UNIVERSITY OF CALIFORNIA, SANTA CRUZ

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO

SANTA BARBARA • SANTA CRUZ

SANTA CRUZ, CALIFORNIA 95064

UNIVERSITY OF CALIFORNIA OBSERVATORIES/LICK OBSERVATORY
DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS

March 15, 2008

Dr. Arden L. Bement, Jr., Director
National Science Foundation
4201 Wilson Blvd., Suite 1205
Arlington, VA 22230

Dr. Michael D. Griffin, Administrator
Office of the Administrator
NASA Headquarters
Washington, DC 20546-0001

Dr. Samuel W. Bodman, Secretary of Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

The Honorable Bart Gordon, Chairman
Committee on Science and Technology
House of Representatives
Washington, DC 20515

The Honorable Daniel K. Inouye, Chairman
Committee on Commerce, Science and Transportation
United States Senate
Washington, DC 20510

The Honorable Ted Kennedy, Chairman
Committee on Health, Education, Labor and Pensions
United States Senate
Washington, DC 20510

Dear Dr. Bement, Dr. Griffin, Secretary Bodman, Chairman Gordon, Chairman Inouye, and Chairman Kennedy:

I am pleased to transmit to you the Annual Report of the Astronomy and Astrophysics Advisory Committee for 2007–2008.

The Astronomy and Astrophysics Advisory Committee was established under the National Science Foundation Authorization Act of 2002 Public Law 107-368 to:

(1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy;
(2) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy as they relate to the recommendations contained in the National Research Council's 2001 report entitled Astronomy and Astrophysics in the New Millennium, and the recommendations contained in subsequent National Research Council reports of a similar nature;

The attached document is the fifth such report. The report has been significantly restructured this year to highlight the key issues that concern the Committee. The areas of most concern are under Broad Issues, followed by Interagency aspects that have been the focus of the Committee's deliberations, and then issues and recommendations for DOE, NSF, and NASA regarding their support of the nation's astronomy and astrophysics research enterprise.

I would be glad to provide you with a personal briefing if you so desire.

Sincerely yours, on behalf of the Committee,

Garth D. Illingworth
Chair, Astronomy and Astrophysics Advisory Committee

cc: Representative Ralph Hall, Ranking Member, Committee on Science and Technology, House of Representatives
Senator Ted Stevens, Ranking Member, Committee on Commerce, Science and Transportation, United States Senate
Senator Michael Enzi, Ranking Member, Committee on Health, Education, Labor and Pensions, United States Senate
Senator Barbara Mikulski, Chairwoman, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate
Senator Richard Shelby, Ranking Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, United States Senate
Senator Byron Dorgan, Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate
Senator Pete Domenici, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations, United States Senate
Senator Bill Nelson, Chairman, Subcommittee on Space, Aeronautics and Related Agencies, Committee on Commerce, Science and Transportation, United States Senate

Senator David Vitter, Ranking Member, Subcommittee on Space, Aeronautics and Related Agencies, Committee on Commerce, Science and Transportation, United States Senate
Senator John F. Kerry, Chairman, Subcommittee on Science, Technology, and Innovation, Committee on Commerce, Science and Transportation, United States Senate
Senator John Ensign, Ranking Member, Subcommittee on Science, Technology, and Innovation, Committee on Commerce, Science and Transportation, United States Senate
Representative Alan B. Mollohan, Chairman, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations, House of Representatives
Representative Rodney Frelinghuysen, Ranking Member, Subcommittee on Commerce, Justice, Science and Related Agencies, Committee on Appropriations, House of Representatives
Representative Peter J. Visclosky, Chairman, Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives
Representative David L. Hobson, Ranking Member, Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives
Representative Brian Baird, Chairman, Subcommittee on Research and Science Education, Committee on Science and Technology, House of Representatives
Representative Vernon Ehlers, Ranking Member, Subcommittee on Research and Science Education, Committee on Science and Technology, House of Representatives
Representative Mark Udall, Chairman, Subcommittee on Space and Aeronautics, Committee on Science and Technology, House of Representatives
Representative Tom Feeney, Ranking Member, Subcommittee on Space and Aeronautics, Committee on Science and Technology, House of Representatives
Dr. John H. Marburger, III, President's Science Advisor, Director, Office of Science and Technology Policy, Executive Office of the President
Dr. Kathryn L. Beers, Assistant Director, Physical Sciences and Engineering, Office of Science and Technology Policy, Executive Office of the President
Dr. John Henry Scott, Senior Policy Analyst, Physical Sciences and Engineering, Office of Science and Technology Policy, Executive Office of the President
Mr. Paul Shawcross, Science and Space Branch Chief, Office of Management and Budget
Ms. Amy Kaminski, Program Examiner, NASA, Office of Management and Budget
Dr. Joel Parriott, Program Examiner, NSF, Office of Management and Budget
Mr. Kevin Carroll, Energy Branch Chief, Office of Management and Budget
Dr. Michael Holland, Program Examiner, DOE, Office of Management and Budget
Dr. Kathie L. Olsen, Deputy Director, National Science Foundation
Dr. Tony F. Chan, Assistant Director, Directorate for Mathematical and Physical Sciences, National Science Foundation
Dr. G. Wayne Van Citters, Division Director, Division of Astronomical Sciences, National Science Foundation
Dr. Eileen Friel, Executive Officer, Division of Astronomical Sciences, National Science Foundation
Dr. Dana E. Lehr, Associate Program Director, Division of Astronomical Sciences, National Science Foundation
Dr. S. Alan Stern, Associate Administrator for the Science Mission Directorate, National Aeronautics and Space Administration
Dr. Colleen N. Hartman, Deputy Associate Administrator for the Science Mission Directorate, National Aeronautics and Space Administration
Dr. Paul Hertz, Senior Scientist, Science Mission Directorate, National Aeronautics and Space Administration

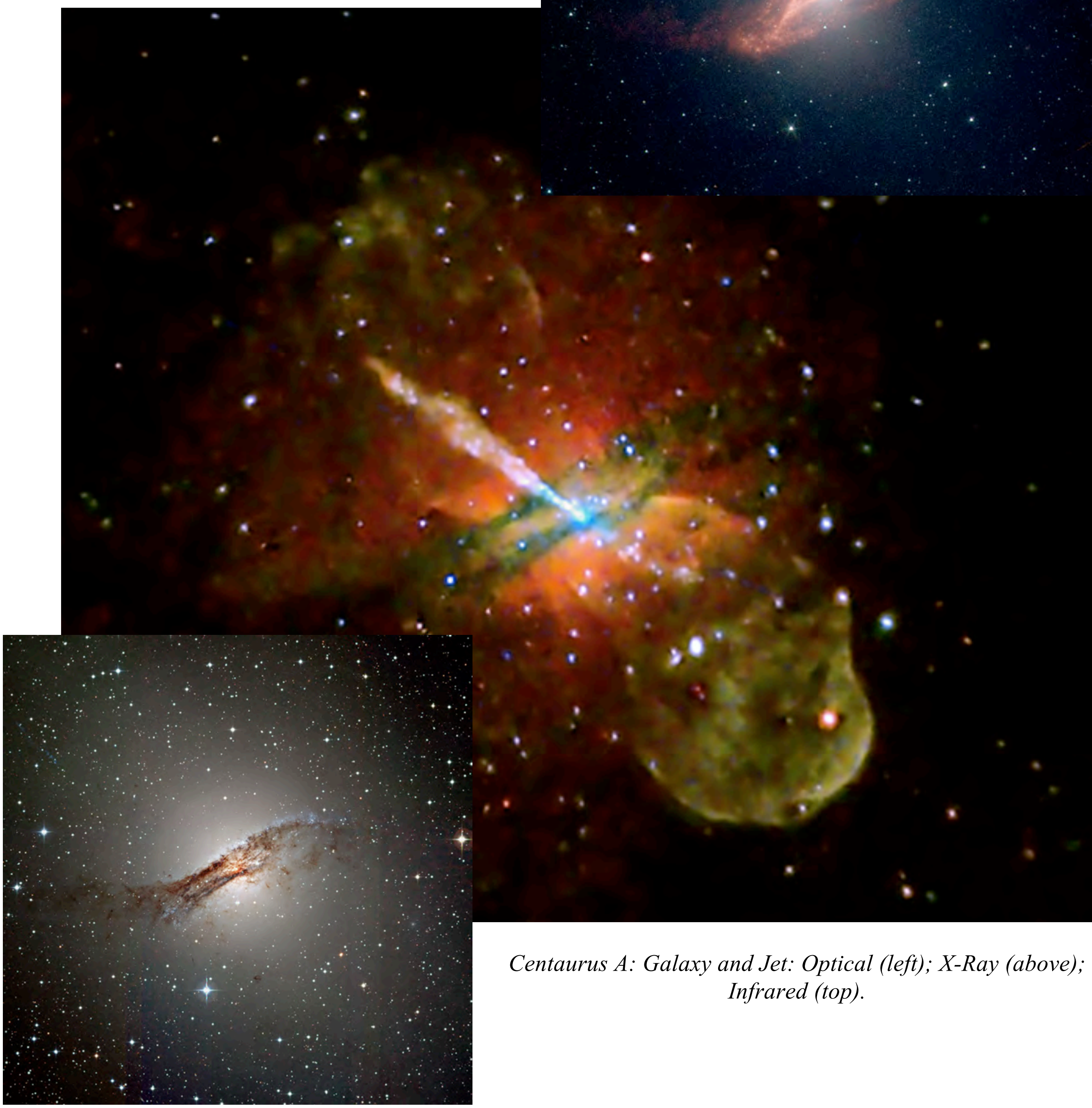
- Dr. Jon Morse, Director, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
- Dr. Richard Howard, Deputy Director, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
- Dr. Michael Salamon, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
- Dr. Eric Smith, Astrophysics Division, Science Mission Directorate, National Aeronautics and Space Administration
- Dr. Ray Orbach, Director, Office of Science, U.S. Department of Energy
- Dr. Dennis Kovar, Acting Associate Director, Office of High Energy Physics, U.S. Department of Energy
- Dr. Kathleen Turner, Program Manager, Office of High Energy Physics, U.S. Department of Energy
- Dr. Charles Elachi, Director, NASA Jet Propulsion Laboratory
- Dr. Edward Weiler, Director, NASA Goddard Space Flight Center
- Mr. Chuck Atkins, Chief of Staff, Committee on Science and Technology, House of Representatives
- Ms. Janet Poppleton, Ranking Chief of Staff, Committee on Science and Technology, House of Representatives

Astronomy and Astrophysics Advisory Committee Members:

- Dr. Bruce Balick, University of Washington
- Dr. Bruce Carney, University of North Carolina at Chapel Hill
- Dr. Scott Dodelson, Fermi National Accelerator Laboratory
- Dr. Wendy Freedman (Chair-Elect), Observatories of the Carnegie Institution of Washington
- Dr. Katherine Freese, University of Michigan
- Dr. Rocky Kolb, University of Chicago
- Dr. Daniel Lester (Vice-Chair), University of Texas at Austin
- Dr. E. Sterl Phinney, California Institute of Technology
- Dr. Marcia Rieke, University of Arizona
- Dr. Keivan G. Stassun, Vanderbilt University
- Dr. Christopher Stubbs, Harvard University
- Dr. Alycia Weinberger, DTM, Carnegie Institution of Washington

2008 ANNUAL REPORT

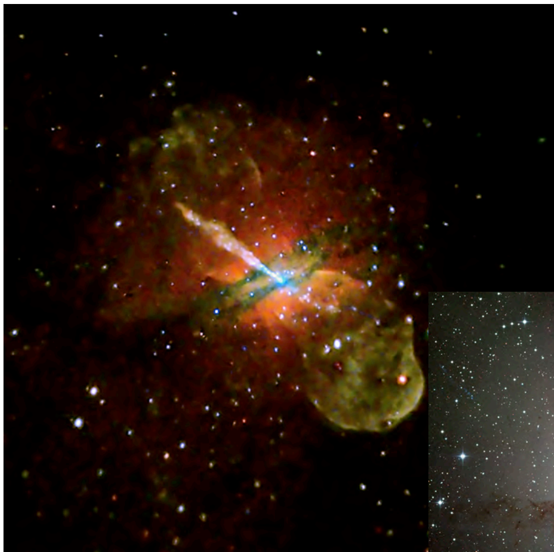
ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE



Centaurus A: Galaxy and Jet: Optical (left); X-Ray (above); Infrared (top).

Table of Contents

Astronomy and astrophysics missions and telescopes play a major role in the public perception of science through the spectacular images and remarkable events they describe. Recent discoveries announced during the last year are highlighted at various places in the document.

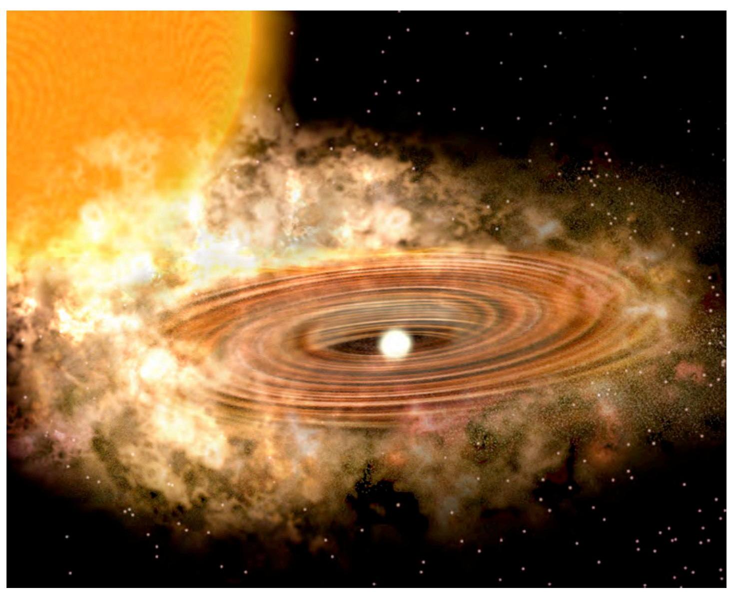


Cover page X-ray image. A Chandra Observatory image of the nearby galaxy Centaurus A provided one of the best views to date of the effects of an active supermassive black hole. The black hole drives a huge jet of high energy particles, extending to the outer reaches of the galaxy emitting X-rays as they go. (Credit: NASA/CXC/CfA, R.Kraft et al.)

Cover page infrared image (right): A Spitzer Space Telescope image of Centaurus A, showing the remnant of an accreted spiral galaxy that is probably feeding the black hole. (Credit: NASA/JPL-Caltech/J. Keene SSC/Caltech). Cover page optical image (center): Centaurus A from the ESO Wide-Field Imager on La Silla 2.2 m Telescope. (Credit: Optical: ESO/VLT/ISAAC/M.Rejkuba et al.)

Observations of an interacting binary star surrounded by a disk of hot gas imply that similar disks around a wide variety of astronomical objects—including binary stars and supermassive black holes, are all likely to be much larger than previously believed. Scientists worked with high school teachers and students to produce these results by combining information from the NSF supported telescopes at Kitt Peak National Observatory with NASA's Spitzer Space Telescope.

(Credit: P.Marenfeld and NOAO, AURA, NSF, NASA, Spitzer)



2008 ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

This report covers many issues and topics across three agencies, the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the U.S. Department of Energy (DOE) Office of Science, whose contributions to scientific research, and US scientific and technological leadership, have been remarkable.

The Executive Summary identifies individual items with section numbers that correspond to the supporting text in the main body of the report. The main body of the report follows page XI. The charge to the Committee is outlined in §1, and the context for the AAAC's activities is given in §2. The report starts with issues of the highest priority and concern for the AAAC under Broad Issues (§3). Interagency Issues follow in (§4), and subsequent sections focus on the agencies, DOE (§5), NSF (§6), and NASA (§7). Appendices follow that contain more detail on several longstanding topics.

EXECUTIVE SUMMARY

Background

Humankind has embarked on a remarkable quest – to understand the universe. The nature of dark matter and dark energy in the universe, the formation of galaxies at the earliest times, the nature of massive black holes, and the formation and life of stars and planetary systems are part of the fabric of our extraordinary scientific venture in astronomy. Together, NASA, NSF, and the DOE Office of Science are providing opportunities for astronomical research that demonstrate US scientific and technological leadership.

The strategic framework for this leadership is built on the decade-long plans of the National Research Council (NRC) Astronomy and Astrophysics Decadal Survey Committees, the most recent of which is the 2000 *Astronomy and Astrophysics in the New Millennium*[1]. The next such Survey (the 2010 Astronomy and Astrophysics Decadal Survey) is about to begin and is expected to report in early 2010. The recommendations given in our report are intended to further the implementation of the 2000 Decadal Survey and of more recent NRC studies such as *Connecting Quarks with the Cosmos*[2] (*CQC*). As our report highlights, the 2010 Astronomy and Astrophysics Decadal Survey comes at a crucial time for the astronomical community, and for the policy makers and the agencies with whom our community works so closely.

The diversity that flourishes under the three agencies is central to the scientific success and public visibility achieved in astrophysics over the last several decades. Joint programs among NASA, NSF and DOE are increasingly of great benefit to the nation's astronomy and astrophysics research enterprise. *By drawing on the different strengths of the agencies' approaches to achieving the science goals of the astronomical community, the nation realizes greatly enhanced value from its investment in astronomy.*

In response to the need to address the increasingly important interfaces among the agencies that support astronomy and astrophysics, the Astronomy and Astrophysics Advisory Committee (AAAC) was established in 2002 (and updated in 2005 to include DOE) by the Executive Branch and Congress to: 1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of NSF, NASA and DOE; 2) assess, and make recommendations regarding, the status of the activities of NSF,

---

[1] http://www.nap.edu/openbook.php?isbn=0309070317
[2] http://www.nap.edu/openbook.php?isbn=0309074061

NASA and DOE as they relate to the recommendations contained in the National Research Council's 2000 Decadal Survey report, and the recommendations contained in subsequent National Research Council reports of a similar nature. This annual report is the fifth by the AAAC.

The AAAC has dealt with many issues over the last year. Two stand out for their impact: the budget problems and the selective advocacy of individual missions in Congress. The impact of the NASA science budget cuts has been given considerable attention by the AAAC over the last 2 years, but the concern is spreading to astronomy and astrophysics in NSF and DOE as a result of the FY08 Omnibus appropriation. These issues are highlighted below.

The NASA Astrophysics program has many powerful missions in operation and more are coming, but serious challenges lie ahead. Under the new leadership in the Science Mission Directorate, and in the Astrophysics Division, a number of changes are being implemented that will address previous AAAC concerns such as the balance between small, medium and large missions within the program and the adequacy of Research and Analysis (R&A) funding. The focus of our attention for NSF has been on major new facilities and the Major Research Equipment and Facilities Construction (MREFC) process used for their construction, and on the broad Senior Review assessment of facilities that was carried out by the Division of Astronomical Sciences (AST). A major challenge is balancing funding of the operations of current and future facilities. The discussions with DOE have centered on joint programs with NASA and NSF, including the excellent progress on the Gamma-ray Large Area Space Telescope (GLAST), the joint NASA/DOE sponsored Beyond Einstein Program Assessment Committee (BEPAC) study by the NRC, and the resulting initiative to move forward on the Joint Dark Energy Mission (JDEM). The increasing interest by DOE in enhancing their dark-energy and dark-matter searches is warmly welcomed by the Committee.

Working with the agencies, the AAAC has set up several subcommittees (Task Forces) to evaluate the scientific approaches that will best enable progress in key areas. The first was the Task Force on CMB Research (TFCR), which produced a comprehensive and exciting report in 2005. The excellent Dark Energy Task Force (DETF) report was accepted and transmitted to the agencies in mid-2006. The Dark Matter Scientific Assessment Group (DMSAG) report was transmitted by the AAAC in mid-2007. The ExoPlanet Task Force (ExoPTF) will complete its report this spring (2008) on its development of a roadmap for extra-solar planet detection and characterization, both on the ground and in space. The excellence of these reports is a testament to the science community's willingness to spend the time and energy it takes to establish a prioritized, cost-effective program of research capabilities, facilities and missions.

