Mission Directorate:	Science
Theme:	Astrophysics

Theme Overview

NASA's goal in Astrophysics is to discover how the universe works, explore how the universe began and developed into its present form, and search for life elsewhere. Three broad scientific questions emanate from this goal: 1) How do matter, energy, space and time behave under the extraordinarily diverse conditions of the cosmos? 2) How did the universe originate and evolve to produce the galaxies, stars, and planets we see today? 3) What are the characteristics of planetary systems orbiting other stars, and do they harbor life?

The Astrophysics Theme addresses these questions via an integrated strategy incorporating a robust research program, 14 operating missions, and 10 flight projects in various stages of planning and execution. Considerable concept definition and technology work is being conducted to define future mission candidates for Astrophysics, and these will be prioritized in the National Research Council's (NRC) decadal survey process now underway. The Astrophysics programs that support the integrated strategy are as follows:

The Physics of the Cosmos Program (which incorporates the former Beyond Einstein Program) contains missions that can explore the most fundamental and extreme physical conditions of the universe, from black holes to dark energy. They will study the building blocks of our own existence at the most basic level: the matter, energy, space and time that create the living Universe.

The Cosmic Origins program comprises projects that enable the study of how galaxies, stars and planetary systems came into being, how they evolve, and ultimately how they end their lives.

The Exoplanet Exploration program conducts advanced telescope searches for Earth-like planets and habitable environments around other stars.

The Astrophysics Explorer Program conducts small PI-led missions that are selected under the Heliophysics Explorer program. Explorer missions are opportunities for innovative science that fill the scientific gaps between the larger missions.

The Astrophysics Research Program prepares for the next generation of missions by supporting both theoretical research and applied technology investigations. These research activities exploit data from current missions and suborbital science investigations to advance NASA science goals, and also provide hands-on workforce training of students and early-career scientists and engineers.

For more information, please see http://nasascience.nasa.gov/astrophysics

Mission Directorate:	Science
Theme:	Astrophysics

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	**1,304.9**	**1,103.9**	**1,076.3**	**1,109.3**	**1,149.1**	**1,158.7**	**1,131.6**
Astrophysics Research	136.0	149.0	156.1	178.1	188.4	194.6	199.6
Cosmic Origins	850.0	684.1	687.7	669.4	667.5	640.5	599.2
Physics of the Cosmos	111.1	116.8	103.3	114.4	151.7	176.4	202.0
Exoplanet Exploration	72.1	46.2	42.5	54.1	83.0	93.8	117.6
Astrophysics Explorer	135.7	107.9	86.7	93.3	58.5	53.3	13.2
FY 2010 President's Budget Request	**1,281.2**	**1,120.9**	**1,074.1**	**1,042.7**	**1,126.3**	**1,139.6**	**--**
Astrophysics Research	135.0	151.9	160.0	165.0	177.2	188.0	--
Cosmic Origins	819.2	667.2	598.9	550.3	523.8	452.3	--
Physics of the Cosmos	128.3	147.7	188.5	213.9	291.4	330.3	--
Exoplanet Exploration	68.1	46.2	57.3	86.9	123.5	167.3	--
Astrophysics Explorer	130.7	107.9	69.5	26.6	10.4	1.7	--
Total Change from FY 2010 Request	**23.6**	**-17.0**	**2.2**	**66.6**	**22.7**	**19.1**	**--**

Plans for FY 2011

Astrophysics Research

Senior Reviews for operating missions and archives will be conducted in the spring of 2010. A comparative evaluation of all Astrophysics operating missions is conducted every two years. A comparative evaluation for the archives is conducted every four years. The science output is evaluated by an independent expert panel, and decisions are made as to which missions will receive funding for extended operation.

In R&A, peer-reviewed investigations will be selected in the areas of past missions data analysis, theoretical studies, and modeling of the astrophysical phenomena targeted by past, current, and future missions. Laboratory studies of astrophysical phenomena, limited ground-based observing, and suborbital missions will also continue in FY 2011.

The Balloons Project will continue to work toward advancing the capability of the new super-pressure balloon, which will be used to carry large scientific experiments to the brink of space for 100 days or more.

Cosmic Origins

The James Webb Space Telescope will continue to make progress towards its launch date in June, 2014.

Hubble Space Telescope will continue operations.

The Stratospheric Observatory For Infrared Astronomy (SOFIA) will complete open door flight testing and will conduct the first competed science observations.

Herschel (moved to Cosmic Origins from the Physics of the Cosmos Program) will continue prime operations.

Physics of the Cosmos

Planck will continue prime operations. Fermi will remain in its prime operations phase and Chandra will continue on in extended operations.

Exoplanet Exploration

Kepler will continue prime mission operations.

Astrophysics Explorer

The High-Resolution Soft X-Ray Spectrometer (SXS) instrument (scheduled to fly on the Japanese Astro-H mission in FY 2014) will complete mission Critical Design Review.

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission will complete integration and testing in FY 2011, in preparation for launch in January 2012.

The WISE (Wide-field Infrared Survey Explorer) Mission will be in prime operations. The Gravity and Extreme Magnetism (GEMS) mission, selected in FY 2009 for a launch in FY 2014, will be in formulation.

Relevance

Relevance to national priorities, relevant fields, and customer needs:

NASA's Astrophysics Theme is guided by the Space Act and subsequent legislation, and by U.S. National Space Policy and related policies, which call on NASA to conduct space missions to advance scientific understanding of the universe. In doing so, NASA follows a long-standing tradition of establishing its science priorities through consultation with world-class experts via the National Research Council's decadal survey process. The most recent Astrophysics decadal survey was published in 2001, and the next one is under development for release in 2010. Astrophysics also receives tactical-level advice from the external science community via the Astrophysics Subcommittee of the NASA Advisory Council, and advice on cooperative activities from the Congressionally chartered, NSF-managed Astronomy and Astrophysics Advisory Committee.

NASA enables research to understand the structure, content, and evolution of the universe. This research provides information about humankind's origins and fundamental physics that govern the behavior of matter, energy, space, and time. NASA leads the world in space-based research into the most compelling questions of modern physics, such as the nature of dark matter and dark energy, high-energy cosmic rays, tests of gravity and general relativity, and insight into cosmic inflation during the very early universe. NASA works proactively with the National Science Foundation and Department of Energy in exploring the interfaces between astronomy and physics, and in the search for life in the universe.

Relevance to education and public benefits:

Stunning images produced from Astrophysics operating missions continue to inspire the public, revealing the beauty of our universe and the science behind those images. NASA provides the tools to translate the science for the classroom and other learning venues in ways that meet educator needs.

Hubble images are featured on the Space Telescope Science Institute's "Amazing Space" Web site which provides curriculum support tools to classrooms in every state in the union. Spitzer's "Cool Cosmos" Web site offers explorations into the world of the infrared, and Chandra delivers authentic data sets to educators to enhance lessons by allowing students to use the same data that professional researchers use.

A consortium of Astrophysics missions have been featured in a traveling museum exhibit, "Alien Earths", to inform and inspire the public on critical questions related to the search for life elsewhere in our universe. The Astrophysics Exoplanet Exploration Program, in conjunction with the Astronomical Society of the Pacific, has sponsored the creation of "Night Sky Network" amateur astronomy clubs around the nation. NASA also provides toolkits and professional development training to support these groups of space enthusiasts as they help strengthen the public understanding of astronomy and space science.

Mission Directorate:	Science
Theme:	Astrophysics

Performance Achievement Highlights:

The fourth Hubble Servicing Mission (SM4) was completed successfully in May, 2009. Herschel and Planck launched in May 2009 as well. The JWST mission made progress toward launch in FY 2014 and held a successful Critical Design Review (CDR) for the Integrated Science Instrument Module (ISIM) in March 2009. The Kepler mission, designed to survey our region of the Milky Way Galaxy to detect and characterize hundreds of Earth-size and smaller planets in or nearby the habitable zone sucessfully launched March 6, 2009.

Astronomers have taken a direct image of an extra solar planet with the Hubble Space Telescope. The planet circles the bright southern star Fomalhaut, located in the constellation Piscis Australis. The astronomers estimate that the planet, called Fomalhaut b, is no more than three times Jupiter's mass, which is enormous compared to Earth but a proverbial needle in a haystack for planet hunters, considering it is located 25 light-years away. Since the Fomalhaut system is only 200 million years old, extremely young by planetary standards, images like this help astronomers study how planets and planetary systems evolve around stars.

NASA's Wilkinson Microwave Anisotropy Probe (WMAP) satellite observes the most ancient light in the universe, cosmic microwave background radiation which is the radiant heat left over from the Big Bang. Recent publications based on WMAP data accurately describe the features of the early universe and reveal hints about how it began. The WMAP team determined the universe's age to be 13.7 billion years, with accuracy better than one percent (or 0.12 billion years, a small amount when working on such a vast scale), its shape (uncurved) with a precision of 0.5 percent, and its rate of expansion with accuracy better than four percent. The WMAP results also show that only 4.6 percent of the universe exists in atoms, with the remainder in dark matter and dark energy. This supports the theory that the vast majority of the mass in the observable universe is made up of dark matter and dark energy. For more on this mission go to map.gsfc.nasa.gov/.

The Spitzer Space Telescope was prolific in star formation science this year, providing new insights into how stars form and how their natal disks of dust and gas go on to form their planetary systems. Using Spitzer infrared images researchers have uncovered newborn stars at the center of the Milky Way galaxy. Before now, there were only a few clues that stars can form in the galaxy's core. The heart of the Milky Way is cluttered with stars, dust, and gas, and at its very center is a supermassive black hole. Conditions there are harsh, with fierce stellar winds, powerful shock waves, and other factors that make it difficult for stars to form. The dust made it difficult to locate baby stars. However, the Spitzer infrared instruments made it possible to identify more than 100 candidates for young stars, all less than one million years old. The press release and images are available at www.spitzer.caltech.edu/Media/releases/ssc2009-13/release.shtml.

NASA's Chandra X-ray Observatory has been helping researchers better understand the nature of dark energy and through it, a better understanding of the origin and destiny of the universe. Dark energy is responsible for the acceleration of the universe's expansion. In December 2008, researchers released illustrations from their examination of galaxy cluster Abell 85, one of 86 clusters observed by Chandra to trace how dark energy has stifled the growth of these massive structures over the last seven billion years. By using Chandra to observe the hot gas in the galaxy clusters, they determined the change in the masses of clusters over time. The growth of the galaxy structures was initially driven only by the attractive force of gravity, but then the repulsive force of dark energy helped drive expansion. For more information and images go to chandra.harvard.edu/press/08_releases/press_121608.html.

