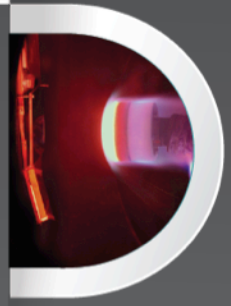


Pioneering Concepts/Developing Innovation Community

NASA Innovative Advanced Concepts (NIAC)
nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.

Space Technology Research Grants (STRG)
seeks to accelerate the development of "push" technologies to support future space science and exploration needs through innovative efforts with high risk/high payoff while developing the next generation of innovators through grants and fellowships.

Center Innovation Fund (CIF)
stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.



Creating Markets & Growing Innovation Economy

Centennial Challenges
directly engages nontraditional sources advancing technologies of value to NASA's missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.

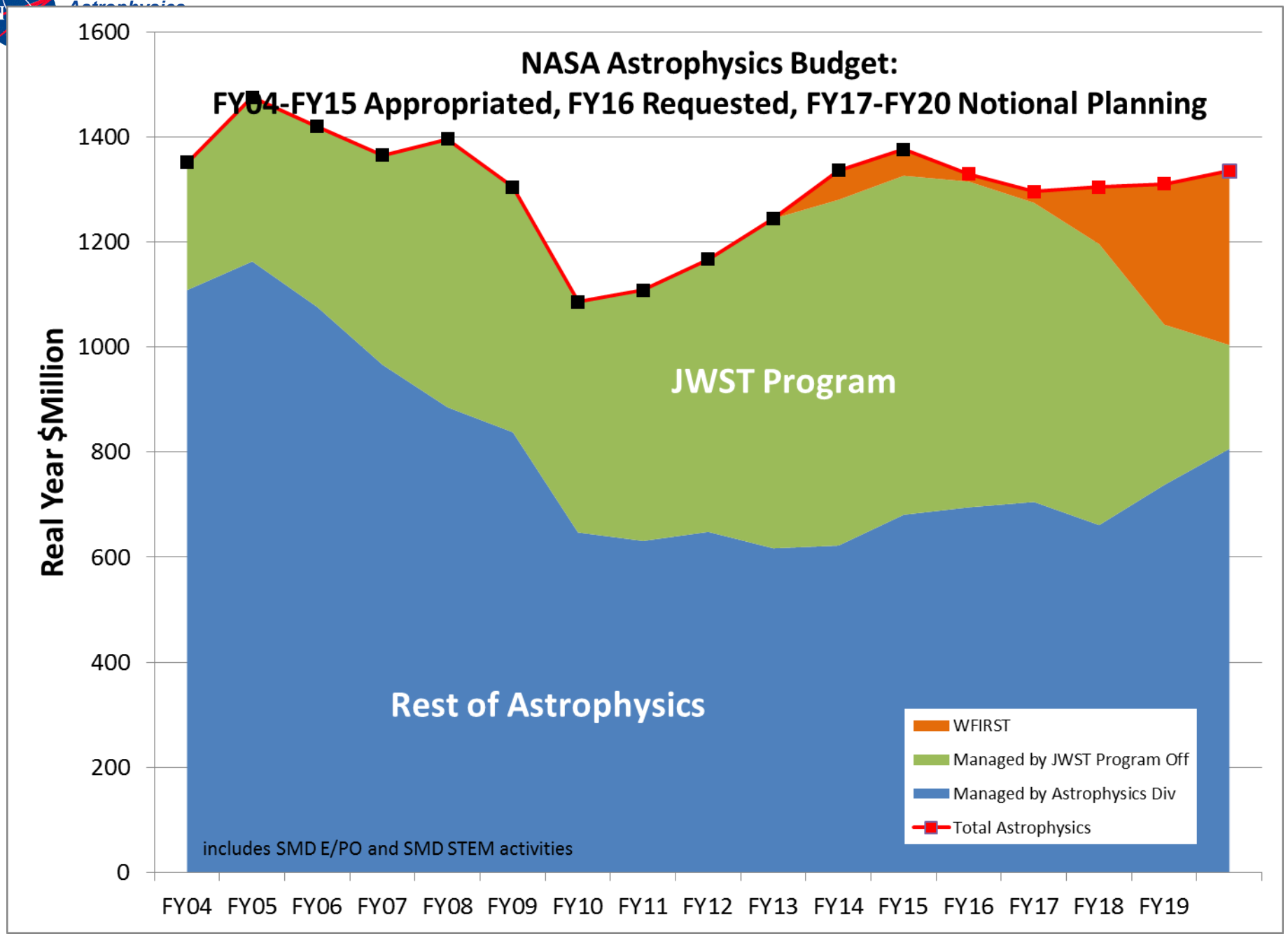
Flight Opportunities
facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)
Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency's needs and developing the Nation's innovation economy.