Recommendations on Broad Issues and Interagency (§3, §4)

The continuing support in the Administration and Congress for basic research is widely acknowledged as a key step in building a robust R&D base in the physical sciences. The support by the Executive for NSF and DOE Office of Science (and NIST) through the American Competitiveness Initiative (ACI) in the FY07, FY08 and FY09 President's Budget Requests has been matched by Congressional interest in innovation and competitiveness. The Congressional concerns about the nation's science and technology capabilities were manifested through H.R. 2272, *America Creating Opportunities to Meaningfully Promote Excellence in Technology and Science Act* (America COMPETES) that was signed into law by the President in August 2007. We note that, unlike ACI, America COMPETES explicitly states that NASA should be a "full participant in all interagency activities to promote competitiveness and innovation and to enhance science, technology, engineering and mathematics education." This inclusion is very rational – NASA is critical to national competitiveness and innovation. Unfortunately, turning this broad support into appropriate levels of funding for any of the agencies has proven to be a challenge. The FY07 Joint Funding Resolution appropriation did provide some welcome increases, especially in a continuing resolution situation, but the FY08 Omnibus ended up with NSF and DOE Science budgets that were significantly below the request level. The likely prospect of a continuing resolution this year exacerbates moving forward on ACI and America COMPETES. In reality, significant progress has not occurred on either the Administration initiative ACI or the law as per America COMPETES. This leads us to:

The AAAC's strongest recommendation this year is that the goals of ACI and America COMPETES be realized for the NSF and the DOE Office of Science, and that the NASA science funding be enhanced, in accord with America COMPETES. Doing so would be entirely consistent with the commitment to innovation and competitiveness already demonstrated by the Administration through ACI and Congress through America COMPETES (§3.1).

As the budget challenges grow the AAAC is increasingly concerned that the astronomical community's efforts to carry out strategic planning (like the Astronomy and Astrophysics Decadal Survey) and to implement changes through orderly peer review or peer involvement processes (like the Senior Reviews) are being undermined. A central tenet of such strategic planning is to use community-based groups to deal with the implementation details, namely the NRC committees like the Space Studies Board (SSB), the Board on Physics and Astronomy (BPA) and their subcommittee the Committee on Astronomy and Astrophysics (CAA), FACA committees such as the AAAC, and other FACA advisory committees and ad hoc groups at the agency level. Unfortunately, over the last few years the astronomy community has seen an increased level of "lobbying" by individuals or groups for their projects outside the long-established community processes. This effort by individuals or groups subverts the community's broad strategic plans and upends the peer review process that is the foundation of cohesive, representative decision-making. This is particularly true of direction to move the Space Interferometry Mission (SIM) into development. The $2B required for SIM would devastate the Astrophysics budget. The American Astronomical Society recently released a statement (in full in §3.2) regarding the negative impact of efforts by individuals or group members to get specific Congressional language to benefit a particular project or to alter priorities. It notes "... The American Astronomical Society opposes all attempts to circumvent the established and successful community-based priority-setting processes currently in place." The concern of the AAAC is:

The AAAC welcomes the continuing interest and support of Congress for the astronomical research program at NASA, NSF and DOE, but hopes that representations from individuals or groups for projects of interest to the petitioners do not lead to directives or earmarks that distort the astronomy community's strategic, consensus-driven priorities (§3.2).

The AAAC fulfills a tactical role in the implementation of the strategic plans developed by the Decadal Survey, and, as such, gets a front-row view of the challenges and issues that arise as the agencies work to implement the Survey recommendations. It is clear that the upcoming 2010 Decadal Survey is of crucial importance to policy makers and to the astronomy community. The current project backlog in Decadal priority far exceeds what can realistically be done in the coming Decade, even if significant funding growth occurs. The astronomy community must establish a much more realistic zero-based plan through an end-to-end assessment of the science goals and resulting projects. To do so, *all* projects not under construction should be discussed and considered in the 2010 Decadal Survey (including, e.g., the Giant Segmented Mirror Telescope – GSMT, Constellation-X – Con-X, the Large Synoptic Survey Telescope – LSST, the Laser Interferometer Space Antenna – LISA, SIM and other ExoPlanet missions, the Square Kilometer Array – SKA; all were recommended in the 2000 Decadal Survey). In addition, the AAAC hopes that the success of the BEPAC process in assessing technical readiness and lifecycle cost, as well as scientific excellence, to develop its recommendations will be a model for the next Decadal Survey. The use by the 2010 Decadal Survey committee of realistic, independent cost estimates and technical readiness will lead to a much more robust set of recommendations that are more likely to be implemented. The detailed assessments of the AAAC Task Forces have also provided implementation strategies of significant value to the 2010 Decadal Survey. The AAAC suggests that:

The experience gained by the AAAC in helping to implement the recommendations of the 2000 Decadal Survey is represented in its Task Force reports and its Annual Report. We encourage the agencies to discuss the AAAC Task Force reports and the AAAC Annual Report in their interactions with the Survey Committee and its Panels, as the AAAC plans to do when it meets with the 2010 Decadal Survey Chair. Given the uncompleted queue from the 2000 Decadal Survey, the AAAC feels that it is essential that *all* projects not under construction be considered again (e.g., GSMT, LSST, Con-X, LISA, SIM, etc.). The AAAC strongly encourages the agencies and the NRC to build on the success of the BEPAC process, which used, in addition to scientific excellence, independent assessments of technical readiness and lifecycle cost to develop its recommendations. We hope that this approach will be a model for the next Decadal Survey (§3.3).

The AAAC report outlines a number of activities relating to interagency issues (§4) for DOE Office of Science High Energy Physics (HEP), NSF Division of Astronomical Sciences (AST) and NASA Astrophysics Division. (1) The four AAAC Task Forces are discussed in §4.1. The final report of the ExoPlanet Task Force (the most recent) will be transmitted in Spring 2008. While a joint activity, its recommendations are discussed under NASA since the most immediate issues relate to NASA. (2) The increasing number of interagency programs whose implementation we support is discussed in §4.2, though we express particular concern about the Alpha Magnetic Spectrometer (AMS) if its huge cost to be launched on an Expendable Launch Vehicle (ELV) – \$0.57B-\$1B – would have to be borne by the Astrophysics Division. We would not support such a reallocation of funds from Astrophysics because of the major impact on its program, and on astronomy Decadal Survey priorities. (3) The AAAC was delighted to hear that NSF and NASA have agreed to a joint solicitation for implementing and managing a Virtual Astronomical Observatory (VAO). (4) The AAAC strongly encourages the Office of Science Technology Policy (OSTP), working with the agencies, to provide a general summary of key principles and guidelines regarding "lessons learned" that will be of broad utility for a wider community as interagency projects become much more common. (5) While a small matter, the issue of funding of AAAC meetings is becoming a significant sink of time and energy. The AAAC hopes that discussions among NSF, NASA and DOE will lead to an equitable and routine sharing of its travel costs, and/or that AST be able to fund the AAAC travel costs under its R&RA account, as it does for proposal and other reviews.

The AAAC is very encouraged by the interest in cooperation that has developed between DOE HEP, NSF AST and PHY, and NASA Astrophysics, and by their support for the Task Forces. We welcome the continuing interest by OSTP in the processes and issues relating to the joint programs. The AAAC hopes that the current budget challenges will not lessen the commitment of the agencies to joint programs and missions (§4).

Recommendations for the Agencies (§5, §6, §7)

The three agencies have very distinct missions and procedures. To do justice to the issues that arise that affect the overall success of the astronomy and astrophysics endeavor, we discuss aspects of each agency that impact or pertain to the smooth functioning of their astronomy and astrophysics programs, particularly in the context of the Interagency issues and implementation of Decadal priorities (see §5, §6 and §7).

DOE (§5)

(DOE HEP funding – §5.2). The appropriated funding for DOE HEP was down 12% compared to the FY08 request, and 8.4% below the FY07 appropriation. This was a great concern since DOE HEP is on a path towards developing a robust program in astrophysics related to some of the most exciting areas of astrophysics and of high energy physics – namely, dark energy, dark matter, neutrinos and high energy gamma rays. These science fields lie at the boundary of astrophysics and particle physics and promise great insights. The AAAC hopes very much that the current budget problems do not impact the growing role of DOE in these frontier research areas.

(Dark matter and dark energy – §5.3). The AAAC strongly endorses the DMSAG recommendation for increasing support for the dark matter direct detection efforts to ~$10M, commends DOE HEP for its support of dark energy experiments like the Dark Energy Survey (DES), and is delighted to see the progress that DOE and NASA are making towards realizing the JDEM mission, as BEPAC recommended. The AAAC recommends that the DOE HEP further develop their support for R&D and programs in the areas of dark energy and dark matter, giving particular attention to supporting DETF Stage III projects that provide a framework for the much more expensive Stage IV projects (JDEM and LSST).

(BEPAC/JDEM – §5.3). We applaud the responses of HEP to the recommendations of the AAAC Task Forces, and the growing collaborations that HEP is developing with NASA Astrophysics and NSF Astronomy. The recent announcement of an understanding that NASA and DOE will work towards a JDEM mission that will be a medium-class strategic mission with a competitively-selected, PI-led dark energy science investigation, and that they will partner in the fabrication and operation of instrumentation necessary to execute the science investigation was welcomed by the AAAC. The AAAC hopes that the appropriated budgets for FY09 and beyond for both DOE and NASA can accommodate the timeline for a mid-decade launch of this $600-800M JDEM mission.

NSF (§6)

(Astronomy and ACI/America COMPETES – §6.1). The AAAC believes that astronomy can contribute substantially to the goals of ACI and America COMPETES and has suggested that the agency and the Committee discuss approaches to demonstrate more clearly the value of astronomy research.

(MREFC and major projects – §6.2). We appreciate the NSF's support for the Atacama Large Millimeter Array (ALMA), and hope that the Advanced Technology Solar Telescope (ATST) moves forward expeditiously within MREFC to a New Start. We remain very interested in progress on the Large Synoptic Survey Telescope (LSST), as well as on policy issues related to projects with substantial private funding like the Giant Segmented Mirror Telescope (GSMT). The AAAC remains concerned about the clarity of the MREFC process, and recommends that the experience gained with the new processes that were instituted per NSB 0577 be used to identify ways to make MREFC function effectively.

(ATST – §6.2.2, §6.5.2). The AAAC welcomed the inclusion of ATST into the MREFC account in a pre-New Start phase called D&D. The implementation of this phase within the MREFC account was welcomed by the AAAC, since we have been recommending that such funds be made available. However, the removal of an equivalent amount from AST is effectively a cut to AST's budget, which we did not recommend.

(Priorities and proposal sequencing – §6.2.3). The acceptance of proposals by the NSF for major facilities without consideration for Decadal Survey priorities is a concern that has been expressed by the Senior Review, by CAA, and by the AAAC. This concern would be alleviated by procedures for proposal acceptance that are more sensitive to community priorities, and allow for a go/no-go acceptance decision before a lower priority program is accepted.

(Senior Review – §6.3, §6.3.1, §6.3.2). The AAAC is very supportive of the Senior Review process. The very broad nature of the Senior Review, essentially dealing with the full portfolio of AST programs and facilities, distinguished it from the more mission-focused Senior Reviews that are undertaken at NASA. As such, it was a very different activity, more akin to a "portfolio" review, and therefore impacted a very broad segment of the astronomical community. The Committee recognizes that phasing out facilities that are returning scientific data and results is very difficult for those involved with the facilities. The agency budgets cannot support all current programs, even with a growing budget, while retaining the ability to move forward into new and dramatically more powerful facilities. We regret that efforts by members of the science community to circumvent the Senior Review process through Congressional action are disrupting community priorities and processes.

(NOAO – §6.3.3). We recognize that the changes suggested by the Senior Review have been disruptive for the National Optical Astronomy Observatory (NOAO), but the guidance on a balanced approach between utilization of current facilities and future facilities is leading to a stronger observatory. The AAAC hopes that this leads to much-needed future stability for NOAO.

(Gemini-NOAO synergy – §6.3.3). The AAAC recommends that AST catalyze discussions within the community with support and assistance, leading to a more integrated operation for Gemini and NOAO. The upcoming Decadal Survey should also provide an opportunity for consideration of an integrated approach. Such integration should lead to efficiencies in the operation, planning and utilization of the facilities and provide a better focus for the US optical-infrared national effort. More clarity on the US side is likely to be welcomed by our international partners.

(Mid-Scale instrumentation – §6.4). The AAAC is very supportive of efforts by AST to identify funding for mid-scale instrumentation and infrastructure, and encourages the agency to develop a program that deals with needs at scales between the Major Research Instrumentation (MRI) program and MREFC.

(Decadal Survey major projects – §6.5.3, §6.5.4). The AAAC views the need for a robust, comprehensive and encompassing 2010 Decadal Survey as being of paramount importance to maintain the credibility of the astronomical community's strategic planning process. We have recommended that all prior prioritized projects not in construction be revisited in the 2010 Decadal Survey, including GSMT, LSST, and comparable major space projects like Con-X, LISA, and SIM, for example. While LSST has submitted a construction proposal for NSF and DOE funding, it is still very early in the process, and so the AAAC recommends that the Decadal Survey committee should give consideration to the role of LSST within the overall strategic plan that the Survey will develop.

(Major project partnerships – §6.5.4, §6.5.5, A2). The AAAC continues its discussion of the challenges of partnerships that involve comparable investments from private sources and the Federal government, and recommends that OSTP and the NSF continue their consideration of this issue. The AAAC hopes that it is an issue on which the Decadal Survey can offer guidance, but the policy issues will ultimately require resolution within the Executive Branch. (The detailed AAAC report discussion is in Appendix A2).

NASA (§7)

(NASA Astrophysics funding – §7.1, §7.2). The NASA Science Mission Directorate (SMD) delivers world-leading research opportunities. Its missions like Hubble and the Mars Rovers are known to a large fraction of the population. Its astrophysics missions have produced two Nobel prizes in Physics. The current Astrophysics Division program is strong. However, the large cuts in Astrophysics in FY09 portend a different future, transitioning to one where the launch frequency, and eventually the operating mission diversity, drops substantially beyond 2010. The Astrophysics budget falls by $203M from $1365.5M in FY08 to $1162.5M in FY09, and then continues to decrease over the next 4 years until it is only $1116.0M in FY13. The Astrophysics budget in 2012 is 30% lower than the 2007 budget in inflation-adjusted terms (2.4% inflation). Realizing even the highest priorities of the next Decadal Survey report in 2010 will be difficult. The AAAC is very concerned that one of NASA's strongest and most visible programs, across the nation and around the world is becoming a lot less robust, especially in a decade when new technologies and new launch capabilities could bring about missions of unparalleled capability. The AAAC recommends that NASA science be funded consistent with the goals of America COMPETES.

(Lifecycle cost – §7.4, §7.5). The AAAC greatly appreciates the willingness and interest in NASA SMD in making available "lifecycle" cost information on current and future missions. The problems of the last Decadal Survey stem in significant part from the use of cost estimates that were large underestimates (by 3x or more) of the true cost of the mission over the 10-15 years encompassed by the Decadal Survey recommendations, from conceptual development to technology demonstration to construction through operations. The use of lifecycle costs, with robust cost estimates at each of the mission phases (A through E), would make the Survey priorities more realistic, and more likely to be implemented. The AAAC recommends that NASA provide lifecycle cost estimates for any missions under discussion. The request by NASA and DOE that the BEPAC committee evaluate technical readiness and assess the cost estimates for the missions under consideration was a very forward-thinking approach. The AAAC welcomed this approach and suggests that it becomes a baseline activity during such comparative reviews (including the upcoming 2010 Decadal Survey).

(ExoPlanet Task Force report – §7.6). The ExoPlanet Task Force (ExoPTF) final report will be transmitted to NSF and NASA in spring 2008. The ExoPTF was initiated by the AAAC to develop a broad implementation plan on the ground and in space in the exciting but challenging area of extrasolar planet search and characterization. Its recommendations are built around a phased program that encompasses research, instrumentation, facility utilization, and new missions and projects, on the ground and in space, separated into three time periods, 1-5 yrs, 5-10 yrs and 10-15 yrs. The AAAC recommends that NASA and NSF use this report in developing their detailed plans for exoplanet research, in the context of the overriding recommendations of the 2010 Decadal Survey (who will also use this report as input for their deliberations and recommendations). In particular, given the pressure on the astrophysics budget and the limited opportunities post-2009, the AAAC recommends that any new medium class or larger ExoPlanet mission only proceed if it is prioritized to do so by the Decadal Survey.

(ExoPTF Astrometric Mission – §7.6). The recommendation by the ExoPTF for an astrometric mission explicitly focused on planet searches has been the source of much discussion. The astrometric mission recommended in the ExoPTF report is *not* the Space Interferometry Mission (SIM). Equating the ExoPTF recommendation for a narrow angle astrometric mission to SIM, or even "SIM Lite", is premature, until an independent technical review and cost assessment is done. The ExoPTF explicitly recommended a detailed review of technology before embarking on its recommended narrow angle astrometry mission. In addition, the AAAC recommends that these astrometric missions (SIM, SIM Lite, ExoPTF astrometry mission) be considered by the 2010 Decadal Survey, consistent with our recommendation for other major missions.

(BEPAC/JDEM – §7.7). The joint NASA-DOE BEPAC study by the NRC last year recommended JDEM as the first mission to be done in the Beyond Einstein program. In addition, BEPAC provided additional recommendations regarding the other missions in its review that will feed into the Decadal Survey process. Given its attention to science, cost and technical readiness, BEPAC was a pathfinder for the 2010 Decadal Survey. The AAAC was very encouraged by the speed with which DOE HEP and NASA Astrophysics have reached an understanding on JDEM. It is now identified as a medium-scale, cost-capped, competitively-selected mission at the Einstein Probe scale, or roughly \$600M-\$800M. The AAAC strongly supports the joint effort to carry out the JDEM mission in response to the BEPAC study.

(Balance – §7.8, §7.8.1-5). The new leadership at SMD has taken significant steps towards achieving a more balanced program of astrophysics missions, with increased investment in Small Explorer (SMEX) and suborbital opportunities. The reinstatement of the Nuclear Spectroscopic Telescope Array (NuSTAR) was a very positive step. The emphasis on cost management in all missions, from small to large, is also encouraging. By bolstering the R&A budget, and providing a strong focus on research support, SMD has responded well to very serious concerns within the science community. The planned outyear budget cuts for the Astrophysics Division do raise concerns that it will be very hard to initiate a program of frequent missions and opportunities, especially in response to the 2010 Decadal Survey.

(Future Strategic Missions – §7.3, §7.8.5). When JWST is launched it will be 25 years from concept inception. Future large missions and the required technologies have long lead times. The Astrophysics Division solicited proposals for Astrophysics Strategic Mission Concept Studies last year. These are ~$1M studies aimed at understanding the technology requirements for a large suite of medium and large concepts beyond Constellation-X (Con-X), the Laser Interferometer Space Antenna (LISA) and SIM. The AAAC is very supportive of this forward-looking effort, since the large investment in a new human spaceflight program, including new crew vehicles and launchers, suggests opportunities for space astronomy (some of which will be considered in these studies). The new Ares V launch vehicle would allow very large payloads (both in mass and volume) to be lofted. Such a capability could open up entirely new opportunities for space astronomy.