Independent Reviews:

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Relevance	Senior Review Panel	04/2008	Comparative review of operating missions. Missions are ranked in terms of science return. In the most recent review, Swift and Chandra missions ranked highest, while RXTE and GP-B ranked lowest. Results and the report can be found at http://nasascience.nasa.gov/about-us/science-strategy/senior-reviews/AstroSR08_Report.pdf	04/2010
Performance	National Research Council	05/2006	Congressionally-mandated review by the NRC. The resulting letter report found that "It is vital that the strong, balanced science program in astronomy and astrophysics that has served the nation so well continue to be sustained as any new policy is implemented."	TBD
Relevance	National Research Council	05/2001	Decadal survey to set science and mission priorities for NASA's Astrophysics program. The report, Astronomy and Astrophysics in the New Millennium (NRC, 2001), found that "NASA's Great Observatories have revolutionized understanding of the cosmos, while the extremely successful Explorer program provides many targeted small-mission opportunities. There are now fewer opportunities for missions of moderate size, however..." The process to create the next Decadal Survey began in 2008.	2010

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Research

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	136.0	149.0	156.1	178.1	188.4	194.6	199.6
Astrophysics Research and Analysis	60.0	60.0	60.2	64.7	65.8	67.4	69.1
Balloon Project	25.6	26.7	27.1	32.4	32.7	35.3	36.8
Other Missions and Data Analysis	50.4	62.3	68.7	80.9	89.8	91.9	93.7
FY 2010 President's Budget Request	135.0	151.9	160.0	165.0	177.2	188.0	--
Astrophysics Research and Analysis	60.0	61.1	62.5	64.0	66.2	67.8	--
Balloon Project	24.6	26.7	28.8	32.4	33.2	35.8	--
Other Missions and Data Analysis	50.4	64.1	68.6	68.5	77.9	84.4	--
Changes from FY 2010 Request	1.0	-3.0	-3.9	13.1	11.2	6.7	--

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Research

Program Overview

The Astrophysics Research Program provides funding to analyze the data from NASA missions to understand astronomical events such as the explosion of a star, the birth of a distant galaxy, or the motion of planets around their parent stars. The program also supports basic research for scientists to work out the consequences of their theories, and to understand how they can best use data from NASA missions to develop new knowledge about the cosmos.

NASA's policy is to make the data from its space science missions available to everyone. This data is archived in the Astrophysics Data Centers, located at universities and NASA centers throughout the country, from which users can download them. The Centers also provide tools that enable users to combine different sets of data, or to examine how the appearance of the sky changes when it is observed with different kinds of light. For example, the remnant of an exploding star (a supernova) looks very different in pictures taken in visible light and in X-rays. More information can be found at http://nasascience.nasa.gov/astrophysics/astrophysics-data-centers.

The Astrophysics Research Program also supports the early development of new technologies for future NASA missions. The first step is usually to show that the technology can work in the laboratory. The next step in developing a new type of scientific instrument is often to fly it on a high-altitude balloon mission, or on a sounding rocket flight that takes it briefly outside the Earth's atmosphere. Instruments for balloons and sounding rockets are not as costly as for an orbital mission, and they can be built quickly to respond to unexpected opportunities. The equipment is usually retrieved after the flight, so that novel instruments can be tested, improved and flown again. These suborbital flights are important in training the next generation of scientists and engineers to better compete in the 21st century, and to maintain U.S. leadership in science, engineering, and technology.

For more information on the Astrophysics Research Program, please see http://nasascience.nasa.gov/researchers/sara/highlights.

Plans For FY 2011

The Astrophysics Research Program will continue to conduct and enable high-quality astrophysical research consistent with NASA's goals and science programs.

The Balloons project will conduct 16-20 flights and conduct 2 foreign campaigns.

In addition to ongoing awards, the Education and Public Outreach Project will competitively select approximately 40 new proposals for small awards averaging $15,000 a year and approximately 15 new proposals for mid-range awards averaging $130,000 a year.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Research

Project Descriptions and Explanation of Changes

Astrophysics Research & Analysis (R&A)

This project solicits basic research proposals for investigations that are relevant to NASA's programs in astronomy and astrophysics and includes research over the entire range of photons, gravitational waves, and particles of cosmic origin. The R&A project seeks to support research that addresses the best possible state-of-the-art detector technology development for instruments that may be proposed as candidate experiments for future space flight opportunities; science and/or technology investigations that can be carried out with instruments flown on suborbital sounding rockets, stratospheric balloons, or other platforms; and supporting technology, laboratory research, and/or (with restrictions) ground-based observations that are directly applicable to space astrophysics missions.

Within the R&A project, the Astrophysics Theory program (ATP) supports efforts to develop the basic theory for NASA's space astrophysics programs. Astrophysics Theory topics include: star formation, supernovae and gamma-ray bursts, large scale cosmic structures and dark matter, and dark energy and the cosmic microwave background.

All Research and Analysis grants selected for funding by the Astrophysics Theme are broadly competed through NASA's Research Opportunities in Space and Earth Sciences (ROSES). Grant proposals must relate directly to both Agency and Theme goals and objectives, and all proposals are peer-reviewed by a mix of scientific disciplines and are selected based upon merit.

Balloons

Balloons have been used for decades to conduct scientific studies. While the basics of ballooning have not changed, balloon size and capabilities have increased, and their dependability has improved greatly. The Wallops Flight Facility manages the NASA Balloon Project. The project offers inexpensive, high-altitude flight opportunities for scientists to conduct research and test new technologies prior to spaceflight application. The science experiments being done by balloons cover a wide range of disciplines such as astrophysics, solar and heliospheric physics, as well as Earth upper-atmosphere chemistry.

The Columbia Scientific Balloon Facility (CSBF) provides the services of launching large (400 ft. dia), unmanned, high-altitude (120,000 ft.) research balloons, tracking, and recovering the scientific experiments suspended beneath them, for NASA centers and universities from all over the world. Balloons operating above the polar regions are deployed from Antarctica, Australia, and Sweden.

Other Missions and Data Analysis

Included in this line item are the following projects:

-Astrophysics Data Curation and Archival Research (ADCAR): The Astrophysics Theme has established an archive structure beyond the scope of individual missions, to receive data and make them accessible by creating an ensemble of primarily wavelength-specific astrophysics archives. After the completion of a mission, all archive activities are taken over by the relevant active multi-mission archive. ADCAR covers the activities of the Astrophysics Data Centers and NASA's participation in the Virtual Astronomical Observatory (VAO). For more information see http://nasascience.nasa.gov/astrophysics/astrophysics-data-centers

-Astrophysics Data Program: Over the years, NASA has invested heavily in the development and execution of an extensive array of space astrophysics missions. The magnitude and scope of the archival data from those missions enables science that transcends traditional wavelength regimes and allows researchers to answer questions that would be difficult, if not impossible, to address through an individual observing program. To capitalize on this invaluable asset and enhance the scientific return on NASA mission investments, Astrophysics Data Analysis provides support for investigations whose focus is on the analysis of archival data from NASA space astrophysics missions.

-The Astrophysics Senior Review budget provides funding for future operating mission extensions. The Senior Review is conducted every two years and is a comparative evaluation of all operating missions in their extended phase. Science output for these missions is evaluated, and a ranking process determines which missions will continue to receive funding for extended operations.

-Keck Single Aperture is a data archive for the High Resolution Echelle Spectrometer (HIRES) instrument in the Keck Observatory. This instrument provides the radial velocity data used to find exoplanets.

-Directorate Support, Space Science: This project funds Agency-level services provided to the Science Mission Directorate. These services include Defense Contract Audit Service (DCAS) contract administration, Defense Contract Audit Agency (DCAA) audit services and NASA Contract Assurance Services (NCAS) for all of SMD's projects.

-Education and Public Outreach: This project supports development and dissemination of new educational and outreach products that utilize SMD science discoveries. Opportunities are provided for students and educators, citizen scientists, and the public to engage in authentic experiences working with NASA data and NASA research communities. Efforts are carried out through competitively selected awards, ranging from $15,000-$130,000 per year. The project also supports four Science Education and Public Outreach Forums to foster ongoing engagement of the target audiences through community communication and feedback.

Program Commitments

Commitment/Output FY 2011	Program/Project	Changes from FY 2010 PB Request
Annual peer-reviewed solicitation for research grant opportunities	Research Program/R&A	None

Program Management

The Science Mission Directorate provides program management, with individual projects managed at Goddard Space Flight Center and the Jet Propulsion Laboratory.

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	Mission Senior Review Panel	5/2008	A comparative evaluation of all the Astrophysics operating missions.	4/2010
Quality	Archival Senior Review Panel	05/2008	Comparative review of the efficiency and cost effectiveness of the archives. For more information on the 2008 Senior Archival review see: http://nasascience.nasa.gov/astrophysics/astrophysics-data-centers/ApArchSR-2008_final.pdf	05/2012
Quality	Balloon working group	06/2009	Evaluate the operation of the Balloon project from a scientific standpoint. The main result of this meeting was a review of the Super-Pressure Balloon development in preparation of an invited oral presentation on June 9, 2009 to the Particle Astrophysics and Gravitation Panel of the on-going Astro2010 Decadal Study. The Decadal Study recommendations are expected in the August-September 2010 timeframe.	06/2010

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	850.0	684.1	687.7	669.4	667.5	640.5	599.2
Hubble Space Telescope (HST)	203.1	112.6	102.7	104.5	99.8	98.0	98.6
James Webb Space Telescope (JWST)	466.9	440.3	444.8	379.2	335.2	259.3	119.2
Stratospheric Observatory for Infrared Astronomy (SOFIA)	77.4	72.8	79.6	80.1	79.2	81.1	81.3
Other Missions And Data Analysis	102.5	58.4	60.6	105.7	153.4	202.2	300.1
FY 2010 President's Budget Request	836.3	690.2	621.9	573.2	544.6	466.7	--
Other Missions and Data Analysis	17.2	23.0	23.0	22.9	20.8	14.4	--
Hubble Space Telescope (HST)	207.7	112.6	101.6	94.6	91.1	93.2	--
James Webb Space Telescope (JWST)	446.9	441.4	385.1	354.6	335.6	259.8	--
Stratospheric Observatory for Infrared Astronomy (SOFIA)	72.8	72.8	74.0	75.8	77.6	79.1	--
Other Missions And Data Analysis	91.7	40.4	38.3	25.3	19.4	20.2	--
Changes from FY 2010 Request	13.6	-6.1	65.8	96.2	123.0	173.9	--

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins

Program Overview

The science goal of Cosmic Origins is to understand the entire sweep of evolution of the universe, from the cosmic big bang to the present. Cosmic Origins missions explore how the expanding universe grew into a grand, cosmic web of galaxies, how stars and planets formed within the galaxies, and how stars create the heavy elements, such as carbon, that are essential for life. Even though major breakthroughs in our knowledge of the cosmos have already been made with the current suite of missions, Cosmic Origins science questions remain vital. How did the rich structure we observe in the universe today, its planets, stars and galaxies, originate from the tiny fluctuations in the density of matter and energy imprinted by the big bang? What was the nature of the first stars and galaxies, which are so faint and distant that they have never been observed? How did galaxies and the enormous black holes within them form and evolve? How do stars and planets form? What are the conditions needed for life to originate? Are we alone? To address these fundamental questions NASA has developed the world's most sophisticated space observatories and is now building even more advanced facilities such as the James Webb Space Telescope. The submillimeter and far-infrared parts of the spectrum are just now being examined by missions like Herschel and soon by SOFIA. In the future, larger telescopes (with mirror diameters of 10 meters or longer) will be required to resolve galaxies and stellar nurseries at these wavelengths and in the ultraviolet. Future collaboration will also be critical for continued progress answering the questions that form the intellectual impetus behind Cosmic Origins.