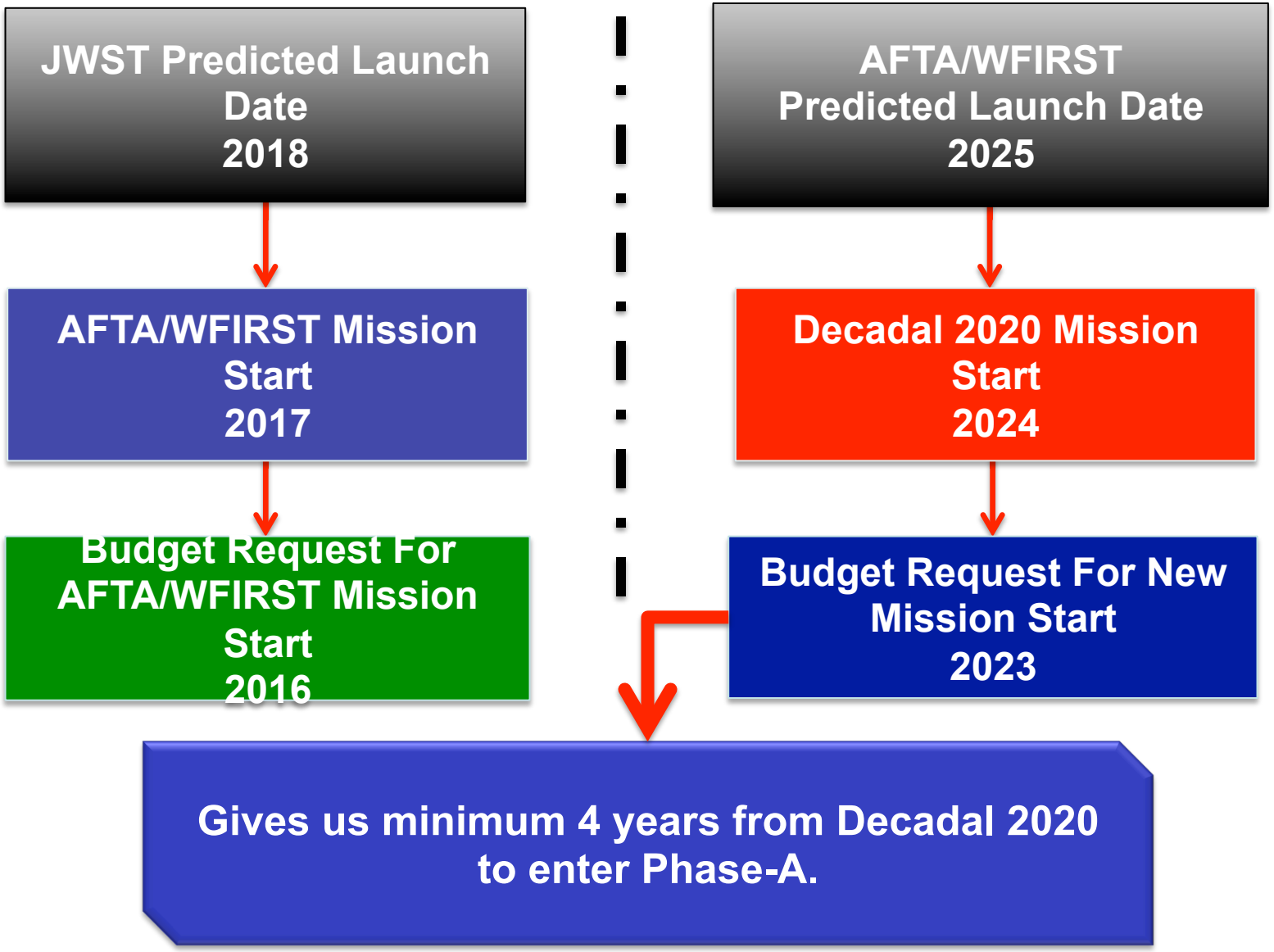
FY 2015 Tentative Solicitation Schedule

STMD Program	Solicitations	FY 2015 Targeted Release			
		Q1	Q2	Q3	Q4
NASA Innovative Advanced Concepts (NIAC)	NIAC Phase I	X			
	NIAC Phase II		X		
Space Technology Research Grants (STRG)	Early Career Faculty (ECF)		X		
	Early Stage Innovations (ESI)			X	
	NASA Space Technology Research Fellowships (NSTRF)-Fall 2015	X (Sept)			
Game Changing Development (GCD)	GCD Technology Topics	X			
	GCD Technology Topics			X	
Technology Demonstration Missions (TDM)	Technology Demonstration Mission Topics				X
Small Spacecraft Technology (SST)	SST Development and Demonstration		X		
	SST Partnerships		X		
Flight Opportunities Program (FOP)	FOP Technology Topic	X (Sept)		X	
Small Business Innovative Research (SBIR)	SBIR/STTR Phase I	X			
	SBIR/STTR Phase II	X			