(Technology Development – §7.8.5). Technology development continues to be underfunded. This was one of the areas that were lost when the science budgets were cut so dramatically two years ago. The AAAC would like to remind SMD of the importance of this area, and to recommend the implementation of a significant technology development effort focused on the research community. This would mesh well with the goals of ACI and America COMPETES.

(Future Observatories – §7.4, §7.9). Three of the Great Observatories are still operating and returning remarkable data: the Hubble Space Telescope (HST), the Chandra X-ray Observatory and the Spitzer Space Telescope. The Stratospheric Observatory for Infrared Astronomy (SOFIA) is moving towards its first science demonstration in 2009. JWST is poised to undergo two major reviews, the overall Preliminary Design Review (PDR) and the Non-Advocate Review (NAR), in April 2008. Spitzer is in its last full year of operation and preparing for the first year as a “warm” mission. HST is operating but awaiting a major upgrade in its capabilities in Servicing Mission 4 (SM4) later in 2008. The future operations of both Spitzer (“warm”) and Chandra are being considered as part of a broadly-based Senior Review. The AAAC would like to note that the vitality and breadth of the current program is a great testament to NASA’s capabilities, but that the breadth is shrinking. JWST will be the only large space observatory operating in by the middle of the next Decade.

(SMD Advisory Process – §7.10). SMD lacks a committee that encourages dialogue between SMD and the science community on broad-ranging issues that cut across the SMD divisions. An “integrating body” for NASA science would be in the best interests of both NASA and the science community in restoring an important two-way communication link that has contributed to the success of NASA science in the past. The current NAC Science committee does not represent the breadth of the SMD science community. The AAAC recommends that a cross-divisional committee be convened so that broader issues can be discussed in an interdisciplinary forum, even if the formal reporting path is through the NAC.

COMMITTEE MEMBERS

Bruce Balick, University of Washington

Bruce Carney, University of North Carolina at Chapel Hill

Scott Dodelson, Fermi National Accelerator Laboratory

Wendy Freedman, (Chair-Elect) Observatories of the Carnegie Institution of Washington

Katherine Freese, University of Michigan

Garth D. Illingworth, (Chair) University of California Santa Cruz, UCO/Lick Observatory

Rocky Kolb, University of Chicago

Daniel Lester, (Vice-Chair) University of Texas at Austin

E. Sterl Phinney, California Institute of Technology

Marcia Rieke, University of Arizona

Keivan G. Stassun, Vanderbilt University

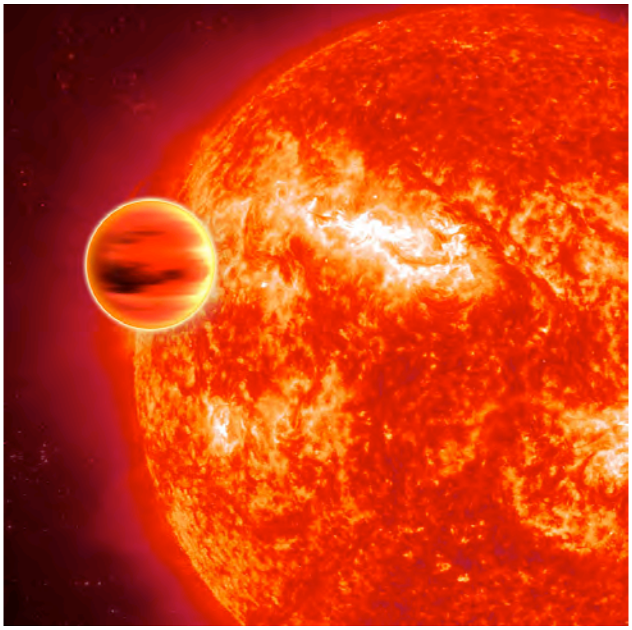
Christopher Stubbs, Harvard University

Alycia Weinberger, DTM, Carnegie Institution of Washington

The astronomy and astrophysics community continues to produce results that deepen our understanding of the Universe and excite the public imagination.

Researchers using NASA's Spitzer Space Telescope have learned what the weather is like on hot giant planets around other stars. HD 189733b is whipped by roaring winds and also has hot water vapor in its atmosphere. This is the first detection of water, a primary biological ingredient for life, on a planet in another solar system. The gas planet HD 149026b is the hottest yet discovered. HD 209458b, showed hints of tiny sand grains in its atmosphere that could be part of high, dusty clouds unlike anything seen around planets in our own solar system.

(Credit: ESA/NASA/JPL/G. Tinetti – artist: ESA/C. Carreau)



ACKNOWLEDGEMENTS

We have met with many key people involved in the nation's astronomy and astrophysics enterprise over the last year. We deeply appreciate their willingness to take the time to interact with us, to listen to us, and to provide us with insights and understanding of broader issues. Our appreciation goes to NASA Administrator Mike Griffin, NSF Director Arden Bement and Deputy-Director Kathie Olsen, and NSF MPS Assistant Director Tony Chan for their interest in the Committee's activities, and their generous commitments of time to meet with us. The discussions with OMB Examiners Amy Kaminski, Joel Parriott and Michael Holland are always fascinating for their insights, and we greatly appreciate their interest in a strong science enterprise. We greatly appreciate the interactions and support of OSTP scientists Kate Beers and John Henry Scott. They have provided a key interface and support for science in the Administration. The interest in the AAAC's activities by members of the Congressional staff were greatly appreciated, with particular thanks to Dick Obermann, Jim Wilson and Ed Feddeman.

There are many others from the agencies who have attended our meetings and provided us with excellent insight and advice, and we truly appreciate their wisdom. Our deliberations have involved presentations and discussions with many members of the community, as well, and have left us always impressed with their dedication and commitment to doing the best science possible within the budgetary constraints that necessarily frame the nation's scientific research enterprise.

We owe very special thanks to our Task Force chairs and team members. The DMSAG, chaired by Henry Sobel has produced an excellent report that was transmitted to the agencies in mid-2007, and the ExoPTF, chaired by Jonathan Lunine is about to deliver its final report to the AAAC, for likely transmittal this spring.

We particularly appreciate the support and involvement with the Committee of those from the agencies who have worked with the AAAC to keep it informed and who have responded to our many questions. We truly appreciate their commitment to the science community, its strategic programs, and to the advisory process that they have supported so diligently.

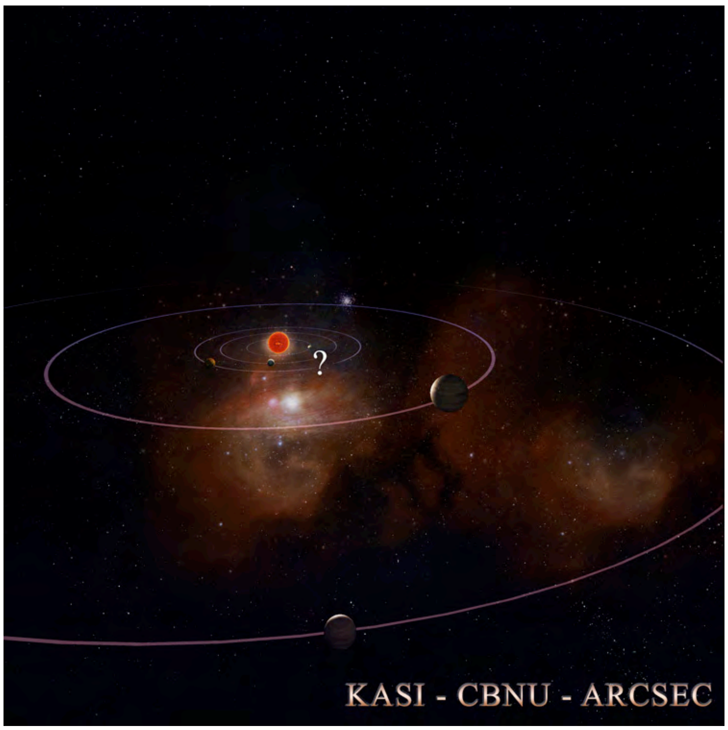
The AAAC would like to particularly thank the HEP Associate Director Robin Staffin, Acting Associate Director Dennis Kovar and Program Manager Kathy Turner for the time and interest they have shown in the AAAC's activities and for their contributions to discussions on many issues. Their efforts in working with us to help build a robust astrophysics program in the areas of interest to HEP are much appreciated. We would like to particularly thank Robin Staffin and wish him well in his new position.

The AAAC greatly appreciates the efforts of those at NASA who have helped re educate us as to the issues and challenges in running the largest astronomy and astrophysics research program in the world. The AAAC would like to commend Acting Director Rick Howard, for his efforts on behalf of the astronomical community for over a year while a new Director was being found. We welcomed the involvement, support and interest of the new Astrophysics Division Director Jon Morse, and of Michael Salamon our Federal official from NASA. Jon (and Alan Stern, the SMD AA) helped us greatly by finding travel support when NSF could not do so. Discussions with Alan Stern, Colleen Hartman, Paul Hertz and Eric Smith were, as always, informative and very helpful. Steve Ridgway deserves particular mention and thanks for the great effort that he put in as the ExoPTF responsible official (along with Dana Lehr). The success of the Task Forces owes a great deal to the subcommittee's Federal officials who ensure that the committee functions well and appropriately. Dana and Steve did an excellent job.

The NSF has contributed substantially to the operation of the AAAC, in time and in effort, and we deeply appreciate their interest in our activities. Wayne Van Citters, Eileen Friel and Dana Lehr deserve special mention for their support and interest in the Committee and its recommendations, and their willingness to

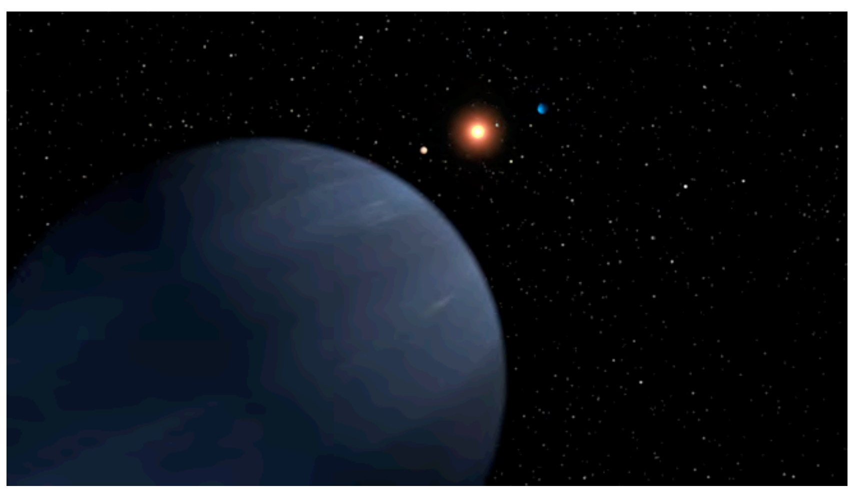
patiently explain the issues pertaining to the way the government does business. Many others from NSF AST have contributed, with special mention for Craig Foltz and Nigel Sharp. To the dedicated (and overworked) people in the astronomy division, we offer again our thanks. We particularly appreciate the support from AST and the Director's office for the S&E funds that have enabled the Committee members to travel, and the excellent facilities of the Boardroom for our meetings. We hope that ways are found to support AAAC travel without it impacting the S&E account in future.

The AAAC's Executive Secretary from NSF AST, Dana Lehr, has worked incredibly hard on our behalf, and we are very grateful for her efforts, support and very pragmatic advice. Her responsiveness, hard work and guidance on our behalf have played a key role in making the AAAC a voice for science.



Luckily for humankind, the elements released in supernovae make their way into stardust and ultimately into planets. Our discovery of exosolar planets accelerates every year in a quest to understand how they are similar or now to our own. NSF-funded scientists found a scaled-down version of our Solar System, containing two giant planets somewhat smaller than Jupiter and Saturn. They used gravitational microlensing, a phenomenon predicted by Einstein's General Theory of Relativity. They inferred that systems constructed like ours are common in the Galaxy.

(Credit: Cheongho Han et al., Korea Astronomy and Space Science Institute)



Meanwhile, extensive work by scientists supported by NASA and NSF yielded a fifth planet around the star 55 Cancri; it is now the system with the most known planets after our own. The new fifth planet is within the star's habitable zone in which water could exist as a liquid. Though the planet is a giant ball of gas, liquid water could exist on the surface of a moon, if it had one.
(Credit: Debra Fischer et al.; NSF-NASA; Lick; Keck; Artist Concept: JPL)

2008 ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

1.0 CHARGE

The Federal research enterprise in astronomy and astrophysics is a remarkably productive activity with great visibility to the public. Through its use of innovative technologies and cutting edge research programs, the Federal investment in astronomical research has demonstrated U.S. scientific and technological vitality, and has resulted in profound insights about the universe.

The organizational effectiveness of this enterprise was addressed in 2002 by the National Academy of Science (NAS) Committee on the Organization and Management of Research in Astronomy and Astrophysics (COMRAA). In their report, *U.S. Astronomy and Astrophysics: Managing an Integrated Program,* COMRAA recommended the establishment of an advisory committee to address the increasingly important interfaces among the agencies involved in supporting astronomy and astrophysics: the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the U.S. Department of Energy (DOE). Support for this by the Executive Branch and Congress led to the establishment of the Astronomy and Astrophysics Advisory Committee (AAAC) under the NSF Authorization Act of 2002, modified in 2004 to include DOE (as of March 2005), with the joint goals to:

1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of NSF, NASA, and DOE and
2) assess, and make recommendations regarding, the status of the activities of NSF, NASA and DOE as they relate to the recommendations contained in the National Research Council's 2000 Decadal report, and the recommendations contained in subsequent National Research Council reports of a similar nature. (See Appendix B for the full language.)

The formal inclusion of the DOE reflected the increasing activities of the Office of High Energy Physics (HEP) in astronomy and astrophysics and was a very welcome addition.

2.0 CONTEXT AND ACTIVITIES

The Decadal reports in astronomy and astrophysics from the National Academy of Sciences (NAS) play a critical role in evaluating and setting priorities for the nation's astronomy and astrophysics program funded by NSF, NASA and DOE. These reports are produced by the National Research Council (NRC) as the operating body of the National Academies in providing services to government. The 2000 NRC Decadal Survey *Astronomy and Astrophysics in the New Millennium*[3] (hereafter called the Decadal Survey), followed by the NRC report *Connecting Quarks with the Cosmos*[4] (CQC), set out an exciting, viable program for astronomical research that the AAAC heartily endorses. The 2005 NRC Letter Report from the *Committee to Assess Progress Toward the Decadal Vision in Astronomy and Astrophysics*[5] reaffirmed the vitality and relevance of the program outlined in the Decadal Survey. The AAAC fully concurs with the NRC committee's assessment that "the suite of projects recommended in the Decadal report provides the flexibility to explore the universe across a wide range of conditions. A broad portfolio of activities is a powerful tool for exploration." In addition to the broad strategic framework that is developed through the

[3] http://www.nap.edu/books/0309070317/html/
[4] http://www.nap.edu/books/0309074061/html/
[5] http://www.nap.edu/catalog.php?record_id=11230

Decadal Survey process, the NRC also produces reports of a more focused nature. While there are many such reports, two very influential recent reports demonstrate the excellence and clarity that NRC reviews can bring to complex issues. One was the report on HST in 2005 (*Assessment of Options for Extending the Life of the Hubble Space Telescope*[6]) and the other was the 2007 Beyond Einstein Program Assessment Committee (BEPAC) report (*NASA's Beyond Einstein Program: An Architecture for Implementation*[7]). Both of these studies involved a mix of scientists, engineers and managers and provided a level of insight into the scientific goals, complexities of mission development, the technical and the actual lifecycle costs that are needed for decision making in the current era. They are pathfinders for the 2010 Decadal Survey.

We have also taken particular note of issues and concerns raised during the year by NAS committees such as the Board on Physics and Astronomy (BPA) and the Committee on Astronomy and Astrophysics (CAA), since they have a particular role to play as the custodians and champions of the Decadal Survey and other similar NAS surveys.

The broad suite of missions and projects developed by the astronomical community working with NASA and NSF, and increasingly by DOE, is key to the scientific success and public visibility achieved in astrophysics over the last several decades. Increasingly NASA, NSF and DOE are involved in cooperative, collaborative, and joint ventures. While challenges arise from the different approaches to supporting research, joint programs (such as the Gamma-Ray Large Area Space Telescope, GLAST) or synergistic activities (such as the concurrent operations of the Hubble Space Telescope, HST, with 8-meter-class ground telescopes) enable more efficient use of national resources for scientific endeavors. A healthy scientific research budget is essential for each agency – NSF, NASA and DOE – if we are to continue to build on these joint and synergistic activities. The AAAC's comments on ACI and America COMPETES, and the budgets for science, are discussed in §3.1. A vibrant, healthy and productive research program is a key component of a nation that is to remain scientifically and technologically innovative and competitive.

Responding to CQC, the report of the NSF-NASA-DOE National Science and Technology Council (NSTC) working group was released early in 2004. This report, *A 21st Century Frontier of Discovery: The Physics of the Universe*[8] (POU), is an excellent example of interagency cooperation for dealing with initiatives that are of mutual interest to more than one agency. The AAAC has formulated four Task Forces, several in conjunction with the NSF-DOE High Energy Physics Advisory Panel (HEPAP), to address tactical issues relating to specific important research areas in astronomy and astrophysics and in particle physics. The Task Forces will play a major role in guiding the agencies during planning for future budgets and will provide input for the next Decadal Survey. These Task Forces include: the Task Force on CMB Research (TFCR), whose report was accepted in mid-2005; the Dark Energy Task Force (DETF), whose report was accepted in mid-2006; the Dark Matter Scientific Assessment Group (DMSAG), whose report was accepted in mid-2007; and the ExoPlanet Task Force (ExoPTF), which was formed to assess the opportunities for extra-solar planet detection and characterization on the ground and in space, and whose report is in the final stages of review by the AAAC. It is expected that it will be transmitted prior to the May 2008 meeting of the AAAC.

The AAAC views its role as a tactical one, dealing with the implementation of the recommendations made in the Decadal Surveys which are the astronomical community's highest-level strategic plans. As the astronomical community ramps up to carry out the Decadal Survey the AAAC has been considering how it will carry out its work and develop its recommendations. Clearly, the Committee does not want to be making recommendations that could potentially impact the implementation of the new 2010 Decadal Survey recommendations. Nonetheless, the AAAC cannot become dormant for the next two years. Activities will continue, within the agencies and elsewhere, and so the Committee will need to continue its advisory role, as

6 http://www.nap.edu/catalog.php?record_id=11169
7 http://www.nap.edu/catalog.php?record_id=12006
8 http://www.ostp.gov/html/physicsoftheuniverse2.pdf

it is mandated to do, but with particular sensitivity to minimizing any recommendations that could impact on the subsequent recommendations and priorities from the upcoming Decadal Survey when its report is released in 2010.

This report summarizes the findings and recommendations of the AAAC for the one-year period between 16 March 2007 and 15 March 2008. The structure of this report differs from previous reports. The detailed list of projects and programs has been removed, and placed under a more structured format by broad topical areas, while still explicitly dealing with both the components of its charge, (1) interagency and (2) progress on the strategic goals. A section has been added on science highlights as well. This is followed by discussion of some of the broad issues that are, or will, impact the implementation of the community's objectives, of issues of an interagency nature, and then discussion of topics and items by agency.

The AAAC held four meetings in that period. Face-to-face meetings were held at the NSF on 10-11 May 2007 and 11-12 October 2007 and 11-12 February 2008 (the latter was supported by NASA). Telephone conferences were held to review a draft of this report on 10 March 2008. The AAAC meeting agendas and minutes, as well as reports, can be found at http://www.nsf.gov/mps/ast/aaac.jsp

We greatly appreciate the efforts of the many agency staff, members of the Executive and members of the astronomical community who provided support and information to us during our deliberations over the past year. The AAAC has also found the willingness of the agencies to engage in very open and direct dialog on a wide range of issues to be of great value in developing mutual understanding of the challenges of implementing an ambitious scientific program. We are very impressed with the professional, supportive approach that the agencies have taken in working with the community to realize the goals of the Decadal Survey and of reports such as CQC.