For more information, please see: http://nasascience.nasa.gov/about-us/smd-programs/cosmicorigins

Plans For FY 2011

Hubble Space Telescope plans to start a multi-cycle treasury program to coordinate scientific observations over several years.

JWST will continue to make progress towards its launch date in June 2014. The Optical Telescope Element Flight Backplane Assembly is scheduled to be completed, and the Flight Model Science Instruments are scheduled to start delivery.

SOFIA will complete open door flight testing and will conduct the first competed science observations.

If successful during the 2010 Senior review process, Spitzer will continue warm science operations.

Herschel will continue its prime operations in FY 2011.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins

Project Descriptions and Explanation of Changes

Hubble Space Telescope (HST)

Hubble Space Telescope launched in FY 1990 and is currently in an extended operations phase. Servicing Mission 4 (SM4), completed in FY 2009, added new batteries, gyros and instruments to extend its life even further into the future. One of NASA's most successful and long-lasting science missions, HST has beamed hundreds of thousands of images back to Earth, shedding light on many of the great mysteries of astronomy. Its gaze has helped determine the age of the universe, the identity of quasars, and the existence of dark energy. Development of the capability to safely de-orbit HST after its mission has concluded is underway within the Cosmic Origins program. The timing for this activity will be determined by the status of the observatory and the orbital conditions that would drive an uncontrolled reentry.

James Webb Space Telescope

JWST is currently in development phase and launch is scheduled for FY 2014 on a European Space Agency-supplied Ariane-5 rocket for a five-year science mission (10-year goal) to study the origin and evolution of galaxies, stars, and planetary systems. The JWST spacecraft will have a large mirror, 21.3 feet in diameter, and a sunshield the size of a tennis court. Neither the mirror nor the sunshield fit into the rocket fully open, so both will fold up and open only after JWST is in space. JWST will reside at the Sun-Earth L2 point, which is about one million miles from the Earth. The telescope and instruments will operate at cryogenic temperature in order to achieve infrared performance. Additional funding has been added to restore depleted reserve levels. See project page for more detail.

Stratospheric Observatory for Infrared Astronomy (SOFIA)

SOFIA, currently in development, is a Boeing 747SP airborne observatory with a 2.5 meter reflecting telescope that will study the universe in the infrared spectrum. Besides this contribution to science progress, SOFIA will be a major factor in the development of new observational techniques, new instrumentation and in the education of young scientists and teachers in the discipline of infrared astronomy. The project will be at Full Operational Capability (FOC) in CY 2014. See project page for more detail.

Other Missions and Data Analysis

Included in this line item are:

-The Spitzer Space Telescope, in extended operations, is an infrared telescope utilizing 2 channels of the IRAC instrument to study the atmosphere of exoplanets, looking for the earliest clusters of galaxies, near earth asteroids and providing a 360 degree map of our galaxy. Spitzer completed its cryogenic mission in FY 2009, and is now conducting warm operations. Continued warm operations will be reviewed in the 2010 Senior Review.

-The Herschel Space Observatory is a collaborative mission with the European Space Agency and launched on May 14, 2009. It has the largest single mirror ever built for a space telescope and it will collect long-wavelength radiation from some of the coldest and most distant objects in the universe. NASA has contributed to instruments onboard Herschel and will also host U.S. astronomer access to data through the NASA Herschel Science Center.

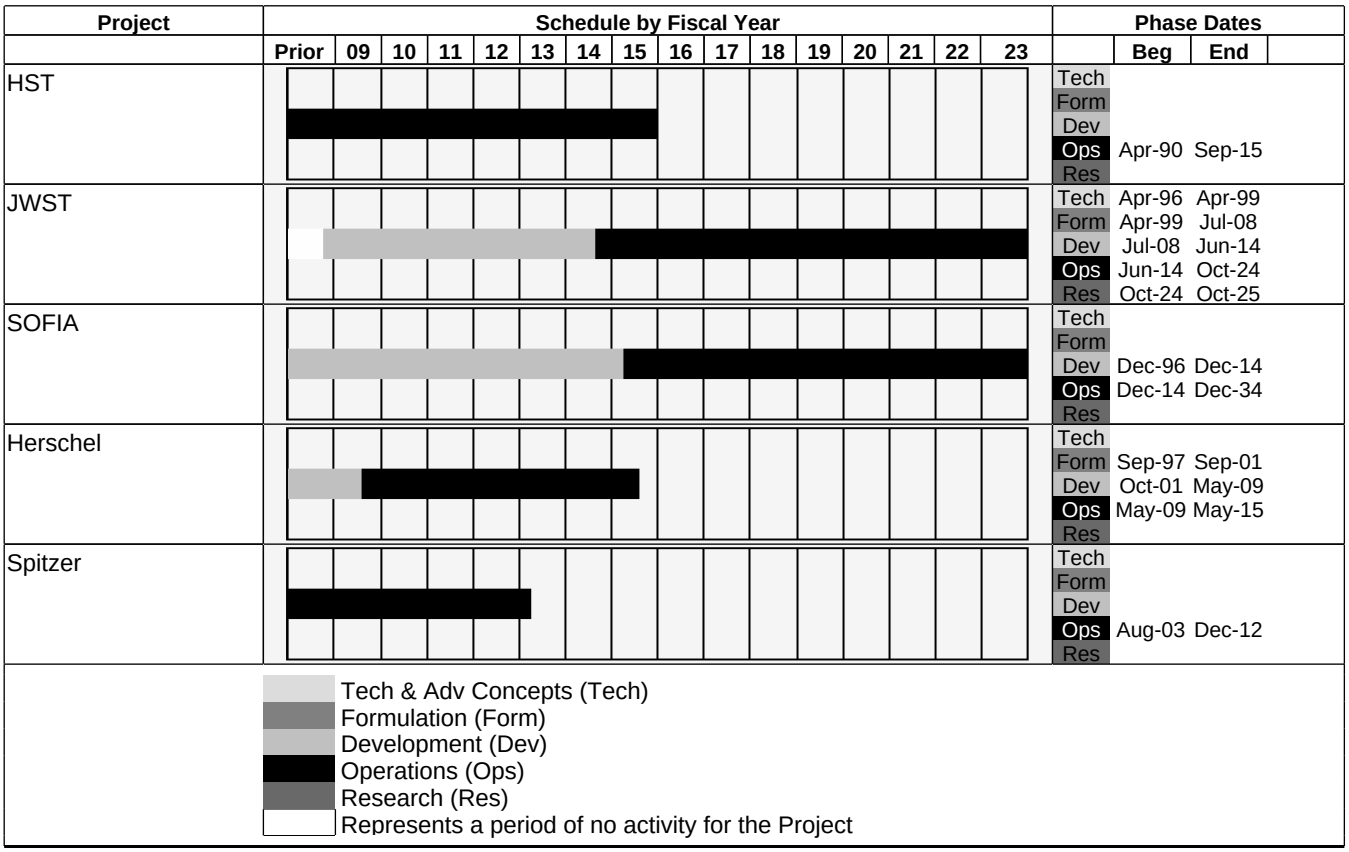
-Cosmic Origins Supporting Research & Technology supports Hubble fellowships and program-specific research and early technology development efforts.

-Cosmic Origins Future Missions supports future mission studies based on the recommendations of the upcoming Astrophysics decadal review.

-Cosmic Origins Program Management provides programmatic, technical, and business management, as well as program science leadership and coordination for education and public outreach products and services.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins

Implementation Schedule



Program Management

Cosmic Origins project management responsibility is as follows:

Project	Management Responsibility	NASA Center Performers	Cost-Sharing Partners
HST	GSFC	GSFC	None
JWST	GSFC	GSFC, JPL, JSC	European Space Agency (ESA) and Canadian Space Agency (CSA)
SOFIA	DFRC	DFRC, ARC	German Space Agency (DLR)
Spitzer	JPL	JPL	None
Herschel	JPL	JPL	European Space Agency (ESA)

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins

Acquisition Strategy

The HST Space Telescope Science Institute (STScI) is run under contract to NASA by the Association of Universities for Research in Astronomy (AURA). The STScI is responsible for the science program selection, grant administration, planning, scheduling, and public outreach activities for the Hubble Space Telescope (HST). The Basic Period of the HST STScI Contract with AURA ends on April 30, 2010. There are two contract options, the first of which runs May 1, 2010-April 30, 2013, and is planned to be exercised in FY 2010.

The HST Mission Operations functions (observatory engineering analysis, trending, and health and safety activities) are performed under a separate contract. The HST Mission Operations and Systems Engineering Services contract extension will expire on June 30, 2011. A new HST Missions operations contract will be required, and contract procurement activity has started for this activity.

As a result of the ongoing 2010 decadal survey, there may be priority missions identified that will require acquisition strategy decisions in the FY 2011 time frame leading to initiating of formulation activities.