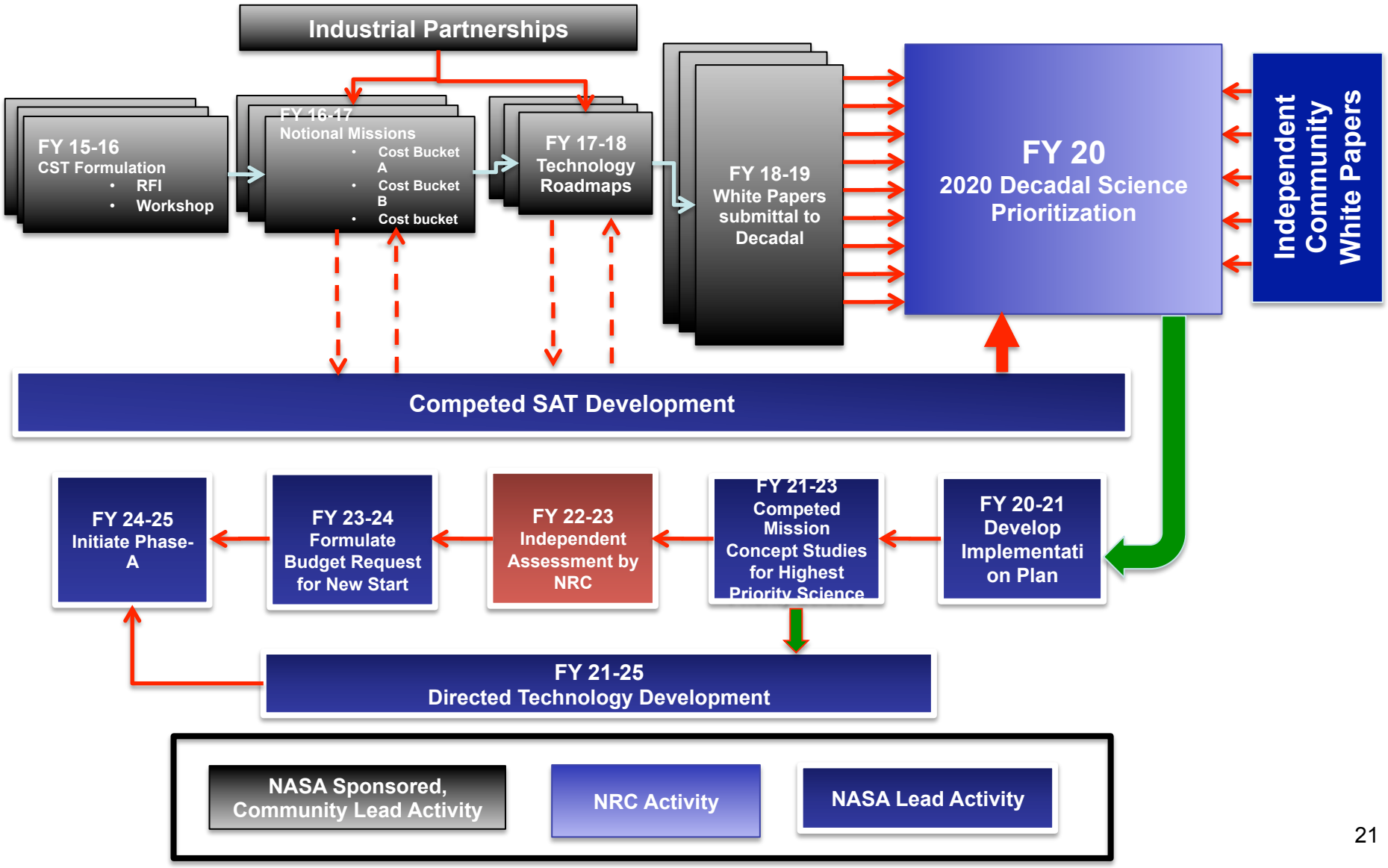
18


NASA Astrophysics Budget:
FY04-FY15 Appropriated, FY16 Requested, FY17-FY20 Notional Planning
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
Rest of Astrophysics
includes SMD E/PO and SMD STEM activities
WFIRST
Managed by JWST Program Off
Managed by Astrophysics Div
Total Astrophysics
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19

