National Aeronautics and Space Administration

Astrophysics

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Astrophysics Subcommittee

February 23, 2012

Agenda

- Science Highlights
- Organizational Changes
- Program Update
- President's FY13 Budget Request
- Addressing Decadal Survey Priorities

Chandra Finds Milky Way's Black Hole Grazing on Asteroids

- The giant black hole at the center of the Milky Way may be vaporizing and devouring asteroids, which could explain the frequent flares observed, according to astronomers using data from NASA's Chandra X-ray Observatory. For several years Chandra has detected X-ray flares about once a day from the supermassive black hole known as Sagittarius A*, or "Sgr A*" for short. The flares last a few hours with brightness ranging from a few times to nearly one hundred times that of the black hole's regular output. The flares also have been seen in infrared data from ESO's Very Large Telescope in Chile.
- Scientists suggest there is a cloud around Sgr A* containing trillions of asteroids and comets, stripped from their parent stars. Asteroids passing within about 100 million miles of the black hole, roughly the distance between the Earth and the sun, would be torn into pieces by the tidal forces from the black hole.
- These fragments then would be vaporized by friction as they pass through the hot, thin gas flowing onto Sgr A*, similar to a meteor heating up and glowing as it falls through Earth's atmosphere. A flare is produced and the remains of the asteroid are eventually swallowed by the black hole.
- The authors estimate that it would take asteroids larger than about six miles in radius to generate the flares observed by Chandra. Meanwhile, Sgr A* also may be consuming smaller asteroids, but these would be difficult to spot because the flares they generate would be fainter.
- Planets thrown into orbits too close to Sgr A* should be disrupted by tidal forces, although this would happen much less frequently than the disruption of asteroids, because planets are not as common. Such a scenario may have been responsible for a previous X-ray brightening of Sgr A* by about a factor of a million about a century ago. While this event happened many decades before X-ray telescopes existed, Chandra and other X-ray missions have seen evidence of an X-ray "light echo" reflecting off nearby clouds, providing a measure of the brightness and timing of the flare.

Credit: X-ray: NASA/CXC/MIT/F. Baganoff et al.

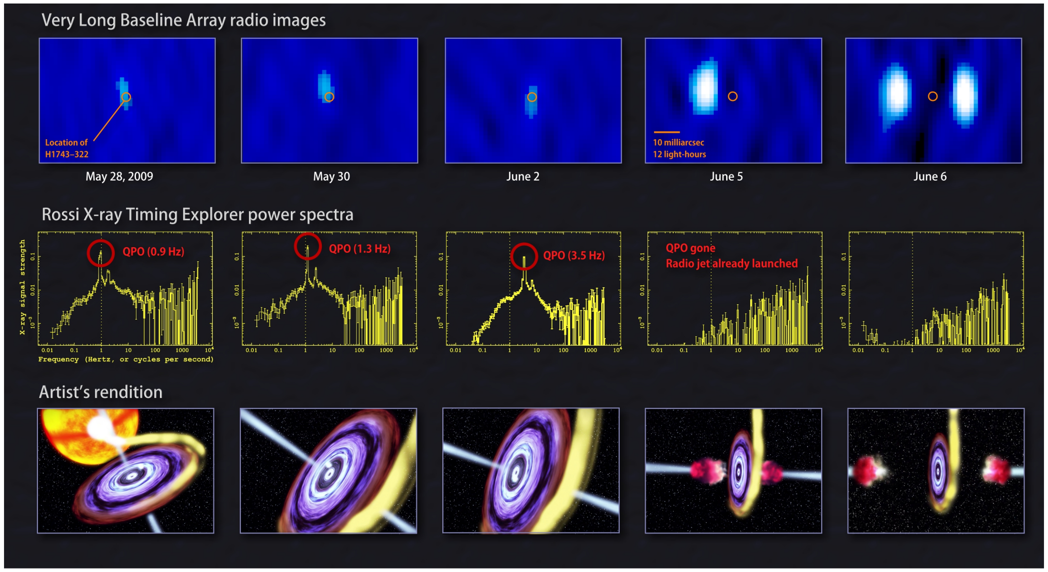
The above image from NASA's Chandra X-ray Observatory shows the center of our Galaxy, with a supermassive black hole known as Sagittarius A* in the center. The image contains nearly a million seconds of Chandra observing of the region around the black hole, with red representing low-energy X-rays, green as medium-energy X-rays, and blue being the highest.

Hubble Solves Mystery on Source of Supernova in Nearby Galaxy

This image of supernova remnant 0509-67.5 was made by combining data from two of NASA's Great Observatories. Optical data of SNR 0509-67.5 and its accompanying star field, taken with the Hubble Space Telescope, are composited with X-ray images from the Chandra X-ray Observatory. The result shows soft green and blue hues of heated material from the X-ray data surrounded by the glowing pink optical shell, which shows the ambient gas being shocked by the expanding blast wave from the supernova. Ripples in the shell's appearance coincide with brighter areas of the X-ray data.

- Using NASA's Hubble Space Telescope, astronomers have solved a longstanding mystery on the type of star, or so-called progenitor, that caused a supernova in a nearby galaxy. The finding yields new observational data for pinpointing one of several scenarios that could trigger such outbursts.
- Based on previous observations from ground-based telescopes, astronomers knew that a kind of supernova called a Type Ia created a remnant named SNR 0509-67.5. The type of system that leads to this kind of supernova explosion has long been a high importance problem with various proposed solutions but no decisive answer. All these solutions involve a white dwarf star that somehow increases in mass to the highest limit. Astronomers failed to find any companion star near the center of the remnant, and this rules out all but one solution, so the only remaining possibility is that this one Type Ia supernova came from a pair of white dwarfs in close orbit.
- The Type Ia supernova that resulted in the creation of SNR 0509-67.5 occurred nearly 400 years ago for Earth viewers. The supernova remnant lies in the Large Magellanic Cloud (LMC), a small galaxy about 170,000 light-years from Earth. The bubble-shaped shroud of gas is 23 light-years across and is expanding at more than 11 million miles per hour (5,000 kilometers per second).
- Data from Hubble's Advanced Camera for Surveys, taken in 2006 with a filter that isolates light from glowing hydrogen, were combined with visible-light images of the surrounding star field that were taken with Hubble's Wide Field Camera 3 in 2010. These data were then merged with X-ray data from the Chandra X-ray Observatory taken with the Advanced CCD Imaging Spectrometer (ACIS) in 2000 and 2007.

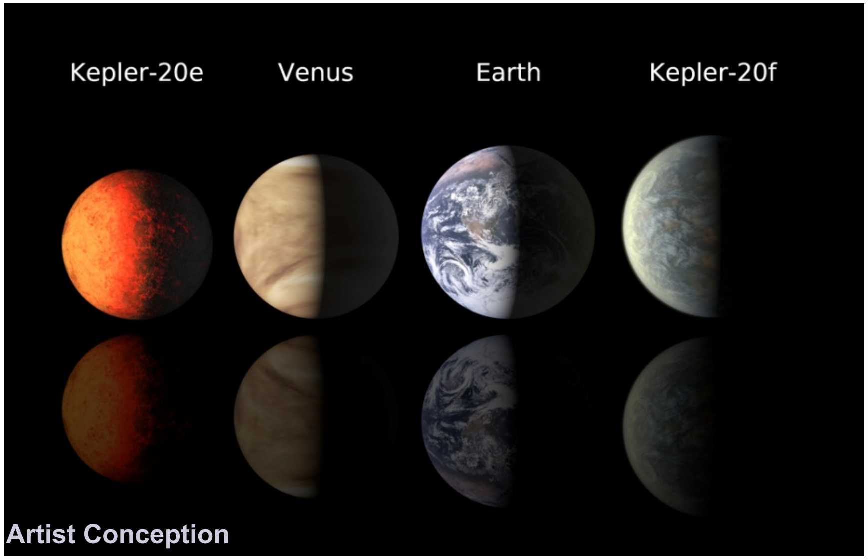
RXTE Helps Pinpoint Launch of ‘Bullets’ in a Black Hole’s Jet

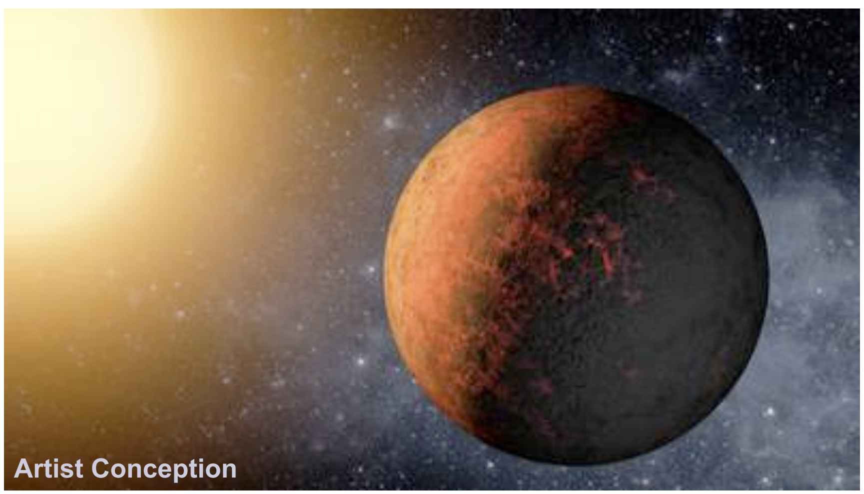


- After 16 years of operations, the Rossi X-ray Timing Explorer spacecraft was decommissioned on 1-5-2012.
- RXTE opened a new window into the workings of neutron stars and black holes.
- Astronomers established the existence of highly magnetized neutron stars (known as magnetars).
- The first accreting millisecond pulsars were discovered.
- The first observational evidence of "frame-dragging" in the vicinity of a black hole, predicted by Einstein's general theory of relativity, was seen.
- The astronomical community recognized the RXTE research with five major awards. These include four Rossi Prizes (1999, 2003, 2006 and 2009) and the 2004 NWO Spinoza prize.

- Using observations from NASA's Rossi X-ray Timing Explorer (RXTE) satellite and NSF’s Very Long Baseline Array (VLBA) radio telescope, an international team of astronomers has identified the moment when a black hole in our galaxy launched super-fast knots of gas into space.
- Radio imaging by the VLDB (top row), combined with simultaneous X-ray observations by RXTE (middle), captured the transient ejection of massive gas. Racing outward at about one-quarter the speed of light, these "bullets" of ionized gas are thought to arise from a region located just outside the black hole's event horizon, the point beyond which nothing can escape.
- By tracking the motion of these bullets with the VLBA, astronomers were able to link the ejection event to the disappearance of X-ray signals seen in RXTE data. These signals, called quasi-periodic oscillations, vanished two days earlier than the onset of the radio flare that astronomers previously had assumed signaled the ejection.
- The research centered on the mid-2009 outburst of the binary system H1743–322, located ~28,000 light-years away toward the constellation Scorpius. Discovered by NASA's HEAO-1 satellite in 1977, the system is composed of a normal star and a black hole of modest but unknown masses. Their orbit around each other is measured in days, which puts them so close together that the black hole pulls a continuous stream of matter from its stellar companion. The flowing gas forms a flattened accretion disk millions of miles across, several times wider than our sun, centered on the black hole. As matter swirls inward, it is compressed and heated to tens of millions of degrees, so hot that it emits X-rays.
- Some of the infalling matter becomes re-directed out of the accretion disk as dual, oppositely directed jets. Most of the time, the jets consist of a steady flow of particles. Occasionally, though, they morph into more powerful outflows that hurl massive gas blobs at significant fractions of the speed of light.

First Earth-size Planets Around a Sun-like Star Outside Our Solar System

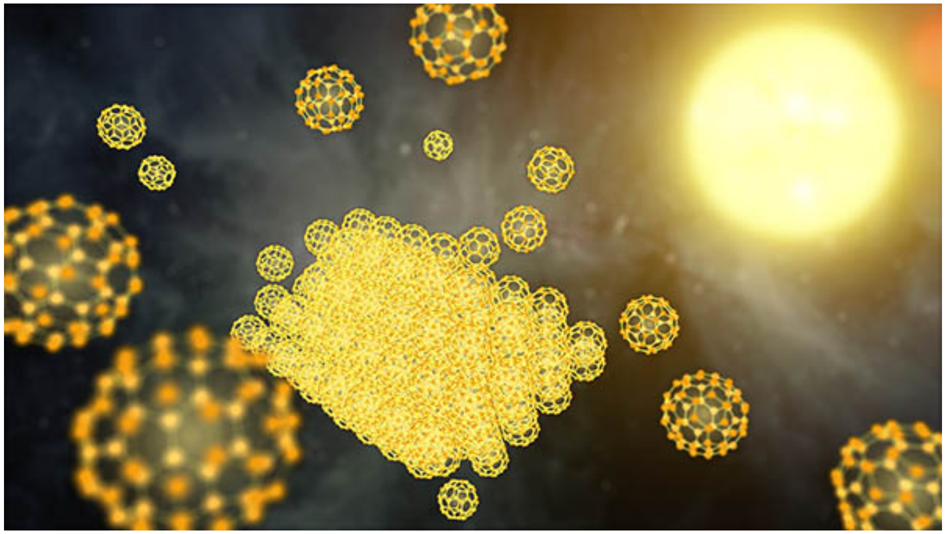




This is an artist's conception of Kepler-20e, the first planet smaller than the Earth discovered to orbit a star other than the sun.

- The Kepler mission has discovered the first Earth-size planets orbiting a sun-like star outside our solar system. The planets, called Kepler-20e and Kepler-20f, are too close to their star to be in the so-called habitable zone where liquid water could exist on a planet's surface, but they are the smallest exoplanets ever confirmed around a star like our sun (as of December 20, 2011).
- Kepler-20e is slightly smaller than Venus, measuring 0.87 times the radius of Earth. Kepler-20f is a bit larger than Earth, measuring 1.03 times its radius. The new planets are thought to be rocky. They reside in a five-planet system called Kepler-20, about 1,000 light-years away in the constellation Lyra.
- The Kepler-20 system includes three gas planets that are larger than Earth but smaller than Neptune. Kepler-20b, the closest planet, Kepler-20c, the third planet, and Kepler-20d, the fifth planet, orbit their star every 3.7, 10.9 and 77.6 days. The arrangement of the planets from the closest to its star to the farthest is: b, e, c, f and d, with the ordering of the letters reflecting the time at which the planets were initially discovered.
- The host star belongs to the same G-type class as our sun, although it is slightly smaller and cooler. The system has an unexpected arrangement. In our solar system, small, rocky worlds orbit close to the sun and large, gaseous worlds orbit farther out. In comparison, the planets of Kepler-20 are organized in alternating size: large, small, large, small and large.