No changes to acquisition activities are planned for JWST or SOFIA.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

FY 2011 Budget Request

Budget Authority ($ millions)	Prior	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	BTC	LCC TOTAL
FY 2011 President's Budget Request	**2,085.3**	**466.9**	**440.3**	**444.8**	**379.2**	**335.2**	**259.3**	**119.2**	**517.3**	**5,047.3**
Formulation	1,800.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,800.2
Development / Implementation	285.1	466.9	440.3	444.8	379.2	335.2	259.3	52.0	0.0	2,662.8
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.2	517.3	584.5
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
FY 2010 President's Budget Request	**2,085.3**	**446.9**	**441.4**	**385.1**	**354.6**	**335.6**	**259.8**	**--**	**634.9**	**4,943.6**
Formulation	1,800.2	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	1,800.2
Development / Implementation	285.1	446.9	441.4	385.1	354.6	335.6	259.8	--	72.8	2,581.3
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	562.1	562.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0
Changes from FY 2010 Request	**0.0**	**20.0**	**-1.1**	**59.7**	**24.5**	**-0.5**	**-0.5**	**--**	**-117.6**	**103.7**
Formulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	--
Development / Implementation	0.0	20.0	-1.1	59.7	24.6	-0.4	-0.5	--	-72.8	81.5
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	-44.8	22.4
Other	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	--	0.0	-0.2

Note: The FY 2011 LCC number in the table above is understated by $47.6M due to the difference between the FY 2010 enacted bill and the pending FY 2010 initial operating plan, and the removal of Construction of Facilities funds. Assuming approval of the initial operating plan, and with the inclusion of CofF funds, the estimated lifecycle cost will be $5095.2M, and the estimated development cost will be $2710.4M.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Explanation of Project Changes

Since confirmation in late 2008, the JWST project has made excellent progress. All Observatory components have successfully completed their preliminary design reviews. All science instruments have successfully completed their critical design reviews, and the Integrated Science Instrument Module (ISIM) Critical Design Review (CDR) was successfully held in March 2009. The ISIM structure was delivered to GSFC in August 2009. The Spacecraft Bus PDR was successfully completed in July 2009, and the Optical Telescope Element CDR was also held successfully in October 2009. The Engineering Development Unit Primary Mirror Segment was cryogenically tested in April 2009 and has almost competed its final planned polishing.

Several technical issues have occurred with the NIRCam instrument optics meeting wavefront error specifications, which have required additional project funds in FY 2011 and FY 2012 to correct. The JWST project is replanning the remaining work in all areas and working to maintain the current schedule, requirements, and LRD. Any revisions to project schedule and cost will be evaluated by the JWST SRB as part of the Critical Design Review (CDR) currently scheduled for April 2010.

Funding in FY 2010 through FY 2012 for the construction of the Thermal Vacuum Chamber A facilities at Johnson Space Center has been removed from the project budget, per Congressional direction.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Project Purpose

The James Webb Space Telescope (JWST) was identified by the National Research Council as a top priority new initiative for astronomy and physics for the decade. JWST is a large, deployable, space-based infrared astronomical observatory, scheduled for launch in June 2014. The mission is a logical successor to the Hubble Space Telescope (HST), extending beyond Hubble's discoveries by looking into the infrared spectrum, where the highly red-shifted early universe must be observed, where cool objects like protostars and protoplanetary disks emit strongly, and where dust obscures shorter wavelengths.

The four main science goals are:
- Search for the first galaxies or luminous objects formed after the big bang.
- Determine how galaxies evolved from their formation until now.
- Observe the formation of stars from the first stages to the formation of planetary systems.
- Measure the physical and chemical properties of planetary systems and investigate the potential for life in those systems.

Hubble has told us much about distant objects, but its infrared coverage is limited. Light from distant galaxies is redshifted, by the expansion of the universe, into the infrared part of the spectrum (from the visible). By examining light redshifted beyond Hubble's sight, JWST will be able to observe things farther away, as their light has taken longer to reach us. Hence it will be looking back further in time.

JWST will explore the mysterious epoch when the first luminous objects in the universe came into being after the big bang. The focus of scientific study will include first light of the universe, assembly of galaxies, origins of stars and planetary systems, and origins of the elements necessary for life.

The telescope is scheduled to launch in June 2014 from Kourou, French Guiana, on an ESA-supplied Ariane 5 rocket. Its operational location is the L2 Lagrange point, which is about one million miles from the Earth.

For more information, please see: http://www.jwst.nasa.gov

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Project Parameters

JWST will be optimized for infrared astronomy, with some capability in the visible range. JWST's instruments are Near Infrared Camera (NIRCam), Mid Infrared Instrument (MIRI), Near Infrared Spectrograph (NIRSpec), and the Fine Guidance Sensor (FGS).

NIRCam is an imager with a large field of view and high angular resolution. It covers a wavelength range of 0.6 - 5 micrometers and has 10 mercury-cadmium-telluride (HgCdTe) detector arrays. These are analogous to charge coupled devices found in ordinary digital cameras. NIRCam is a science instrument but also a wavefront sensor, which is used to align and focus the optical telescope.

NIRSpec enables scientists to obtain simultaneous spectra of more than 100 objects in a 9-square-arcminute field of view. It provides medium-resolution spectroscopy over a wavelength range from 0.6 - 5 micrometers. NIRSpec employs a micro-electromechanical system "microshutter array" for aperture control, and it has two HgCdTe detector arrays.

MIRI is an imager/spectrograph that covers the wavelength range of 5 - 28 micrometers and it has three arsenic-doped silicon detector arrays. The camera module provides wide-field broadband imagery, and the spectrograph module provides medium-resolution spectroscopy over a smaller field of view compared to the imager. The nominal operating temperature for the MIRI is 7 degrees above absolute zero, which is possible through an on-board cooling system.

The FGS is a guider camera that is incorporated into the instrument payload in order to meet the image motion requirements of JWST. This sensor is used for both guide star acquisition and fine pointing. The sensor operates over a wavelength range of 1 - 5 micrometers and has two HgCdTe detector arrays. Its field of view provides a 95% probability of acquiring a guide star for any valid pointing direction. The FGS tunable filter camera is a wide-field, narrow-band camera that provides imagery over a wavelength range of 1.6 - 4.9 micrometers, via tunable Fabry-Perot etalons that are configured to illuminate the detector array with a single order of interference at a user-selected wavelength. The camera has a single HgCdTe detector array.

The JWST Ground Operations, Science Support Center and archives will be at the Space Telescope Science Institute in Baltimore, MD.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Project Commitments

JWST is scheduled to launch in June 2014 and, after six months of on-orbit checkout and commissioning, it will complete five years of mission operations (with a goal of 10 years of operations.)

Project Element	Provider	Description	FY 2010 PB Request	FY 2011 PB Request
Observatory	Northrop Grumman Aerospace Systems, Redondo Beach, California	Includes Optical Telescope Element (OTE), Spacecraft, Sunshield, Observatory AI&T and commissioning. The Observatory shall be designed for at least a 5-year lifetime.	Same	Same
Integrated Science Instrument Module (ISIM)	NASA Goddard Space Flight Center	Contains the Science Instruments (SIs) and Fine Guidance Sensor (FGS). Provides structural, thermal, power, command and data handling resources to the SIs and FGS.	Same	Same
Near-Infrared Camera (NIRCam) instrument	University of Arizona; Lockheed Martin	Optimized for finding first light sources, and operating over the wavelength range 0.6-5 microns.	Same	Same
Near-Infrared Spectrometer (NIRSpec)	European Space Agency (ESA)	Operating over the wavelength range 0.6-5 microns with three observing modes.	Same	Same
Mid-Infrared Instrument (MIRI)	ESA; University of Arizona; Jet Propulsion Laboratory	Operating over the wavelength range 5-27 microns, providing imaging, coronagraphy, and spectroscopy.	Same	Same
Fine Guidance Sensor	Canadian Space Agency (CSA)	Provides scientific target pointing information to the observatory's attitude control sub-system.	Same	Same
Launch Vehicle	European Space Agency (ESA)	Ariane V ECA	Same	Same
Science Operations Center and Mission Operations	Space Telescope Science Institute (STScI)	Mission Operations and Science Operations Center	Same	Same

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Schedule Commitments

JWST was approved to enter implementation in July 2008.

Milestone Name	Confirmation Baseline	FY 2010 PB Request	FY 2011 PB Request
Development			
Non-Advocate Review/Preliminary Design Review	March,2008	Same	Same
Start phase C/Implementation	July 2008	Same	Same
Critical Design Review	April 2010	Same	Same
Systems Integration Review (SIR)	May 2012	Same	February 2013
Launch Readiness Date	June 2014	Same	Same
Start Phase E	December 2014	Same	Same

Development Cost and Schedule Summary

Project	Base Year	Base Year Develop-ment Cost Estimate ($M)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Date	Current Year Milestone Date	Milestone Change (months)
James Webb Space Telescope	2009	2,581.1	2010	2,710.4	5	Launch	06/2014	06/2014	0

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Delta
Total:	**2,581.1**	**2,710.4**	**129.3**
Payload	178.4	293.3	114.9
Spacecraft	875.4	1,422.1	546.7
Systems I&T	67.3	68.7	1.4
Ground Systems	206.8	242.0	35.2
Science/technology	10.5	11.9	1.4
Other (launch services and project management)	1,242.7	624.3	-618.4
Programmatic Construction of Facilities (transferred to Construction appropriation)	0.0	48.1	48.1

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Project Management

Goddard Space Flight Center is responsible for James Webb Space Telescope project management.

Project Element	Project Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Observatory	GSFC	GSFC	None
Mission management and System Engineering	GSFC	GSFC	None
Integrated Science Instrument Module (ISIM)	GSFC	GSFC	None
NIRCam	GSFC	GSFC	None
NIRSpec	ESA	None	ESA
MIRI	GSFC	JPL, ARC	ESA
Fine Guidance Sensor - Tunable Filter (FGS-TF)	CSA	None	CSA
Ariane 5 ESA launch vehicle and launch operations	ESA	None	ESA
Ground control systems and science operations and control center	GSFC	None	None

Acquisition Strategy

JWST is being built by Northrop Grumman Aerospace Systems (Redondo Beach, CA), teamed with Ball (Boulder, CO), ITT (Rochester, NY) and Alliant Techsystems (Edina, MN). Selections were made via NASA Request For Proposal.

The Space Telescope Science Institute (STScI), in Baltimore, MD, is developing the Science and Operations Center and associated services.

The Integrated Science Instrument Module (ISIM) is being provided by GSFC.

The University of Arizona, Tucson is providing the near-infrared science camera (NIRCam), along with Lockheed Martin's Advanced Technology Center in Palo Alto, California. The selection was made via a NASA Announcement of Opportunity.

The European Space Agency is providing the Mid-Infrared Instrument (MIRI) with management and technical participation by ARC and JPL, which was selected for this role after an internal NASA competition. The Europeans are also providing the Near-Infrared Spectrometer (NIRSpec) and an Ariane 5 launch vehicle.