Looking Ahead
Potential Start Date of Decadal 2020 Mission

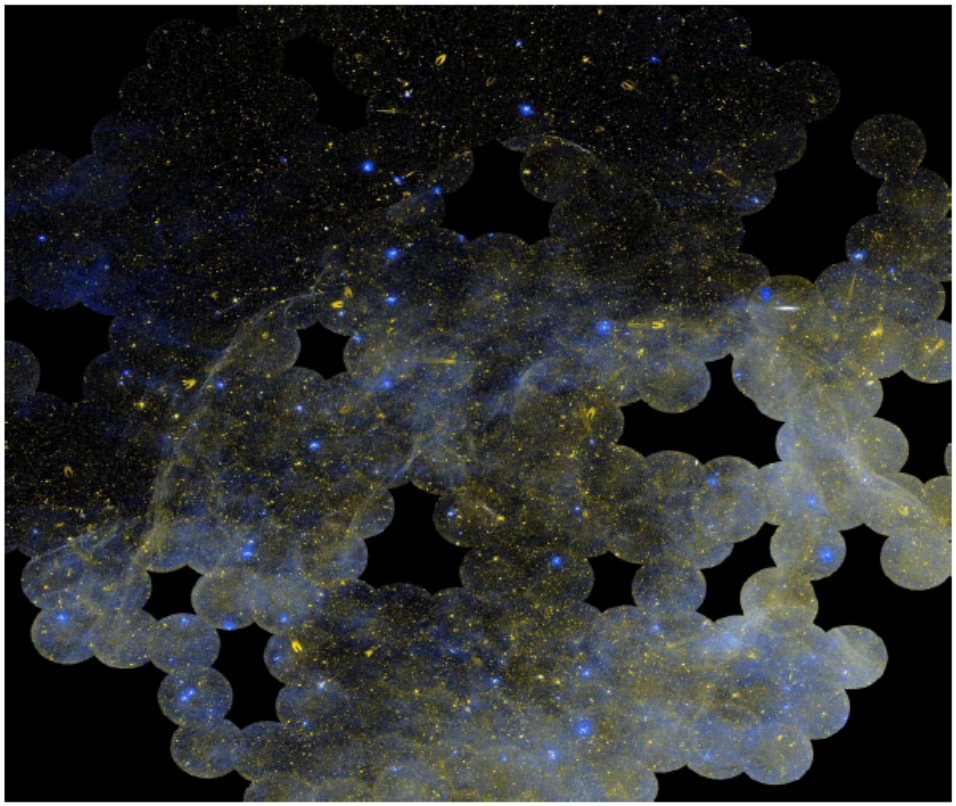


Roadmap To Decadal 2020



EUROPEAN ULTRAVIOLET-VISIBLE OBSERVATORY

"Building galaxies, stars, planets and the ingredients for life between the stars"



The UV sky from GALEX All Sky Survey

ESA Cosmic Visions

June 4, 2015 - M4 Selection for further study – launch in 2025:

- Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (ARIEL)
- Turbulence Heating ObserveR (THOR)
- X-ray Imaging Polarimetry Explorer (XIPE)

Past Selections (blue astrophysics)

L1 – JUICE – 2022 (Planetary)
L2 - Athena - 2028
L3 - eLISA - 2034

M1 – Solar Orbiter – 2018 (Heliophysics)
M2 – Euclid - 2020
M3 – PLATO - 2024

S1 – CHEOPS - 2017

Should we try to collaborate with ESA on the M4 mission?

Planning for the 2015-2016 Mid-Decade Review

- The NASA Authorization Act of 2005 requires assessments of NASA's science programs that include mid-decade reviews.
  - The Astrophysics Mid-Decade Review will be during 2015-2016
  - Study will be co-sponsored by NASA, NSF, and DOE (the Agencies)
- Given the funding circumstances that are substantially below those assumed in the Decadal Survey, the committee's review will describe:
  - The most significant scientific discoveries, technical advances, and relevant programmatic changes in astronomy and astrophysics since the Decadal Survey;
  - How well the Agencies' programs address the strategies, goals, and priorities outlined in the Decadal Survey and other NRC reports;
  - Progress toward realizing these strategies, goals and priorities; and
  - Any actions that could be taken to maximize the science return of the Agencies' programs.
- The Agencies are in the process of charging the NRC, and formation of the Study Committee will begin soon **(Jackie Hewitt, Chair).**

Planning for the 2015-2016 Mid-Decade Review

Directions in *New Worlds, New Horizons* relevant to NASA (paraphrased)

- LISA: If LISA is not L1, or LISA Pathfinder is not successful, or equal partnership is not possible, then conduct review to reconsider LISA's prioritization. (p.9, p.213)
  - NASA working toward partnership on ESA L3, will invest in enabling technology and LPF; anticipate review by 2020 Decadal Survey regarding priority of strategic partnership on ESA L3.
- IXO: If IXO is L1, conduct review then (maybe) invest immediately in technology. By mid-decade, invest aggressively in technology. (p. 9, p. 214, p. 215)
  - NASA planning on partnership on ESA Athena, investing in technology now, expect details of partnership to be established soon; anticipate partnership well underway by time of 2020 Decadal Survey.
- New Worlds: If precursor science is favorable, conduct review then (maybe) downselect technology and invest to ready a mission for the 2020 decadal survey. (p. 20, p.195, p.216)
  - NASA maturing multiple technologies and studying multiple architectures in advance of 2020 Decadal Survey, not planning to downselect technology prematurely; anticipate review by 2020 Decadal Survey regarding priority – and possibly size and architecture – of strategic mission.
- Inflation Probe: If B-mode detected, conduct review then (maybe) invest in technology for an all-sky mission. (p.198, p.217)
  - NASA maturing multiple detector technologies, considering potential partnerships on ESA and JAXA led missions; anticipate review by 2020 Decadal Survey regarding priority of probe-class mission.
- DSIAC: Conduct review to see whether any contingencies have occurred and recommend action. (p.102, p.237)