3.0 BROAD ISSUES

Several areas are of such importance and touch on issues across the agencies that the Committee decided this year to identify and discuss these under a common framework at the beginning. They are (not unexpectedly) (§3.1) budget issues, especially those linked to ACI and America COMPETES, (§3.2) the impact of earmarks and congressional direction that impacts on community strategic priorities, and (§3.3) the upcoming Decadal Survey.

3.1 NSF, DOE and NASA Science: The American Competitiveness Initiative and America COMPETES

A major guiding and strengthening force for the nation's research effort came into being as part of the President's FY07 budget request. The American Competitiveness Initiative (ACI) was widely applauded for its recognition of the challenges faced by the nation in staying at the forefront of scientific and technological development. The 2005 NRC Augustine report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*[9], consolidated widespread concern about our future competitiveness and catalyzed efforts to improve the situation. Research is a precursor to innovative activities and underpins a technologically competitive society. The FY07, FY08 and FY09 President's budget requests sought new investments under the ACI at the Department of Energy Office of Science, at the National Institute of Standards and Technology (NIST), and at the National Science Foundation. These investments will result in clear benefits in national leadership in science and technology, and constitute the

[9] http://www7.nationalacademies.org/cosepup/

first steps toward an eventual objective of "doubling" the research budgets. NASA's Science Mission Directorate was not been included in the ACI, an omission that continues to be questioned.

Congressional interest in innovation and competitiveness, and concerns about the Nation's science and technology capabilities, were manifested through H.R. 2272, *America Creating Opportunities to Meaningfully Promote Excellence in Technology and Science Act* (America COMPETES) that was signed into law by the President in August 2007. The leadership exhibited by Congress in this area was widely appreciated. The support of both the Executive and the Congress for a strong research base is crucial if significant changes are to be made. Unlike ACI, America COMPETES did provide for NASA to be a "full participant in all interagency activities to promote competitiveness and innovation and to enhance science, technology, engineering and mathematics education." This inclusion is very rational – NASA is critical to national competitiveness and innovation. There is no question that NASA is a major source of science and technology funding, and the agency indisputably supports much basic research. This research contributes to the vitality of the national skill set, has engendered great public visibility, has encouraged young people to move into science and engineering, and has been shown to yield important, marketable spin-offs.

America COMPETES provided for NASA to be a "full participant in all interagency activities to promote competitiveness and innovation and to enhance science, technology, engineering and mathematics education." This inclusion is very rational – NASA is critical to national competitiveness and innovation.

The message from the Federal government at all levels is that innovation and competitiveness, as represented through basic research, is a key to the future strength of the nation. Yet, the reality after the budget process has worked its way to a conclusion through the appropriation process is that funding for research at the three agencies of particular interest to this Committee, NSF, DOE and NASA, has increased only marginally. The FY07 appropriations, done through a continuing resolution, did demonstrate the strength of support for the research agencies NSF and DOE Science, since significant increases were allocated – a rare event for a continuing resolution. The request increases for FY08 were very encouraging. Unfortunately, when it came to the bottom line on the FY08 appropriation, the initial support and increases for science in the early Congressional FY08 budget discussions were lost. When the negotiations with the Administration reached an impasse in December 2007, and the resulting Omnibus was released, it contained minimal increases for NSF and DOE Science and NASA. The impact at DOE in HEP was substantial and immediate with substantial personnel losses. The impact on NSF Astronomy was also serious as expected increases for the facilities and new projects evaporated.

The FY09 President's request contains large increases for DOE Office of Science (18.8% relative to the FY08 appropriation) and for NSF (16.0% for Research and Related Activities, or 13.0% overall, relative to the FY08 appropriation), with the goal of getting these agencies back on the "doubling" track, but only, as expected, the 1% increase for NASA SMD. For NSF Astronomy (AST) the requested increase is 14.8%, for DOE High Energy Physics (HEP) it is 16.8%, while at NASA, the Science Mission Directorate budget falls by 6%, and the Astrophysics Division budget falls by 14%, all relative to the FY08 appropriation. The request is very positive for HEP and AST, but not so for NASA Astrophysics. The opportunity to move ahead on exciting new projects will be lost beyond FY10, when the budget is 17% lower than now (22% in inflation-adjusted terms). The impact of this budget decline is substantial, and is discussed in §7, and particularly §7.4. By 2012 the outyear Astrophysics budget projection is down by 30% in inflation-adjusted terms, indicating a

The opportunity to move ahead on exciting new projects will decrease substantially from FY09 when the NASA Astrophysics budget is 14% lower than now. By 2012 the NASA Astrophysics budget is down by 21%, or 30% in inflation-adjusted terms, indicating a significant loss in science opportunities, just after the new Decadal Survey is released in 2010.

significant loss in science opportunities. The impact of such cuts becomes critical beyond 2010 when the new Astronomy and Astrophysics Decadal Survey will be released by the NRC.

The AAAC notes that the Appropriations Committees also indicated their considerable concern about the NASA SMD science budget in the FY08 Omnibus appropriation, when they wrote: "The Appropriations Committees are disappointed by the Administration's request of a less than one percent increase for fiscal year 2008 and projected minimal increases of approximately one percent over the next several years. The Nation's investment in research at NASA has made the U.S. the undisputed leader in the study of space and the earth's environment. NASA's programs in space science, Earth science, microgravity science, and astrobiology are the types of basic research investments advocated in the National Academies' Rising Above the Gathering Storm report." The AAAC hopes that Congress and the Administration can work together to support increased funding for NASA science.

The AAAC recognizes the challenges this year for the Federal budget, but strongly encourages Congress to appropriate the requested FY09 funding levels for NSF and DOE. In the not unlikely event of a continuing resolution until the new Administration is in place, the AAAC hopes that the requested budgets will be fully implemented in calendar year 2009. If increases are not implemented, but kept at the FY08 appropriated funding levels through FY09, momentum towards an increased research budget will be lost, leading to less-than-inflation increases, and setbacks to major projects. The opportunities envisaged by America COMPETES will be lost.

3.2 The Impact on Community Strategic Planning Processes by Petitioning for Directives and Earmarks

The Astronomy and Astrophysics community has long been commended for its commitment to strategic planning and its willingness to make choices. The Decadal Surveys, with their development of a strategic framework for projects and missions on 10 yr timescales, have been seen as a model approach by policy makers, funding agencies and Congressional committees. They are not perfect, but each decade we have learnt and improved the Survey to where they are now being emulated by other communities. A central tenet of such Surveys is that they form a strategic framework with prioritized missions and projects. The science community then uses community-based groups to deal with the implementation details, namely with NRC committees like the SSB, the BPA and their subcommittee the CAA, FACA committees like the AAAC, and other FACA advisory committees and groups at the agency level.

Unfortunately over the last few years the community has seen an increased level of "lobbying" by individuals or groups for their projects that is done outside the long-established community processes for strategic planning. This subverts the community's broad strategic plans and upends the peer review process that is the foundation of cohesive, representative decision-making. This leads to frustration within the agencies, the Executive and Congress, as well as in the community, that some groups are ignoring and undercutting a widely-supported strategic planning process, and its recommended priorities, to advance their own projects and agenda. It is clear that this will have detrimental impacts on the astronomy community as a whole. The AAAC has become increasingly concerned about the number of directives and earmarks that are being seen in appropriations language as a result of individuals or groups petitioning for a particular program. The impact on the plans that have been developed through robust community-based peer review processes is substantial.

The broad concern regarding these activities has resulted recently in the American Astronomical Society (AAS) releasing a statement "On Community-based Priority Setting in the Astronomical Sciences" that was adopted by the AAS on 24 January 2008:

"The American Astronomical Society and each of its five divisions strongly endorse community-based priority setting as a fundamental component in the effective federal funding of research. Broad community input is required in making difficult decisions that will be respected by policy makers and stake-holders. The decadal surveys are the premier examples of how to set priorities with community input. Other National Academy studies, standing advisory committees, senior reviews, and town hall meetings are important components. Mid-decade adjustments should also be open to appropriate community input. Pleadings outside this process for specific Congressional language to benefit projects or alter priorities are counterproductive and harm science as a whole. The American Astronomical Society opposes all attempts to circumvent the established and successful community-based priority-setting processes currently in place."

The Astronomy community has long been commended for its strategic planning and its willingness to make choices. Unfortunately the community has seen an increased level of "lobbying" by groups or individuals for their projects. This subverts the community's broad strategic plans and upends the peer review process that is the foundation of cohesive, representative decision-making.

The President of the AAS, Craig Wheeler noted that: "The American Astronomical Society has recently ratified a set of policies under which the Society will strive for the most productive science with finite resources. We feel that the best way to accomplish this is to have broad community input in establishing scientific priorities based on realistic cost estimates. Our statement also makes clear that the Society does not condone attempts by individual facilities or missions to engineer specific directed congressional language that has the likelihood of subverting those priorities arrived through broad community input such as the decadal surveys sponsored by the National Research Council."

The AAAC fully concurs with these statements and would like to add some comments on specific language in two areas, because of their potential impact. First on NASA and SIM:

Over the last year a committee chartered of the AAAC, the Exoplanet Task Force (ExoPTF) has been working to define a program for finding and studying planets around other stars. This is a rapidly growing field and will be one of the main areas of discussion in the 2010 Astronomy and Astrophysics Decadal Survey that will start this summer (2008). The ambitious programs of the last decade like TPF that were discussed in this area are now seen as far too expensive, given the resources in SMD and Astrophysics (TPF would likely be at least as expensive as JWST, and does not yet have the needed technical maturity). SIM's lifecycle cost is now estimated by NASA to be $2.6B 2007 dollars. The SIM that was largely passed through the 2000 Decadal Survey as a mission in progress which was originally a $250M program in the 1990 Decadal Survey. It was thus expected to be a moderate scale mission for the decade in the 2000 survey. The subsequent cost growth that occurred twice after the 2000 Decadal Survey report was completed has pushed it into an entirely new category ("Large" missions), and therefore needs to be reprioritized in that category. At this time SIM (or "SIM Lite") and the recommendations of the ExoPTF should engage with the processes that have served the science community, the agencies, OMB and the authorizing and appropriating committees so well, and be considered by the upcoming Decadal Survey.

In this context, the recent directive regarding SIM development from the Appropriations Committees was seen as extremely damaging by the AAAC and science community at large:

"A total of $60,000,000, an increase of $38,400,000 above the budget request, has been provided for the Space Interferometry Mission (SIM). The Appropriations Committees disagree with the Administration's budget request of refocusing the Navigator Program to fund only core interferometry and related planet-finding science and reducing SIM to a development program. It should be noted that this mission was recommended by the National Academies Decadal Astrophysics report in 1990 and 2000 and should be considered a priority. With the funds proposed, NASA is to begin the development phase of the program in order to capitalize on more than $300,000,000 already invested by the agency. The SIM program has successfully passed all its technological milestones and is thus ready for development."

By moving SIM into "development" at this time, at the request of members of the science community, Congress is committing SMD and the Astrophysics Division to spend a further ~$2B on SIM, for a mission which received its priority ranking in the 1990 Decadal Survey as a moderate $250M mission. This move comes just as the astronomical community is about to enter into its 2010 Decadal Survey strategic planning activity. Given the upcoming budget cuts in the SMD Astrophysics Division, the effect of doing SIM now would be to largely preclude any other significant missions for the first half of the coming Decade. The Decadal Survey's options for NASA Astrophysics would be effectively eliminated, rendering much of the discussion on space science astrophysics missions moot. The important prioritization processes (e.g., National Academy Astronomy and Astrophysics Decadal Survey) that the astronomy community uses have been widely heralded within Congress and the Executive as a model for other science communities. The AAAC hopes that, through understanding the impact of this decision, and the impact on the astronomical community prioritization processes, that Congress reconsiders the action that it has just undertaken on SIM. By allowing SIM, or SIM Lite, and the ExoPlanet Task Force report recommendations to undergo serious discussion and consideration within the Decadal Survey a much more robust and achievable planet search program, utilizing ground and space facilities will result.

The second area that was a particular concern related to NSF AST and the Senior Review:

The NSF AST Senior Review was undertaken by a broadly-based committee who invested a very large amount of effort into a very challenging task, with substantial inputs from the facilities and the science community through town meetings and written input. The AAAC is very supportive of the Senior Review process and goals. However, we have become very concerned about the efforts that are being made by individuals through Congress, and by letters that go directly to the NSF Director, in support of individual projects or programs that were slated for reduced support. This greatly undercuts the broad community planning efforts that have given us a reputation as developing an orderly strategic process and for utilizing science-based reviews. It is obvious to us in discussions that a reputation for responsible planning and prioritizing is fragile; goodwill takes years to develop, but only a little time and self-interest to damage. We recognize the challenges and concerns that arise when facilities are slated for reduced operations or closure, but we also note that the Senior Review and AST have strongly encouraged the affected facilities to find other partners. It is the view of the AAAC that partnerships formed amongst groups with strong self-interest in the facilities will make for a much more robust and long-term program.

We consider that a robust operational future is particularly likely to develop for the Arecibo Observatory, provided substantial local participation is allowed to develop. The stability and benefits on all sides will be greatly enhanced by strong local participation from the local government, business and universities in Puerto Rico. However, such efforts can be greatly undercut if the participants feel that the Observatory will resort to "funding as usual". This will be a lost opportunity to bring long-term stability to Arecibo for Puerto Rico and the science community. The Congressional language (below) relating to Arecibo in the FY08 Omnibus was thus a concern to us, and we hope that the community members involved come to recognize the potential loss inherent under an approach that might impact the negotiations in Puerto Rico.

"The Appropriations Committees express concern over the conclusions of the NSF's Division of Astronomical Sciences Senior Review with regard to the Arecibo Observatory. The Committees believe that this Observatory continues to provide important scientific findings on issues of near-space objects, space weather, and global climate change, as well as numerous other research areas. The Committees believe that these endeavors will have scientific merit far beyond the end of this decade. As such, the Committees hope the Division of Astronomical Sciences will reconsider its conclusions regarding future funding for the Arecibo Observatory. …"

"Further, the Appropriations Committees are concerned that NASA may reduce support for the Arecibo Observatory which is used by NASA to observe and detect NEOs. The Committees believe that this observatory continues to provide important scientific findings on issues of near-space objects, space weather, and global climate change, as well as numerous other research areas. The Committees believe that these endeavors will have scientific merit far beyond the end of the decade. NASA is directed to provide additional funding for the Arecibo Observatory."

The AAAC welcomes the continuing interest and support of Congress for the astronomical research program at NASA, NSF and DOE, but hopes that the representations from the community for individual projects of interest to the petitioners do not lead to directives that distort the astronomy community's strategically and consensus-driven priorities, nor lessen opportunities for future support that are likely to be more stable in the long-term. An added and very real risk is that facilities that are of high priority for the broad science community must then be shut down to operate a lower-priority facility for which non-consensus efforts have garnered Congressional support.

3.3 The 2010 Astronomy Decadal Survey

The Astronomy and Astrophysics Decadal Survey defines a strategic plan for the astronomy community that the Executive, the agencies and Congress have found to be an extremely useful document. Unfortunately, most of the recommendations from the 2000 Decadal Survey remain undone. Given this backlog, the upcoming 2010 Decadal Survey is of crucial importance to policy makers and to the science community. The current project backlog far exceeds what can realistically be done in the coming Decade, even if significant funding growth occurs. The science community must establish a much more realistic zero-based plan and do it through an end-to-end assessment of the science goals and resulting projects. This will require a reconsideration of ***all*** projects, with the exception of those that are under construction.

Unfortunately, most of the recommendations from the 2000 Decadal Survey remain undone. The science community must establish a much more realistic zero-based plan and do it through an end-to-end assessment of the science goals and resulting projects. This will require reconsideration of **all** ***projects, with the exception of those under construction.***

The central reason why we are in this predicament is poor understanding (and recognition) of the costs involved in our missions and projects, and a number of political factors. Both the science community and the agencies failed to fully understand the implications of the cost estimates that were being used. It is clear that the 2010 Decadal Survey needs to use end-to-end "lifecycle" costing, and to make an effort to preclude the "undercosting" of projects so that they get a "foot in the door" in the recommended list. As a guide, most projects in prior Decadal Surveys were a factor 3 (the "π factor") lower in cost than what is now recognized as likely, with some that are as much as 10x lower. The commitment within the astronomy community and within the agencies to be realistic is reassuring, especially given the experience with the BEPAC committee which showed that an NRC group can deal very well with technical readiness and cost issues, especially with the right mix of experienced people.

Several cases that are discussed at particular points in this report deserve mention in the context of being revisited by the 2010 Decadal Survey. SIM is an obvious case, given the recognition that it is now a major $2.6B mission lifecycle, and that nearly 8 years of scientific and technical advances have occurred in the exoplanet field since the last Decadal Survey (where the consideration of SIM was cursory since it was assumed to be a moderate mission that would be ready for development soon thereafter – its subsequent cost growth when independently reviewed, and two major rescoping exercises, led to long delays and put the mission into a very much larger cost category). To ensure that the progression in future is more orderly the AAAC recommends that any future exoplanet mission be considered by the Decadal Survey (including SIM or SIM Lite, and/or an exoplanet strategic medium-scale mission), utilizing the ExoPlanet Task Force report. The AAAC also believes that it is important that LSST be discussed in the 2010 Decadal Survey. LSST is, in lifecycle cost terms, a billion-dollar ground-based program (actual expenditure year dollars, though only about 75% of the total cost will be borne by the Federal government, shared by NSF and DOE). As mentioned in §6.5.3, such deliberations should not impact LSST's timescale for MREFC approval as a New Start. LSST needs to undertake and pass several significant steps as it approaches MREFC Readiness Phase and then as it undergoes the MREFC-mandated reviews. It must also reach comparable project status within DOE HEP.

Over the last two years the AAAC has had a number of discussions regarding the upcoming Decadal Survey with the NRC Committee on Astronomy and Astrophysics (CAA) Co-Chairs Meg Urry and Chuck Bennett, and NRC CAA Senior Program Officer Brian Dewhurst. The AAAC's tactical role, providing advice on the implementation of the Decadal Survey recommendations, provides it with some "front-line" experience on how well these very important NRC studies achieve their goals. Our collective experience suggests that there are several key areas where the Decadal Survey process could be improved. These include (i) careful re-consideration and ranking of the unfinished projects and missions ("carry-over" projects), (ii) development of a more explicit science framework, (iii) consideration of the tradeoffs between continuing to support missions with high levels of annual operation costs *vs.* using those resources to initiate new small, intermediate or large missions, (iv) developing a process that might allow iteration on the Decadal Survey recommendations during the decade, and (v) establishing more realistic cost estimates, partly through more-informed evaluations and reviews of the mission and project costs. Concerns were also expressed to the Senior Review by many members of the astronomical community regarding their sense of being disconnected from the Decadal Survey process. These concerns also need to be addressed in the upcoming Survey by improving communication and feedback, and should be balanced with the objective of an efficient and convergent process. The AAAC Task Force reports will also provide invaluable input, given the level of effort that went into those reports by the community (through the Task Force members time and energy, but also through the "white papers" from the community).

The 2010 Astronomy and Astrophysics Survey is currently being defined through negotiations between the agencies and the NRC. The Survey process is expected to start this summer. The importance of this process was highlighted for us again recently. The SMD AA recently restated in the March 13 2008 FY09 Budget Request Hearing before the House Committee on Science and Technology's Subcommittee on Space and Aeronautics that one of his top priority goals was to follow the science Decadal Surveys. A second and related goal of his was cost control of missions. Given its attention to science, cost and technical readiness, the BEPAC NRC study was a pathfinder for the process and structure of the 2010 Decadal Survey, as well as providing a very detailed and informed input on the Beyond Einstein mission set to the Decadal Survey. The AAAC hopes that the success of the BEPAC process will guide the NRC and the Decadal Survey committee to a mission and project set that has a similar level of cost and technical realism to match their scientific excellence.