The Canadian Space Agency is providing the Fine Guidance Sensor.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	James Webb Space Telescope

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	SRB	N/A	Critical Design Review	04/2010
Performance	SRB	N/A	Systems Integration Review/Authority to Proceed into Assembly Integration and Testing	05/2012
Performance	SRB	N/A	Flight Readiness Review/Authority to Launch	06/2014

Project Risk Management

Title	Risk Statement	Risk Management Approach and Plan
JWST Manufacturing, I&T	JWST has a long, complicated cryogenic integration and test which has never been performed at this scale.	JWST Standing Review Board regularly reviews the optical telescope element (OTE) testing and observatory-level integration and test planning.
JWST Partnership Risk	Because JWST is an international collaboration, NASA may incur schedule and cost impacts caused by challenges in Europe and Canada that are outside of NASA's control. Experience with similar collaborations indicates that this is likely to occur.	NASA has written clearly-defined interfaces and is actively managing and complying with export controls (ITAR).

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	Stratospheric Observatory for Infrared Astronomy (SOFIA)

FY 2011 Budget Request

Budget Authority ($ millions)	Prior	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	BTC	LCC TOTAL
FY 2011 President's Budget Request	**660.1**	**77.4**	**72.8**	**79.6**	**80.1**	**79.2**	**81.1**	**81.3**	**1,761.9**	**2,973.3**
Formulation	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
Development / Implementation	625.1	77.4	72.8	79.6	80.1	79.2	81.1	0.0	0.0	1,095.3
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.3	1,761.9	1,843.2
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
FY 2010 President's Budget Request	**660.0**	**72.8**	**72.8**	**74.0**	**75.8**	**77.6**	**79.1**	**--**	**1,843.4**	**2,955.5**
Formulation	35.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	35.0
Development / Implementation	625.0	72.8	72.8	74.0	75.8	77.6	79.1	--	0.0	1,077.1
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	1,843.4	1,843.4
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0
Changes from FY 2010 Request	**0.0**	**4.6**	**0.0**	**5.6**	**4.3**	**1.6**	**2.0**	**--**	**-81.5**	**17.8**
Formulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	--
Development / Implementation	0.1	4.6	0.0	5.6	4.3	1.6	2.0	--	0.0	18.2
Operations / Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	-81.5	-0.2
Other	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	-0.2

Note: The FY 2011 LCC number in the table above is understated by $2.1M due to the difference between the FY 2010 enacted bill and the pending FY 2010 initial operating plan. Assuming approval of the initial operating plan, the estimated lifecycle cost will be $2975.4M, and the estimated development cost will be $1097.3M.

Explanation of Project Changes

SOFIA development costs were increased by $17.8M in the current budget horizon to reflect increased hanger cost requirements.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	Stratospheric Observatory for Infrared Astronomy (SOFIA)

Project Purpose

The SOFIA mission will study many different kinds of astronomical objects and phenomena, including star birth and death, formation of new solar systems, identification of complex molecules in space, planets, comets and asteroids in our solar system, nebulae and dust in galaxies (ecosystems of galaxies), and black holes at the center of galaxies. The infrared light of these objects is only partially visible from the ground due to water vapour in the Earth's atmosphere. However, at high altitudes the influence of water vapour is negligible, allowing better observation of these astronomical objects.

It will be NASA's only far-infrared mission when Spitzer runs out of helium, and it is the only mid-infrared mission until JWST. SOFIA's reconfigurability and flexibility ensures cutting edge technology as well as the ability to address new scientific questions. For more information, please see http://www.nasa.gov/mission_pages/SOFIA/index.html

Project Parameters

The Stratospheric Observatory for Infrared Astronomy (SOFIA) was designed as a highly-modified Boeing 747SP aircraft with a large open-port cavity aft of the wings, housing a 2.5 meter telescope optimized for infrared/sub-millimeter wavelength astronomy. SOFIA will operate in flight at 41,000 feet, and at full operational capability will have eight instruments. SOFIA will ramp up to 960 science hours per year, and flights will last six to eight hours on average.

Germany has provided the telescope assembly and assists with mission operations. NASA has provided, refurbished and modified the airplane, and provides the Science Operations Center.

The U.S. instruments include High-speed Imaging Photometer for Occultation (HIPO), First Light Infrared Test Experiment CAMera (FLITECAM), Faint Object InfrRed CAmera for the SOFIA Telescope (FORCAST), CAlTech Submillimeter Interstellar Medium Investigations Receiver (CASIMIR), Echelon-Cross-Echelle Spectrograph (EXES), and High-resolution Airborne Wideband Camera (HAWC). The two German instruments are German Receiver for Astronomy at Terahetz Frequencies (GREAT), and Field Imaging Far-Infrared Line Spectrometer (FIFI LS).

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	Stratospheric Observatory for Infrared Astronomy (SOFIA)

Project Commitments

SOFIA will initiate science observations in FY 2010, and will begin 20 years at full operational capability as an airborne observatory in December 2014.

Project Element	Provider	Description	FY 2010 PB Request	FY 2011 PB Request
Platform	DFRC/L3/MPC	Refurbished Boeing 747SP modified to accommodate telescope	Same	Same
Science Center	ARC/USRA	Science Center will schedule observations, and manage data acquisition and processing	Same	Same
Telescope	Germany (DLR)	2.7m diamter, dual mirror	Same	Same
Flight Operations	DFRC/CSC DyneCorp	Flight crew, maintenance, and fuel	Same	Same
High-speed Photometer for Occultations (HIPO)	Lowell Observatory	Simultaneous high-speed time-resolved imaging photometry at two optical wavelengths	Same	Same
First Light Infrared Test Experiment Camera (FLITECAM)	UCLA	Large field-of-view, narrow- and broad-band photometric imaging and low-resolution spectroscopy from 1 to 5.5 µm	Same	Same
Faint Object Infrared Camera for SOFIA Telescope (FORCAST)	Cornell University	Large field-of-view, narrow- and broad-band photometric imaging and moderate-resolution spectroscopy from 4 to 42 µm	Same	Same
Caltech Submillimeter Interstellar Medium Investigations Receiver (CASIMIR)	Caltech	Modular, dual-channel heterodyne instrument for high-resolution spectroscopy between 150 and 600 µm	Same	Same
Echelon-Cross - Echelle Spectrograph (EXES)	ARC	Echelon Spectrometer, 5-28 microns R=105, 104, or 3000	Same	Same
High-resolution Airborne Wideband Camera (HAWC)	University of Chicago	Far-Infrared Bolometer Camera ,50-240 microns	Same	Same
German Receiver for Astronomy at Terahetz Frequencies (GREAT)	Germany (DLR)	TBD	Same	Same
Field Imaging Far-Infrared Line Spectrometer (FIFI LS)	Germany (DLR)	TBD	Same	Same

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	Stratospheric Observatory for Infrared Astronomy (SOFIA)

Schedule Commitments

The development and test plan has been modified to enable earlier science observations by the science community to be concurrent with the late phases of aircraft flight testing. The current plan provides for initial science observations with a subset of science instruments in FY 2010, followed by completion of the remaining science instruments and refinement of telescope performance, at which point Full Operational Capability in December 2014 is reached.

Milestone Name	Confirmation Baseline	FY 2010 PB Request	FY 2011 PB Request
Development			
First Flight	2000	2007	2007
First Science (Early Science)	N/A	2009	2010
Full Operational Capability (FOC)	N/A	2014	2014

Development Cost and Schedule Summary

Project	Base Year	Base Year Development Cost Estimate ($M)	Current Year	Current Year Development Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Date	Current Year Milestone Date	Milestone Change (months)
Stratospheric Observatory for Infrared Astronomy (SOFIA)	2007	919.5	2010	1,097.3	19	FOC	12/2013	12/2014	12

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Delta
Total:	**919.5**	**1,097.3**	**177.8**
Aircraft/Spacecraft	657.7	745.6	87.9
Other Costs	62.2	61.0	-1.2
Science/Technology	199.6	290.7	91.1

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Cosmic Origins
Project In Development:	Stratospheric Observatory for Infrared Astronomy (SOFIA)

Project Management

The overall Stratospheric Observatory for Infrared Astronomy (SOFIA) project, and the SOFIA airborne system is managed by Dryden Flight Research Center. The SOFIA science is managed by Ames Research Center.

Project Element	Project Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Platform	DFRC	DFRC	Germany - DLR/DSI
Science	ARC	None	Germany - DLR/DSI
Mission Operations and Data Analysis	ARC	None	Germany - DLR/DSI
Instruments	ARC	None	Germany - DLR/DSI

Acquisition Strategy

Dryden Flight Research Center (DFRC) manages the program and the platform project (airframe and telescope). DFRC is working with L-3 Communications (Waco,Texas), and MPC Products Corporation (Skokie,IL) to support the completion of the development, integration and test of the airborne platform system. L-3 modified the Boeing 747SP aircraft to install the telescope provided by Germany (DLR/DSI). MPC is developing the telescope cavity door drive system. DFRC is also working with CSC DynCorp (El Segundo, CA) to provide aircraft maintainence support.

Ames Research Center (ARC) manages the science project. ARC is working with University Space Research Association (Columbia, MD) for the science planning, ground science facilities, science instrument and technology development, and education and public outreach for SOFIA.

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	Standing Review Board	7/2009	Early science project review. Determined that plan for early science had merit.	4/2010

Project Risk Management

Title	Risk Statement	Risk Management Approach and Plan
Telescope cavity acoustics	If the telescope cavity acoustic resonance occurs above specified sound pressure levels, then additional mitigation work would be required	External wind tunnel and computational fluid dynamics modeling have been complete to design the cavity, and mitigation approaches.
Late delivery of Cavity Door Drive System	Late delivery of software that operates the telescope observation doors on the aircraft will impact the schedule to initiate open door flight testing and science observations.	NASA has stationed a NASA representative at the vendor's facility to support and oversee the vendor until delivery of the software. NASA has reviewed and revised the schedule for testing of the software for schedule efficiency.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Physics of the Cosmos

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	111.1	116.8	103.3	114.4	151.7	176.4	202.0
Other Missions and Data Analysis	111.1	116.8	103.3	114.4	151.7	176.4	202.0
FY 2010 President's Budget Request	111.1	124.7	165.5	191.0	270.6	315.9	--
Other Missions and Data Analysis	111.1	124.7	165.5	191.0	270.6	315.9	--
Changes from FY 2010 Request	0.0	-7.9	-62.2	-76.6	-118.9	-139.5	--

Program Overview

The Physics of the Cosmos (PCOS) Program focuses on some of the most profound questions in contemporary science: How did the universe begin? What is the universe composed of, and what is its ultimate fate? What are the fundamental laws that govern the workings of space, time, matter and energy?