Astrophysics Division

Preparing for the 2020 Decadal Survey
Large Mission Concepts

- The 2020 Decadal Survey will prioritize large space missions to follow JWST and WFIRST.
  - To enable this prioritization, NASA needs to provide information on several candidate large space mission concepts for consideration by the 2020 Decadal Survey Committee.
- What information needs to be provided to the Decadal Survey committee to enable prioritization of large missions
  - Science case
  - Strawman design reference mission with strawman payload
  - Technology development needs
  - Cost requirements assessment
- NASA needs to initiate technology development for candidate large missions so that technology will be ready when needed.
  - Technology needs to be sufficiently mature when it is time to start the highest priority large mission in the 2020 Decadal Survey.
  - The next large mission after WFIRST could be started when funding becomes available as WFIRST approaches launch in the early or mid-2020s.

Astrophysics Division

Preparing for the 2020 Decadal Survey
Large Mission Concepts

- Study 3-4 large mission concepts as candidate prioritized large missions
  - Science case
  - Technology assessment
  - Design reference mission with strawman payload
  - Cost assessment
- Community Plan
  - 2015: PAGs gather community input on selecting concepts for study
  - 2016: Appoint STDTs and Center study office, STDT assess technology
  - 2017: Fund technology development through SAT, STDT works
  - 2018: STDT submits DRM for cost assessment
  - 2019: STDT issues report, input to Decadal Survey
- Community workshops (incomplete list)
  - Mar 19, Joint PAG EC meeting, Baltimore
  - Jun 3-5, Far-IR workshop, Pasadena
  - Jun 13-14, ExoPAG meeting, Chicago
  - Jun 25-26, UV-Vis SIG meeting, Greenbelt
  - Jun 29-Jul 1, HEAD & PhysPAG meeting, Chicago
  - Aug 1, Joint PAG session @ IAU General Assembly, Honolulu

Astrophysics Division

Preparing for the 2020 Decadal Survey
Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 decadal survey.
- **UV/Optical/IR Surveyor** –The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.

Astrophysics Division

Preparing for the 2020 Decadal Survey
Large Mission Concepts

Part A – 2015

- Identify a small set of candidate large mission concepts to study
  - NASA draws a small set of candidate mission concepts from existing roadmap and strategic documents
  - Incorporate community input through the three Astrophysics Program Analysis Groups (PAGs)

Part B – 2016-2019

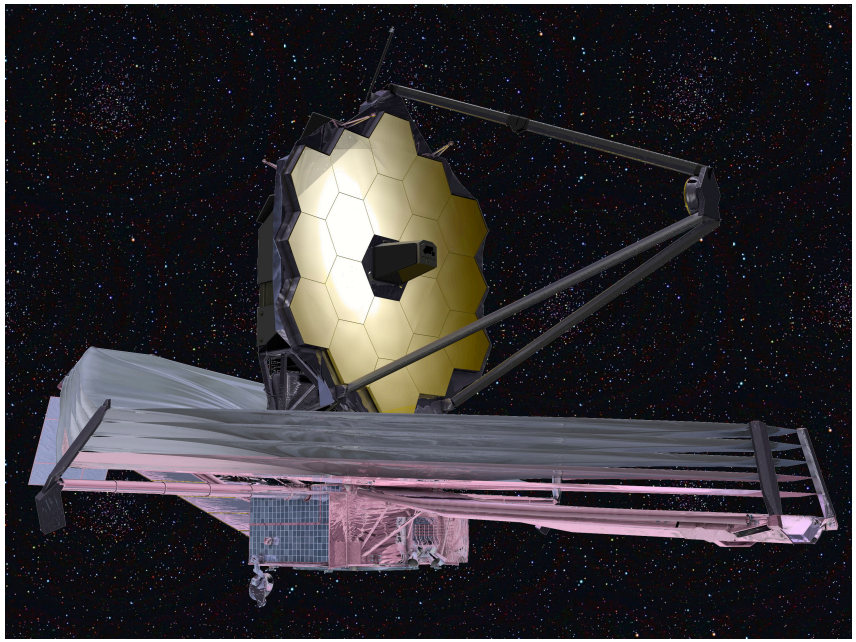
- Initiate studies
  - Includes community-based Science and Technology Definition Teams
- Conduct studies
  - Includes NASA Center-provided engineering teams
- Identify technology requirements to motivate early technology development
  - Enables funding through existing Astrophysics technology programs
- Deliver results to 2020 Decadal Survey committee

Planning for the 2020 Decadal Survey: An Astrophysics Division White Paper
available at http://science.nasa.gov/astrophysics/documents