The AAAC decided at its last meeting that it would be very useful for the Committee to discuss the role of the AAAC with the Chair of the upcoming 2010 Decadal Survey when the membership of that committee is announced. The AAAC felt that a discussion should be useful for the 2010 Survey Chair also given that the AAAC has been deeply involved in the tactical implementation of the previous Decadal Survey's recommendations through its role to "assess, and make recommendations regarding, the status of the activities of NSF, NASA and DOE as they relate to the recommendations contained in the National Research Council's 2000 Decadal report, and the recommendations contained in subsequent National Research Council reports of a similar nature". Given the AAAC's interest in communicating with the Chair (and through the Chair to the 2010 Decadal committee) the AAAC felt that it was valuable to state its (updated) recommendations from last year's report regarding the Decadal Survey so that they were readily available to the committee and panel. They are given below.

AAAC TASK FORCE REPORTS: Over the last several years, four subcommittees of the AAAC ("Task Forces") have developed a series of very thorough and insightful documents in several key areas of astrophysics (CMB, Dark Energy, Dark Matter detection and exoplanet searches). These studies solicited and obtained substantial community input and represent a year of intense work in each case by an expert group of astronomers and astrophysicists working in those fields. They were developed under FACA guidelines and represent a very careful attempt to provide broad recommendations while minimizing conflict of interest. These are important documents that speak to the community's assessment of how best to proceed with the broad scientific aims of the Decadal Survey. We hope that the NRC 2010 Decadal Survey makes the Survey committee and its panels aware of these documents, and request that the agencies feature the reports in their presentations to them.

"CARRY-OVER" PROJECTS: With the support of the agencies, a broadly-based Astronomy and Astrophysics Decadal Survey NRC study will be undertaken in the next few years to consider the community's goals and priorities for the next decade. It is very obvious that almost none of the high-priority recommendations from the last Decadal Survey will be completed this decade. Traditionally, unfinished projects have been "carried over" into the next decade's plan. To do so this time would largely render a new study moot; since the previously recommended program is so incomplete, the carry-over items could essentially preclude any new programs. Thus, there is a growing sense that the next Decadal Survey will have to re-assess and re-prioritize the unfinished mission and projects if it is to develop an exciting, viable and "saleable" program for the next decade. The question of "what is to be reconsidered and what is not" is not an easy one to answer, and the best solution probably is that the Decadal Survey committee should discuss ***all*** programs not well under construction, and decide on their ranking in the current Survey. Experience has shown that even programs well on their way to completion can develop significant problems and cost growth, and so advice from the NRC Decadal Survey committee could provide guidance on how to deal with the impact of any such changes on other programs, i.e., the priorities for any delays or cancellations.

SCIENCE FRAMEWORK: Connecting Quarks with the Cosmos (CQC) enjoyed considerable visibility because of its very well developed science discussion and focus on broad science questions. This resonated with policy and decision makers. Given the challenge involved in developing a realistic program in the next Decadal Survey, with current project and mission costs and likely budgets, it will be important to highlight and utilize the science framework and goals more explicitly in the 2010 Decadal Survey, rather as CQC did. Since it probably will be impractical to give every community a "piece of the pie" in the 2010 Survey, the Survey committee will ultimately need to resort to making even tougher choices than in the past – and these should be done on the basis of science priorities that have been established as part of the same overall process. On a related issue, CQC also indicated that the 2000 Decadal Survey was not fully inclusive of areas whose interest in astrophysics was growing. It is now obvious that particle astrophysics should be included, but there may be fields whose relationship is like particle astrophysics was in 2000. The 2010 Survey should carefully consider the boundaries and encompass fields whose relationships with astronomy are growing.

TRADEOFFS – NEW vs. OPERATING PROGRAMS: The next Decadal Survey may need to give consideration to the tradeoffs between continuing to support missions with high levels of annual operation costs *vs.* using those resources to initiate new small, intermediate or large missions. For example, some consideration might be given to recommending mechanisms for evaluating the science return of ongoing missions such as HST and SOFIA whose outyear annual costs are high (in FY13 HST reduces to ~$95M per year, while SOFIA is ~$60-77M, depending on whether a partner can be found to share in the operations cost), against, for example, more frequent Explorer/Discovery/Probe missions. Senior reviews have traditionally been used where the discussion focuses on whether the mission is returning good science, but in the case of such expensive operations, the central question is whether the science being done is better than what might be done with a new mission such as an Explorer or even a future intermediate or large mission. Such questions are better handled by a broadly-based review than by one that focuses solely on a single program's science productivity. The approach that is needed is more akin to the recent NSF AST Senior Review which, with its very broadly based assessment of the field, provided a much more comprehensive "portfolio" evaluation. The Decadal Survey is ideally positioned to do this. The Decadal Survey could provide recommendations on some of the difficult tradeoffs of operating current facilities and missions *vs.* starting new projects.

RE-EVALUATION DURING THE DECADE: Related to this is developing a process that might allow iteration during the decade on the Decadal Survey recommendations in a way that carries "corporate memory" of the discussions and issues that framed the choices made in the Decadal Survey. This is not easy to do, but one possible mechanism might be to reconvene (a subset of) the Decadal Survey committee at times when it becomes clear that major changes have occurred in the overall science budget or individual mission/project timescales and costs. This would presumably be done only when the scale of changes was beyond that which could be readily dealt with by the standing NRC committees that deal with Astronomy and Astrophysics issues (the SSB, BPA, CAA) and which would be done in conjunction with those standing committees.

COST ESTIMATES: Better cost estimates are clearly needed for the upcoming Decadal Survey, along with an assessment of the likely agency budgets for astronomy. The recognition that this is a serious issue with the last Survey has led already to extensive discussion of how to improve the cost estimates. Both the science community and NASA see this as a crucial issue for the 2010 Survey (NASA SMD AA Alan Stern highlighted the need for better cost management in his recent Congressional testimony). A key issue will be to balance the level of cost reliability with what can realistically be done before and during the Decadal Survey process. A realistic goal may be to (i) establish common ground rules (e.g., any cost estimates would most usefully include both full lifecycle costs and costs within the coming decade), (ii) provide independent cost estimates (not just cost estimates from the project proponents), (iii) aim to provide costs that are less systematically underestimated, and (iv) include experts in project management and cost assessment in the deliberations. The BEPAC committee demonstrated that robust reviews can be done through the NRC processes that include realistic cost and readiness assessments. It requires the right mix of people on the committees and some support for experienced, external cost-assessment groups.

4.0 INTERAGENCY ACTIVITIES/ISSUES

The AAAC is charged to "assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of NSF, NASA, and DOE". This section deals with a number of areas, missions and projects, and issues that have been the focus of our attention, not only over the last year but also over the last few years. The most prominent aspect of this section deals, very appropriately, with the four Task Forces that the AAAC has requested be constituted to deal with broad issues of high scientific priority that had particular implications for interagency support and involvement.

4.1 Task Forces

4.1.1 Implementation of Task Force Recommendations

The AAAC transmitted final reports to the agencies from the Task Force on CMB Research (TFCR) in October 2005, from the Dark Energy Task Force (DETF) in June 2006, and from the Dark Matter Scientific Assessment Group (DMSAG) in September 2007. The ExoPlanet Task Force (ExoPTF) report is nearing completion and will be transmitted to the agencies by mid-spring 2008. These reports will also provide valuable input for the upcoming 2010 Decadal Survey. These task forces have delivered reports of uniformly excellent quality with great insights. As noted above, they are important and substantial reports that speak to the community's assessment of how best to proceed with the broad scientific aims of the Decadal Survey. Their recommendations have been a balanced combination of optimism and realism. The reports have proven to be a very valuable resource. The AAAC considers these Task Forces to be one of its most important contributions to developing interagency science programs and projects that are timely, cost effective and of the highest scientific rank.

A key question surrounds the implementation of the recommendations in these reports. The AAAC Task Forces involve many scientists from the community in a time-consuming effort to identify a path forward in an area that has been recognized by both the community and the agencies as being of high priority. At the completion of their reports and the subsequent transmittal to the agencies by the AAAC, a key question asked by the Task Force members and other scientists is "what happens now?" This is a very appropriate question. The AAAC recognizes that there will be differences of approach that depend (i) on the report topic, (ii) on the scale of the mission/program/project/activity that has been recommended by the Task Force, and (iii) on the agencies involved and how they support research programs and instrumentation developments. It would be valuable for the AAAC, and, through the AAAC, for the community to develop a clearer understanding of the responses and the approaches that will likely occur. An example occurred with the announcement by DOE HEP of a solicitation of research proposals relating to dark energy where ~$3M was designated as being available for dark energy R&D. The responses from the agencies will differ according to the scale of the activity.

Four task forces have delivered reports of uniformly excellent quality with great insights. The AAAC considers these Task Forces to be one of its most important contributions to developing interagency science programs and projects that are timely, cost effective and of the highest scientific rank.

In the coming year, starting in the May 2008 meeting, the AAAC would be interested in further discussion with the agencies about how these recommendations will be folded into agency planning and roadmapping activities, Research and Analysis (R&A) funding, and instrument and facility planning. In addition, the AAAC, the Task Forces and the agencies have all discussed the Task Force reports as being valuable input to the upcoming 2010 Decadal Survey. The AAAC will specifically ask the Decadal Survey to utilize these reports, but the AAAC, and the Task Forces chairs and members, would be appreciative if the agencies could also encourage the NRC to use these reports as part of the input to the Decadal Survey committee and its Panels, and to mention them in their presentations to the Survey Committee and its Panels.

4.1.2 ExoPlanet Task Force (ExoPTF)

The detection and characterization of planets around other stars has become one of the exciting research fields of our time, with great public interest. The search for planets involves both space missions and ground-based programs. The technological challenges associated with planet searching and characterization are formidable. This has led to a number of extremely innovative techniques and approaches being developed and applied on the ground and under consideration for use in future facilities in space. In the near term a number of space missions, including the Hubble Space Telescope (HST), the Spitzer Space Telescope, the COnvection, ROtation and planetary Transits (COROT) experiment and the Kepler mission are or will be used to address a broad range of scientific questions about the frequency and variety of planetary systems. Several missions are under discussion for the future, including medium-class missions, and large missions like the Space Interferometry Mission (SIM), a Terrestrial Planet Finder-Coronograph (TPF-C), a Terrestrial Planet Finder-Interferometer (TPF-I), and the ESA Darwin space interferometer. However, these are all very ambitious multi-billion dollar programs, comparable to JWST in most cases. Such expensive missions require very careful evaluation and prioritization through the Decadal Survey process, and careful advocacy. Great advances are also being made on the ground with precision spectrographs, with plans for ambitious adaptive optics (AO) capabilities that might realize imaging resolution now only possible from space.

Given the great interest in the field of exoplanet research – and the challenges and high cost of both ground- and space-based experiments and missions – the AAAC recommended that the agencies consider the establishment of a Task Force to develop a strategic plan for planet detection and characterization, as well as planetary formation, with consideration of the relative roles and contributions of future ground-based programs and space missions. NSF and NASA responded very positively, and the ExoPTF held its first meeting in February 2007. The ExoPTF has submitted its report to the AAAC for review and it is expected that it will be completed and transmitted to the agencies this spring (2008). The AAAC greatly appreciates the agencies' support for the ExoPTF, and particularly appreciates the efforts of the Chair Jonathan Lunine, the very considerable efforts and contributions of the Task Force members, and the very positive community response on the call for White Papers (with 85 received). Such a report, as well as being a guide for agency planning, will also provide very valuable input to the next Decadal Survey.

The ExoPTF recommendations were built around a phased program with two parallel scientific tracks involving M dwarfs and F, G, and K dwarfs, respectively. The program encompassed research, instrumentation, facility utilization, and new missions and projects, on the ground and in space, separated into three time periods, 1-5 yrs, 5-10 yrs and 10-15 yrs. The program grew increasingly ambitious in its scale as time progressed, appropriate for a long-term study in an exciting, rapidly developing area. The AAAC recommends that NASA and NSF use this report to guide their detailed plans for exoplanet research, consistent with the broad recommendations of the 2010 Decadal Survey (who, it is expected, will use this report as input for their deliberations and recommendations).

4.1.3 Dark Matter Scientific Assessment Group (DMSAG)

Understanding the nature of the mysterious dark matter that dominates the mass of the universe and plays a central role in the formation and aggregation of galaxies is one of the great scientific quests of our time. Its detection and understanding is important to both particle physics and astronomy. The direct detection of dark matter is developing into a vibrant field, with numerous approaches that could be followed. There is significant interest in identifying the most promising experimental approaches for the direct detection of dark matter using particle detectors. While this is an area most directly of interest to the High Energy Physics Advisory Panel (HEPAP), the astrophysical community's great interest in this question and in the potential role of astrophysical constraints led the AAAC to suggest that DOE HEP and NSF Division of Physics (PHY) and AST form a joint Task Force to provide advice on priorities and strategies for the direct detection and study of dark matter. The agencies responded positively and have asked both committees to jointly establish a Dark Matter Scientific Assessment Group (DMSAG) to advise the DOE HEP and NSF PHY and AST concerning the U.S. dark-matter direct-detection research program. Such an activity also builds on recommendations in the interagency working group report, *The Physics of the Universe: A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy*[10], that was produced under the auspices of OSTP. It was also explicitly identified as a high priority activity in the astrophysics arena in the EPP2010: Elementary Particle Physics in the 21st Century committee report of the National Academy, *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics*[11].

The DMSAG identified a path to significant advances with a modest increase in funding that would ensure the continuation of US leadership. The DMSAG makes a strong case that substantial progress could be made that would ensure the continuation of US leadership. They suggest an increase to about $10M per year to accomplish this goal. This would be consistent with the EPP2010 recommendations. The AAAC strongly endorses increased support for the dark-matter direct-detection efforts. The DMSAG charge, members and the report can be found at: http://www.nsf.gov/mps/ast/dmsag.jsp.

4.1.4 Dark Energy: The Dark Energy Task Force (DETF)

The discovery of dark energy at the end of the 1990's is one of the most remarkable and confounding scientific surprises of our time. Dark energy was discovered using observations of distant supernovae from ground-based telescopes and was further constrained by higher redshift observations in space with the Hubble Space Telescope (HST). A number of complementary approaches, such as weak gravitational lensing, distant supernovae, the evolution of galaxy clusters, and the growth of structure in the matter of the Universe, are now being utilized for their potential in identifying the nature of the dark energy. The Decadal Survey and CQC (plus its implementation companion *Physics of the Universe*) recommended that two major approaches to this effort be developed in the longer-term: a ground-based program Large Synoptic Survey Telescope (LSST) and a space-based mission known as the Joint Dark Energy Mission (JDEM).

However, many groups both within the U.S. scientific community and internationally are actively working to address dark energy on a shorter timescale using existing facilities or updates to those facilities. To assist in defining a framework for the agencies in the near-to-intermediate term, the AAAC recommended that a Task Force be formed. NASA, NSF and DOE responded very positively to this request and established the Dark Energy Task Force (DETF). The DETF activity generated a high level of interest in the community; the committee received over 50 white papers in response to its solicitation for input. In mid-2006 the DETF report[12] was completed, accepted by both the AAAC and the High Energy Physics Advisory Panel (HEPAP), and transmitted to the agencies. (See http://www.nsf.gov/mps/ast/detf.jsp for the DETF charge, membership, report and transmittal letters.)

The DETF findings and recommendations clearly show the value of an expert study, where the objective is to establish a broadly based framework within which experiments and projects can be prioritized and carried out within the limited budgets of the agencies. The DETF noted that a program that includes multiple

---

[10] http://www.ostp.gov/html/physicsoftheuniverse2.pdf
[11] http://books.nap.edu/catalog.php?record_id=11641
[12] http://www.nsf.gov/mps/ast/aaac/dark_energy_task_force/report/detf_final_report.pdf

techniques could provide an order-of-magnitude increase in their figure of merit. They found that "this would be a major advance in our understanding of dark energy." The DETF reported, "No single technique is sufficiently powerful and well established that it is guaranteed to address the order-of-magnitude increase in our figure-of-merit alone. Combinations of the principal techniques have substantially more statistical power, much more ability to discriminate among dark energy models, and more robustness to systematic errors than any single technique. Also, the case for multiple techniques is supported by the critical need for confirmation of results from any single method." This very important result suggests that, within a cost-capped situation, a variety of approaches will be more important than a single, very accurate (but likely costly) program that utilizes only a subset of the four science techniques considered by the DETF (baryon oscillations, clusters, supernovae and weak lensing). Such feedback is immensely valuable to the field, to proposers of projects, and to the agencies that will fund the developments.

The DETF report provides guidance for the optimization of near- and intermediate-term activities, as well as for JDEM and LSST, and we hope that DOE, NASA and NSF will continue to work together to utilize the DETF recommendations in their planning and review processes, particularly in the near-term for DETF-classified Stage III projects. The joint effort by DOE HEP and NSF AST on the Dark Energy Survey (DES) is also a very welcome development, as is the 2007 and 2008 funding at the $3-4M level that DOE HEP is competitively awarding in dark energy R&D funds as part of a broad Stage III effort. The AAAC recommends that the agencies coordinate their plans and activities in this area and that particular attention be given to supporting Stage III projects as a means of making progress quickly and providing a framework for the much more expensive Stage IV projects.

4.1.5 Cosmic Microwave Background: Task Force on CMB Research (TFCR)

Measurements of the Cosmic Microwave Background (CMB) radiation have led to a remarkable series of discoveries of the universe. The CMB offers a pristine view of the universe when it was only 400,000 years old, a small fraction of its present age of 13.7 billion years, at a when it was evolving very rapidly. That the brightness of the CMB was found to be so uniform across the sky led to the inflation theory for the origin of the universe. These measurements and results have been the result of a long program of careful detector development and testing through ground- and balloon-based telescopes supported by NSF that led to the recent spectacular success of the NASA Wilkinson Microwave Anisotropy Probe (WMAP) Explorer satellite mission. One of the key chapters in cosmology remains to be written – the ambitious goal of probing the first instants of the universe and testing inflation by definitive measurements of the polarization of the CMB. This goal was highlighted in both the *Connecting Quarks with the Cosmos* (CQC) and *Physics of the Universe* (POU) reports.

The AAAC enthusiastically supported the effort to set up a Task Force to develop a joint NSF-NASA-DOE strategic plan leading to definitive measurements of the CMB polarization. The final report[13] of that group, the Task Force on CMB Research[14] (TFCR), was accepted by the AAAC and HEPAP late in 2005. The AAAC noted that the TFCR report set a very high standard for subsequent studies and will be a resource for many years to come, particularly during the next Decadal Survey process. The TFCR's comprehensive and valuable study will provide a basis for moving forward in this exciting area on a broadly-based program for CMB polarization research. The ultimate goal is probing the first instant of the universe (the inflation epoch). The NRC report, EPP2010: Elementary Particle Physics in the 21st Century committee report of the National Academy, *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics*[15] recently highlighted the importance of CMB research.