Spitzer Finds Solid Buckyballs in Space



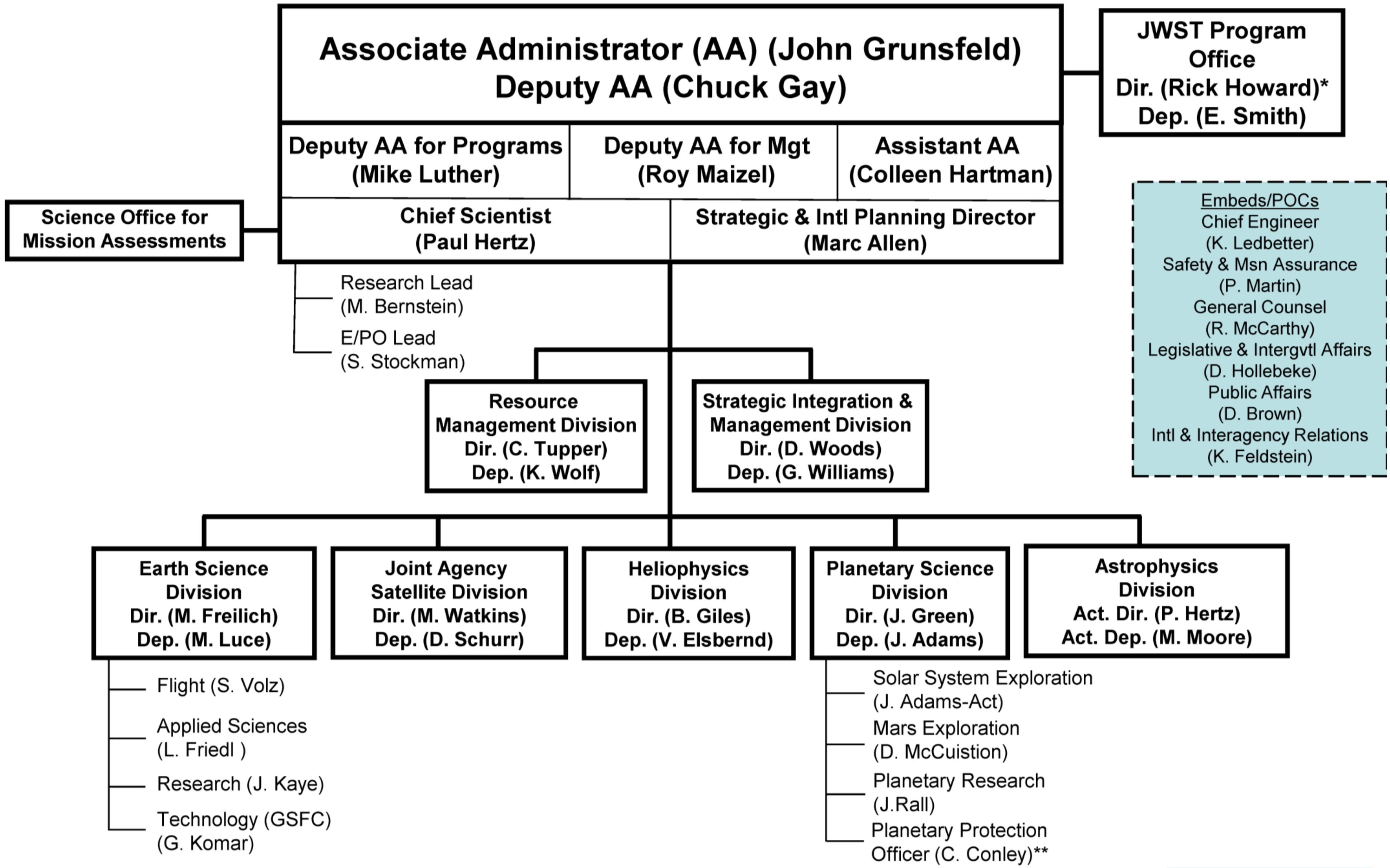
Artist Concept - Credit: NASA/JPL-Caltech

NASA's Spitzer Space Telescope has detected the solid form of buckyballs in space for the first time. To form a solid particle, the buckyballs must stack together, as illustrated in this artist's concept showing the very beginnings of the process.

Buckyballs have been found on Earth in various forms. They form as a gas from burning candles and exist as solids in certain types of rock, such as the mineral shungite found in Russia, and fulgurite, a glassy rock from Colorado that forms when lightning strikes the ground. In a test tube, the solids take on the form of dark, brown "goo.

- Astronomers using data from NASA's Spitzer Space Telescope have, for the first time, discovered buckyballs in a solid form in space. Prior to this discovery, the microscopic carbon spheres had been found only in gas form in the cosmos.
- Formally named buckminsterfullerene, buckyballs are named after their resemblance to the late architect Buckminster Fuller's geodesic domes. They are made up of 60 carbon molecules arranged into a hollow sphere, like a soccer ball. Their unusual structure makes them ideal candidates for electrical and chemical applications on Earth, including superconducting materials, medicines, water purification and armor.
- In this discovery, scientists detected tiny specks of matter, or particles, consisting of stacked buckyballs. They found the particles around a pair of stars called "XX Ophiuchi," 6,500 light-years from Earth, and detected enough to fill the equivalent in volume to 10,000 Mount Everests.
- Buckyballs were detected definitively in space for the first time by Spitzer in 2010. Spitzer later identified the molecules in a host of different cosmic environments.
- In all of those cases, the molecules were in the form of gas. The recent discovery of buckyballs particles means that large quantities of these molecules must be present in some stellar environments in order to link up and form solid particles. The research team was able to identify the solid form of buckyballs in the Spitzer data because they emit light in a unique way that differs from the gaseous form.

SMD Organization Chart



* Direct report to NASA Associate Administrator
** Co-located from the Front Office

January 2012

Astrophysics Division Organization Chart

February 1, 2012

Resource Management
Holly Degn +
David Darbouze +

Director (Acting)
Paul Hertz
Deputy Director (Acting)
Michael Moore

Lead Secretary: Kelly Johnson
Secretary: Leslie Allen
Program Support Specialist: Sheila Gorham

Asst Dir for Innovation & Technology: Michael Moore (acting)
PE for Tech & Ops Missions: William (Billy) Lightsey *
Asst Dir for Policy & Planning: Vacant

Communications
Division E/PO POC: Hashima Hasan (Lead)
Division PAO POC: Ilana Harrus *
Information Manager: Lisa Wainio *

Astrophysics Research

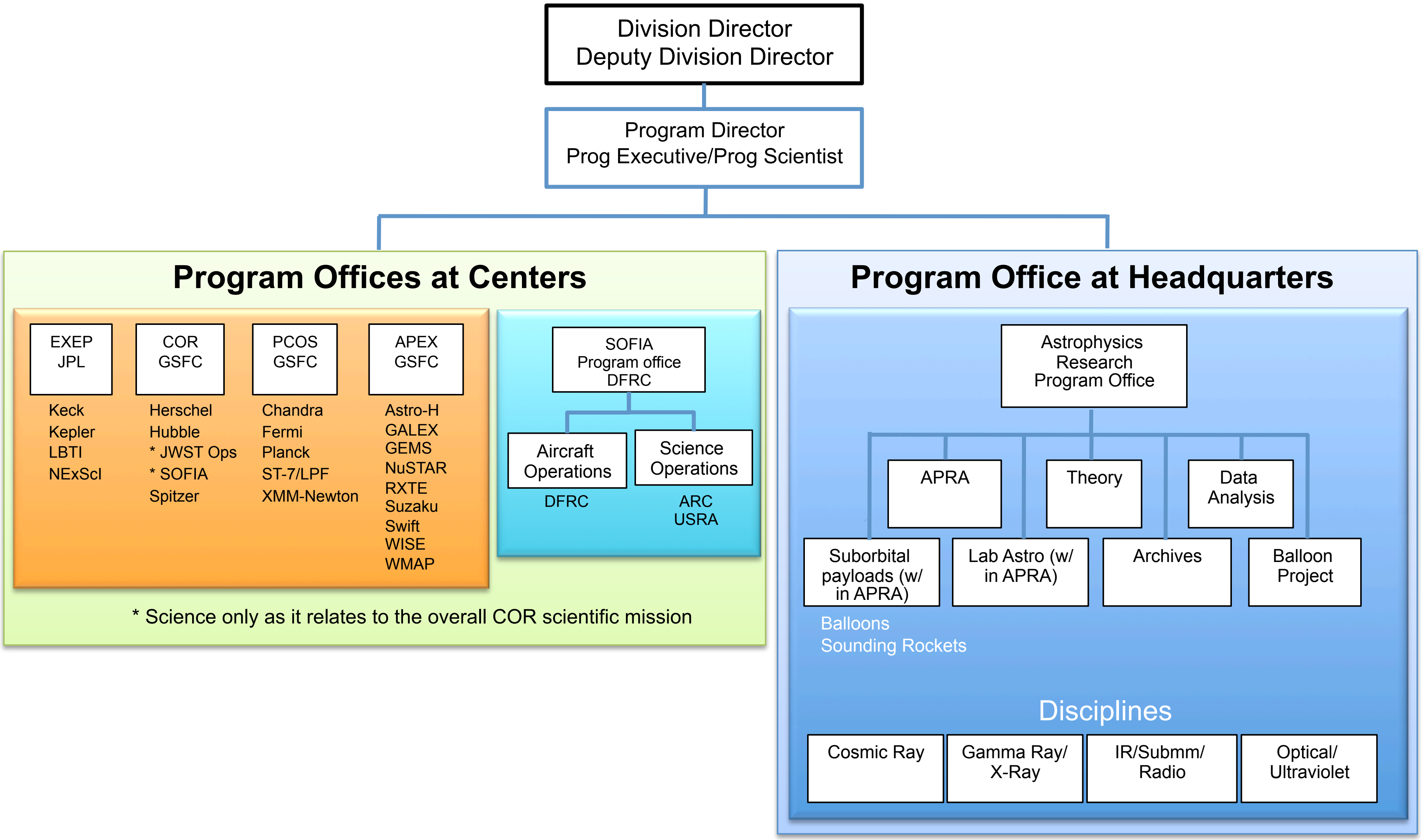
Program Manager: Linda Sparke
Program Support: Tina Swindell *
Astrophysics Data Analysis: Doug Hudgins
Astrophysics Theory: Linda Sparke
Origins of Solar Systems: Mario Perez *
APRA lead: Ilana Harrus *
Cosmic Rays, Fundamental Physics: Vernon Jones
Gamma Ray/X-ray: Ilana Harrus *, Wilt Sanders *
Lou Kaluzienski
Optical/Ultraviolet: Mario Perez *
Hashima Hasan
IR/Submillimeter/Radio: Chris Davis *, Doug Hudgins
Glenn Wahlgren *, Bill Danchi *
Lab Astro: Glenn Wahlgren *
ADCAR:Archives: Hashima Hasan
Astrophysics POC for Sounding rockets: Wilt Sanders *
Balloons Program: Vernon Jones (PS), Mark Sistilli (PE)

Programs / Missions

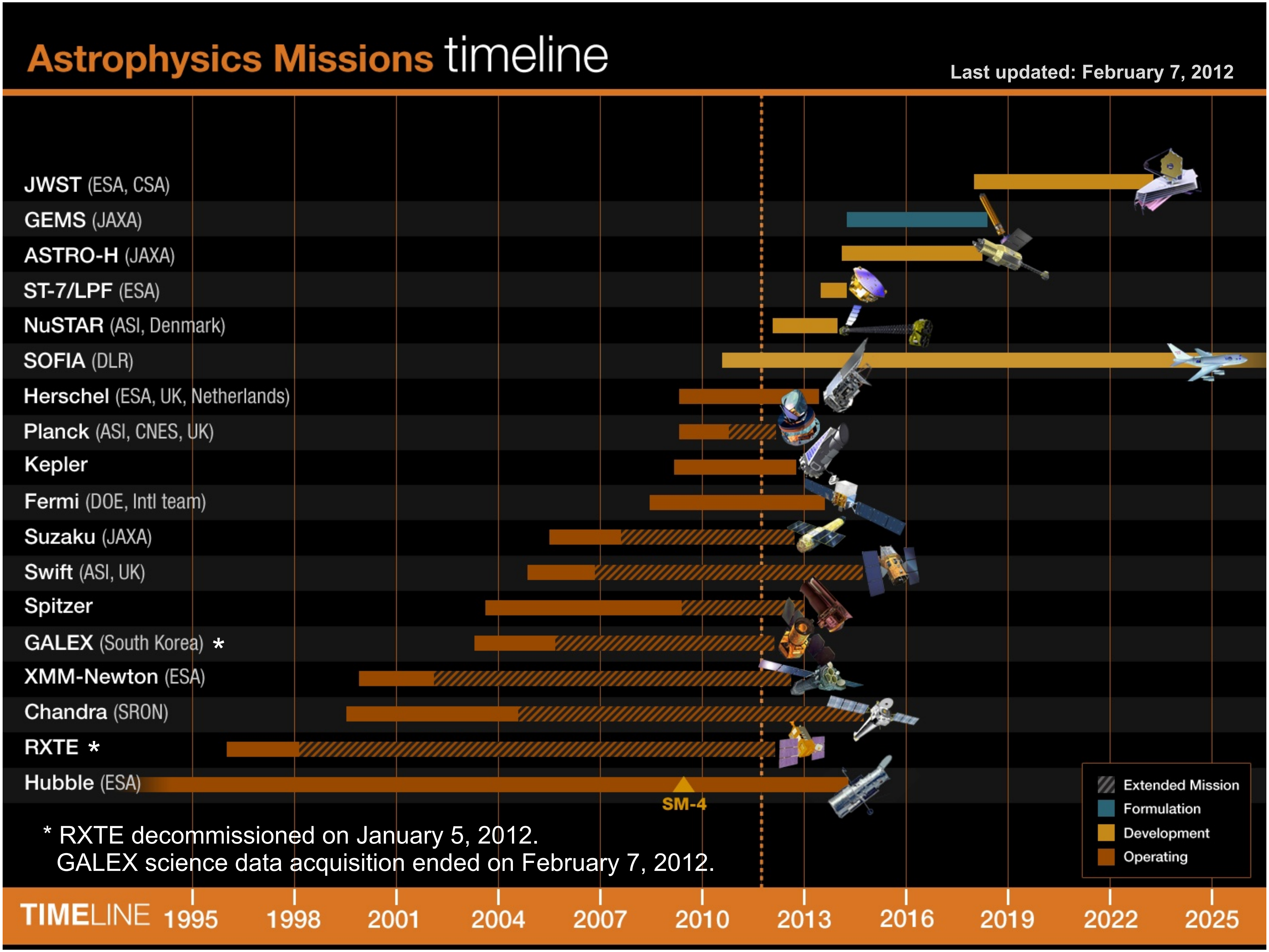
	Program Scientist	*Program Executive*
Exoplanet Exploration (EXEP)		
LEADS	**Doug Hudgins**	**Lia LaPiana**
Keck	Mario Perez *	Mario Perez *
Kepler	Doug Hudgins	Jaya Bajpayee *
LBTI	Mario Perez *	Michael Moore
NExScI	Mario Perez *	Lia LaPiana
Cosmic Origins (COR)		
LEADS	**Mario Perez** *	**Michael Moore**
Herschel	Bill Danchi *	Jaya Bajpayee *
HST Ops	Richard Griffiths *	John Gagosian
JWST	Hashima Hasan	N/A
SOFIA	Chris Davis *	John Gagosian
Spitzer	Bill Danchi *	Jaya Bajpayee *
Physics of the Cosmos (PCOS)		
LEADS	**Rita Sambruna**	**Jaya Bajpayee** *
Chandra	Wilt Sanders *	Jaya Bajpayee *
Fermi	Ilana Harrus *	Jaya Bajpayee *
Planck	Bill Danchi *	Jaya Bajpayee *
ST-7/LPF	Wilt Sanders *	Anne-Marie Novo-Gradac
XMM-Newton	Lou Kaluzienski	Jaya Bajpayee *
Astrophysics Explorers (APEX)		
LEADS	**Wilt Sanders** *	**Anne-Marie Novo-Gradac**
Astro-H	Lou Kaluzienski	Anne-Marie Novo-Gradac
GALEX	Mario Perez *	Jaya Bajpayee *
GEMS	Richard Griffiths *	Lia LaPiana
NuSTAR	Lou Kaluzienski	Mark Sistilli
RXTE	Ilana Harrus *	Jaya Bajpayee *
Suzaku	Lou Kaluzienski	Jaya Bajpayee *
Swift	Ilana Harrus *	Jaya Bajpayee *
WISE	Bill Danchi *	Jaya Bajpayee *
WMAP	Bill Danchi *	Jaya Bajpayee *