Astrophysics Division

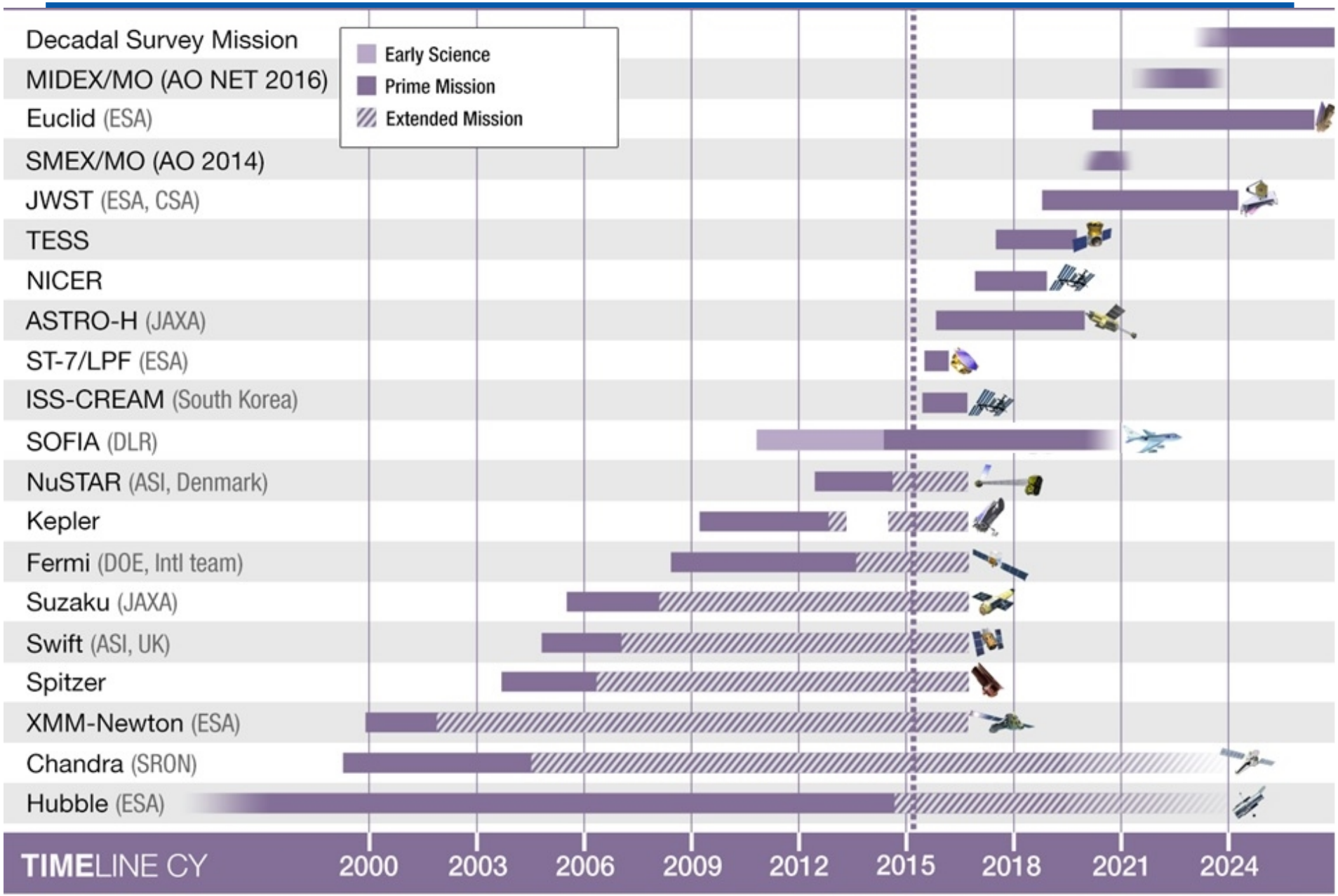
Preparing for JWST Science

- Need to ensure a smooth transition of JWST management back into the Astrophysics Division when prime ops begin.
- Need to ensure that the budget is right. Adequate to reap the science benefits of JWST. Balanced to enable appropriate GO funding.
- Constrained to permit development of future observatories.