[13] http://nsf.gov/mps/ast/tfcr_final_report.pdf
[14] http://nsf.gov/mps/ast/tfcr.jsp
[15] http://books.nap.edu/catalog.php?record_id=11641

4.2 Interagency Projects and Missions: GLAST, BEPAC, JDEM, LSST, AMS, etc.

In the 5 years since the AAAC was formed, we have seen increasing numbers of interagency projects, and increasing planning for future projects. All the Task Forces that the AAAC has initiated relate to scientific issues that are recognized as being of high priority within the science community from the Decadal Surveys and like reports but which require interagency collaboration for optimal progress. Other missions and projects have developed as interagency from the "bottoms-up" and have developed because it has been an effective approach to accomplishing the scientific goals. Many of these projects are discussed within the agency specific sections, because of issues that arise there, or because that is the natural focus since all projects have a lead agency (a clear "lessons-learned" from a number of past major projects, both national and international). The interagency projects that have received particular attention from the AAAC over the last few years include GLAST, LSST, JDEM, Beyond Einstein and BEPAC, while we have been aware of developments in other joint projects such as VERITAS. The AAAC appreciates the willingness of the agencies to provide updates on these and other projects and would encourages further efforts on the projects currently under discussion, such as JDEM, LSST and others.

One of these interagency efforts, and one that is of particular importance because of its pioneering aspect for the interagency process is GLAST, the first substantial NASA-DOE collaboration. The AAAC was pleased to see that the Gamma-ray Large Area Space Telescope (GLAST) is on track for a launch in May 2008. GLAST is a very important gamma-ray space mission. It is the highest ranked space mission in the "moderate" category in the 2000 Decadal Survey. GLAST will be an order of magnitude more sensitive than the earlier Compton Gamma Ray Observatory (CGRO), and should discover thousands of new high-energy sources. It will have a major impact on our understanding of the astrophysics of sources that emit high-energy radiation. The primary instrument on GLAST, the Large Area Telescope (LAT), has been built in partnership between DOE and NASA (with four foreign partners). GLAST is the first such major program to be developed in partnership between the two agencies, and the AAAC has been particularly interested in the "lessons-learned" from this project (it has been a key part of the OSTP discussions with the agencies re this question). Given its size, a moderate scale mission, it is a pathfinder for future, similar joint efforts such as the Joint Dark Energy Mission (JDEM). A successful GLAST mission will bring great scientific progress, as well as provide a useful working model for future NASA-DOE partnerships. While GLAST is an NASA-DOE project, the NSF plays a key role through its ground-based facilities (such as the VLBA and the EVLA, as well as the large optical-IR telescopes) that will be used to understand these sources.

LSST and JDEM are two major projects that are undergoing discussion within NSF AST and DOE HEP, and NASA Astrophysics and DOE HEP respectively. LSST was highly ranked in the 2000 Astronomy Decadal Survey, while JDEM has developed in response to CQC and recent science discoveries. At $600-800M lifecycle (JDEM) and $800M lifecycle (LSST; FY06 dollars) both are substantial programs, and are undergoing, or will undergo, the full gamut of reviews as they move towards implementation.

Not all interagency activities necessarily have a golden lining from our perspective. AMS is one such mission. This DOE and international project has a long history, but there is now considerable uncertainty about whether it can be launched by the space shuttle to its home on ISS in the small number of remaining launches, since these are dedicated, with the exception of one mission to HST for SM4, to completing the ISS. One suggestion has been to reconfigure AMS for an expendable launch vehicle (ELV) launch. The NASA Administrator has made it clear that if Congress directs NASA to take such a step, that SMD and Astrophysics in particular would have to provide the hundreds of millions of dollars that such a launch would cost ($0.57-1B, in the recent NASA report to the Appropriations Committee). This would have a devastating impact on an already highly constrained Astrophysics Division budget. This program has not been included in any of the astronomy and astrophysics Decadal Surveys, nor any comparable NRC strategic study, yet the inclusion in the program would do great damage to astronomy priorities. The AAAC feels strongly that an AMS ELV launch should not be funded from the current Astrophysics Division budget. The Committee recommends that Astrophysics Division funds not be used without a strong community consensus that the scientific priority of AMS justifies the cost and loss of other science opportunities. If further developments occur on an ELV launch for AMS, the AAAC would appreciate further discussions with OSTP and with NASA.

The AAAC has been concerned for some time that the Beyond Einstein program has not been able to move forward. The decision to carry out an NRC study through the Beyond Einstein Program Assessment Committee (BEPAC) to identify a mission for a potential funding opportunity ("wedge") was viewed very favorably by the AAAC. The BEPAC study[16] was carried out under the NRC's Board on Physics and Astronomy (BPA) and the Space Studies Board (SSB) by the *Committee on NASA's Beyond Einstein Program: An Architecture for Implementation.* Of particular interest to the AAAC was the decision by DOE HEP to share in the cost of the study. The BEPAC report recommended JDEM as the first mission to be done in the Beyond Einstein program (JDEM is being discussed as a medium-scale, cost-capped, competitively-selected mission at the Einstein Probe scale, or roughly $600M-$800M), and provided additional recommendations regarding the other missions in its review that will feed into the Decadal Survey process.

The AAAC welcomed that discussions had progressed between DOE HEP and NASA Astrophysics to an understanding that: (i) NASA and DOE will work towards a JDEM mission that will be a medium-class strategic mission with a competitively-selected, PI-led dark energy science investigation; (ii) they will partner in the fabrication and operation of instrumentation necessary to execute the science investigation; (iii) DOE's cost for the fabrication and operations phase is estimated at this time to be less than or up to $200M (FY08$), roughly 25% of the expected total lifecycle mission cost; (iv) the current planning schedule has a solicitation (AO) for a JDEM mission that would be released late in FY08 (after a draft in summer) and a particular concept selected in FY09 for conceptual design; and (v) that the planned launch is expected by the middle of the next Decade. These developments were viewed by the AAAC as a very important step in this major inter-agency project. The AAAC hopes that the appropriated budgets for FY09 and beyond can accommodate the timeline being worked by the two agencies.

The AAAC is very encouraged by the interest in cooperation that has developed between DOE HEP, NSF AST and PHY, and NASA Astrophysics, and the interest by OSTP in the joint programs. The Committee recognizes that added interfaces create challenges and place demands on time through added meetings and discussions, but the outcome is already becoming apparent through a more exciting science program.

4.3 National Virtual Observatory (NVO)

A National Virtual Observatory (NVO) effort was recommended as the top-ranked small program by the Decadal Survey. NVO is a joint NASA-NSF program. The NVO will provide a "virtual sky" based on the enormous data sets being created now and on the even larger ones proposed for the future. Its goal is to provide uniform access to numerous astronomical data archives and catalogs, obtained both from ground-based and space-borne telescopes and covering the entire wavelength spectrum from gamma-rays through x-rays, ultraviolet, visible, infrared to radio wavelengths. Such data sets are orders of magnitude larger, more complex, and more homogeneous than in the past. The NVO will maximize the scientific productivity of both existing and new facilities by providing the ability to match and correlate data from such vastly different sources. It empowers astronomers to mine the data archives to maximum benefit. In essence, the NVO will enable new modes of research for professional astronomers, enhancing efficiency for researchers

[16] http://www7.nationalacademies.org/ssb/BeyondEinsteinPublic.html

while also minimizing duplication of observations. It will provide the public an unparalleled opportunity for education and discovery. The NVO can be a great tool for attracting young people into science, given their familiarity with digital data and imagery, and for their education, and that of people of all ages. The 2005 NRC Augustine report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*[17] gave particular emphasis to the importance of developing such interest and enthusiasm for science.

The AAAC was delighted to hear recently that NSF and NASA have created a joint program for implementing and managing the concept of the National Virtual Observatory (NVO) by developing a memorandum of understanding (MOU) for a joint solicitation for establishing the operations and management of NVO. We are particularly grateful to those at the two agencies who shepherded this program through many quagmires. The expectation is that the Virtual Astronomical Observatory (VAO), as it is now called to distinguish it from the development NVO project, will be operated as a distributed center. Proposals for operation of the VAO are expected to come from collaborations and consortia of institutions. The solicitation for the VAO has been released, and the AAAC looks forward to witnessing the ready accessibility of the extensive datasets from missions and projects across astronomy.

The AAAC expects that the capabilities of the VAO will encourage and stimulate more widespread archiving of data by institutions and organizations that are currently not planning to do so, and will be interested to hear about its use to strengthen the O/IR System. The AAAC would also be interested in having discussions develop with DOE regarding their future involvement in the VAO as collaborative projects occur.

4.4 Antarctica and the South Pole

Concerns about communication to the South Pole Station led to discussions in our 2007 report regarding the interactions between NSF (primarily the NSF Office of Polar Programs – OPP) and NASA concerning the communication link using the Tracking and Data Reply Satellite (TDRS). These discussions made us aware of the considerable investment in Polar facilities in areas of interest for the AAAC, and some of the joint NASA-NSF efforts that are being undertaken. NSF manages the U.S. Antarctic Program and provides logistic support for all U.S. scientific operations in Antarctica. One particular area that has seen increasing NSF and NASA activity is the annual scientific balloon campaign during the Antarctic summer. This annual expedition has enabled a wide variety of forefront scientific research in Antarctica. NSF provides the infrastructure and logistics support for NASA balloon launches, while NASA provides the crucial satellite communications link. The scientific returns are enhanced from this agency partnership.

NASA and the National Science Foundation recently achieved a new milestone in conducting scientific observations from balloons by launching and operating three long-duration flights within a single Antarctic summer. This collaboration began in 1989, initially with one balloon launch every other year, turning very soon to every year, then increasing to two launches per Antarctic summer at the end of 1990s. Demanding science and excellent atmospheric conditions over the Antarctica in the austral summer led the two agencies to sign an agreement in 2003 aimed at increasing the launch tempo to three balloons per season. With modest investments but considerable effort by both agencies, this goal has been now achieved.

Unique atmospheric circulation over Antarctica during its summer months allows scientists to launch balloons from a site near McMurdo Station, the NSF's logistics hub in Antarctica, and recover them from nearly the same spot weeks later. During that time, each balloon circles the continent one to three times. Antarctic balloon flights can last much longer than flights in other places because constant daylight means

[17] http://www7.nationalacademies.org/cosepup/

no day-to-night temperature fluctuations on the balloon, which helps it stay at a nearly constant altitude during the flight. The Antarctic atmospheric circulation pattern allows for long and continuous observations of a variety of phenomena from a single instrument at a fraction of the cost of launching a satellite into space, with reusable instrument packages. As an example of the types of projects, the three payloads launched in December 2007 from McMurdo were the University of Maryland's Cosmic Ray Energetics And Mass (CREAM) experiment, the Balloon-borne Experiment with a Superconducting Spectrometer (BESS) developed jointly by NASA's Goddard Space Flight Center, Greenbelt, MD and Japan's High Energy Accelerator Center, Tsukuba, Japan, and the Louisiana State University's Advanced Thin Ionization Calorimeter (ATIC).

The AAAC recognizes the considerable value of these activities for novel science experiments and welcomes the progress that NASA and NSF are making on shared ventures in the Antarctic.

4.5 Lessons-Learned Interagency Study

After discussion at several meetings during 2005, the AAAC sent a letter[18] to the agencies outlining the value of a "lessons-learned" activity that would provide guidance to the agencies, OMB, OSTP and Congress on what problems arose regarding GLAST and how they were dealt with, and whether, in retrospect, different approaches could have been taken that might have minimized some of the problems. We also noted that it would also be valuable to cover other interagency projects, such as the NSF-DOE-Smithsonian Very Energetic Radiation Imaging Telescope Array System (VERITAS), so the experiences of all three agencies in the astrophysics arena could be captured. The AAAC recognized that there is no "one-size-fits-all" approach – the nature of the cooperation on joint projects depends both on the project and the agencies involved – and that it would be valuable if the report could capture how any differences in approach were handled. This is clearly a "living process" in that current and future activities will add to the experience in interagency projects, but it is of considerable value to summarize what has been learned to date.

The AAAC sent a letter in 2006 to the agencies outlining the value of a "lessons-learned" activity on what problems arose regarding the first large-scale interagency activity – GLAST – and how they were dealt with. The AAAC strongly encourages OSTP, working with the agencies, to provide a general summary of the key principles and guidelines from the report. They will be of broad utility for a wider community as interagency projects become much more common.

The letter submitted to the agencies in early 2006 recommended that the agencies undertake the production of a report incorporating the thoughts and experiences regarding process, oversight, coordination, and resolution of technical and fiscal challenges for GLAST and VERITAS (and for other projects, as appropriate, e.g., JDEM, CMB experiments), including the issues involved in international collaborations. Such a report could be used within the agencies and advisory groups such as the AAAC as a guide for future collaborative efforts. OSTP has taken the lead on this and has reported to the AAAC that they have undertaken such an activity. OSTP noted that a report has been prepared that is for internal Executive Branch use and will not be available publicly because of the need for open dialogue during the discussions. The AAAC recognizes that some aspects of "lessons-learned" discussions could be more productive and likely to surface more problem areas if carried out as a "closed" activity.

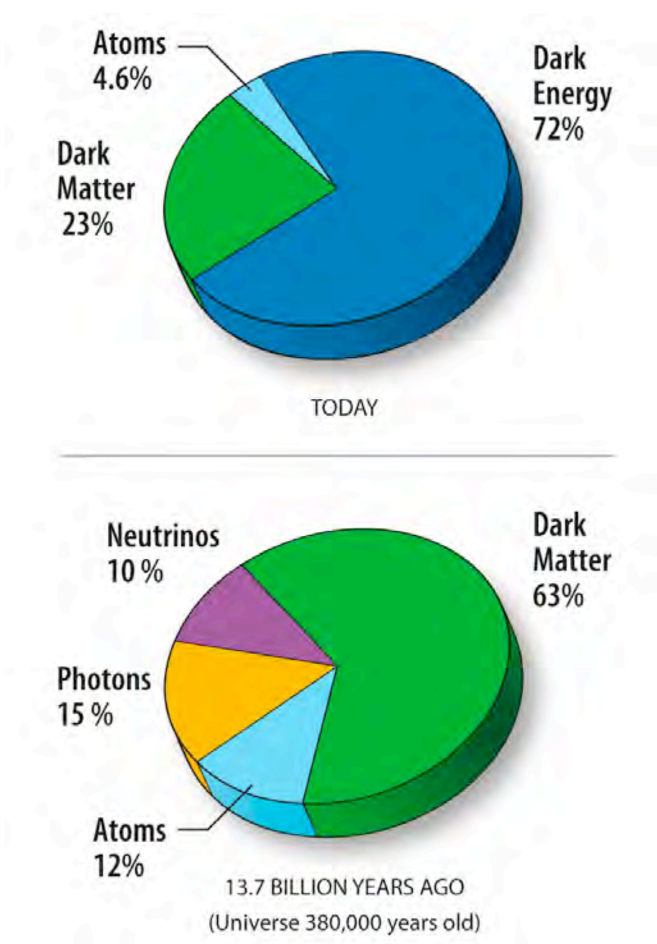
However, there are many issues of a general nature that would be valuable for the science community and for policy makers who are involved with interagency projects to understand. Understanding some of the challenges, timescales, and requirements for a successful interagency project will be efficient and cost-

[18] http://www.nsf.gov/attachments/104203/public/lessonslearned_aaac.pdf

effective for all concerned. In addition, the experience within the agencies is lost with time, particularly as those involved move on to other positions. The AAAC strongly encourages OSTP, working with the agencies, to provide a general summary of key principles and guidelines that will be of broad utility for a wider community as interagency projects become much more common.

4.6 Funding for Committee Meetings

For the life of the AAAC, travel funding for AAAC members to attend its meetings has come from the NSF AST Salaries and Expenses (S&E) account. This has proved to be a major burden for the agency and the AST Division since travel under its S&E account is very often constrained. Last year the AAAC came close to having to cancel a meeting, and was saved by help from the NASA SMD AA's office. The same thing happened this year for the February 2008, and the face-to-face meeting only occurred because the Astrophysics Division at NASA provided travel. The May 2008 meeting may have to be canceled, because of the FY08 budget limits on S&E, at a time when it is particularly important to follow up on issues raised by the AAAC Annual Report. The S&E situation is not expected to improve at NSF. The burden of AAAC travel is disproportionately loaded onto the S&E account at NSF. The AAAC hopes that discussions with other agencies will lead to an equitable sharing of the travel costs in a routine way, and/or that AST be able to fund AAAC under its R&RA account, as it does for proposal and other reviews.



NASA's orbiting satellite Wilkinson Microwave Anisotropy Probe (WMAP) reported on 5 years of data. It has determined the age of the Universe to exquisite accuracy at 13.73 billion years. Today's cosmic soup is only about 5% ordinary atoms, 23% dark matter and 72% dark energy. WMAP showed that when the Universe was only 380,000 years old, neutrinos were much more important, making up 10% of the Universe whereas there was negligible dark energy. WMAP was launched in 2001 and continues to operate.

(Credit: NASA / WMAP Science Team)

Before the first galaxies like the one on page 39 were formed, perhaps there were "dark stars." Researchers supported by DOE and NSF suggest that concentrations of dark matter particles could have been high enough in the early Universe to create stars powered by collisions of particles rather than the nuclear fusion that powers today's stars.

(Credit: NSF, DOE, D.Spolyar, K. Freese, P. Gondolo.)

5.0 DEPARTMENT OF ENERGY OFFICE OF SCIENCE

The AAAC has welcomed the increasing involvement of the Office of High Energy Physics (HEP) of the DOE Office of Science in many exciting aspects of the astronomy and astrophysics research enterprise – dark matter, dark, energy, neutrino detection, high energy gamma rays, the birth of the universe, etc. These fields lie at the boundary of astrophysics and particle physics and promise great insights. We applaud the responses of HEP to the recommendations of the AAAC Task Forces, and the growing collaborations that HEP is developing with NASA Astrophysics and NSF Astronomy.

The AAAC hopes very much that the current budget problems do not impact the growing role of DOE in these frontier research areas. The recent discussions with NASA, resulting from the BEPAC recommendation for JDEM as the first Beyond Einstein mission, towards a solicitation for a jointly-funded JDEM mission was particularly welcomed by the AAAC. The AAAC recommends that the HEP further develop their support for R&D and programs in the areas of dark energy and dark matter, giving particular attention to supporting DETF Stage III projects that provide a framework for the much more expensive Stage IV projects (JDEM and LSST). The AAAC strongly endorses increased support for the dark matter direct detection efforts, and recommends that the DOE and NASA work towards realizing the JDEM mission as BEPAC recommended.

5.1 Context

The U.S. Department of Energy (DOE) Office of High Energy Physics (HEP) in the Office of Science is becoming increasingly involved in research efforts related to astronomy and astrophysics. The AAAC has discussed developments and issues with HEP over the last year and greatly appreciates the involvement of DOE in the Nation's astronomy and astrophysics enterprise. The increasing cooperation of DOE on joint projects with NSF and NASA is viewed very positively by the AAAC. DOE HEP is contributing in significant ways to projects that will explore a variety of cosmological and astrophysical phenomena. These efforts address a number of basic questions of great interest to the astronomical, particle astrophysics and high energy physics communities, with dark energy and dark matter being very visible examples, as highlighted in the *Connecting Quarks with the Cosmos* (CQC) and *Physics of the Universe* (POU) reports.

The report of the National Academy committee EPP2010: Elementary Particle Physics in the 21st Century, *Revealing the Hidden Nature of Space and Time Charting the Course for Elementary Particle Physics*[19], identified three areas of astrophysics that were of particular interest to the particle physics community. The focus of this report was on the Large Hadron Collider (LHC) and the International Linear Collider (ILC) – astrophysics was identified as the next highest recommendation. Within the astrophysics recommendation, the three areas that were singled out were dark matter, CMB research and dark energy. Interestingly the AAAC has worked with HEP (and NSF Physics) in all three of these areas, and several projects are underway or under consideration (see below). The interest and excitement engendered by these topics in the particle physics community is demonstrated by the high fraction (>50% in recent years) of the most-cited papers in particle physics that come from astrophysics and cosmology (source: SPIRES at SLAC). For example, in 2005 and 2006, astrophysics and cosmology papers were 4 of the top 5 and 3 of the top 5, respectively (and 6 of the top 10 in both years, and 24 and 27 out of the top 50, respectively).