+ *Member of the Resources Mgmt Division*
* *Detailee, IPA, or contractor*
JWST now part of the JWST Program Office.

Astrophysics Division at a Glance

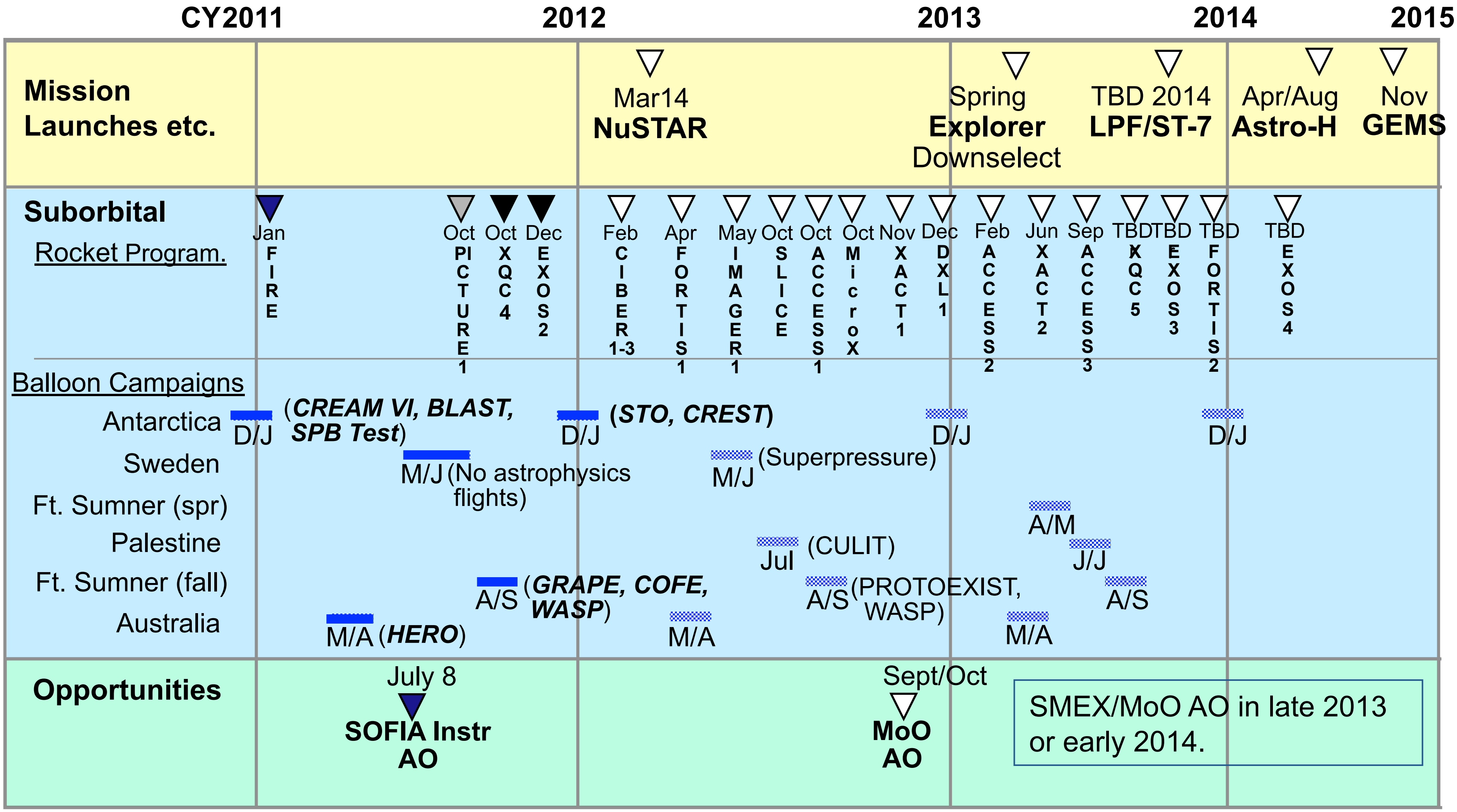


Launch-CY2011
Launch-CY2012
Launch-CY2013
XMM-Newton (ESA)
Swift
Suzaku (JAXA)
Fermi
INTEGRAL (ESA)
RXTE
(Decommissioned—2012)
GALEX
Herschel (ESA)
Planck (ESA)
NuSTAR
WISE
(Decommissioned—2011)
Hubble
Chandra
Kepler
Spitzer
SOFIA



Astrophysics Missions timeline
Last updated: February 7, 2012
JWST (ESA, CSA)
GEMS (JAXA)
ASTRO-H (JAXA)
ST-7/LPF (ESA)
NuSTAR (ASI, Denmark)
SOFIA (DLR)
Herschel (ESA, UK, Netherlands)
Planck (ASI, CNES, UK)
Kepler
Fermi (DOE, Intl team)
Suzaku (JAXA)
Swift (ASI, UK)
Spitzer
GALEX (South Korea) *
XMM-Newton (ESA)
Chandra (SRON)
RXTE *
Hubble (ESA)
SM-4
* RXTE decommissioned on January 5, 2012.
GALEX science data acquisition ended on February 7, 2012.
Extended Mission
Formulation
Development
Operating
TIMELINE
1995
1998
2001
2004
2007
2010
2013
2016
2019
2022
2025

Astrophysics Mission Events



Last Updated: February 22, 2012

Astrophysics - Missions in Formulation & Implementation

Project	Overall previous months				This Month					Comments
	-4	-3	-2	-1	O	T	C	S	P	
Physics of the Cosmos	G	G	G	G	G	G	G	G	G	
ST-7 (NET Apr 2014)	G	G	G	G	G	G	G	G	G	NASA microvalve thrusters are now certified through mid-2014.
Explorer Program										
NuSTAR (Mar 21, 2012)	Y	Y	Y	Y	Y	G	G	Y	G	LRD no earlier than Mar 21, 2012 due to launch vehicle issues.
Astro-H (Aug 2014)	Y	Y	Y	Y	Y	G	Y	Y	R	Engineering model dewar functional testing duration under negotiation.
GEMS (Nov 2014)	Y	Y	R	Y	G	G	G	G	G	ICE/CATE/JCL activity for KDP-C has started. Mission PDR Feb 23-24.
FINESSE, TESS, NICER, GUSSTO				G	G	G	G	G	G	Phase A reports due Sep 21, 2012.
Cosmic Origins	G	G	G	G	G	G	G	G	G	
SOFIA (ongoing)	G	G	G	G	G/Y	G/Y	G	G/Y	G/Y	Challenging segment 3 schedule. Working to reduce telescope pointing errors and jitter.
Exoplanet Exploration	G	G	G	G	G	G	G	G	G	
Balloon Prog (ongoing)	G	G	G	G	G	Y	G	G	G	Antarctica campaign successfully completed. Sweden campaign next with Superpressure Balloon flight.

O: Overall, C: Cost, S: Schedule, T: Technical, P: Programmatic

G On plan, adequate margin

Y Problems, working to resolve within planned margin

R Problems, not enough margin to recover

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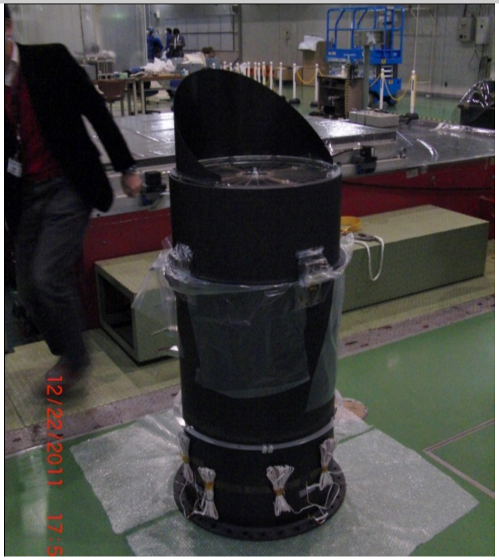
Accomplishments & Significant Events



Engineering model mirror fit check at JAXA

Astro-H

- Japanese government has approved Astro-H budget for the new fiscal year.
- The engineering model Calorimeter Spectrometer Insert (detector) has completed all pre-ship activities and is now packed and ready for shipment to Japan.
- Build-up of the engineering model Aperture Assembly has begun.
- Passed Mission CDR February 2012.

NuSTAR Observatory

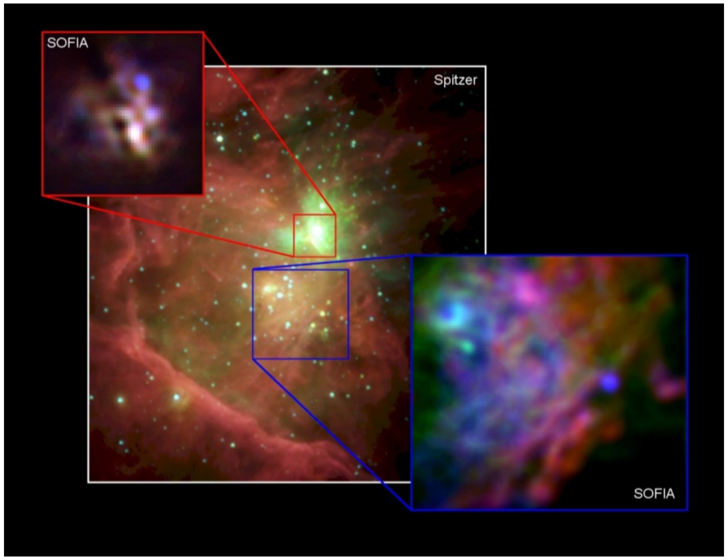
NuSTAR

- March 14 launch readiness date approved at Jan 6 SMD/DPMC.
- NuSTAR Observatory was shipped from OSC (VA) to Vandenberg Air Force Base (VAFB) January 24-27.
- Spacecraft mated to Pegasus on February 17, 2012.
- NuSTAR Observatory/Pegasus launch vehicle will be shipped from VAFB to Kwajalein Island in early March 2012.
- Risk to launch date due to launch vehicle issues. March 21 LRD current plan.

Accomplishments & Significant Events (cont.)

SOFIA

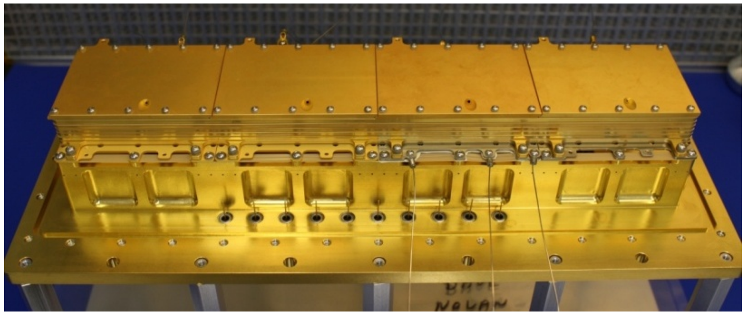
- Completed Segment 2 Development and 45 early science and telescope characterization flights.
- Started Major Observatory Upgrades (aircraft avionics upgrades, new platform wiring installation, telescope pre-cooling system).
- Selected 13 teams of Airborne Astronomy Ambassadors (26 educators from 14 states) for Cycle 1 Science Flights in 2012-13.
- Proposals received for second generation instruments. Selection anticipated Spring 2012.
- Approximately 130 Cycle 1 GO proposals received.



SOFIA Looks at the Heart of the Orion Nebula.

GEMS

- Polarimeter instrument completed TRL-6 activities Oct 2011.
- SMD/DPMC held Jan 13, 2012. Project given permission to continue to Confirmation Review in April 2012.
- Instrument and Mission PDR's February 21-24, 2012, Confirmation Review (KDP-C) planned for April 2012.