Astrophysics Division

Astrophysics Timeline



Dates beyond 2016 are contingent upon the results of the 2016 Senior Review

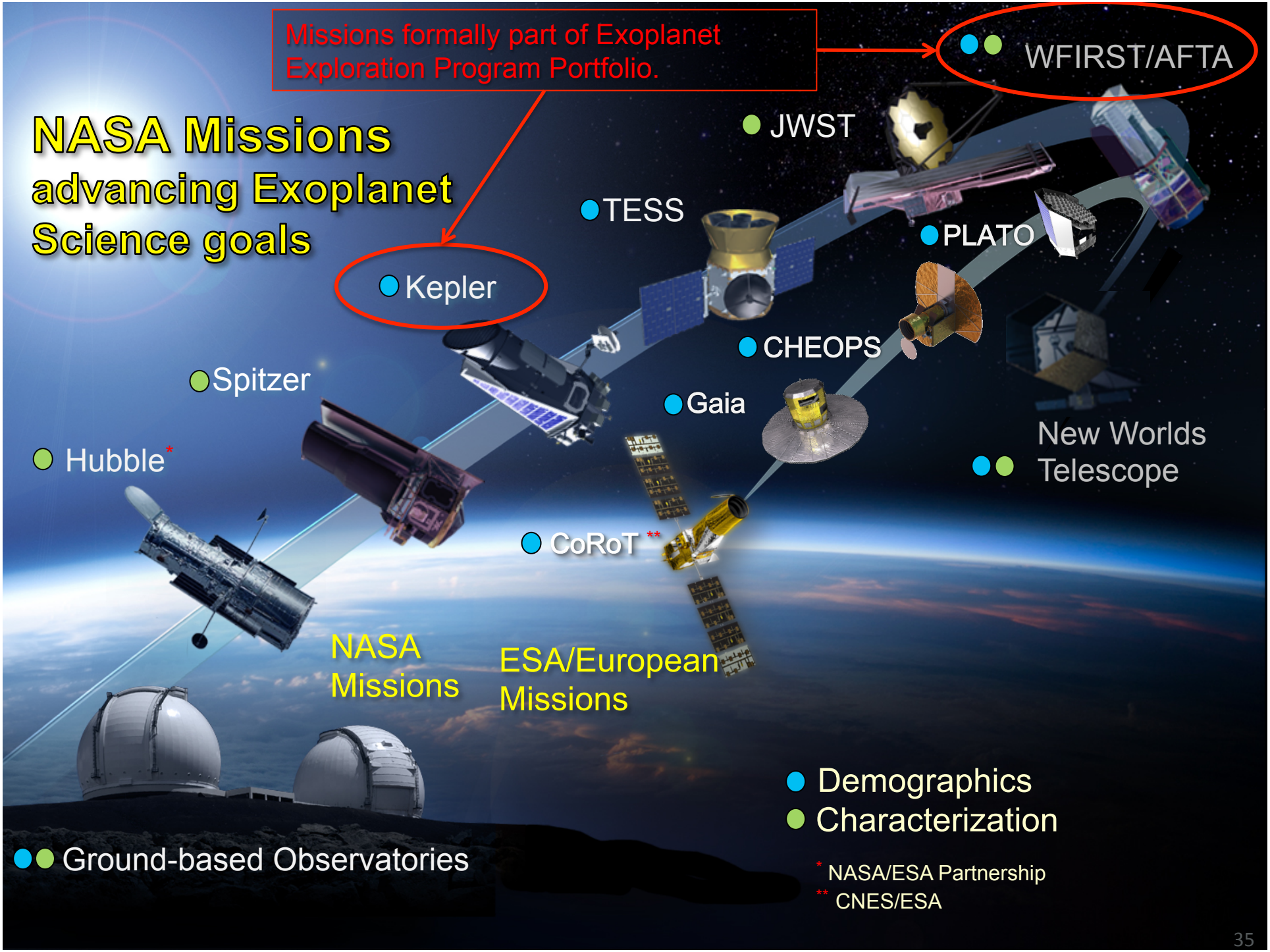

Formulation
Implementation
Primary Ops
Extended Ops
XMM-Newton (ESA)
Swift
Suzaku (JAXA)
Fermi
Euclid (ESA)
JWST
Hubble
Kepler
Spitzer
ASTRO-H (JAXA)
Chandra
NICER (on ISS)
TESS
NuSTAR
LISA
Pathfinder (ESA)
SOFIA
May 2015

BACKUPS

Astrophysics PAGs

NASA Advisory Council (NAC)	→ NASA / Charlie Bolden
Science Committee	→ SMD / John Grunsfeld
Astrophysics Subcommittee	→ Astrophysics / Paul Hertz

COPAG	ExoPAG	PhysPAG
Program Scientist: Mario Perez Mike Garcia Program Executive: Jeanne Davis Program Manager: Mansoor Ahmed (GSFC) Chief Scientist: Susan Neff Deborah Padgett (GSFC)	Program Scientist: Doug Hudgins Martin Still Program Executive: John Gagosian Program Manager: Gary Blackwood (JPL) Chief Scientist: Wes Traub (JPL)	Program Scientist: Rita Sambruna Wilt Sanders Program Executive: Jeanne Davis Program Manager: Mansoor Ahmed (GSFC) Chief Scientist: Ann Hornschemeier Peter Bertone (GSFC)


Missions formally part of Exoplanet Exploration Program Portfolio.
WFIRST/AFTA
NASA Missions
advancing Exoplanet Science goals
JWST
TESS
PLATO
Kepler
CHEOPS
Spitzer
Gaia
New Worlds Telescope
Hubble*
CoRoT **
NASA Missions
ESA/European Missions
Demographics
Characterization
Ground-based Observatories
* NASA/ESA Partnership
** CNES/ESA

NN-EXPLORE Partnership

NASA and the NSF have teamed up to establish "NN-EXPLORE" – the NASA/NSF EXoPLanet Observational REsearch partnership.