[19] http://books.nap.edu/catalog.php?record_id=11641

5.2 Budget and Impacts

The AAAC welcomed the increases for the DOE Office of Science from the American Competitiveness Initiative (ACI) that were initially in the FY07 budget request ($4.1B, or +14% over the FY06 $3.6B), and then also in the FY08 budget request ($4.4B, or +7.2% over the FY07 request). Concerns that the momentum on the ACI increases would be lost were greatly alleviated by the Congressional support for DOE science in the FY07 Joint Resolution, where DOE's Office of Science was one of the few agencies to receive a significant increase (to $3.8B or +5.6%). The AAAC, like the science community broadly, welcomed the initial support for the DOE Office of Science FY08 budget in Congress, but were very concerned at the dramatic change that occurred in the Omnibus Appropriation for FY08 in December 2007.

The appropriated funding for DOE Office of Science increased much less than expected from the FY08 request (a loss of 11.4% relative the FY08 request – and a net gain of only 2.5% relative to the FY07 appropriation). This barely kept up with inflation. However, HEP was particularly impacted, down 12% compared to the FY08 request, and 8.4% *below* the FY07 appropriation. This $63M cut had an immediate large impact on science experiments and personnel, coming as it did well into the fiscal year for HEP (the cuts had to be absorbed within in the remaining 75% of the year, with serious constraints imposed by personnel termination timescales and procedures). The large layoffs at Fermilab and at SLAC were testimony to the impact on HEP.

The appropriated funding for DOE HEP was down 12% compared to the FY08 request, and 8.4% below the FY07 appropriation. This is a great concern since HEP was on a path towards developing a robust program in astrophysics related to some of the most exciting areas of astrophysics related to high energy physics – namely, dark energy, dark matter, neutrinos and high energy gamma rays.

This was a great concern, since HEP was on a path towards developing a robust program in areas of astrophysics related to high energy physics – namely, dark energy, dark matter, neutrinos and high energy gamma rays. These are expanded upon in "Science" below. The AAAC is very concerned that the budget impacts from the FY08 appropriation, particularly if continued through this year into 2009 as part of a continuing resolution, could dramatically weaken the momentum in these exciting areas. The Committee welcomed the increases requested in the FY09 President's budget that would return DOE Office of Science to the "doubling" track (a requested 18.8% increase for DOE Office of Science, and a 16.8% increase for HEP relative to the FY08 appropriation). However, a variety of events might lead to similar problems next year in the FY09 appropriation. The AAAC very strongly recommends that Congress enact the requested increases and returns DOE Office of Science (and particularly, from our perspective, HEP) back to the "doubling" track as espoused by ACI and the 2007 H.R. 2272, *America Creating Opportunities to Meaningfully Promote Excellence in Technology and Science Act* (America COMPETES). We hope that the strong interest within both the Executive and Congress in re-establishing and strengthening the Nation's fundamental research base is reflected in the FY09 appropriation.

5.3 Astrophysics Science Program

The AAAC played a key role in initiating and guiding three activities of interest to the DOE Office of High Energy Physics, namely the Task Force on Cosmic Microwave Background (CMB) Research (TFCR), the Dark Energy Task Force (DETF), and the Dark Matter Scientific Assessment Group (DMSAG). The DETF and the DMSAG grew out of recommendations made by the AAAC. These Task Forces reported jointly to both the AAAC and the High Energy Physics Advisory Panel (HEPAP). The DETF report was accepted and transmitted to the agencies in mid-2006, while the DMSAG report was accepted and transmitted in 2007.

Examples of the projects that DOE HEP has been considering or has begun to undertake with other agencies fall in several areas. DOE is a partner with NASA on the primary instrument for the Gamma-ray Large Area Space Telescope (GLAST). This program is moving forward towards launch in May 2008. In the area of dark energy, DOE is supporting R&D funding for the Supernova Acceleration Probe (SNAP) concept that could be a proposal for the Joint Dark Energy Mission (JDEM). With NSF as the lead, DOE labs are involved in R&D (particularly for the wide-field camera) for pre-conceptual design for the Large Synoptic Survey Telescope (LSST).

The DMSAG report was transmitted to the agencies last summer. The DMSAG report made an excellent case for additional resources for direct detection of dark matter, identifying what could be done for an additional ~$7-8m beyond current expenditures (for a total around $10M). The AAAC heartily endorsed such an increase. The DMSAG report identified substantial gains that could be made through modest increases in an area where the US has exercised leadership. The additional support would make a significant step towards continuing this leading role. The AAAC urges HEP, jointly with NSF Physics, to increase their support for dark matter direct detection experiments.

DOE HEP also jointly shared in the support of the NRC Beyond Einstein study by the Beyond Einstein Program Assessment Committee (BEPAC) that was requested initially by NASA to identify which among a number of potential missions in the Beyond Einstein program (including, for example, the Laser Interferometer Space Antenna (LISA), Constellation-X (Con-X), JDEM, Inflation Probe (CMBPOL) and Black Hole Finder) should be started in the 2009-10 timeframe if funding becomes available. The consideration of JDEM, the DOE-NASA Joint Dark Energy Mission, was of particular interest to DOE. As discussed earlier, the BEPAC report *NASA's Einstein Program: An Architecture for Implementation*[20] was a remarkable document and gave not only a clear recommendation on what should come first (as requested in the charge), but also very carefully analyzed the likely costs so that the "first" mission could be recommended with confidence that the budget under consideration was adequate. The NRC and the BEPAC committee should be applauded for moving this comprehensive study forward very rapidly. They met the goal of releasing the report in time for the fall budget discussions in preparation for the FY09 request budget release. The BEPAC recommendation for NASA and DOE HEP to move ahead on soliciting proposals for a moderate-scale JDEM mission was a welcome clarification of the path forward in the Beyond Einstein program.

The AAAC welcomed that the subsequent discussions between DOE and NASA have led to an understanding that: (i) NASA and DOE will work towards a JDEM mission that will be a medium-class strategic mission with a competitively-selected, PI-led dark energy science investigation; (ii) they will partner in the fabrication and operation of instrumentation necessary to execute the science investigation; (iii) DOE's cost for the fabrication and operations phase is estimated at this time to be less than or up to $200M (FY08$), roughly 25% of the expected total lifecycle mission cost; (iv) the current planning schedule has a solicitation (AO) for a JDEM mission that would be released late in FY08 (after a draft in summer) and a particular concept selected in FY09 for conceptual design; and (v) that the planned launch is expected by the middle of the next Decade. The AAAC views these developments as a very important milestone, and hopes that the appropriated budgets for FY09 and beyond can accommodate the timeline being worked by the two agencies.

The continuing support of HEP for other dark energy programs is very welcome. The ongoing support for SNAP R&D funds has been enhanced by dark energy R&D funds that are being competitively awarded up to ~$4M in the current year. As in the past solicitation in 2007, ground- and space-based concepts could apply for these funds. We applaud HEP for carrying out these two solicitations for dark energy R&D. The DETF report provides guidance for the optimization of near- and intermediate-term activities, as well as for

[20] http://www.nap.edu/catalog.php?record_id=12006

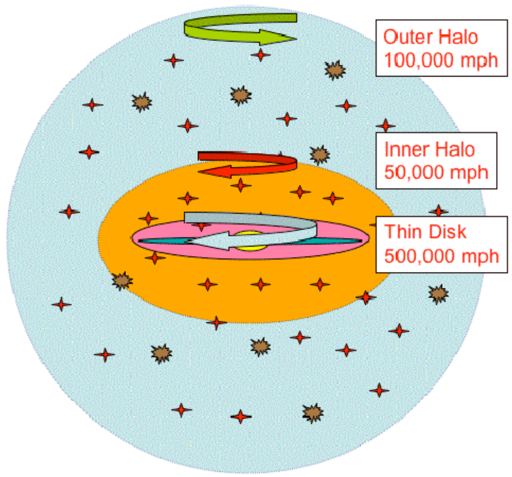
JDEM and a large ground-based telescope, generically identified by the DETF as Large Survey Telescope (LST). The AAAC hopes that DOE, NASA and NSF will work together to utilize the DETF recommendations in their planning and review processes for the near-term for Stage III projects. While LSST is at a preliminary stage at DOE, as noted above, the work being done is a very important aspect of the program.

A key step for LSST and JDEM, and all other aspects of the HEP and related NSF science programs, is the review by HEPAP, through its subcommittee P5, that will report in May on its recommendations for which projects and areas HEP should concentrate on, given a variety of budget scenarios. These areas were outlined in the presentation by HEP Acting Associate Director Dennis Kovar to the AAAC in its February 2008 meeting: Constant effort at the FY 2008 (Omnibus) funding level; Constant effort at the FY 2007 funding level; Doubling of funding starting in FY 2007; Additional funding above the previous level, in priority order, associated with specific activities needed to mount a leadership program that addresses the scientific opportunities identified in the National Academy ("EPP2010") report.

The start of fabrication for the Dark Energy Survey (DES, a project that fits in the DETF Stage III) was welcomed by the AAAC. DES is being considered as a new major item of equipment (MIE). The project is planned as a partnership between DOE and the NSF, which operates the Cerro Tololo Inter-American Observatory (CTIO) 4-m telescope that DES plans to use (following selection through a call for proposals). It also involves international collaborations with the UK, Spain and Brazil. Funding for fabrication is moving ahead following successful scientific and technical readiness reviews by the funding agencies. Fore example, a successful joint NSF/DOE review was held on the camera in Jan 2008. The AAAC welcomes DES as a significant component of the Stage III programs discussed by the DETF.

Many of the programs that have DOE HEP involvement are some of the first examples of major interagency collaborations (e.g., GLAST, VERITAS, JDEM, AUGER, etc), and so they are excellent pathfinders for developing the processes and procedures that will enable enduring and effective joint missions of much larger scale in the future. In 2006 we recommended to the agencies that a "lessons-learned" activity might be a very useful step to take to provide guidance for the future. The agencies and OSTP have done this and produced an internal report. The AAAC applauds this interagency activity, with its OSTP leadership, and hopes that DOE, NSF and NASA can use this effort to strengthen their collaborations. The AAAC remains very interested in the outcome of these discussions and hopes that a synopsis of the broad "lessons-learned" report is made available, even if the full report cannot be made public.

Dark matter is the mysterious substance whose gravity was crucial in forming galaxies like our own Milky Way. Data from the Sloan Digital Sky Survey, an NSF-funded project, show that the Milky Way assembled out of the collisions of smaller galaxies. A remnant of this construction process is seen today in two halos of stars around the Galaxy that rotate in opposite directions. The inner halo formed first from the collision of smaller but massive galaxies that rotated with the Galaxy. It spins clockwise with the Galaxy at 50,000 miles per hour. The outer halo formed later from small galaxies orbiting the Milky Way in the reverse direction. These were torn apart by the Milky Way's gravitational forces, dispersing their stars into the halo. It rotates counterclockwise to the Galaxy at 100,000 miles per hour. (Credit: SDSS-II, Masashi Chiba, Tohoku University)



Ground and space based observatories continue to find astounding new phenomena. Two supernovae, named 2005ap and 2006gy (shown in the picture below), were found to emit at least ten times more energy than ever before seen from a supernova. Observations from Chandra X-ray Observatory in space and the Lick, Hobby-Eberly and Keck Telescopes on the ground show that these enormous explosions probably result from the death of an enormous star, more than a hundred times the size of our own Sun. The earliest stars in the Universe may die in explosions like these. (Credit:NASA, CXC M.Weiss; X-ray: NASA CXC UC Berkeley N.Smith et al.; IR: Lick/UC Berkeley J.Bloom & C.Hansen)

6.0 NATIONAL SCIENCE FOUNDATION

The NSF plays a central and unique role in the Nation's science enterprise. The agency provides resources for basic research that allows innovative, rapid and timely developments to be initiated from within the science community through a peer review process geared to excellence. Such programs can lead to rapid progress on key topics. Astronomy and astrophysics share in this approach to research and have been major contributors to broadening the public's engagement in science.

Astronomical explorations using ground-based telescopes have yielded some of the most exciting discoveries in astronomy and physics in recent times. These include, among others: the discovery of the existence of a mysterious dark energy in the universe; detection of the fluctuation spectrum of the remnant cosmic microwave background radiation which revealed the seeds of all cosmic structure formation; the discovery of extra-solar planets; the mapping of the large-scale structure of the universe; the discovery of the Kuiper Belt region of the solar system; and the determination of the interior structure of the Sun from the seismic study of its internal sound waves. Many of these results have benefited from support from both NASA and NSF, exemplifying the benefit to astronomy and astrophysics of the support by both agencies. We expect that collaborative efforts between NSF and DOE will also grow, and play an important role, as have the physics programs within the NSF Directorate for Mathematical and Physical Sciences (MPS) and the DOE Office of Science. However, NSF primarily through its AST Division will remain at the heart of a broad, ground-based program in astronomy and astrophysics.

6.1 Budget Opportunities and Challenges – ACI and America COMPETES

The AAAC was greatly encouraged, as was the research community across the nation, at the foresight shown by the Administration and Congress in supporting an effort to "double the budget" of the NSF in the 2002 Authorization Act. The lack of any progress on the doubling for several years was disappointing, but we were encouraged when the American Competitiveness Initiative (ACI) was announced with its emphasis on the importance of the physical sciences.

Putting the NSF budget back on a track for significant growth is a key step in meeting the goals of ACI. The FY07 Joint Funding Resolution contained essentially the whole ACI increase for NSF. The 7% increase in FY07 from Congress was a major step forward towards realizing a doubling of the NSF research budget. The AAAC was very encouraged by the subsequent ACI increase of 7.7% for research for NSF in the FY08 budget request. The FY08 Omnibus appropriation was, however, a grave disappointment with the NSF receiving essentially no new funds (less than inflation). This was most unexpected, given the support for NSF budget growth within both the Executive (ACI) and the Congress (America COMPETES). The FY09 President's request puts NSF back on a growth track and, if enacted, would rectify the disappointing FY08 appropriation. For NSF it is 13.0% overall, or 16.0% for Research and Related Activities, relative to the FY08 appropriation. The goal of returning to the "doubling" track is welcome. For NSF Astronomy (AST) the requested increase is 14.8%. However, a Continuing Resolution for FY09, based on the FY08 appropriation, would further exacerbate the difficulties faced by the agency and its research facilities and researchers in dealing with dramatic fluctuations in the budget. We hope that Congressional action of the FY09 budget reflects the FY09 requested increase and moves the NSF further along the path to a substantially larger research budget, as both the Executive and Congressional have supported to date.

Given the enthusiasm for astronomy among the public at large and the role that astronomy plays in science education, its linkage with many of the goals of ACI and America COMPETES seems obvious to the astronomy community. Discussions with MPS Associate Director Tony Chan and AST Director Wayne van Citters at a recent AAAC meeting led to the collective interest in finding ways to make these anecdotal views more tangible and quantitative. The technology areas where astronomy is pushing the frontiers are numerous. The AAAC felt that further discussion and more detailed analysis of the activities supported by AST through grants and through the national observatories will help to quantify the impact that astronomy has had in areas relevant to ACI and America COMPETES[21]. The AAAC would be interested in further discussion in our May 2008 meeting leading to a plan of action that would demonstrate more clearly the value of astronomy research for the goals of ACI and America COMPETES.

Given the enthusiasm for astronomy among the public and the role that astronomy plays in science education, astronomy's linkage with many of the goals of ACI and America COMPETES seems obvious. MREFC facility projects, like those in astronomy, also develop the commercially-valuable skill sets desired by ACI and America COMPETES for scientists and engineers, and do so in unique areas (e.g., robust technologies, data acquisition techniques, system engineering and project management), distinct from those acquired in small scale academic research programs.

6.2 Major Projects and MREFC

The NSF plays a central role in supporting a diverse program of university-based research programs. Increasingly, however, these university-based research programs are dependent on research facilities, many of which are major facilities developed within the MREFC program. Such major projects, initiated from within the Divisions, are becoming increasingly common within NSF as the need for more sophisticated and capable research tools arise. The number of such projects has raised concerns within the NSF, but this is a reflection of the evolving nature of research in many fields, and needs to become a more integral part of the NSF's focus. Support of such facilities, and the resulting research, should be viewed by the NSF as an integral part of its mission. From the perspective of ACI and America COMPETES the skill sets developed for major projects in the areas of robust technologies, data acquisition in challenging environments, system engineering and project management are arguably at least as important for development of a robust industrial base in the nation as small scale research programs.

Astronomy has traditionally relied heavily on major facilities. An example is the extremely powerful Atacama Large Millimeter Array (ALMA). This is a central element of the current program of the Division of Astronomical Sciences (AST). The AAAC appreciates the efforts within MPS and in AST that have kept this important project on track over the last few years. As expressed in a letter[22] to the NSF Director and Deputy Director in 2006, the AAAC greatly appreciated the decision of the NSF Director's Office to support the revised plan and budget for ALMA. The continuing discussion regarding ways to strengthen the Major Research Equipment and Facilities Construction (MREFC) process to minimize unexpected cost growth in major projects is very welcome. Over the last several years the AAAC has been particularly interested in

[21] For example, the software developed to create radio images from complex synthesized radio apertures, such as the VLA and the VLBA, has been adopted for medical, geophysical, and meteorological applications. The software used to construct images made with CAT and MRI imaging devices are older derivatives of this methodology. New medical applications include detection of cancers and other infections, and also real-time monitoring of the effects of hyperthermia on the surrounding tissue. Measuring plate motions in very remote regions of the Earth is an additional application. Another example is the use of astronomical photometry software to provide precise identification of single molecules tagged with nanoprobes designed to bind with a certain type of cell or molecule. This technology enables a key step to truly personalized and predictive medicine, as well as more complex biomolecular structural mapping.

[22] http://www.nsf.gov/attachments/106804/public/alma_aaac.pdf

changes and improvements under discussion for the MREFC activity. This reflects the growing significance of major facility projects for pushing the frontiers of knowledge in astronomy (and not just astronomy). The MREFC process remains complex, with many of the steps and processes lacking clarity. The lack of a clear strategic or facility plan for MREFC projects within the NSF is also a concern (see below). The AAAC has commented on many aspects of MREFC. For clarity and continuity in this discussion re NSF and AST, we have moved the section detailing our thinking on MREFC to an Appendix (A3). That discussion provides the background to the comments that remain in the main body of this report.

6.2.1 "Lifecycle" Costing

The importance of developing a "lifecycle" approach to project conceptual development through construction to operations to decommissioning becomes particularly important as the scale of projects increases. Lifecycle costing involves an end-to-end funding profile for large initiatives that includes both Division- and agency-level contributions during all project lifecycle phases. Attention to these would: expedite the later phases of the design and development process; lower the risk of cost growth; achieve science goals more reliably and quickly; and reduce serious impacts on ongoing research infrastructure within the discipline, including human resources. Consideration of the lifecycle costs for ALMA, and the subsequent estimates of the operations costs, became one of the motivating factors for the Senior Review. The AAAC urges the routine use of lifecycle costing for major projects.

Lifecycle budgeting was addressed in the 2003 NSB report, *Science and Engineering Infrastructure for the 21st Century*[23], (NSB 02-190) from the Committee on Programs and Plans Task Force on Science and Engineering Infrastructure. Under their Recommendation (4): "Strengthen the infrastructure planning and budgeting process through the following actions," they note in item (3): "Develop and implement budgets for infrastructure projects that include the total costs to be incurred over the entire life-cycle of the project, including research, planning, design, construction, commissioning, maintenance, operations, and, to the extent possible, research funding."