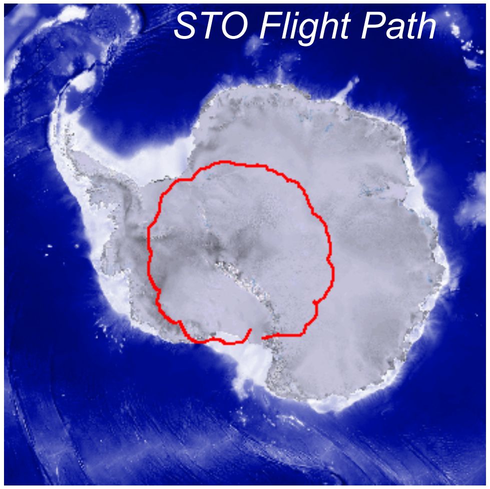
Interior of GEMS Engineering Test Unit Polarimeter

Accomplishments & Significant Events

KEPLER

- Programmatic Accomplishments
  - The mission is currently in Quarter 12, month 2 of operations; the Winter quarterly roll was successfully executed Jan 4-5, and the last monthly science data download was Feb 1-2.
  - First Kepler Science Conference was held Dec 5-9, 2011 at NASA Ames with nearly 500 attendees.
  - Mission data from Quarters 4, 5, and 6 released on Jan 7, 2012. Quarters 7-9 will be released in July 2012, and Quarters 10-12 will be released at the end of prime mission (Nov 2012); from that point forward, there will be no exclusive use period attached to the mission data.
  - SOC 8.1 frozen Jan 4, 2012, ahead of planned Jan 10th date; on schedule for delivery date of Mar 20, 2012.
- Scientific Accomplishments
  - Kepler 22: The Kepler team announced the confirmation of the first planet orbiting in the habitable zone of a Sun-like star; planet has a 289-day orbit, but is 2.4 times Earth radius of the Earth, making it too large to be terrestrial (12/5/2011).
  - Kepler 20: The Kepler Team announced the discovery of the first truly Earth-sized planets; the planets are 1.03 and 0.95 times Earth radius, but orbit too close to their parent star for them to be in the habitable zone(12/20/2011).
  - KOI-961: Astronomers announced the discovery of the smallest planets yet found--just 0.78, 0.73 and 0.57 times Earth radius--in orbit around a red dwarf star (1/11/2012)
  - Kepler 34, 35: Astronomers announced the discovery of two new transiting circumbinary planets, establishing that such ‘two sun’ planetary systems are common, with many millions existing in our Galaxy (1/11/2012).
  - Kepler 23-33: The Kepler team announced the discovery of 11 planetary systems hosting 26 confirmed planets (1/26/2012).

Accomplishments & Significant Events (cont.)



Balloon Program

- STO (Stratospheric Terahertz Observatory) Astrophysics payload was launched from McMurdo, Antarctica on January 14, 2012.
  - STO measured the star formation rate along the galactic plane and provided 3-D maps of the structure, dynamics, and thermodynamics of the galaxy's interstellar medium.
  - The STO PI is Chris Walker from the University of Arizona.
  - STO made one complete revolution around the continent in ~13 days.
  - Five days of cold data obtained due to leak in cryostat; warm data mission after. Minimum science requirements were achieved.
- STO and CREST payloads recovered.

Astrophysics – Operating Missions

Mission	Launch	End Date	Phase	-4	-3	-2	-1	This Month	Comments
Hubble	1990-04-24	2014-05-31	Prime	G	G	G	G	G	
RXTE	1995-12-30	2012-01-05	Ext	G	G	G	G		Sci Ops ended Jan 3, spacecraft decommissioned on Jan 5 after 16 years of operations.
Chandra	1999-07-23	2014-09-30	Ext	G	G	G	G	G	Successfully exercised Science Only Safing Actions twice during recent CME events.
XMM-Newton	1999-12-10	2012-09-30	Ext	G	G	G	G	G	
GALEX	2003-04-28	2012-03-31	Ext	G	G	G	G	G	NASA Sci Ops ended on Feb 7, after 8 years of operations.
Spitzer	2003-08-25	2012-12-31	Ext	G	G	G	G	G	
Swift	2004-11-20	2014-09-30	Ext	G	G	G	G	G	
Suzaku	2005-07-10	2012-09-30	Ext	G	G	G	G	G	
Fermi	2008-06-11	2013-08-18	Prime	G	G	G	G	G	
Kepler	2009-03-07	2012-11-07	Prime	G	G	G	G	G	
Herschel	2009-05-14	2013-05-14	Prime	G	G	G	G	G	
Planck	2009-05-14	2012-02-14	Ext	G	G	G	G	G	Reaches 1000 day milestone.

WISE passes its All-Sky Release Readiness Review. All data will be released on March 14, 2012.

G	On plan, adequate margin	Y	Problems, working to resolve within planned margin	R	Problems, not enough margin to recover

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2012 Senior Review of Operating Missions

Invited Missions	
Planck	Hubble
Chandra	Fermi
Warm Spitzer	Kepler
Swift	
XMM-Newton	
Suzaku	

2012 Senior Review Schedule	
Draft Call for proposals	Jul 1, 2011
Call for Proposals	Aug 10, 2011
EPO SR Proposals Due	Dec 15, 2011
SR Proposals Due	Jan 18, 2012
EPO Section Review	Jan 23 - 25, 2012
SRC Meets	Feb 28 - Mar 2, 2012
Final Report	Mar 30, 2012

Changes to the 2012 Senior Review

- Expanded Senior Review invitation list to cover all astrophysics missions in or entering extended operations.
- EPO review part of 2012 Senior Review.
  - In 2010, the EPO review was performed separately, after the Senior Review.

New Projects in the Senior Review

- Kepler and Fermi were invited to participate in the 2012 Senior Review - completed Level 1 requirements review.
- In 2009, the Astrophysics Subcommittee recommended that Hubble be invited to the 2012 Senior Review.

http://science.nasa.gov/astrophysics/2012-senior-review/

X-Ray & Gravitational Wave Concept Studies

Important Dates

X-Ray Concept Study	
RFI Release	Sept 13, 2011
Responses Due	Oct 28, 2011
CST solicitation release (thru Dear Colleague Ltr)	Oct 3, 2011
CST responses due	Oct 19, 2011
Community Workshop	Dec 2011
Mission Design Activity	Feb-Apr 2012
Draft Report Release	Early June, 2012
Final Report Release	Late June 2012
CAA Presentation	TBD

GW Concept Study	
RFI Release	Sep 27, 2011
Responses Due	Oct 28, 2011
CST solicitation release (thru Dear Colleague Ltr)	Oct 7, 2011
CST responses due	Oct 25, 2011
Community Workshop	Dec 2011
Mission Design Activity	Feb-Apr 2012
Draft Report Release	Early June 2012
Final Report Release	Late June 2012
CAA Presentation	TBD

- Concept Study activity will conclude with presentations to the CAA.
- The study team, including the Community Science Team (CST) will then be disbanded.
- Concept studies being considered for Exoplanet and UV/Optical science.

http://pcos.gsfc.nasa.gov/studies/

X-ray Concept Study Status

- 29 RFI responses were received in late October, 2011.
  - 16 mission concepts; 13 enabling technology
- Open workshop was held Dec 14-15, 2011.
- Three notional missions selected by Community Science Team for further study
  - Calorimeter mission (5000 cm^2 at 1 keV; 2000 cm^2 at 6 keV; DE<3 keV)
  - Gratings mission (500 cm^2 0.2-1.5 keV; R>3000)
  - Wide field imaging mission (5000 cm^2 at 1 keV; FoV>30 arcmin)
- GSFC design lab runs planned for notional missions.
  - “Delta” studies will investigate cost scaling with mission size
- Draft outline for study report has been developed.

Gravitational Wave Mission Concept Study

- 17 Responses to RFI
  - 12 Mission Concepts
  - 3 Instrument Concepts
  - 2 Technology
- At the Workshop (Dec 20-21), Community Science Team recommended Team-X mission studies of:
  - 1 LISA-like concept
  - 1 Geocentric, ultra low-cost concept
  - Possibly 1 non-drag-free concept, pending further analysis

ESA Cosmic Vision Status
Astrophysics

L-Class Missions (L1)

- ✓ October 2007: EJSM-Laplace, IXO & LISA selected for study, with NASA in a key role in all three.
- ✓ February 2011: Assessment phase completed, but Astro2010 and NASA budget preclude proceeding.
- ✓ April 2011: ESA defined new approach – European-led teams to define affordable European-led missions with limited international participation for launch in early 2020s.
- ✓ ATHENA (Advanced Telescope for High ENergy Astrophysics, replacing IXO), NGO (New Gravitational wave Observatory, replacing LISA), and JUICE (Jupiter Icy Moons Explorer, replacing EJSM-Laplace) studies are underway.
  - ✓ Technical studies completed in November 2011.
  - ✓ Review by ESA advisory bodies in December 2011 – February 2012.
- ✓ February 2012 SPC to consider mission funding and management schemes.
- April 2012: SSAC recommendation to SPC for one mission to enter phase A/B1.
- L1 target launch date ~2022.

ESA Cosmic Vision Status
Astrophysics

M-Class Missions (M1 and M2)

- ✓ October 2011, the Science Programme Committee (SPC) met and approved the SSAC decision on two missions, Euclid and Solar Orbiter, for the release of the industrial 'Invitation to Tender'.
- June 2012, following 'consolidation' of member-state partnerships and agreements, the Science Programme Committee will consider 'adoption' of missions (Cost-at-Completion and Payload Formal Agreement).
- June 2012, Euclid enters Implementation Phase immediately after adoption by the SPC for launch in 2019.

M-Class Mission M3

- ✓ EChO, LOFT, MarcoPolo-R and STE-QUEST selected for Assessment Phase and further downselect for launch in 2022. (PLATO may be included if the mission re-proposes per AWG recommendation.)

Timeline for selection of M-Class missions from: http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=42370

National Academies Report on Euclid

✓ The National Research Council organized an ad hoc study to assess if a proposed NASA plan for a U.S. hardware contribution to the European Space Agency Euclid mission, in exchange for U.S. membership on the Euclid Science Team and science data access, is a viable part of an overall strategy to pursue dark energy, exoplanet detection, and infrared survey science goals articulated in the Astro2010 decadal survey report.

From the Feb 2012 National Academies Report on NASA Participation in Euclid

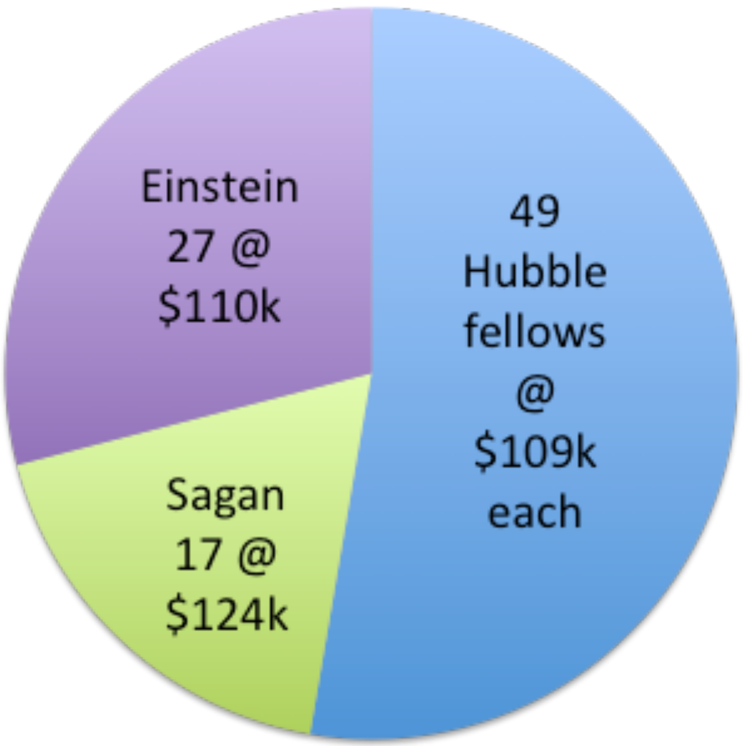
- While WFIRST dark energy measurements are expected to be superior to Euclid's, U.S. participation in Euclid will have clear scientific, technical, and programmatic benefits to the U.S. community as WFIRST and Euclid go forward.
- NASA should make a hardware contribution of approximately $20 million to the Euclid mission to enable U.S. participation. This investment should be made in the context of a strong U.S. commitment to move forward with the full implementation of WFIRST in order to fully realize the decadal science priorities of the 2010 Decadal report.
- In exchange for this small, but crucial contribution, NASA should secure through negotiation with the European Space Agency both a U.S. position on the Euclid Science Team and the inclusion of a team of U.S. scientists in the Euclid Consortium with full data access that would be selected by a peer-reviewed process.

NASA-ESA Collaboration on Euclid

On February 13, NASA expressed to ESA a willingness to collaborate on Euclid

- NASA is ready to provide a hardware contribution in the form of the Near Infrared detectors for the Near Infrared Spectrograph and Photometer instrument.
- ESA would be ready to accept the appointment of a NASA-identified U.S. scientist to the Euclid Science Team who, along with his or her collaborators, would be full members of the Euclid Consortium and have data access as well as authorship rights consistent with the still-to-be-developed policies of the Euclid Consortium, commensurate with the U.S. contribution to the Euclid mission.
- This collaboration will be formalized in a NASA-ESA Memorandum of Understanding (MOU) for cooperation on the Euclid mission.
- NASA is ready to immediately start working with ESA to identify ESA's need dates based on the Euclid development plan and initiate the procurement of the above hardware items in support of the Euclid development schedule.
- Discussions on synergies between Euclid and Wide Field Infrared Survey Telescope (WFIRST) will be undertaken before and during the implementation phase of the WFIRST mission.