- NN-EXPLORE capitalizes on the NOAO share (40%) of the observing time on the 3.5-m WIYN at Kitt Peak National Obs.
- Primary objective is to enable a community-based exoplanet research program that advances NSF research interests and supports the exoplanet observations of NASA missions (e.g. K2, TESS, JWST, etc.).
- The cornerstone of NN-EXPLORE will be a state-of-the-art extreme precision Doppler spectrometer with open access to the U.S. astronomical community (est. delivery 2018).
- Partnership commences with the WIYN 2015B observing semester, using the existing compliment of instruments to conduct observations that advance NN-EXPLORE science goals.

NN-EXPLORE Partnership

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- NN-EXPLORE capitalizes on the NOAO share (40%) of the observing time on the 3.5-m WIYN at Kitt Peak National Obs.
- Primary objective is to enable a community-based exoplanet research program that advances NSF research interests and supports the exoplanet observations of NASA missions (e.g. K2, TESS, JWST, etc.).
- The cornerstone of NN-EXPLORE will be a state-of-the-art extreme precision Doppler spectrometer with open access to the U.S. astronomical community (est. delivery 2018).
- Partnership commences with the WIYN 2015B observing semester, using the existing compliment of instruments to conduct observations that advance NN-EXPLORE science goals.

Astrophysics Division

Astrophysics - Big Picture

- **The FY15 appropriation and FY16 budget request provide funding for NASA astrophysics to continue its programs, missions, and projects as planned**
  - The total funding (Astrophysics including JWST) is flat at ~$1.3B through FY20
  - Fully fund JWST to remain on plan for an October 2018 launch
  - Fund continued pre-formulation and technology work leading toward WFIRST
  - Restore SOFIA to the budget with a reduction in FY15 and full funding beyond
  - Provide funding for SMD's education programs
- **The operating missions continue to generate important and compelling science results, and new missions are under development for the future**
  - Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Suzaku, Swift, XMM-Newton continued following the 2014 Senior Review
  - SOFIA is in prime operations as of May 2014
  - Missions on track for launch include LISA Pathfinder (2015), ASTRO-H (2015), NICER (2016), TESS (2017), JWST (2018), Euclid (2020)
  - New Explorers being selected (SMEX in 2015, MIDEX in 2017), WFIRST being studied, NASA joining ESA's Athena and ESA's L3 gravitational wave observatory
- **Progress being made against recommendations of the 2010 Decadal Survey**
  - Update to the Astrophysics Implementation Plan has been released
  - NRC Mid Decade Review (with NSF, DOE) to begin in early 2015
  - NASA initiating large mission concept studies for 2020 Decadal Survey

Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:	
Large-scale 1. WFIRST	Preformulation and focused technology development for WFIRST/AFTA (a 2.4m version of WFIRST with a coronagraph) are underway to enable a new start NET FY2017. Budget line established for an Astrophysics Decadal Strategic Mission.
Large-scale 2. Augmentation to Explorer Program	Astrophysics Explorers planned budget increased to support decadal cadence of AOs including SMEX AO in Fall 2014 and MIDEX AO in late 2016/early 2017.
Large-scale 3. LISA	Discussing partnership on ESA's L3 gravitational wave observatory and participating in ESA-led assessments in 2014-2015. Strategic astrophysics technology (SAT) investments plus support of LISA Pathfinder.
Large-scale 4. IXO	NASA is pursuing a partnership on ESA's L2 Athena X-ray observatory; the Athena study phase, with U.S. participation, is underway. Strategic astrophysics technology (SAT) investments.
Medium-scale 1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST, strategic astrophysics technology (SAT) investments, and exoplanet probe mission concept studies. Established partnership with NSF to develop extreme precision Doppler spectrometer as facility instrument. Exozodi survey using LBTI

Astrophysics Division

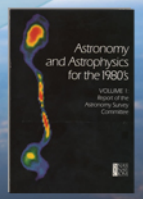
Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:	
Medium-scale 2. Inflation Probe Technology Development Program	Balloon-borne investigations plus strategic astrophysics technology (SAT) investments.
Small-scale. Research Program Augmentations	Increased annual R&A budget by 10% from FY10 to FY12 and another 10% from FY14 to FY16. Within R&A: established Theoretical and Computational Astrophysics Networks (TCAN) program with NSF; funding available for astrophysics theory; funding available for lab astrophysics; funding available for suborbital payloads.
Small-scale. Intermediate Technology development Augmentation	Established competed Strategic Astrophysics Technology (SAT) program element; directed technology funding for WFIRST and other large-scale decadal priorities.
Small-scale. Future Ultraviolet-Visible Space Capability	Strategic Astrophysics Technology (SAT) investments.
Small-scale. SPICA (U.S. contribution to JAXA-led)	Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.

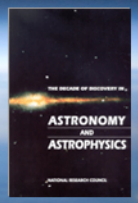
ASTROPHYSICS

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST