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Astronomy in the FY 2004 Budget

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HIGHLIGHTS

- The National Aeronautics and Space Administration's[1] (NASA) Office of Space Science[2] (OSS) would begin a new effort dubbed "Project Prometheus"[3] to enhance planetary exploration by improving current technologies already in use that provide electric power from radioisotopes and begin new research on reactors, advanced heat-to-power conversion and power management and distribution technologies. These two efforts will increase science return for space missions by decreasing travel times and increasing the amount of electricity available to power scientific instruments and communications devices. Project Prometheus also includes funding for a new mission, the Jupiter Icy Moons Orbiter, which would search for evidence of subsurface oceans on Europa,[4] Ganymede[5] and Callisto[6].

- The National Science Foundation's (NSF[7]) division of Astronomical Sciences (AST[8]) budget is proposed to increase by about 13.5 percent from a level of $161.25 million to $183.07 million. AST provides funding directly to astronomical researchers. Arguably one of the most important discoveries of our age was made with support from the NSF. Dr. Geoff Marcy

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[1] http://www.nasa.gov
[2] http://spacescience.nasa.gov
[3] http://spacescience.nasa.gov/missions/prometheus.htm
[4] http://www.the-planet-jupiter.com/europa-moon/europa-pictures.html
[5] http://www.the-planet-jupiter.com/ganymede/ganymede-pictures.html
[6] http://www.the-planet-jupiter.com/callisto/callisto-pictures.html
[7] http://www.nsf.gov
[8] http://www.nsf.gov/mps/ast

and colleagues[9] used NSF support (as well as NASA and other institutions) to perfect a new observational technique and use it to detect numerous planets around other stars.[10]

- NASA's OSS would also continue its successful Mars Exploration Program[11] with an increased budget requested for FY 2004 of just under $570 million. Two Mars Exploration Rovers[12] are being prepared for launch in the summer of 2003 and will arrive in early 2004. These rovers will search for water-affected materials on the surface and will, in a sense, serve as robotic field geologists.

- Astronomy is unique in the science community in the production of prioritized lists of projects requiring federal support. These so-called "Decadal Surveys" represent community consensus on the relative importance of scientific research projects. The surveys are carried out under the auspices of the National Academy of Sciences/National Research Council and sponsored by the funding agencies. The most recent astronomy and astrophysics survey is entitled *Astronomy and Astrophysics in the New Millennium.*[13] Two new reports were released in 2002, one that prioritizes the needs of the Planetary Science community (*A New Science Strategy for Solar System Exploration*[14]) and the second that covers the Solar and Space Physics community (*Solar and Space Physics: A Community Assessment and Strategy for the Future*[15]).

INTRODUCTION

The sky belongs to all of humanity and astronomy has a special role to play in bringing knowledge of the cosmos to us all. Beginning with the earliest recorded history, the sky and the objects to be seen there have been observed, debated and analyzed. Only in modern times have we truly found our place in the Universe. We live out our lives on a

[9] http://exoplanets.org/teamframe.html
[10] http://exoplanets.org/
[11] http://mars.jpl.nasa.gov
[12] http://mars.jpl.nasa.gov/missions/future/2003.html
[13] http://books.nap.edu/catalog/9839.html
[14] http://www.nationalacademies.org/ssb/ssefrontpage.html
[15] http://www4.nationalacademies.org/cpsma/SSBDisc.nsf

relatively small planet orbiting a rather normal star in an average galaxy. Just in this century, astronomers have determined how the chemical elements that make up our Earth (and us!) were formed in supernova explosions. Astronomers have managed to trace the history of the Universe back to its very first moments when all matter and light were compressed into a dense energetic state that rapidly expanded (for as yet unknown reasons) forming our Universe. This cosmic explosion is now known as the Big Bang. In the past decade, astronomers have finally discovered planets around other stars, confirming that our solar system is not unique and also discovered that the Universe is not just expanding, but that it is expanding faster and faster in a kind of "runaway" situation. Amazingly, the newest results indicate that the nature of roughly 95 percent of the matter and energy content of the Universe is completely unknown to us. Each new discovery creates new questions and new technological needs. Astronomy is truly an exciting, vibrant science that adds meaning to our human existence.

NASA provides roughly 75 percent of the federal funding[16] for astronomical research in the United States. When the budget for the Office of Space Science is changed, many American astronomers can be affected. NASA continues to provide observing opportunities for astronomers beyond the hindering absorption of the atmosphere. However, approximately two-thirds of federal support for ground-based astronomy, including nearly all support for radio astronomy, is provided by NSF.[17] NSF funds the construction and operation of the U.S. National Observatories.[18] These observatories play a critical role for researchers from smaller institutions for which large observing facilities are too expensive to construct and operate. They also provide access for American astronomers to the sky in the Southern hemisphere, where many important astronomical objects are located and cannot be observed from Northern hemisphere locations (*e.g.* the Magellanic Clouds, our nearest galactic neighbors). Lately, the Department of Energy has undertaken new astronomical research projects and the Smithsonian Institution and the Department of Defense also fund astronomical research, though on a smaller scale than both NASA and NSF.