Astrophysics Postdoctoral Fellowships



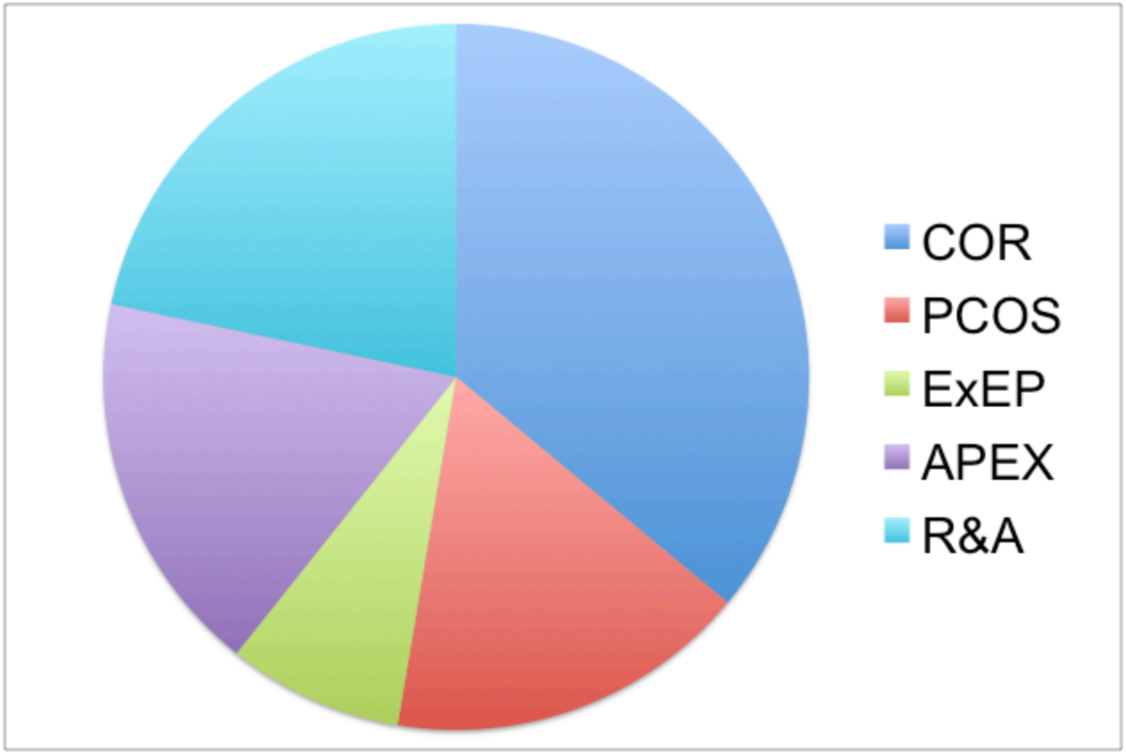
Hubble, Einstein and Sagan postdoc fellowships now support 93 fellows at a cost of ~$11M/year

The New Nancy Grace Roman Technology Fellowship in Astrophysics will:

- Provide early career researchers the opportunity to develop the skills necessary to lead astrophysics flight instruments/projects and become principal investigators of future astrophysics missions.
- Develop innovative technologies that have the potential to enable major scientific breakthroughs.
- Foster new talent by putting early-career instrument builders on a trajectory towards long-term positions.

FY2012 NASA Astrophysics Budget

$643.5M Total *



* Does not include SMD budgets that are bookkept in the Astrophysics budget line

SMD FY 2013 Program/Budget Strategy

- Continue to provide the most productive Earth & space science program for the available resources
  - Guided by national priorities
  - Informed by NRC Decadal Surveys recommendations
- Continue to responsibly manage the national investment in robotic space missions
  - Confirm new missions only after sufficient technology maturation and budgets at an appropriate confidence level
  - Closely manage JWST to the new cost and schedule baseline
- Plan and conduct a new Mars program with other NASA organizations to meet both human exploration and science goals
- Adequately budget for launch services acquired for SMD by NASA's Launch Services Program (LSP):
  - Availability and reliability for medium class
  - Encourage cost constraining measures for intermediate/large class

SMD Budget Request Summary

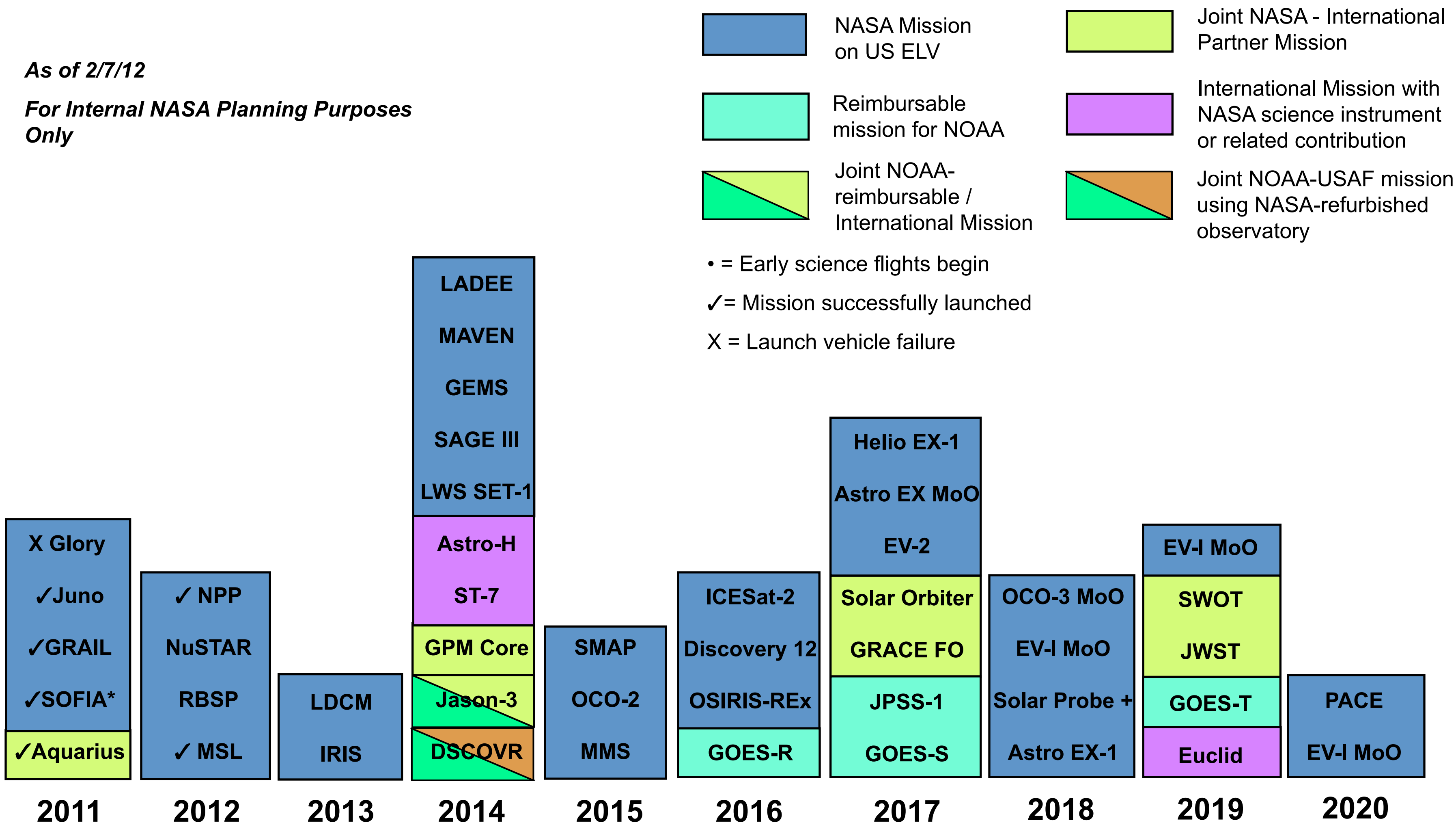
	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
Science	**$4,919.7**	**$5,073.7**	**$4,911.2**	**$4,914.4**	**$4,914.4**	**$4,914.4**	**$4,914.4**
Earth Science	$1,721.9	$1,760.5	$1,784.8	$1,775.6	$1,835.5	$1,826.2	$1,772.8
Earth Science Research	$461.1	$440.1	$433.6	$461.7	$485.1	$497.3	$508.1
Earth Systematic Missions	$841.2	$881.1	$886.0	$787.6	$813.2	$835.6	$756.4
Earth System Science Pathfinder	$182.8	$188.3	$219.5	$270.9	$275.6	$224.2	$234.4
Earth Science Multi-Mission Opera	$147.4	$163.4	$161.7	$170.2	$172.9	$176.5	$177.6
Earth Science Technology	$52.8	$51.2	$49.5	$50.1	$52.1	$54.1	$56.1
Applied Sciences	$36.6	$36.4	$34.6	$35.0	$36.7	$38.4	$40.1
Planetary Science	$1,450.8	$1,501.4	$1,192.3	$1,133.7	$1,102.0	$1,119.4	$1,198.8
Planetary Science Research	$158.8	$174.1	$188.5	$222.5	$233.4	$231.7	$230.3
Lunar Quest Program	$130.2	$139.9	$61.5	$6.2			
Discovery	$192.0	$172.6	$189.6	$242.2	$235.6	$193.8	$134.3
New Frontiers	$213.2	$160.7	$175.0	$269.8	$279.6	$259.9	$155.1
Mars Exploration	$547.4	$587.0	$360.8	$227.7	$188.7	$266.9	$503.1
Outer Planets	$91.9	$122.1	$84.0	$80.8	$78.8	$76.2	$76.3
Technology	$117.3	$144.9	$132.9	$84.6	$85.9	$90.9	$99.6
Astrophysics	$631.1	$672.7	$659.4	$703.0	$693.7	$708.9	$710.2
Astrophysics Research	$146.9	$164.1	$176.2	$189.1	$205.1	$211.5	$218.7
Cosmic Origins	$229.1	$237.3	$240.4	$228.5	$215.1	$205.3	$205.7
Physics of the Cosmos	$108.7	$108.3	$111.8	$109.6	$96.3	$92.7	$74.6
Exoplanet Exploration	$46.4	$50.8	$56.0	$41.6	$43.3	$42.4	$45.6
Astrophysics Explorer	$100.0	$112.2	$75.1	$134.3	$133.9	$157.0	$165.6
James Webb Space Telescope	$476.8	$518.6	$627.6	$659.1	$646.6	$621.6	$571.1
Heliophysics	$639.2	$620.5	$647.0	$643.0	$636.7	$638.3	$661.6
Heliophysics Research	$160.8	$175.2	$178.9	$162.6	$168.5	$170.3	$171.6
Living with a Star	$218.4	$196.3	$232.6	$212.2	$286.2	$336.6	$351.7
Solar Terrestrial Probes	$168.3	$188.7	$189.4	$179.8	$64.5	$46.7	$53.4
Heliophysics Explorer Program	$91.7	$60.2	$46.1	$88.4	$117.5	$84.8	$84.8
New Millennium	$0.1						

FY 2014-FY 2017 estimates are notional

NASA Science Missions By Launch Year
(Fiscal Years 2011-20 – FY13 Budget Request)

As of 2/7/12

For Internal NASA Planning Purposes Only



Astrophysics Budget Features

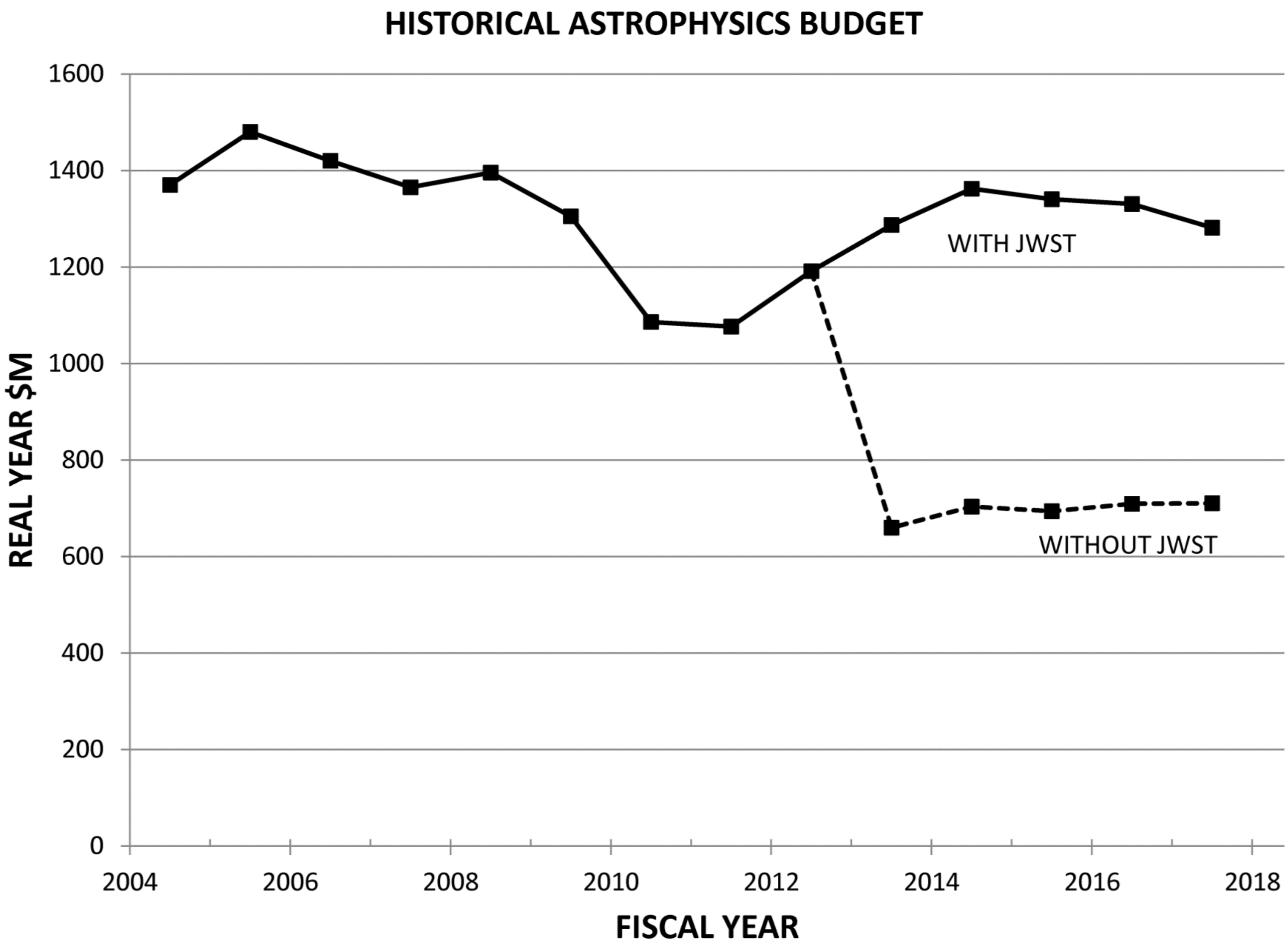
What's changed

- Astro-H and GEMS budgets have been rephased to accommodate programmatic changes
- A partnership is being pursued with ESA's Euclid mission
- Future mission funding within the three strategic programs is sufficient for only mission concept studies; mission-specific technology development will cease
- Balloons and R&A have been held flat to address other priorities
- Launch of next Explorer mission and mission of opportunity (to be downselected in 2013) has been delayed by one year

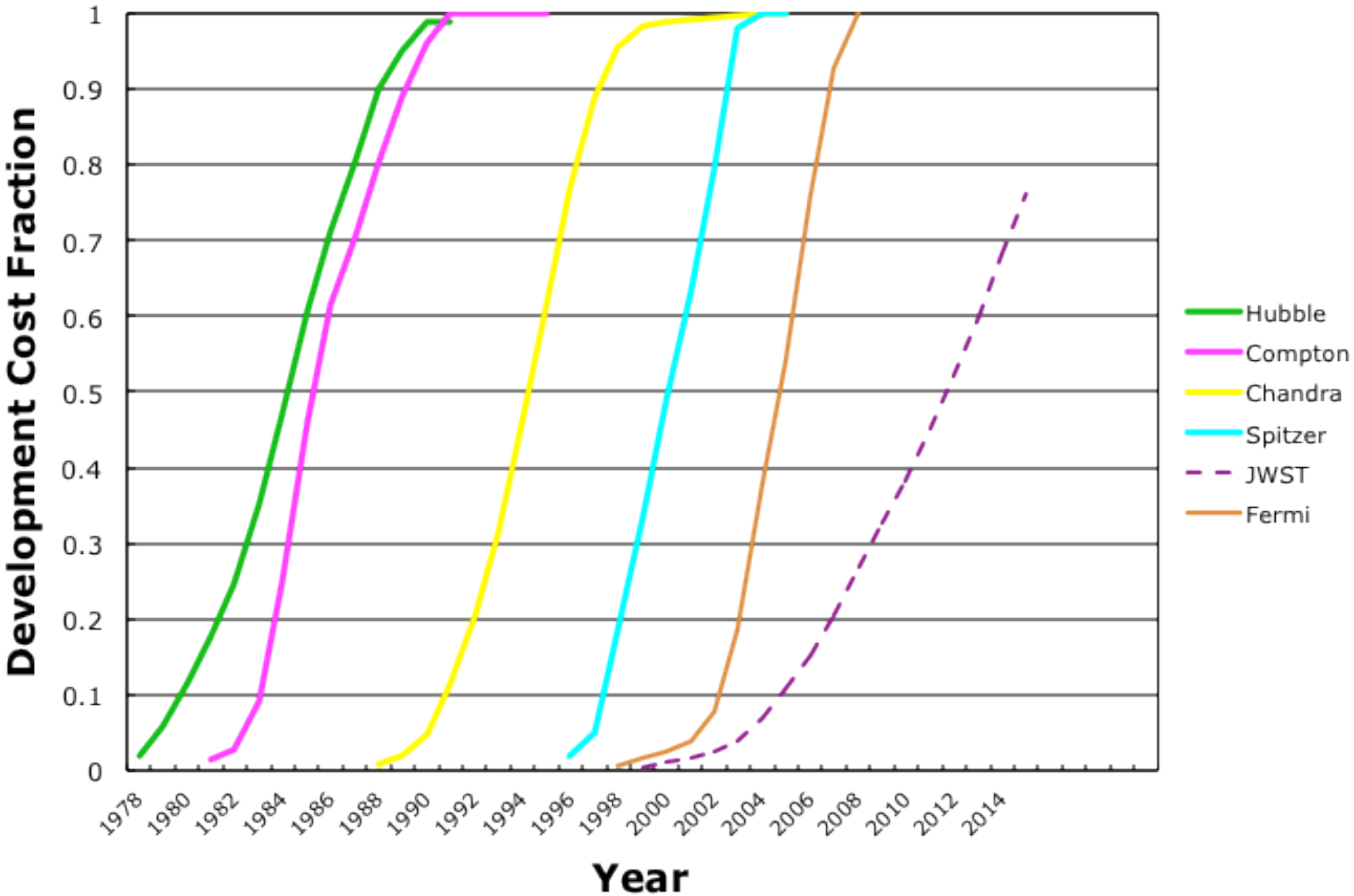
What's the same

- SOFIA continues development and early science flights
- Hubble, Chandra, Spitzer, Fermi, Kepler, and other operating missions (subject to 2012 Senior Review)
- Keck Interferometer operations will cease in 2012, per plan

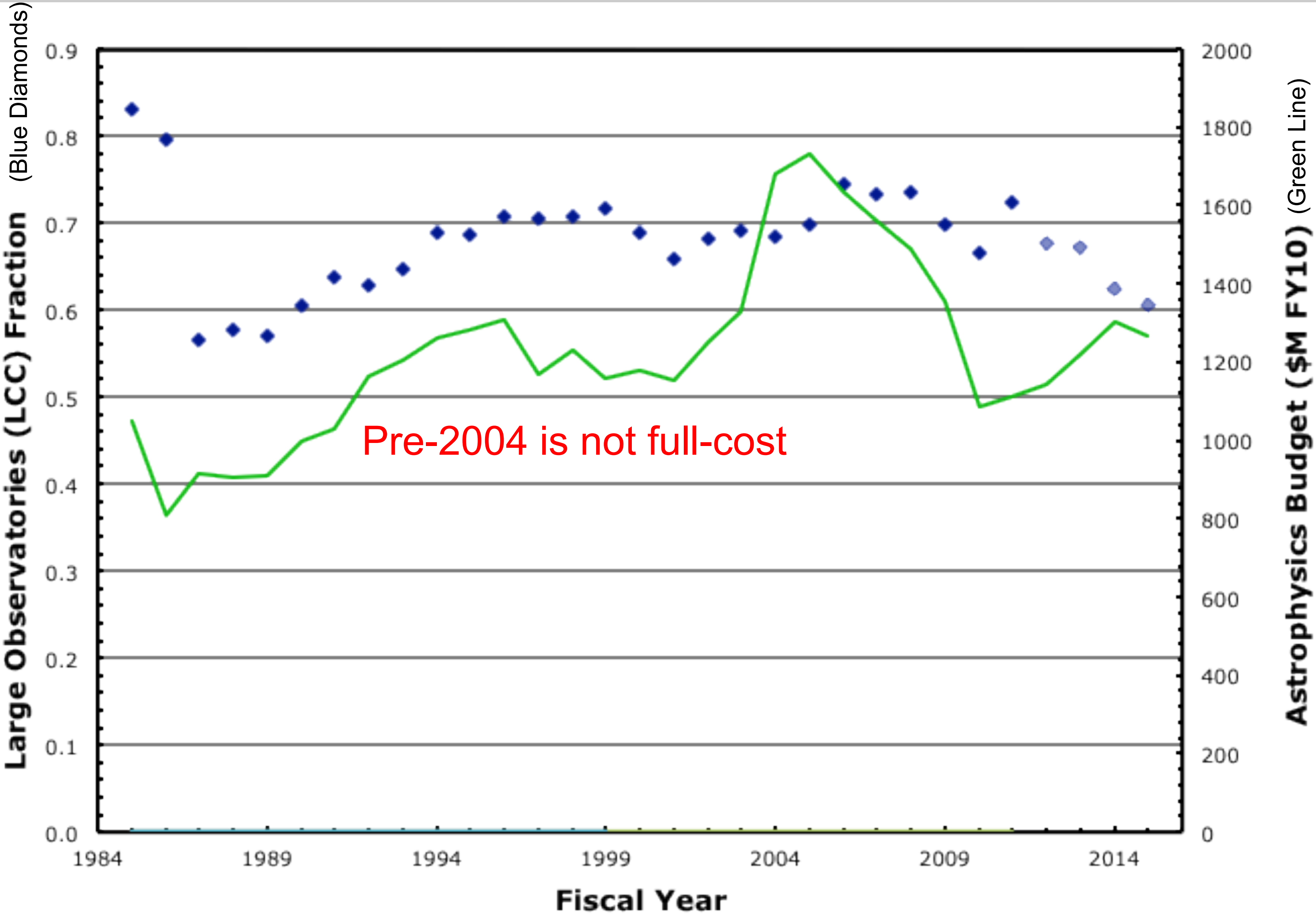
NASA's Investment in Astrophysics



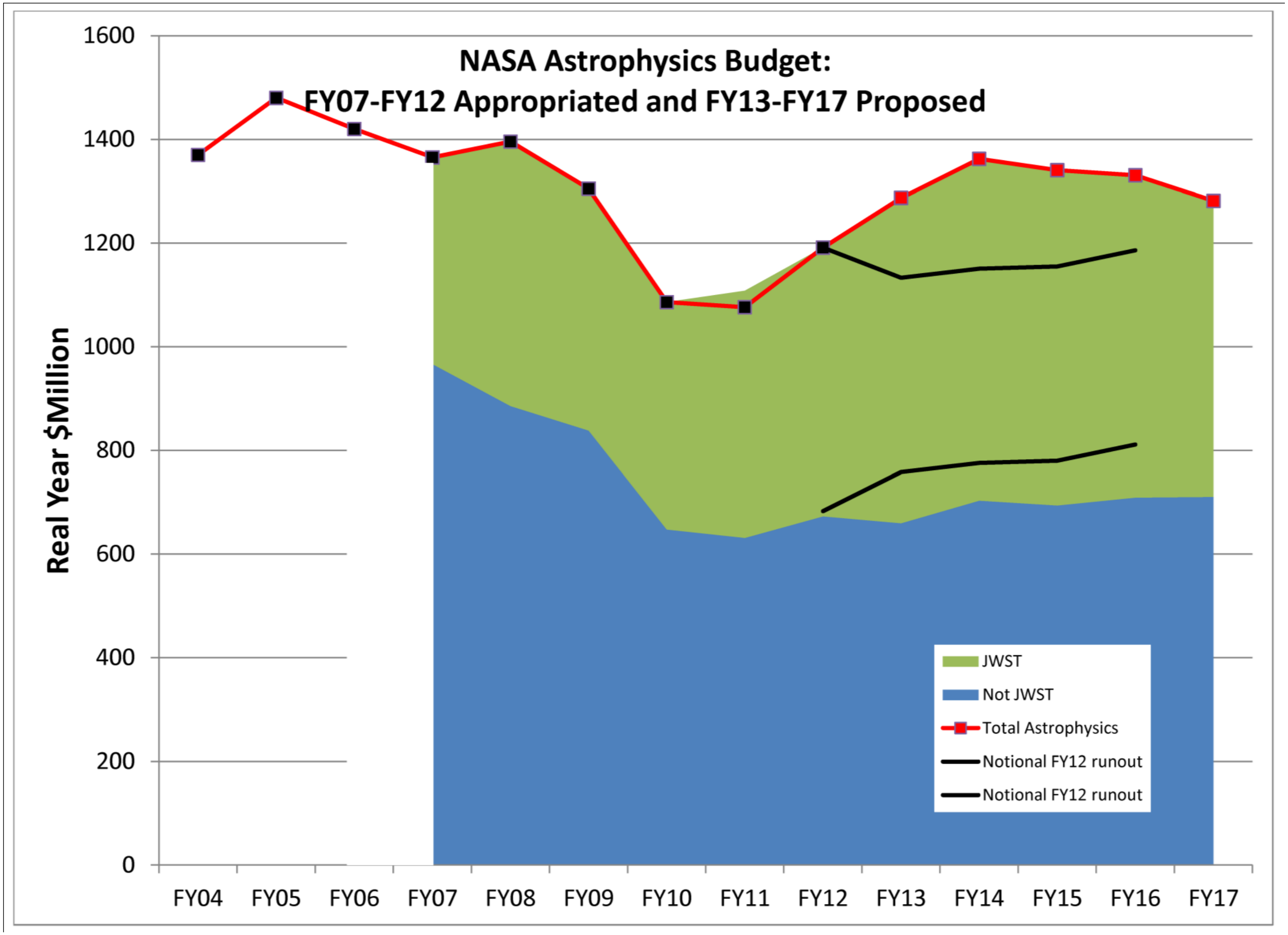
Missions in Development



Flagship Missions vs Astrophysics Budget



President’s FY13 Budget Request for Astrophysics



Explorer Options

- FY13 budget request does not support an AO for both missions and missions of opportunity (MOs) in late CY12.
  - First priority in the Explorer program is completion of Explorers in development: NuSTAR, SXS/Astro-H, GEMS.
  - Second priority is to downselect and fund the development of one mission and one MO from the projects currently conducting Phase A studies.
- Identifying Explorer AO options is straightforward: (i) identify total mission budget (including Launch Vehicle and required HQ reserves, neither of which is included in the PI cost cap); (ii) see when Phase B and a reasonable profile can be accommodated within the future mission line; (iii) back up 2 years from Phase B start for a 2-step AO release date (a little less for a 1-step AO for MOs).
- The Astro2010 Decadal Survey said to "Enable rapid response to science opportunities; augments current plan by 2 MIDEXs, 2 SMEXs, and 4 MoOs."
  - "This survey recommends that the annual budget of the astrophysics component of the Explorer program be increased from $40 million to $100 million by 2015."
  - The Astrophysics Explorer budget is $134M in FY15 and $166M in FY17.

Explorer Options (continued)

- Astro2010 Decadal Survey:

  The committee therefore recommends, as its second priority in the large category of space-based projects, that NASA should support the selection of two new astrophysics MIDEX missions, two new astrophysics SMEX missions, and at least four astrophysics MOs over the coming decade. AOs should be released on a predictable basis as close to annually as possible, to facilitate missions of opportunity. Further, the committee encourages inclusion of suborbital payload selections, if they offer compelling scientific returns. To accommodate this plan, an annual budget increase would be required for the astrophysics portion of the program from its current average value of about $40 million per year to a steady value of roughly $100 million by 2015.

- Astrophysics Division has proposed to SMD a series of AOs:
  - An AO for a MO with a $50-60M cost cap in Sep/Oct 2012
  - An AO for a SMEX and a MO late CY2013 or early CY2014 with the cost caps and actual dates TBD by summer 2012
- Another option examined was:
  - An AO for a SMEX and a MO in Oct/Nov 2013
  - An AO for a EX and a MO in Oct/Nov 2016

WFIRST (Wide-Field Infrared Survey Telescope)

- Science Definition Team has delivered its interim report in July 2011.
  - Copy of the report can be found at: *http://wfirst.gsfc.nasa.gov/science/WFIRST_Interim_Report.pdf*
  - The Interim Design Reference Mission (IDRM) is a proof of concept that a mission can be constructed that is compliant with the Astro2010 recommendation for groundbreaking observations in Dark Energy, Exoplanet and NIR sky surveys.
- Updated guidance given to Science Definition Team Dec 8, 2011.
  - Accounts for updated events since initial kickoff meeting.
  - Second Design Reference Mission being studied.
  - Second DRM will not duplicate capabilities of Euclid, LSST, and JWST in advancing science objectives of WFIRST.
- Science Definition Team met Feb 2-3, 2012. Next meeting March 1-2, 2012.
- Final report due June 2012.

WFIRST

- Astro2010 recommended WFIRST as the highest priority large mission; WFIRST remains NASA's first priority for a large astrophysics mission following JWST.
  - The President's FY13 NASA budget request includes no new large missions; Astrophysics expects none before we successfully complete JWST.
- The FY13 budget request does not fund a start on WFIRST; it would be unrealistic to expect such funding before JWST is launched.
  - WFIRST will not launch in this decade (2018 + 7 yrs = 2025).
  - Astrophysics does not anticipate budget growth in the foreseeable future.
  - FY13 budget request does not support WFIRST technology development as originally planned.
- In the meantime, NASA is proceeding in parallel as follows:
  - Through the Science Definition Team and Design Reference Missions, establish a basis for WFIRST planning.
  - Partner on ESA's Euclid to advance the science of Astro2010 and WFIRST. NASA's contribution to Euclid does not slow WFIRST development: reduced budget flexibility in FY13-FY17 would not allow significant progress on WFIRST.
  - Advance the technology required for WFIRST as the budget allows.

Astrophysics Research Program

	FY04 Final $k	FY05 Final $k	FY06 Final $k	FY07 Final $k	FY08 Final $k	FY09 Final $k	FY10 Final $k	FY11 Final $k	FY12 Projected
Particle Astro	$ 8,248	$ 7,671	$ 8,544	$ 7,631	$ 6,672	$ 8,201	$ 8,260	$ 8,243	$ 8,585
High Energy	$ 14,548	$ 13,693	$ 14,779	$ 12,782	$ 12,406	$ 13,886	$ 14,110	$ 13,911	$ 14,548
UV/Opt/IR/ Sub-mm	$ 20,409	$ 18,742	$ 21,851	$ 17,442	$ 19,094	$ 22,353	$ 21,534	$ 21,295	$ 23,032
Other	$ 1,019	$ 854	$ 338	$ 394	$ 594	$ 670	$ 673	$ 641	$ 1,627
APRA Total	$ 44,224	$ 40,960	$ 45,511	$ 38,250	$ 38,765	$ 45,110	$ 44,577	$ 44,090	$ 47,791
Orig Solar Systems	$ 4,209	$ 3,872	$ 4,150	$ 3,673	$ 2,965	$ 3,000	$ 2,807	$ 2,944	$ 2,978
Astro Theory Program	$ 7,860	$ 7,363	$ 10,245	$ 10,227	$ 11,696	$ 11,890	$ 12,262	$ 12,577	$ 13,226
R&A (399131)	$ 56,293	$ 52,195	$ 59,906	$ 52,150	$ 53,426	$ 60,000	$ 59,646	$ 59,611	$ 63,995
ADAP/LTSA	$ 16,986	$ 15,700	$ 15,189	$ 12,641	$ 12,013	$ 14,384	$ 13,258	$ 14,132	$ 16,320
Core Research	$ 73,279	$ 67,895	$ 75,095	$ 64,791	$ 65,439	$ 74,384	$ 72,904	$ 73,743	$ 80,315
TPF/FS	$ 2,000	$ 2,000		(Foundation Science; now in ATP)					
Beyond Einstein FS	$ 4,000	$ 3,000	$ 2,000						
ASMCS (399131)		Mission concept studies			$ 3,452	$ 442			
PCOS SR&T				(Fundamental Physics; now in APRA)			$ 968	$ 184	
Technology Fellows									$ 600
TOTAL	$ 79.3M	$ 72.9M	$ 77.1M	$ 64.8M	$ 68.9M	$ 74.8M	$ 73.9M	$ 73.9M	$ 80.9M
		$7M cut	smaller cut	15% cut	partial recovery	more recovery	flat	flat	growth!

In response to the Astro2010 Decadal Survey recommendations

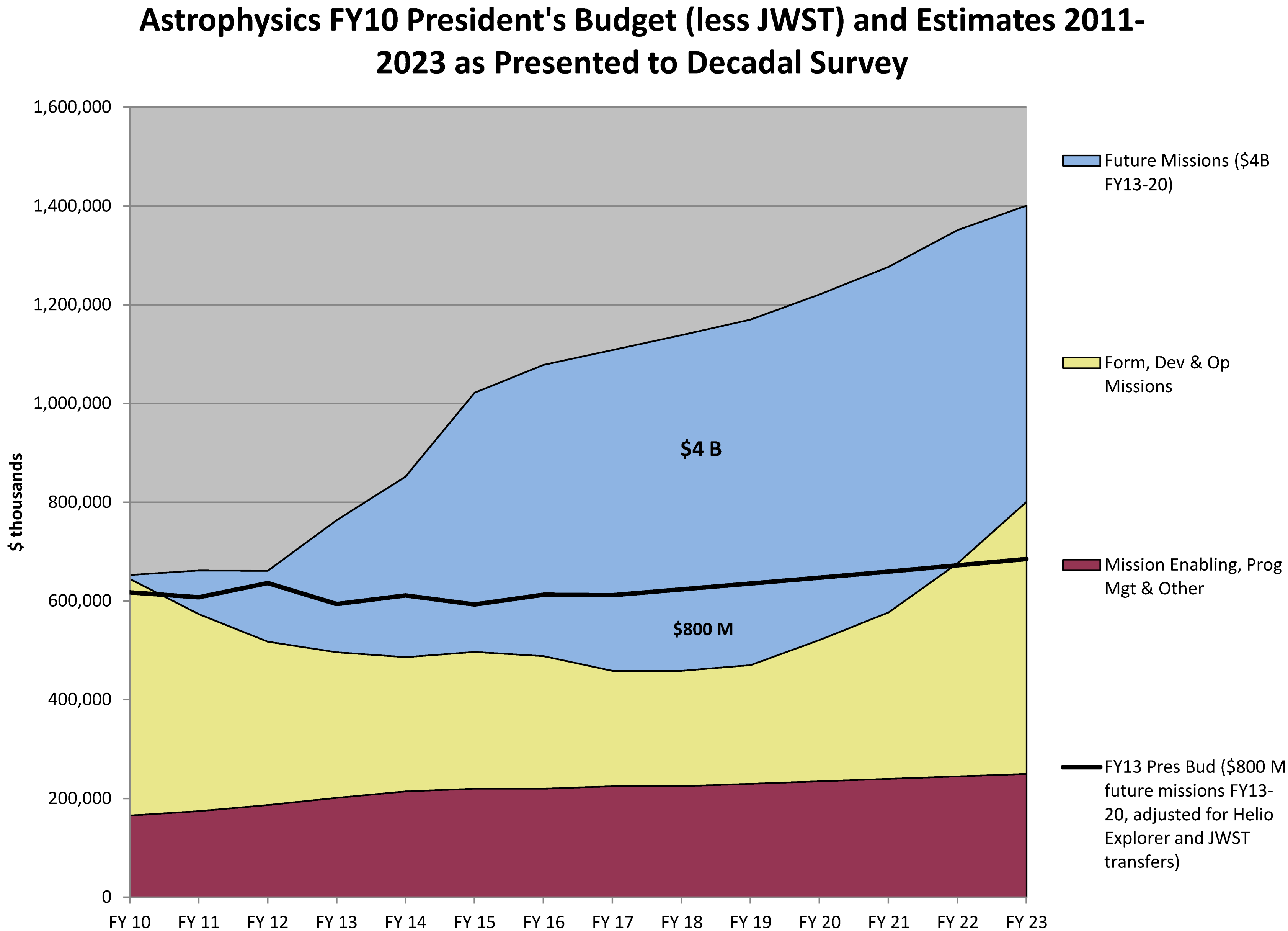
-- the budget for research awards increased by 10% in FY12

-- Theory and Computation Networks: AAAC studying NASA-NSF program

Planning

- The Astro2010 decadal survey prioritized a funding wedge of $3.7B over the decade.
- The “more conservative budget projection” based on the FY11 President’s budget request was $3.0B. Under that more conservative scenario, Astro2010 stated:
  - “In the event that insufficient funds are available to carry out the recommended program, the first priority is to develop, launch, and operate the WFIRST mission, and implement the Explorer program and core research program recommended augmentations. The second priority is to pursue the New Worlds Technology Development Program, as recommended, to mid-decade review by a decadal survey independent advice committee (as discussed in Chapter 3), to start LISA as soon as possible subject to the conditions discussed above, and to invest in IXO technology development as recommended. The third priority is to pursue the CMB Technology Development Program, as recommended, to mid-decade review by a decadal survey implementation advice committee. It is unfortunate that this reduced budget scenario would not permit participation in the JAXA-SPICA mission unless that mission’s development phase is delayed.” (pgs 237-238)
- After removing JWST from the calculation, the runout of the President’s FY13 budget over FY12-FY21 (the decade in Astro2010) has a funding wedge of about $800M ($80M/yr average).

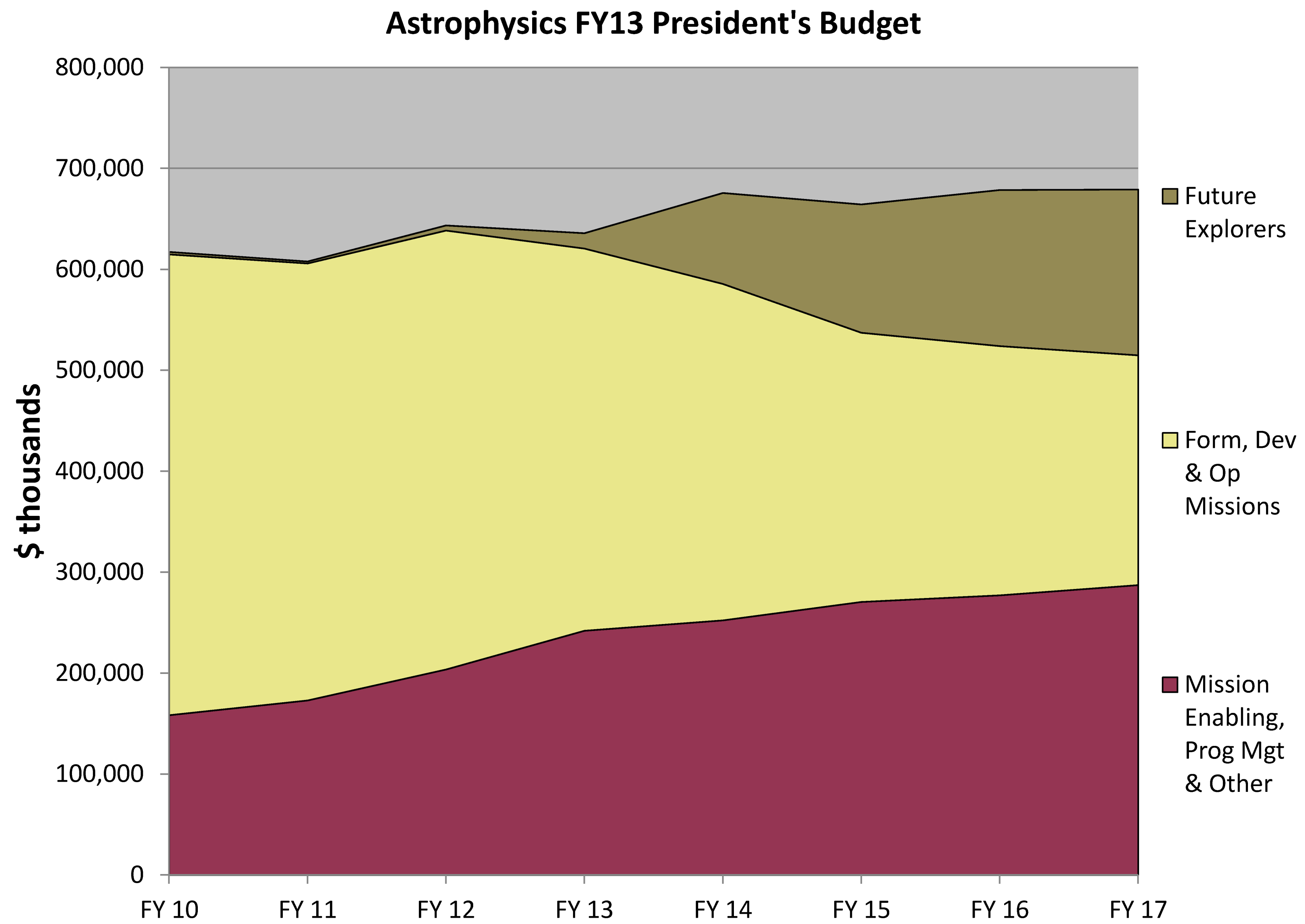
Changes since the Astro2010 Decadal Survey



Planning (continued)

- Astro2010 priorities for a constrained budget:
  - "The first priority is to develop, launch, and operate the WFIRST mission, and implement the Explorer program and core research program recommended augmentations." (pgs 237-238)
- The $800M funding wedge within the runout of the President's FY13 budget request over the decade has been used for:
  - Explorer augmentation: Grows to an augmentation of $70M/yr in FY16
    - Total budget for Future Explorers is $150M/yr
  - SR&T: $15M/yr starting in FY13, growing to $27M/yr in FY17
    - Applied to all three programs.
  - R&A and suborbital: augmentation and reallocation starting in FY12
    - APRA: $1M/yr Suborbital Payloads, $0.5M/yr Lab Astrophysics, $1M/yr Detectors and Supporting Technology
    - $0.3M/yr Astrophysics Theory Program
    - $1.5M/yr Theory and Computation Networks
    - $2M/yr Astrophysics Data Analysis Program
    - $1M/yr Roman Technology Fellows
  - Senior Review: $12M/yr starting in FY15

Balance in President's FY13 Budget



Planning (continued)

- NASA's plans for going forward.
  - Make near term decisions for FY13 including:
    - Fund NASA participation in Euclid
    - Fund GEMS UFE (HQ reserves) and growth (to be confirmed at KDP-C)
    - Respond to 2012 Senior Review
    - Remove some SAT calls from ROSES-11
  - Work with Program Offices to develop a rebalanced plan including technology development, postdoc fellows, and mission concept planning.
    - Priorities include technology development (directed and competed) that may have both near term value (suborbital, Explorers) and lead to advancing decadal priorities with strategic missions, including WFIRST.
  - Work with the advisory structure (APS, PAGs, SAGs) to prioritize the opportunities.
- NRC Mid-Decade Review will comment on NASA's balance between working toward five large missions for the next decadal survey and realizing the science of WFIRST and Astro2010 within the current budget.

Astrophysics PAGs

PhysPAG

- TechSAG completed its assessment of the near-term and long-term PCOS technology needs. The report was used to formulate the Program Annual Technology Report (PATR). TechSAG has evolved into two separate SAGs, the X-ray and Gravity Wave SAGs, whose tasks are being defined.
- The IPSAG is working to provide quantitative metrics and assessments to NASA in regard to a future Inflation Probe mission.
- Creation of Gamma-Ray SAG approved by APS in Oct 2011.
- PhysPAG website: *http://pcos.gsfc.nasa.gov/physpag.php*

COPAG

- SAG1: Science Objectives for an UVOIR Flagship Mission (4-8 m).
- SAG2: Determine technology focus areas for a monolithic 4m Aperture UV/Optical/NIR mission with Internal Coronograph for Exoplanet Imaging.
- SAG3: Determine technology focus areas for a segmented 8 m Aperture UV/Optical/NIR mission with External Occulter for Exoplanet Imaging.
- SAG4: Determine technology focus areas for future Far IR Instruments.
- Technology assessment concluded in 2011 and input was incorporated in the Cosmic Origins PATR.
- COPAG websites: *http://cor.gsfc.nasa.gov and http://copag.pbworks.com/*

ExoPAG

- Current Dear Colleague is out for 3 new members of the Executive Committee to replace members rotating off.
- 7 Science Analysis Groups (SAGs) currently active:
  - Debris Disks & Exozodiacal Dust; Potential for Exoplanet Science measurements from Solar System Probes; Planetary Architecture and Dynamical Stability; Planetary Measurements Needed for Exo-planet Characterization; ExoPlanet Flagship Requirements and Characteristics; State of Precision RV measurements for planetary census; ExoPlanet Probe Requirements and Characteristics
- ExoPAG website: *http://exep.jpl.nasa.gov/exopag/*

Astro2010 Decadal Report Status - Priorities

Program Scale	Recommendation	Science	Total Cost (U.S. share)	Launch Date
Large	**WFIRST** (NASA/DOE collaboration)	Dark energy, exoplanets, and infrared survey-science	$1.6B	2020
Large	**Explorer Program** Augmentation	Enable rapid response to science opportunities; augments current plan by 2 MIDEXs, 2 SMEXs, & 4 MoOs	$463M	Ongoing
Large	**LISA** (requires ESA partnership)	Open low-frequency gravitational-wave window for detection of black-hole mergers and compact binaries and precision tests of general relativity	$2.4B ($1.5B)	2025
Large	**IXO** (partnership with ESA and JAXA)	Black-hole accretion and neutron-star physics, matter/energy life cycles, and stellar astrophysics	$5.0B ($3.1B)	2020s
Medium	**New Worlds Technology Development Program**	Preparation for a planet-imaging mission beyond 2020, including precursor science activities	$100-200M	>2020
Medium	**Inflation Probe Technology Development Program**	CMB/inflation technology development and preparation for a possible mission beyond 2020	$60-200M	>2020
Small	**Astrophysics Theory Program** Augmentation	Broad	$35M additional	
Small	(Definition of) a **future UV-optical space capability**	Technology development benefiting a future UV telescope to study hot gas between galaxies, the interstellar medium, and exoplanets	$40M	
Small	**Intermediate Technology Development** Augmentation	Broad; targeted at advancing the readiness of technologies at TRL 3 to 5	$2M/yr additional, increasing to $15M/yr additional by 2021	
Small	**Laboratory Astrophysics** Augmentation	Basic nuclear, ionic, atomic, and molecular physics to support interpretation of data from JWST and future missions	$2M/yr additional	
Small	**SPICA** mission (U.S. contributions to JAXA-led)	Understanding the birth of galaxies, stars, and planets; cycling of matter through the interstellar medium	$150M	
Small	**Suborbital Program** Augmentation	Broad, but including especially cosmic microwave background and particle astrophysics	$15M/yr additional	
Small	**Theory and Computation Networks** (NASA, NSF, DOE)	Broad; targeted at high-priority science through key projects	$5M/yr NASA	

Astro2010 Decadal Report Status - Response

Program Scale	Recommendation	Recommended Funding	Current Response FY13
Large	**WFIRST**	$1.6B	SDT and DRMs in FY12
Large	**Explorer** Augmentation	$463M	$20M/yr augmentation in FY14 growing to a $70M/yr augmentation in FY16
Large	**LISA** Technology	$852M	$3.4M in FY12; only PCOS SAT in FY13 and beyond
Large	**IXO** Technology	$200M	$6M in FY12 (including PCOS SAT); only PCOS SAT in FY13 and beyond
Medium	**New Worlds Technology**	$100-200M	$9M in FY12 (including EXEP SAT); funding increases by $12M/yr in FY15 growing to an increase of $15M/yr in FY17
Medium	**Inflation Probe Technology**	$60-200M	$0.3M in FY12 (SAT only); only PCOS SAT in FY13 and beyond; several APRA investigations are relevant
Small	**Astrophysics Theory Program** Augmentation	$35M additional	$0.3M/yr augmentation starting in FY12
Small	(Definition of) a **future UV-optical space capability**	$40M	$6M in FY12 (including SAT); included in COR SR&T growing by an additional $6M by FY15
Small	**Intermediate Technology Development** Augmentation	$2M/yr additional, increasing to $15M/yr additional by 2021	Included in 3 Program SAT augmentations toward 5 prioritized areas
Small	**Laboratory Astrophysics** Augmentation	$2M/yr additional	$0.5M/yr augmentation over $3M/yr baseline starting in FY12; includes one large investigation
Small	**SPICA** mission (U.S. contributions to JAXA-led)	$150M	Candidate for Explorer Mission of Opportunity
Small	**Suborbital Program** Augmentation	$15M/yr additional	$1M/yr augmentation for payloads over $22M/yr baseline; zero augmentation for Balloon Project
Small	**Theory and Computation Networks** (NASA, NSF, DOE)	$5M/yr NASA	$1.5M/yr for 3 years; to be reviewed after 3 years
N/A	**Additional core program augmentations**	N/A	Roman Technology fellows: $1M/yr; in FY13 new program; Astrophysics Data Program: $2M/yr augmentation over $14M baseline; APRA SR&T: $1M/yr augmentation over $20M baseline

Backup Slides

Astrophysics Program Content

	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
				(FY14-17 estimates are notional)			
Astrophysics	**631.1**	**672.7**	**659.4**	**703.0**	**693.7**	**708.9**	**710.2**
Astrophysics Research	146.9	164.1	176.2	189.1	205.1	211.5	218.7
Astrophysics Research and Analysis	59.6	64.6	64.2	65.5	66.8	68.2	69.5
Balloon Project	26.8	31.6	31.3	31.2	32.8	34.2	34.3
Other Missions and Data Analysis	60.5	67.9	80.6	92.3	105.4	109.2	114.8
Keck Single Aperture	2.2	2.3	2.4	2.4	2.5	2.5	2.5
Astrophysics Data Analysis Program	14.1	16.3	18.3	18.5	18.5	19.1	19.1
Astrophysics Data Curation and Archival	20.8	20.1	20.0	19.6	21.7	22.1	22.2
Astrophysics Senior Review			16.3	24.5	33.5	35.2	40.0
Education and Public Outreach	13.2	15.4	10.1	10.1	10.1	10.1	10.1
Directorate Support - Space Science	10.1	13.7	13.5	13.9	14.0	14.5	14.5
Directed Research and Technology				3.3	5.2	5.6	6.4
Cosmic Origins	229.1	237.3	240.4	228.5	215.1	205.3	205.7
Hubble Space Telescope (HST)	91.7	95.7	98.3	98.3	94.3	90.2	90.5
SOFIA	79.9	84.2	85.5	88.0	88.0	86.0	85.9
Other Missions And Data Analysis	57.6	57.4	56.6	42.2	32.8	29.1	29.3
Spitzer Space Telescope	22.7	17.8	9.8				
Herschel	24.6	24.0	20.8	15.8	5.8		
Cosmic Origins SR&T	7.9	10.6	19.4	19.5	20.7	21.7	21.8
Cosmic Origins Future Missions	0.7	1.0	1.7	1.7	1.0	2.0	2.0
Cosmic Origins Program Management	1.7	4.0	4.9	5.2	5.3	5.4	5.5

Astrophysics Program Content (cont'd)

	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
				(FY14-17 estimates are notional)			
Physics of the Cosmos	108.7	108.3	111.8	109.6	96.3	92.7	74.6
Chandra X-Ray Observatory	60.6	54.7	56.6	56.6	56.6	56.7	51.2
Fermi Gamma-ray Space Telescope	22.3	25.3	25.0	24.5	17.5	12.9	
Planck	8.1	7.2	6.8	4.6	0.8		
XMM-Newton	1.2	2.1	1.9	1.9			
Physics of the Cosmos SR&T	13.9	15.0	14.9	15.3	15.3	16.0	16.2
Physics of the Cosmos Program Management	2.3	3.1	4.7	5.0	5.1	5.2	5.3
Physics of the Cosmos Future Missions	0.3	1.0	1.8	1.7	1.0	2.0	2.0
Exoplanet Exploration	46.4	50.8	56.0	41.6	43.3	42.4	45.6
Kepler	16.8	19.6	13.6	0.2			
Large Binocular Telescope Interferometer	1.5	2.0	3.8	2.9	2.0	0.5	0.5
Keck Operations	3.6	3.2	3.3	3.4	3.5	3.5	3.5
Keck Interferometer	0.1	0.4					
Wide Field Infrared Space Telescope	3.6						
Exoplanet Exploration SR&T	14.9	18.1	28.0	28.2	30.8	31.1	34.3
Exoplanet Exploration Program Management	4.8	6.0	6.1	5.7	5.9	6.0	6.0
Exoplanet Exploration Future Missions	1.2	1.5	1.2	1.2	1.2	1.2	1.2

Astrophysics Program Content (cont'd)

	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
				(FY14-17 estimates are notional)			
Astrophysics Explorer	100.0	112.2	75.1	134.3	133.9	157.0	165.6
Nuclear Spectroscopic Telescope Array (NuSTAR)	36.1	11.8	4.7	4.4			
Gravity and Extreme Magnetism	23.0	63.2	46.4	32.9	2.7	0.2	
Other Missions and Data Analysis	41.0	37.2	24.1	97.1	131.2	156.8	165.6
Astro-H (SXS)	16.9	16.2	4.4	1.8	1.0	0.9	
SWIFT	6.3	4.3	4.4	4.4			
Wide-Field Infrared Survey Explorer	7.3	4.5	0.2				
Suzaku (ASTRO-E II)	1.8	0.3	0.3				
GALEX	6.2	0.6					
Wilkinson Microwave Anistropy Pro (WMAP)	1.6	1.0					
Rossi X-Ray Timing Explorer (RXTE)	0.9						
Astrophysics Explorer Future Missions		3.1	10.6	85.6	124.0	149.6	159.3
Astrophysics Explorer Program Management		7.3	4.1	5.3	6.2	6.3	6.4

Morse to APS, February 2011

NWNH Decadal Recommended Space Activities (Notional Plan)

NASA Astrophysics Division

Program Scale	Recommendation	Recommended US Share	FY 2011 PBR	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	5-year total
Large	WFIRST	$1,600	Pre-formulation planning and technology development only						
Large	Explorer Program Augmentation	$463	0.0	1.1	5.4	25.5	47.8	76.4	156.3
				1.1	5.4	25.5	47.8	76.4	156.3
Large	LISA (including ST-7)	$1,500	3.2	4.3	7.9	8.7	8.3	10.0	39.3
				1.1	4.8	5.5	5.1	6.8	23.3
Large	IXO	$3,100	2.3	3.0	6.4	7.0	7.0	7.3	30.7
				0.7	4.1	4.7	4.7	5.0	19.2
Medium	New Worlds Tech Development	$100-200	6.2	8.6	19.7	24.0	25.7	28.9	106.9
				2.4	13.5	17.9	19.6	22.7	76.1
Medium	Inflation Probe Tech Development	$60-200	0.0	0.2	3.5	4.1	4.0	5.0	16.8
				0.2	3.5	4.1	4.0	5.0	16.8
Small	Astrophysics Theory Program Augmentation	+$35M over 10 years	11.8	12.7	15.2	15.3	15.8	16.0	74.9
				0.9	3.4	3.5	3.9	4.2	15.9
Small	Definition of a future UV-optical space capability	$40M over 10 years	0.4	0.1	3.0	3.6	3.6	3.7	13.9
				-0.3	2.6	3.2	3.2	3.3	11.9
Small	Intermediate Tech Dev Augmentation	+$2M/yr, growing to +15M/yr in 2021	20.8	23.0	27.7	27.7	27.2	27.9	133.4
				2.2	6.9	6.9	6.4	7.1	29.6
Small	Laboratory Astrophysics	+$2M/yr	3.2	3.5	4.7	4.7	5.0	5.0	22.9
				0.4	1.5	1.5	1.8	1.8	6.9
Small	SPICA	$150M	Possible competed opportunity						
Small	Suborbital Program	+15M/yr	22.0	25.8	37.6	39.8	40.0	41.0	184.1
				3.8	15.6	17.8	18.0	19.0	74.3
Small	Theory and Computation Networks	+$5M/yr	0.0	0.5	3.0	3.1	3.1	4.0	13.7
				0.5	3.0	3.1	3.1	4.0	13.7

$ in millions, does not include civil servant labor

Top line: FY2012 PBR
Bottom line: augmentation above 2011

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Morse to APS, July 2011

Astrophysics Division

Astro2010 Decadal Survey Agency Response

- Astro2010/NWNH Science Objectives:
  - ✓ Astrophysics programmatic structure is well-aligned with the three scientific thrusts
- Astro2010/NWNH Small-Scale:
  - ✓ Augmented investments in core research and technology programs as recommended:
    - Astrophysics Theory Program
    - Definition of a future UV-optical space capability
    - Intermediate technology development
    - Laboratory Astrophysics
    - Suborbital Program
  - ✓ Initiated discussions with NSF on a joint program for Theory and Computation Networks (discussing with AAAC)
  - ✓ Maintaining discussions with JAXA and ESA on SPICA concept development
- Astro2010/NWNH Medium-Scale:
  - ✓ Augmented Exoplanet technology development support that feed into candidate architectures for a future direct-detection mission.
  - ✓ Initiated technology development support for cosmic inflation probe concepts.
- Astro2010/NWNH Large-Scale:
  - ✓ An Astrophysics Explorer Future Missions budget has been created to increase the flight rate to achieve the recommended four missions and four missions of opportunity selected by the end of the decade.
  - ✓ Support for mission concept planning and technology development relevant to the survey's Large space missions: WFIRST, LISA, IXO. NASA is also exploring potential collaborations on ESA's proposed Medium and Large Cosmic Vision missions.

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