These fundamental questions can be approached by asking more specific questions: What happens to matter, energy, and time at the edge of a black hole where Einstein's theory of gravity is put to its harshest test? What are the natures of dark matter, the unidentified matter that assisted the formation of galaxies, and the mysterious dark energy that is causing the Universe to accelerate? It is possible that the answers to these questions will usher in a revolutionary new understanding of physics.

The Fermi mission, for example, is searching for signs of new laws of physics and what composes the mysterious dark matter. It will attempt to explain how black holes accelerate immense jets of material to nearly the speed of light. The Planck mission will provide the best possible map of the cosmic microwave background, the earliest baby picture of the Universe. The XMM-Newton mission has helped scientists solve a number of cosmic mysteries, ranging from enigmatic black holes to the origins of the universe itself. Chandra will continue to reveal new details of celestial X-ray phenomena such as the collisions of galaxies that directly detect the presence of dark matter. New missions under consideration in the current Astronomy and Astrophysics Decadal survey include the International X-ray Observatory (IXO), which would observe regions near the surfaces of super massive black holes; the Laser Interferometer Space Antenna (LISA), which would peer back to the very beginning of time using the completely unexplored spectrum of gravitational radiation; and the Joint Dark Energy Mission (JDEM), which would focus on the nature and behavior of dark energy.

For more information see: http://nasascience.nasa.gov/about-us/smd-programs/physics-of-the-cosmos

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Physics of the Cosmos

Plans For FY 2011

In FY 2011 Planck will be in full science operations. Planck will complete the first full-sky survey of the cosmic microwave background, and will process the science data to produce the first Planck science results. Then the second full-sky survey will begin to provide critical refinement of cosmic microwave background and further science results.

The Fermi Gamma Ray Space Telescope will continue in its prime operations phase, making observations selected by peer review of observation proposals. Chandra will continue extended mission operations, making observations selected by peer review of observation proposals.

Future PCOS mission studies will continue pending the outcome of the NRC Decadal Survey on Astrophysics, which will evaluate JDEM, IXO, LISA, and other missions in the Astrophysics portfolio.

Project Descriptions and Explanation of Changes

Other Missions and Data Analysis

Included in this line item are:

-Planck, launched in May 2009, is an ESA-led mission with substantial NASA contributions. It will reveal the geometry and contents of the universe, how the universe grew immediately after its birth, and how the stage was set for the universe to evolve into structures that are seen today, such as galaxies. It will provide an order of magnitude increase in precision in its measurement of the Cosmic Microwave Background (CMB).

-Fermi Gamma-ray Space Telescope is a joint NASA/DOE mission formerly called GLAST. Fermi launched in June 2008 and is currently in operational phase. It is designed to detect the highest energy gamma-rays ever measured in a space-based mission and will provide a full-sky map filled with thousands of gamma-ray sources, increasing the current tally by orders of magnitude.

-Chandra, a flagship X-ray observatory currently in extended operations, has allowed scientists to image complex systems in exquisite detail, and to determine the positions of thousands of distant X-ray sources. Chandra has also provided unique information on diverse subjects ranging from the presence and amount of dark matter in the universe to phenomena occurring near the horizons of black holes.

- Physics of the Cosmos Supporting Research & Technology supports Einstein Fellowships and program-specific research and early technology development efforts.

- Physics of the Cosmos Program Management provides programmatic, technical, and business management, as well as program science leadership and coordination for education and public outreach products and services.

- Physics of the Cosmos Future Missions supports future mission studies based on the recommendations of the upcoming Astrophysics Decadal Survey by the National Academy of Sciences. Three missions have completed early technology activities and are under consideration by the 2010 Decadal Survey:

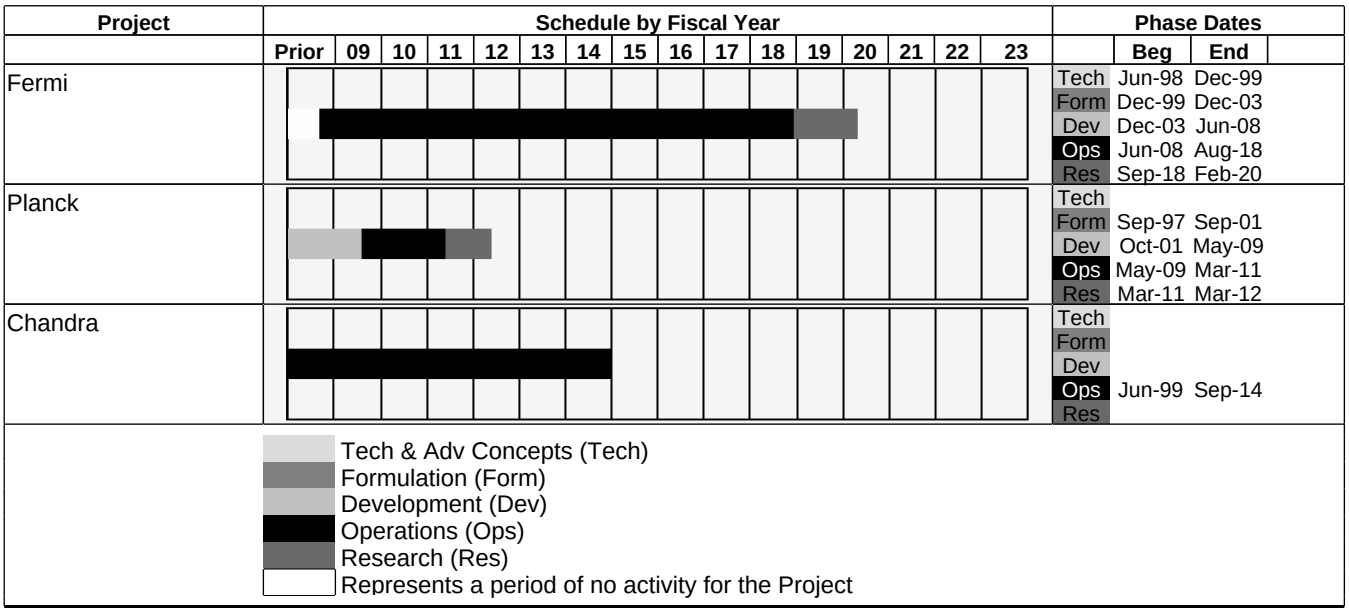
-The Laser Interferometer Space Antenna (LISA), a joint mission with the European Space Agency, will provide a first view of the gravitational radiation spectrum from space, enabling scientists to "see" in new ways how the universe evolved, and allowing powerful new tests of fundamental laws.

-The International X-ray Observatory (IXO) is a joint X-ray observatory with participation from NASA, the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA). Science objectives are the study of black holes and matter under extreme conditions, and the life cycles of matter and energy in the universe.

-The Joint Dark Energy Mission (JDEM) is a space-based observatory that will make precision cosmological observations to measure the effects of dark energy on the recent expansion history of the universe and on the growth of structure in the universe.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Physics of the Cosmos

Implementation Schedule



Program Management

Goddard Space Flight Center has Program management responsibility. Project management is as follows:

Project	Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Fermi	GSFC	GSFC	DOE, Japan, Italy, France, Sweden, and Germany
Planck (Instrumentation)	JPL	JPL	ESA
Chandra	MSFC	MSFC	None

Acquisition Strategy

The acquisition strategies for future Astrophysics missions (such as JDEM, IXO, or LISA) are under development. NASA will seek to maximize the amount of competition to ensure that the best concepts and science are supported.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Exoplanet Exploration

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	72.1	46.2	42.5	54.1	83.0	93.8	117.6
Other Missions and Data Analysis	72.1	46.2	42.5	54.1	83.0	93.8	117.6
FY 2010 President's Budget Request	68.1	46.2	57.3	86.9	123.5	167.3	--
Other Missions and Data Analysis	68.1	46.2	57.3	86.9	123.5	167.3	--
Changes from FY 2010 Request	4.0	0.0	-14.7	-32.8	-40.5	-73.6	--

Program Overview

Today we stand on the threshold of a voyage of unprecedented scope and ambition, promising insight into one of humankind's most timeless questions: Are we alone? Is Earth unique, or are other planets like ours common? One of the most exciting new fields of research within the NASA Astrophysics portfolio is the search for planets, particularly Earth-like planets, around other stars. During the last 15 years, astronomers have discovered over 400 planets orbiting nearby stars. Most of these planets are gas giants, similar in size to the four outer planets in our own Solar System, although the majority orbit much closer to their parent stars than do the giant planets in our system, some as close as 0.04 AU (1 AU = 1 astronomical unit = mean Earth-Sun distance, 93 million miles). Mercury, by comparison, orbits the Sun at a distance of about 0.4 AU (about 37 million miles). This means the planets have "hot" surface temperatures compared to our Earth.

Most of the known extrasolar planets have been discovered with ground-based telescopes using the radial velocity, or the Doppler method, in which one measures the tiny back-and-forth motion of a star as a planet orbits around it. The Doppler method tends to favor the detection of massive planets since the greater the mass of the planet, the greater the "wobble" it induces in the parent star. Approximately sixty planets have been found using a second technique, the transit method, in which one measures the slight dimming of a star's light that occurs as a planet passes between it and the observer, blocking out a bit of the light. The transit method only works on systems in which the planet's orbital plane is nearly parallel to one's line of sight. NASA's Kepler mission, the Agency's first mission dedicated to the study of extrasolar planets, is specifically designed to use the transit method to detect Earth-size and smaller planets, and will provide the first quantitative estimate of how many of the billions of stars in our galaxy have such planets.

In the future, through the use of advanced measurement techniques such as astrometry, interferometry, microlensing and coronagraphy, NASA plans to embark on a series of missions designed to detect and characterize Earth-sized planets that are orbiting in the "habitable zone" of nearby stars (the range of distances at which liquid water could be stable at the planet's surface). The Agency's long-term vision for exoplanet exploration includes missions optimized not only to detect extrasolar planets, but also to directly measure their characteristics and search for the chemical fingerprints of life. For more information, please see: http://exep.jpl.nasa.gov/

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Exoplanet Exploration

Plans For FY 2011

The Exoplanet Exploration Program (EXEP) will fund technology maturation activities for a variety of different techniques for detecting and characterizing extrasolar planets, including space-based interferometric, coronagraphic, and statistical concepts.

Keck Interferometer is operational and will provide U.S. astronomers access to this unique observational facility in support of NASA astrophysics science goals.

Kepler will be in full operations phase, making progress towards identifying potential Earth-size planets.

Project Descriptions and Explanation of Changes

Other Missions and Data Analysis

This line item contains the following projects:

-Kepler, launched in March 2009, finished its in-orbit checkout and began its operations phase during the summer of 2009. It is specifically designed to survey the distant stars in our region of the Milky Way galaxy to detect and characterize hundreds of Earth-size and smaller planets in or near the "habitable zone." The habitable zone encompasses the distances from a star where liquid water can exist on a planet's surface.

-Keck Operations is the NASA portion of the Keck Observatory partnership. NASA uses its share of observing time in support of all astrophysics science programs: Exoplanet Exploration, Cosmic Origins and Physics of the Cosmos. Observation time is competed, selected and managed by the NASA Exoplanet Science Institute (NExScI).

-Exoplanet Exploration Supporting Research & Technology supports Sagan Fellowships and program-specific research and early technology development efforts.

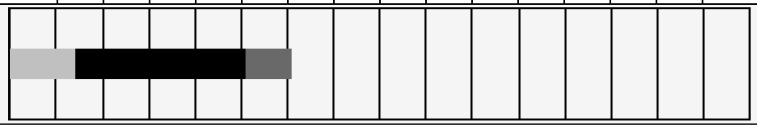
- Exoplanet Exploration Program Management provides programmatic, technical, and business management, as well as program science leadership and coordination for education and public outreach products and services.

- Exoplanet Exploration Future Missions supports future mission studies based on the recommendations of the upcoming 2010 Astrophysics decadal survey. Missions under consideration include the Space Interferometry Mission (SIM). SIM is a mission under study in support of NASA's goal of searching for habitable planets. The project has completed risk reduction engineering, and is studying alternate designs over a range of cost and performance levels.

-If approved for further development, the Large Binocular Telescope Interferometer (LBTI) is the NASA portion of the Large Binocular Telescope (LBT) partnership. The instrument will perform a key science program of exo-zodiacal dust survey around nearby stars.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Exoplanet Exploration

Implementation Schedule

Project	Schedule by Fiscal Year																Phase Dates		
	Prior	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23		Beg	End
Kepler																	Tech		
																	Form	Dec-01	May-05
																	Dev	May-05	Mar-09
																	Ops	Mar-09	Nov-12
																	Res	Nov-12	Nov-13

Tech & Adv Concepts (Tech)
Formulation (Form)
Development (Dev)
Operations (Ops)
Research (Res)
Represents a period of no activity for the Project

Program Management

The Jet Propulsion Laboratory is resposible for program management. Program management is as follows:

Project	Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Kepler	ARC	ARC	None

Acquisition Strategy

The acquisition strategy for the next Exoplanet mission has not yet been determined.

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	Exoplanet Task Force	01/2008	Determine planet-finding research and technology approach & prioritization leading up to the next decadal survey. Report and recommended strategy published and sent to respective agencies. For more information, please see: http://nasascience.nasa.gov/about-us/NAC-subcommittees/nac-documents/2008-01_APS_ExoPTF.pdf	N/A
Performance	SRB	N/A	To conduct an overall assessment of the life cycle cost, schedule and deliverables of the program.	2013

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	**135.7**	**107.9**	**86.7**	**93.3**	**58.5**	**53.3**	**13.2**
Nuclear Spectroscopic Telescope Array (NuStar)	**38.7**	**59.9**	**32.1**	**10.8**	**6.2**	**0.0**	**0.0**
Gravity and Extreme Magnetism	**1.7**	**0.0**	**21.0**	**57.7**	**44.7**	**40.8**	**2.1**
Other Missions and Data Analysis	**95.2**	**48.0**	**33.6**	**24.8**	**7.6**	**12.6**	**11.1**
FY 2010 President's Budget Request	**130.7**	**107.9**	**69.5**	**26.6**	**10.4**	**1.7**	**--**
Wide - Field Infrared Survey Explorer (WISE)	**65.2**	**13.0**	**5.2**	**1.6**	**0.2**	**0.0**	**--**
Nuclear Spectroscopic Telescope Array (NuStar)	**38.7**	**59.9**	**33.7**	**6.8**	**6.4**	**0.0**	**--**
Other Missions and Data Analysis	**26.8**	**35.0**	**30.6**	**18.2**	**3.8**	**1.7**	**--**
Changes from FY 2010 Request	**5.0**	**0.0**	**17.2**	**66.6**	**48.0**	**51.6**	**--**

Program Overview

The Explorer Program provides frequent flight opportunities for world-class astrophysics and heliophysics investigations using innovative and streamlined management approaches for spacecraft development and operations. Explorer missions are highly responsive to new knowledge, new technology, and updated scientific priorities by launching smaller missions that can be conceived and executed in a relatively short development cycle. Priorities are based on an open competition of concepts solicited from the scientific community. The program also enables participation in missions of opportunity provided by other U.S. or international agencies. The program emphasizes missions that can be accomplished under the control of the scientific research community within constrained mission life-cycle costs. The program also seeks to enhance public awareness of space science by incorporating educational and public outreach activities into each mission. For more information, please see Explorer Program at http://explorers.gsfc.nasa.gov/missions.html.

Currently, there are three Explorer missions in the Astrophysics Division: Nuclear Spectroscopic Telescope Array (NuSTAR) is in development, Astro-H and Gravity and Extreme Magnetism (GEMS) (the most recently selected mission) are in formulation. Five previously-launched missions are also supported in this program, as they continue to produce world-class science in their extended mission phases.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer

Plans For FY 2011

The Nuclear Spectroscopic Telescope Array (NuSTAR) will complete the science instrument integration and test activities, and begin final overall integration and test of the combined NuSTAR science instrument/spacecraft bus, in preparation for a FY 2012 launch.

The SXS instrument for Astro-H will complete its critical design review.

Gravity and Extreme Magnetism (GEMS) will complete preliminary design review and confirmation review.

WISE will complete its first sky map and complete its prime mission phase.

Project Descriptions and Explanation of Changes

Nuclear Spectroscopic Telescope Array (NuSTAR)

The Nuclear Spectroscopic Telescope Array (NuSTAR), currently in development, is planned for launch in January 2012. NuSTAR will provide a greater capability for using high-energy X-rays to detect black holes than any currently existing instrument. NuSTAR has been designed to answer fundamental questions about the universe, such as: How are black holes distributed through the cosmos? How were the elements of the universe created? What powers the most extreme active galaxies? This mission will expand the ability to understand the origin of cosmic rays and help predict the destinies of stars and galaxies.

Gravity and Extreme Magnetism SMEX (GEMS)

The Gravity and Extreme Magnetism (GEMS) mission was recently selected to proceed into formulation. GEMS will use an X-ray telescope to explore the shape of space that has been distorted by a spinning black hole's gravity, and probe the structure and effects of the formidable magnetic field around magnetars, dead stars with magnetic fields trillions of times stronger than Earth's.

Other Missions and Data Analysis

Included in this line item are the following projects:

-Launched in December 2009, the Wide-field Infrared Survey Explorer (WISE) will provide an all-sky survey of galaxies in the infrared. During its six-month mission, WISE will map the sky in infrared light, searching for the nearest and coolest stars, the origins of stellar and planetary systems, and the most luminous galaxies in the universe. WISE's infrared survey will provide an essential catalog for the James Webb Space Telescope. As the telescope orbits from the North Pole to the South Pole and then back up to the North Pole, it will observe a circle in the sky. As Earth moves around the Sun, this circle will shift, until WISE has observed the entire sky.

-Suzaku is Japan's fifth X-ray astronomy mission, on which NASA provided five X-ray mirrors, as well as one instrument, the micro-calorimeter spectrometer. Suzaku studies black holes, neutron stars, and quasars, to unravel the physics of high-energy processes and the behavior of matter under extreme conditions.

-Swift studies the position, brightness, and physical properties of gamma-ray bursts. Within seconds of detecting a burst, Swift relays a burst's location to ground stations, allowing both groundbased and space-based telescopes around the world the opportunity to observe the burst's afterglow.

-The Galaxy Evolution Explorer (GALEX) is exploring the origin and evolution of galaxies, the origins of stars and heavy elements, and is conducting an all-sky ultraviolet survey.

-The Wilkinson Microwave Anisotropy Probe (WMAP) studies the early universe by measuring the cosmic microwave background radiation over the full sky. WMAP produced the earliest "baby picture" of the universe, showing temperature variation of microwave light 379,000 years after the big bang, over 13 billion years ago.

-Astro-H is a mission of opportunity currently in formulation, in which NASA will provide the High-Resolution Soft X-Ray Spectrometer (SXS) instrument onboard the Astro-H spacecraft. Astro-H is an X-ray observation satellite under development by JAXA, scheduled for a FY 2014 launch. The mission will trace the growth history of the largest structures in the universe, provide insights into the behavior of material in extreme gravitational fields, determine the spin of black holes and the equation of state of neutron stars, trace shock acceleration structures in clusters of galaxies, and investigate the detailed physics of jets.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer

Implementation Schedule

Project	Schedule by Fiscal Year																Phase Dates		
	Prior	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23		Beg	End
WISE																	Tech		
																	Form	Apr-02	Oct-06
																	Dev	Oct-06	Dec-09
																	Ops	Dec-09	Oct-10
																	Res	Nov-10	Nov-12
Swift																	Tech		
																	Form		
																	Dev		
																	Ops	Apr-04	Sep-12
																	Res		
Suzaku																	Tech		
																	Form		
																	Dev		
																	Ops	May-05	Sep-11
																	Res		
WMAP																	Tech		
																	Form		
																	Dev		
																	Ops	Jun-01	Sep-11
																	Res		
GALEX																	Tech		
																	Form		
																	Dev		
																	Ops	Apr-03	Sep-12
																	Res		
NuSTAR																	Tech		
																	Form	Feb-08	Nov-09
																	Dev	Nov-09	Jan-12
																	Ops	Jan-12	Sep-14
																	Res		
Astro-H																	Tech		
																	Form	Jun-08	Aug-09
																	Dev	Aug-09	Feb-14
																	Ops	Feb-14	Feb-16
																	Res		
GEMS																	Tech		
																	Form	Jun-09	Jul-11
																	Dev	Jul-11	Apr-14
																	Ops	Apr-14	Jan-15
																	Res		

Tech & Adv Concepts (Tech)
Formulation (Form)
Development (Dev)
Operations (Ops)
Research (Res)
Represents a period of no activity for the Project

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer

Program Management

Management of the Astrophysics Explorer Program is assigned to Goddard Space Flight Center (GSFC).