A traditional, but arbitrary, split in funding exists between NASA and NSF with NASA funding *mostly* space-based observing and NSF

[16] http://www.nap.edu/books/0309071399/html/
[17] http://www.nsf.gov/bfa/bud/fy2004/pdf/fy2004_11.pdf
[18] http://www.nsf.gov/mps/divisions/ast/about/c_facilities.htm

funding *mostly* ground-based. This line is often blurred, since both agencies support balloon-based observing and other cross-cutting research. NASA does support ground-based observing when these activities have a direct supporting role for their space missions. A recent example is the Keck Interferometer[19] and both agencies are pursuing collaborative efforts such as the National Virtual Observatory[20] program, which will interconnect databases, telescopic observations, space mission archives and research tools for astronomy and astrophysics. These collaborations reflect the way astronomers pursue their research, using any means necessary to study celestial objects.

ASTRONOMY IN THE NASA BUDGET

Once again, the overall NASA budget will be increasing but, only slightly. From a level of just under $15.3 billion as finally passed for FY 2003, NASA would receive an increase of 0.9 percent to a level of just under $15.5 billion for FY 2004 (see Table II-12). The bulk of this increase would go to the Science, Aeronautics and Exploration portion of the agency's budget, which would also see an overall increase of 12.7 percent, or $450 million to $4.0 billion, while the Space Flight Capabilities (SFC[21]) budget would decrease by $72 million to just under $7.8 billion. Safety issues regarding the Shuttle and a growing debate on the value to the nation of NASA's mission could impact all portions of the agency budget. A "firewall" between the manned and unmanned portions of NASA's budget has more or less been in place for a number of years. Any policy changes impacting the SFC budget will likely not impact the Office of Space Science, beyond servicing the Hubble Space Telescope and the launch method for future missions.

The Office of Space Science (OSS) would experience a very healthy budgetary growth of 12.7 percent from a level of just under $3.6 billion to a FY 2004 total of $4.0 billion. Some of this increase is due to the new full-cost accounting system, which requires NASA to include the full cost of any activity in the appropriate budget line. This has increased the Space Science budget in general as now launch costs and mission operations expenses that were previously included in other portions of the budget are now included in the Space Science budget line.

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[19] http://huey.jpl.nasa.gov/keck/index.html
[20] http://www.srl.caltech.edu/nvo/
[21] http://www.hq.nasa.gov/osf/

The goals of the Space Science Enterprise can be classified into five broad themes[22]:

Solar System Exploration (SSE), $1,359 million: The objective of this theme is to gain a deeper understanding of the formation and evolution of our Solar System and investigate whether life arose beyond Earth.

Mars Exploration (ME), $570 million: This theme seeks to probe into the past and present conditions on Mars, look for extinct/extant life forms and potentially pave the way for human exploration.

Astronomical Search for Origins (ASO), $877 million: This theme seeks to answer questions regarding the formation of stars and planets, the origin and properties of life and whether life exists beyond our home planet.

Structure and Evolution of the Universe (SEU), $432 million: The objective of this theme is to gain a better understanding of the formation and evolution of the universe and deepen our knowledge regarding fundamental laws of space, time and energy.

Sun-Earth Connections (SEC), $770 million: This theme explores the properties of the Sun and the affects of solar activity on Earth.

The OSS has undertaken a series programs/missions under these broad themes. Although too numerous to mention here, a few of the missions/programs stand out as particularly exciting[23] (see Table 1).

The OSS has also undertaken some significant new initiatives including Project Prometheus (discussed in the Highlights section), Optical Communications and Beyond Einstein. Optical Communications is expected to dramatically increase the rate of data transmission while reducing the cost per byte of data returned. In the FY 2004 budget $31 million has been requested for Optical Communications ($233 million over five years). The budget request also includes $59 million ($765 million over five years) for the Beyond Einstein initiative, which seeks to deepen our knowledge regarding black holes, dark energy and the Big Bang. The main components of this program are two Einstein Great

[22] http://www.nasa.gov/about/budget/content/04_spacescience.pdf
[23] http://www.nasa.gov/about/budget/content/04_spacescience.pdf

Observatories – Constellation X and the Laser Interferometer Space Antenna (LISA). [24]

Table 1 – Major Programs/Missions Undertaken by the OSS

Program/Mission[25]	FY 2004 Req. [millions of $] (theme)	Objective
MESSENGER, DAWN and Deep Impact missions	177 (SSE)	MESSENGER - to explore Mercury, DAWN - to orbit around two asteroids, Deep Impact - to probe below the surface of a comet
New Frontier Programs	130 (SSE)	To explore the outer planets of our Solar System
Astrobiology research	68 (SSE)	To improve the ability to find and identify life on other planets
2005 Mars Reconnaissance Orbiter	184 (ME)	Map Martian surface features as small as a basketball (20-30 cm)
2005 Mars smart Lander/Rover	118 (ME)	Traverse tens of kilometers over Mars over a Martian year, digging and drilling for unique samples to study in an onboard laboratory
Hubble Space Telescope Operations, Shuttle Servicing (2005) and Retrieval (2010)	239 (ASO)	Maintain current operational capability of the HST and begin planning for returning it to Earth
James Webb Space Telescope	255 (ASO)	Continue the legacy of the Hubble Space Telescope
Space Interferometry Mission	80 (ASO)	Detect planets around other stars, launch in 2009
Gamma-ray Large Area Space Telescope	116 (SEU)	Study high-energy objects like black holes
STEREO/Solar Dynamics Observatory	166 (SEC)	Provide constant observation of the dynamic Sun from two vantage points
Future Missions	212 (SEC)	Begin planning/construction of future missions

[24] http://universe.gsfc.nasa.gov/
[25] http://spacescience.nasa.gov/missions/index.htm [all missions index]

ASTRONOMY IN THE NSF BUDGET

NSF funds astronomy through its Division of Astronomical Sciences.[26] This funding is split into two basic units, Astronomy Research and Instrumentation (which funds individual researchers, instrument development projects and some research centers such as the center for adaptive optics[27]) and Facilities (which supports the National Astronomy facilities such as the National Radio Astronomy Observatory[28], National Optical Astronomy Observatories[29] (including the National Solar Observatory[30], Gemini 8 meter telescopes[31] and the National Astronomy and Ionosphere Center[32]).

The Astronomy Division budget would increase in the President's FY 2004 budget by 13.5 percent (see Table II-7). The Astronomy Research and Instrumentation portion would rise from $64.3 million to $77.2 million. The Astronomy Facilities would receive an increase of $8.9 million to a FY 2004 proposed funding level of $105.8 million.

Astronomy is also supported within the NSF budget both through the Office of Polar Programs[33] (OPP) and the Major Research Equipment and Facilities Construction (MREFC) budget line. The exact amounts expended by OPP for astronomy research were not available, but several telescopes reside at the South Pole station[34], including a unique instrument (AMANDA[35]) that uses photodetectors buried more than a kilometer deep in the Antarctic ice sheet to detect high energy neutrinos from celestial objects. The Atacama Large Millimeter Array[36] (ALMA) telescope construction continues to be supported in the FY 2004 budget at a level of $50.8 million. ALMA construction is funded within the MREFC budget line. This telescope, an international collaboration, will

[26] http://www.nsf.gov/mps/ast
[27] http://cfao.ucolick.org/
[28] http://www.nrao.edu/
[29] http://www.noao.edu/
[30] http://www.nso.edu/
[31] http://www.gemini.edu/
[32] http://www.naic.edu/
[33] http://www.nsf.gov/od/opp
[34] http://www.nsf.gov/od/opp/antarct/aeroastro.htm
[35] http://alizarin.physics.wisc.edu/
[36] http://www.alma.nrao.edu/

be built in the high *altiplano*[37] of Chile where the absorption of celestial millimeter and sub-millimeter radiation by water vapor is significantly less than at other locations on Earth (also why observing from the pole is worth the expense). (See Table 2 for NSF funding of facilities.)

Table 2 – FY 2003 & 2004 Budget Requests for Astronomy Facilities

Astronomy Facility	FY 2003 Request [millions of $]	FY 2004 Request [millions of $]
Gemini Observatories[31]	12.6	14.2
National Astronomy and Ionosphere Center[32]	9.0	10.3
National Optical Astronomy Observatories[29] and National Solar Observatory[30]	35.7	38.6
National Radio Astronomy Observatory[28]	39.6	42.7

ASTRONOMY ELSEWHERE IN THE BUDGET

Both the Navy and Air Force fund fundamental astronomical research for a variety of reasons related to national security. Although exact numbers were not available, the total amount expended is not as large as either NSF or NASA. DOE also funds astrophysical research under its Office Science. One example is the Supernova Acceleration Probe[38] (SNAP), which would receive $6.9 million in the FY 2004 budget under the High Energy Physics budget. The Smithsonian Institution also supports a wide array of astronomical research through its Center for Astrophysics[39], including telescopes in Hawaii and Arizona. The Submillimeter Array[40], an innovative high-frequency radio telescope is nearing operational completion on the summit of Mauna Kea in Hawaii and the Smithsonian is one of numerous international partners in the Veritas[41] collaboration, which is a gamma-ray observatory system that continues to be developed south of Tucson, Arizona on Mt. Hopkins at the Fred Lawrence Whipple Observatory.[42]

[37] http://www.raingod.com/angus/Gallery/Photos/SouthAmerica/Bolivia/Altiplano.html
[38] http://snap.lbl.gov/
[39] http://cfa-www.harvard.edu/
[40] http://sma-www.harvard.edu/
[41] http://veritas.sao.arizona.edu/
[42] http://linmax.sao.arizona.edu/help/FLWO/whipple.html