Project	Management Responsibility	NASA Center Performers	Cost-Sharing Partners
WISE	GSFC	JPL	None
GALEX	GSFC	N/A	None
NuSTAR	GSFC	JPL	None
Astro-H	GSFC	GSFC	Japan (JAXA)
Swift	GSFC	N/A	None
Suzaku	GSFC	N/A	Japan (JAXA)
WMAP	GSFC	N/A	None
RXTE	GSFC	N/A	None
GEMS	GSFC	GSFC	None

Acquisition Strategy

Explorer projects are selected through competitive Announcements of Opportunity, from which multiple investigations are selected for initial concept studies, followed by a competitive down-select to proceed to the next stage of formulation. Investigations are selected to proceed from one phase to the next through execution of contract options, based on successful technical, cost, and schedule performance in the previous phases.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Development:	Nuclear Spectroscopic Telescope Array

FY 2011 Budget Request

Budget Authority ($ millions)	Prior	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	BTC	LCC TOTAL
FY 2011 President's Budget Request	**16.7**	**38.7**	**59.9**	**32.1**	**10.8**	**6.2**	**0.0**	**0.0**	**0.0**	**164.3**
Formulation	16.7	21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.3
Development / Implementation	0.0	17.1	59.9	32.1	4.5	0.0	0.0	0.0	0.0	113.6
Operations / Close-out	0.0	0.0	0.0	0.0	6.3	6.2	0.0	0.0	0.0	12.4
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FY 2010 President's Budget Request	**16.7**	**38.7**	**59.9**	**33.7**	**6.8**	**6.4**	**0.0**	**--**	**0.0**	**162.2**
Formulation	16.7	21.6	0.0	0.0	0.0	0.0	0.0	--	0.0	38.3
Development / Implementation	0.0	17.1	59.9	33.7	0.0	0.0	0.0	--	0.0	110.7
Operations / Close-out	0.0	0.0	0.0	0.0	6.8	6.4	0.0	--	0.0	13.2
Changes from FY 2010 Request	**0.0**	**0.0**	**0.0**	**-1.6**	**4.0**	**-0.3**	**0.0**	**--**	**0.0**	**2.1**
Formulation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	--
Development / Implementation	0.0	0.0	0.0	-1.6	4.5	0.0	0.0	--	0.0	2.9
Operations / Close-out	0.0	0.0	0.0	0.0	-0.6	-0.3	0.0	--	0.0	-0.8
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	0.0	0.0

Note: The FY 2011 LCC number in the table above is overstated by $3.7M due to the difference between the FY 2010 enacted bill and the pending FY 2010 initial operating plan. Assuming approval of the initial operating plan, the estimated lifecycle cost will be $160.6M, and the estimated development cost will be $109.9M.

Explanation of Project Changes

NuSTAR was approved to enter development at its confirmation review in August 2009. It was confirmed at a budget slightly higher than the FY 2010 President's budget, consistent with the recommendation of the Senior Review Board.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Development:	Nuclear Spectroscopic Telescope Array

Project Purpose

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission will observe the universe at high X-ray energy levels. By focusing higher energy X-rays, NuSTAR will start to answer several fundamental questions about the universe including: How are black holes distributed through the cosmos? How were heavy elements forged in the explosions of massive stars? What powers the most extreme active galaxies?

NuSTAR's primary science goal is to make the first deep observations of regions of the sky in the high energy X-ray band in order to locate massive black holes in other galaxies, locate and examine the remnants of collapsed stars in our galaxy, observe selected very high energy gamma-ray sources, and observe any supernovae of opportunity in the local group of galaxies. NuSTAR's key science products will be sensitive high-energy X-ray survey maps of the celestial sky that will guide the X-ray astronomy community research for several years to come.

For more information see: http://www.nustar.caltech.edu/

Project Parameters

NuSTAR will image the sky in the high energy X-ray band (6-79 KeV) and the spacecraft will be 3-axis stabilized. The primary science instruments will be two identical focusing X-ray telescopes which utilize an extendable 10-meter mast. The launch vehicle will be a Pegasus XL.

Project Commitments

NuSTAR will be launched in January 2012 into a 550km circular orbit around the Earth, with an orbital inclination currently planned for 6 degrees. Prime operations phase is two years.

Project Element	Provider	Description	FY 2010 PB Request	FY 2011 PB Request
Spacecraft	Orbital Sciences Corporation	Spacecraft design, fabrication and testing.	N/A	Same
Mission operations, focal plane assembly and instrument electronics	University of California, Berkeley	Aperture stop, active shield module and mechanical enclosures	N/A	Same
X-ray optics	Columbia University, GSFC and the Danish Technical University	Overall optics assembly management and manufacturing	N/A	Same
Mast, canister and instrument structure	ATK	Delivery of mast, canister and instrument structure for the spacecraft	N/A	Same

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Development:	Nuclear Spectroscopic Telescope Array

Schedule Commitments

NuSTAR was authorized for mission re-start in September 2007 and was authorized to proceed into Phase B in January 2008. Confirmation to proceed into Phase C (implementation) was approved in August 2009.

Milestone Name	Confirmation Baseline	FY 2010 PB Request	FY 2011 PB Request
Development			
Preliminary Design Review	N/A	N/A	June 2009
Confirmation Review	N/A	N/A	August 2009
Critical Design Review	February 2010	N/A	February 2010
Launch	January 2012	N/A	January 2012

Development Cost and Schedule Summary

Project	Base Year	Base Year Development Cost Estimate ($M)	Current Year	Current Year Development Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Date	Current Year Milestone Date	Milestone Change (months)
Nuclear Spectroscopic Telescope Array	2010	109.9	2010	109.9	0	Launch	01/2012	01/2012	0

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Delta
Total:	**109.9**	**109.9**	**0.0**
Aircraft/Spacecraft	15.4	15.4	0.0
Payload(s)	21.5	21.5	0.0
Systems I&T	5.9	5.9	0.0
Launch Vehicle Services	35.8	35.8	0.0
Ground Systems	2.1	2.1	0.0
Science/Technology	1.7	1.7	0.0
Other Costs	27.5	27.5	0.0

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Development:	Nuclear Spectroscopic Telescope Array

Project Management

The Jet Propulsion Laboratory is responsible for NuSTAR Project Management. The Principal Investigator at the California Institute of Technology is responsible for mission science.

Project Element	Project Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Mission Science	JPL	N/A	N/A
Launch Vehicle	KSC	N/A	N/A
Spacecraft, instruments, mast, optics	JPL	GSFC	N/A

Acquisition Strategy

NuSTAR was selected via a NASA Explorers Announcement of Opportunity. The spacecraft is being developed by Orbital Sciences Corporation (OSC) in Dulles, Virginia. X-ray optics are being developed by Columbia University (NY), GSFC (MD), and the Danish Technical University. Launch vehicle acquisition is through KSC.

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	SRB	6/2009	Preliminary Design Review (PDR); received authority to enter Phase C	02/2010
Quality	SRB	N/A	Critical Design Review (CDR). Demonstrates that the preliminary design is appropriate to support proceeding with full scale fabrication, assembly, integration and testing.	2/2010

Project Risk Management

Title	Risk Statement	Risk Management Approach and Plan
Observatory Mass Margin	The combined mass of the spacecraft and instrument forces design changes that tax project programmatic resources.	Remove shells from each object. This would free up about 6-10kg from the instrument.

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Formulation:	Gravity and Extreme Magnetism (SMEX 13)

FY 2011 Budget Request

Budget Authority ($ millions)	FY 2009 Actual	FY 2010 Enacted	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
FY 2011 President's Budget Request	**1.7**	**0.0**	**21.0**	**57.7**	**44.7**	**40.8**	**2.1**
Total Change from 2010 President's Budget Request	**1.7**	**0.0**	**21.0**	**57.7**	**44.7**	**40.8**	**--**

Project Purpose

GEMS will use an X-ray telescope to explore the shape of space that has been distorted by a spinning black hole's gravity, and probe the structure and effects of the formidable magnetic field around magnetars, dead stars with magnetic fields trillions of times stronger than Earth's.

Current missions cannot do this because the required angular resolution is far beyond what is technically feasible and, in the case of magnetic field imaging, can't do this because magnetic fields are invisible. GEMS will use a new technique to accomplish what has been impossible until now. It will build up a picture indirectly by measuring the polarization of X-rays emitted from these violent regions. This will open new discovery space because GEMS is orders of magnitude more sensitive than previous X-ray polarization experiments.

GEMS will be able to tell the shapes of the X-ray-emitting matter trapped near black holes better than existing missions can -- in particular, whether matter around a black hole is confined to a flat disk or puffed into a sphere or squirting out in a jet. Since X-rays are polarized by the space swirling around a spinning black hole, GEMS also provides a method of determining black hole spin independent of other techniques.

Project Preliminary Parameters

The nominal science mission is 9 months in duration. The X-ray Polarimeter Instrument (XPI) will be sensitive from 2 to 10 kev to polarization amplitude and angle. GEMS will study 35 targets including stellar-mass, black holes, seyfert galaxies and quasars, blazars, neutron star pulsars, shell supernovae remnants, and pulsar wind nebulae.

Estimated Project Deliverables

Project Element	Provider	Description	FY 2010 PB Request	FY 2011 PB Request
Spacecraft	Orbital	Small spacecraft based on reusable design	N/A	Same
Instrument Payload	GSFC	X-ray Polarimeter Instrument (XPI)	N/A	Same
Launch Vehicle	TBD	Small Class	N/A	Same

Mission Directorate:	Science
Theme:	Astrophysics
Program:	Astrophysics Explorer
Project In Formulation:	Gravity and Extreme Magnetism (SMEX 13)

Estimated Project Schedule

The GEMS project was selected for formulation in June 2009.

Milestone Name	Formulation Agreement Estimate	FY 2010 PB Request	FY 2011 PB Request
Formulation			
SRR (Mission)	July 2010	N/A	Same
KDP-C	July 2011	N/A	Same
Launch	April 2014	N/A	Same

Project Management

GEMS is part of the Explorers Program managed by GSFC.

Project Element	Project Management Responsibility	NASA Center Performers	Cost-Sharing Partners
Spacecraft	GSFC	None	N/A
X-ray Polarimeter Instrument (XPI)	GSFC	GSFC	N/A
Launch Vehicle	KSC	None	N/A

Acquisition Strategy

The largest portion of the overall project effort has been awarded to Orbital. In Phase B/C/D/E, the contract with Orbital is a cost-plus-award fee.

Independent Reviews

Review Type	Performer	Last Review	Purpose/Outcome	Next Review
Performance	SRB	N/A	Preliminary Design Review; determine if the project is ready to proceed into development	06/2011

Project Risk Management

Title	Risk Statement	Risk Management Approach and Plan
Late Polarimeter Delivery to Instrument I&T	If the Polarimeter does not meet the delivery date to the Instrument I&T, then the mission schedule will be impacted.	The project plans to develop two ETUs of the Polarimeter to test in parallel.

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