One aspect of lifecycle costing deserves particular attention – operations. The importance of careful evaluation of the needed funding level of operations *vs.* science return during the operations period cannot be overstated. Both science operations and upgrades (e.g., new instruments) are key factors during this period. It is this last phase wherein all the cost is "recovered" through science output. Inefficiencies at this time are not cost-effective since they can jeopardize the substantial investments that have been made. A growing concern for major projects is the support of operations, maintenance, and upgrades (e.g., new instrumentation). For example, a $1B project with a typical 10% annual budget for operations, maintenance and upgrades would alone consume ~50% of the AST budget. The need for additional operations funding for these next-generation facilities, in addition to the savings realized from closing or reducing operations of current facility operations in AST, should be considered as future budgets are developed for MPS and AST.

6.2.2 ATST and Design and Development Funding within MREFC

The declaration in 2007 by the NSB that the Advanced Technology Solar Telescope (ATST), a highly-ranked medium project in the Decadal Survey, was ready for inclusion within MREFC was welcome news. Given some remaining issues and activities (Final EIS) with regard to the site at Haleakala on Maui, the project was not designated for a New Start within MREFC. However, it was designated for $2.5M of Design and Development (D&D) funds within the MREFC account. The utilization of this new component of the MREFC (D&D) was seen by the AAAC as a positive step, consistent with one of our recommendations from the last two reports, that, as appropriate, funding be available for late-stage, pre-construction development work so that an upcoming MREFC project is optimally positioned to move into

[23] http://www.nsf.gov/nsb/documents/2002/nsb02190/nsb02190.pdf

construction with minimal risk of technical and schedule problems that could lead to unwelcome and unexpected cost growth. While the identification of D&D funds within MREFC was positive, the elimination of an equivalent amount from the AST budget poses risks for the AST budget in future, and was not consistent with the intent of our recommendation.

6.2.3 Ordering of Projects and Linkage to Strategic Plans

An important issue that has arisen over the years in AAAC discussions concerns the ordering of major facility projects. Other committees have expressed similar concerns. The acceptance of proposals by the NSF for major facilities without consideration for Decadal Survey priorities is a concern that has been expressed by the Senior Review, by CAA, and by the AAAC. The MREFC timescale is now so long that projects entering the MREFC process may take many years before a New Start, and in so doing, can potentially limit the access for other projects. For example, for ATST the lag from Readiness to New Start will be at ~5 years, though this project has been a pathfinder for the revised MREFC process. The usual approach at NSF has been to accept proposals on a first-come, first-served basis. Such an approach, especially given these long time-scales, can distort a Decadal Survey's priorities. An example of this arose 2-3 years ago about half-way through the decade when the previous Decadal Survey's priorities were clearly the baseline. This issue related to the ordering of GSMT and LSST at that time. It was a particular concern for the optical/infrared ground-based astronomy long-range planning group (the OIR Long Range Planning Committee, OIR-LRPC) that was formed to provide input to the Senior Review in 2005. The issues surrounding the sequencing of proposals were discussed in the OIR-LRPC report, *Strategies for Evolution of U.S. Optical/Infrared Facilities*[24]. The group noted that, as one of its findings and associated recommendations, when discussing the (generic) Large Survey Telescope (LST) and the Giant Segmented Mirror Telescope (GSMT) "any LST construction proposal should trigger an evaluation of its impact on the first-ranked project, GSMT. This should be assessed with community input. Public access to scientifically useful data products should be an important criterion." The Senior Review committee also recognized this issue and noted: "The sequencing of GSMT and LST is also a critical issue for AST, as recognized by the [OIR-LRPC]."

While these discussions have pertained to the specific question of GSMT and LSST (generically identified as LST), the general principle applies of developing a broadly-based strategic plan and then maintaining Decadal priorities. It is worthwhile noting that LSST also was recommended in CQC, but unfortunately the lack of project prioritization in CQC, combined with the lack of subsequent "merging" of the recommendations of the Decadal and CQC through an NRC process, left the only clear relative priorities as those in the 2000 Decadal. Such problems will be minimized in future since, in their discussions with the AAAC, the NRC and CAA co-Chairs have indicated that the upcoming 2010 Decadal Survey will be much more inclusive of the broader physics/astrophysics community. The concerns that have been expressed by the Senior Review, by CAA, and by the AAAC with regard to Decadal priorities would be alleviated by procedures for proposal acceptance that are more sensitive to community priorities, and allow for a go/no-go acceptance decision before a lower priority program is accepted.

6.2.4 Facility Plan

One other aspect of the overall process has been highlighted by the AAAC. A Facility Plan outlines the expected timelines for projects, their phasing and timescales and their milestones. It is a rather detailed planning tool, which at any time is an important guiding document, but is also updated periodically to accommodate changes driven by funding and/or technical issues. It is akin to the Strategic plans developed by other Research agencies where major projects constitute a significant component of their activities. It is an essential component of programs such as MREFC. Such a plan provides guidance for the agency and all

[24] http://www.noao.edu/dir/lrplan/lrp-committee.html

stakeholders. Concerns about the rigidity of such plans can be alleviated by periodic reassessment so that the plan is responsive to changing circumstances. Together, the process and Facility Plan should ensure that all stakeholders understand the status, timescale and progress of large projects. The process should also provide opportunities for negotiation with potential international, multi-agency or private partners. Such complexities have become the norm for major astronomy projects, and recognition is needed that procedures and timelines should allow private and/or international partnerships to be folded into the planning and approval processes.

The AAAC supports the broad direction outlined in NSB 05-77 (Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation), though several questions and possible concerns remain. The AAAC was encouraged to see that a Facility Plan was developed, though it remains incomplete in that it does not show likely timelines, phasing and key milestones for each project, nor does it give a sense of what projects may be on the "horizon" within the Divisions, as is done for plans at other agencies where large projects are undertaken. Well-understood timescales and milestones are particularly important for the MREFC process. Projects such a LSST and GSMT that have significant components of private and/or international funding need a clear timeline if they are to progress without disruption and without undue financial impacts at critical times if unexpected delays occur. The value of the Facility Plan (like NSF0824) to current and potential MREFC projects would benefit from the inclusion of these elements. The AAAC hopes that the next version of the Facility Plan is more complete in these areas, and will provide a better sense of the both the near-term and long-term status of projects at various stages, from the Horizon stage, to the Concept stage, to Development, and thence into Readiness.

6.3 AST Senior Review

The Senior Review was undertaken in response to an increasing awareness within the NSF Division of Astronomical Sciences (AST) that it faces significant challenges in moving forward on the many high-priority projects advocated by the Decadal Survey and the Connecting Quarks with the Cosmos (CQC) report. The AAAC is very encouraged by the steps underway within AST to respond to both evolving circumstances and the need for structural changes. The Decadal Survey specifically recommended that NSF AST conduct a "competitive review of NSF astronomy facilities and organizations…about every 5 years." The Senior Review is such an evaluation, and the AAAC commends AST for its successful implementation of this important Decadal Survey recommendation, and its service to the community in carrying out a thorough community-based review process.

The AAAC was very impressed with both the extensive effort undertaken by the Senior Review committee and the thought that went into the very difficult recommendations regarding facility and telescope restructuring and closures. The very broad nature of the Senior Review, essentially dealing with the full portfolio of AST programs and facilities, distinguished it from the more mission-focused Senior Reviews that are undertaken at NASA. As such, it was a very different activity, more akin to a "portfolio" review, and therefore impacted a very broad segment of the astronomical community.

The Senior Review was designed to evaluate the distribution of funding within the Divisional portfolio and to identify strategies a) to begin to provide for the U.S. share of operations funding for ALMA, b) to free up funding within the budget of AST that can be used for design and development funding for high-priority Decadal Survey and CQC projects such as the GSMT and LSST, and c) to identify potential reinvestment in the highest priority existing programs in AST. With every aspect of the current AST program on the table, with the exception of agency-mandated programs and grants to individual researchers, the Senior Review process was initiated with clarity and simplicity. Another key aspect of this process was to identify ways to improve the operational efficiency of the current AST-operated facilities. Considerations of improving the cost-effectiveness of the ongoing research program resonate with the AAAC.

The effort that AST put into holding many "town hall" discussions with the community both before and after the Senior Review was greatly appreciated and was a key element in making the Senior Review a successful and widely accepted process. The AAAC has expressed its strong support for the Senior Review[25] and was very impressed with the care and thought that went into the recommendations regarding the difficult issues of facility re-alignment and closure. The AAAC expects that the Senior Review and its implementation by NSF-AST will position AST for optimizing the program of new and current facilities over the next decade. The role and vitality of all major research facilities operated by AST should be carefully reviewed each decade, possibly timed to precede and inform an upcoming Decadal Survey for their deliberations on the future program.

6.3.1 Senior Review Implementation

The very positive perception generated within NSF by the AST Senior Review has, however, become diluted by the pressures that are being applied through Congress and by letters that go directly to the NSF Director. This greatly undercuts the broad community planning efforts that have given us a reputation as developing an orderly strategic process and for utilizing science-based reviews. A reputation for responsible planning and prioritizing takes years to develop, but only a little time and self-interest to destroy. Moreover, it is important for the coherence of the community and the robustness of its strategic processes that the recommendations of the Senior Review be protected from unexpected earmarks and directives imposed as a result of special petitioning outside the science community's processes.

The Senior Review was a major step that was needed to allow AST to move forward to the very powerful new facilities that are now being constructed or planned for construction. The political and fiscal support needed for the new facilities will be helped by the Senior Review recommendations, but the MREFC investments in major facilities like ALMA, ATST, GSMT and LSST will need substantial operations funds to realize their full potential. The AAAC recommends that the need for added funding for facility operations in AST, as noted above, should be considered as future budgets are developed for MPS and AST.

The AAAC has discussed the Senior Review and reviewed some of the issues that have arisen. While the 14.5% requested increase in the AST budget in FY09 is very positive, the demands on AST resources over the next 5-7 years exceed likely increases. *We fully concur with AST that, even within a growing budget, the cuts recommended by the Senior Review and AST are necessary.* Use of MREFC funds cannot "fix" this problem – they are for construction only. Operations funds come from the AST budget. AST's focus must of necessity change to reflect the needs of these new, powerful and very expensive facilities. A robust program of support for the majority of our current facilities, combined with the operations funding needed for our new and immensely more powerful facilities (e.g., ALMA, EVLA, ATST, LSST, GSMT, etc.), mandate cuts in funding for some current facilities if we are to make a credible case for new funding! Failure to understand this, with complaints to the NSF Director and with efforts to obtain earmarks or direction within Congress, do an immense amount of damage to the credibility of our strategic processes and to our credibility as a community.

6.3.2 Senior Review Recommendations I – Revised Operation Models for Facilities

The Senior Review recommended major changes to the operation of several facilities, the Very Long Baseline Array (VLBA), the Global Oscillation Network Group (GONG), and the Arecibo Observatory (of the National Astronomy and Ionosphere Center, NAIC). If no funds were found from other sources the Senior Review recommended closure. Such recommendations are not made lightly. All these facilities are producing scientific results. Nonetheless, as is widely understood, when budgets are limited, choices have to

[25] http://www.nsf.gov/attachments/103158/public/ast_senior_review-aaac.pdf

be made, especially if the community is to move forward to new science opportunities through the development of new capabilities. Ultimately, closing some facilities is the painful but needed approach, if other appropriate avenues have been explored.

As the Senior Review recommended, other avenues are being investigated. The Senior Review explicitly recommended that the affected facilities explore other funding options. From the discussions with AST, the AAAC feels that substantial effort is being made, with AST help, by the facilities to find alternative support. The combination of individual and organization efforts, along with AST efforts at the government and international level has the potential to be very productive. In particular, NRAO is actively working to look for partners for the VLBA, GONG will remain in operation to overlap with Solar Dynamics Observatory (SDO), with some possibility for longer term partners, while Arecibo is potentially well-placed for partnerships within Puerto Rico and other options within NSF, particularly with the Division of Atmospheric Sciences (ATM) who, we understand, have been briefed throughout this process.

For Arecibo, the possibility of partnerships with the government, universities and businesses within Puerto Rico is a very exciting development. It would be an outstanding solution in terms of local involvement. It is therefore particularly disturbing and counter-productive that individuals have been pushing to have Congressional direction for NSF to continue funding Arecibo. This will likely not lead to a robust solution for Arecibo, causes great problems within NSF for AST, and can disrupt serious efforts to find a viable long-term solution (Congressional direction from appropriations is, by its very nature, year-to-year; the long term budgeting remains within the agency and OMB).

6.3.3 Senior Review Recommendations II – NOAO and GEMINI

The lack of a clear focus for the US national optical-infrared effort is hurting the competitiveness of the US in this area. The contrast with the focus and clarity and capabilities of the European national effort at the European Southern Observatory (ESO) is becoming obvious. Our leadership in optical-infrared astronomy at the national level is slipping away, and the lack of clarity of the role and goals for our national observatories is a major problem. The US optical-infrared system overall is still the most capable of those that exist worldwide, but its lead is diminishing. The two major components of the optical-infrared Federal program, the National Optical Astronomy Observatory (NOAO) and the Gemini Observatory, were evaluated thoroughly by the Senior Review.

First, the Senior Review questioned the increasing focus at NOAO on future facilities like GSMT and LSST. The Senior Review recommended that NOAO refocus its efforts in significant part on current facilities to rebalance the observatory's activities. There is a clear rationale to a balanced approach that allows for scientific return from current telescopes, while also responding to the need for national involvement in the future major projects arising from the Decadal Survey. Finding the right balance will be a challenge within a constrained budget, however. NOAO appears to have taken the recommendations of the Senior Review to heart and is evaluating how to most effectively respond to the many demands being placed on it. Further input will come from recently-released reports such as that from the *Renewing Small Telescopes for Astronomical Research* (ReSTAR) committee, and the planned committee that will give consideration to the role of larger telescopes. The AAAC hopes that the considerable effort undertaken by NOAO and AURA since the Senior Review report to refocus NOAO and find an appropriate balance between the base program and the longer-term mission is recognized by the Decadal Survey and that a more stable future entails.

The second Senior Review recommendation (on the "optical-infrared transition program") dealt with issues pertaining to Gemini and the other Decadal-Survey recommended projects such as GSMT and LSST. The Senior Review was concerned about the high cost and efficiency of the Gemini operation, and they noted: "Decisions on new Gemini instrumentation and negotiations for operation beyond 2012 should be guided by a comparison with the cost, performance, and plans of other large optical telescope." While recent metrics of publications per telescope have shown that Gemini is at parity with other 8-m class telescopes, there is a perception within significant sections of the US community that Gemini is not yet playing in the same league as the ESO VLT, Keck and Subaru. This perception impacts Gemini and the effectiveness of our national optical-infrared program.

One clear anomaly, which has a historical basis, is the separation that occurred between the Gemini Observatory and NOAO. While the rationale for this may have been necessary in the past, it would be useful for the astronomical community to consider the efficiencies and scientific synergies that could be gained from developing a much closer linkage between Gemini and NOAO's facilities. Coherent planning across these facilities, within the context of a national optical-infrared observatory, would minimize overhead and optimize limited resources.

It is clear that any change in the structure would have to be developed carefully with the involvement of NSF-AST, and with the understanding and agreement of our international partners, but it would be useful to see this as a clear goal for optimizing the scientific return on AST's investment, cognizant of the 2012 Gemini renegotiation timeframe (and possibly sooner if the UK has further budget problems). The Decadal Survey and its panels could play a very useful role in laying out what the US astronomical community wants its national optical-infrared facilities to do, and how they might best meet those objectives. A larger role (share) in Gemini for the US might facilitate the development of a stronger national capability in optical-infrared astronomy. Developing a clear picture of what we want from our national facilities would help us in the negotiations with our international partners, and it will also help our partners if we come to the table with a clear vision of what we want. The AAAC recommends that AST initiate discussions within the community, possibly within the context of the upcoming Decadal Survey, that will lead to a more integrated framework for the US optical-infrared national observatories.

6.4 Mid-Scale Instrumentation

The astronomical community depends upon NSF AST for funding to build the next generation of instruments for its telescopes. The current programs within AST are not well structured to either meet the needs of 8-meter-class telescope instrumentation, nor the needs of proposed larger telescopes (e.g., GSMT) where instruments may cost tens of millions of dollars. Funds to support construction of instruments that reap the full benefit of large telescopes sometimes come from private donors, but the NSF role is becoming increasingly important as the instrument cost increases. An attractive funding instrument is the Major Research Instrumentation (MRI) program, but this program is currently capped at $4M, well below the total cost of the types of spectrographs and cameras needed to pursue frontline work in areas such as large-scale structure and star formation, which benefit from large fields of view and high sensitivity. The DETF report highlighted the need for projects and instruments for Stage III work to investigate dark energy. Many of the projects under consideration for these dark energy Stage III activities will exceed this limit, too. A program that fills the niche between the current MRI program and the much larger MREFC program is required – a need which cannot be met by AST's Division-level instrumentation program, in which one 8-meter class telescope instrument would use more than the entire funding line. An MRI cap around $10-20M would be much more appropriate for the scale of projects in astrophysics, and would provide an intermediate scale below the $100M entry-level for MREFC.

The concern expressed here is not new, nor unique to astronomy and astrophysics. The February 2003 NSB report (NSB 02-190), *Science and Engineering Infrastructure for the 21st Century*[26], discusses mid-scale instrumentation. Their recommendation 2 is: "Give special emphasis to the following four categories of infrastructure needs: Increase research to advance instrument technology and build next-generation

[26] http://www.nsf.gov/nsb/documents/2002/nsb02190/nsb02190.pdf

observational, communications, data analysis and interpretation, and other computational tools; Address the increased need for midsize infrastructure; Increase support for large facility projects; Develop and deploy an advanced cyber-infrastructure to enable new S&E in the 21st century." The AAAC concurs with this recommendation and further had previously recommended that AST and MPS give added consideration and visibility to mid-scale instrumentation funding, as it is becoming an increasing critical aspect of the research framework for astronomy and astrophysics.

A key aspect of such instruments, and particularly major research instruments, is the need for a diverse group of experts. Technically skilled instrument designers and engineers, particularly in the era of very large facilities, are central to this challenging task. Unfortunately, a new NSF AST program to support the training of the next generation of astronomical instrument builders, and which was planned to start in 2008, was cancelled due to the loss of the FY08 request budgetary increases for NSF. The need is large for instrumentally-trained scientists and the impact of the delayed start of such an essential program will be felt for many years.

The AAAC was happy to see that AST is trying to find ways to identify funding for a mid-scale funding program for instrumentation, projects and infrastructure. This is highly responsive to community concerns and needs, and resonates strongly with the AAAC since each of its Task Forces have identified high-priority projects that would fall into such a category. The AAAC was disappointed to see that this very worthy initiative was greatly impacted by the FY08 Omnibus appropriation, and hopes that the increases in the FY09 request come to pass through the FY09 appropriation, thereby allowing this very valuable program to move forward.

Funding for a mid-scale funding program for instrumentation, projects and infrastructure is crucial for maximizing the science return from major facilities, and for initiating projects recommended by the AAAC Task Forces. The AAAC was very disappointed that this initiative had to be deferred as a result of the FY08 Omnibus appropriation, and recommends that it be funded in FY09.

6.5 Status of AST MREFC Projects

A major consideration for the AAAC concerns the timing of the large Decadal Survey projects that are under construction or under consideration for construction during this decade: the Atacama Large Millimeter Array (ALMA – a top priority of the 1990 Decadal survey) is currently under construction, while the Advanced Technology Solar Telescope (ATST) is in the MREFC Readiness Phase. A number of other projects remain at various stages of development, including the Giant Segmented Mirror Telescope (GSMT), a major upgrade to the Very Large Array (EVLA), and a Large Synoptic Survey Telescope (LSST). GSMT is the top-ranked ground-based project in the 2000 Decadal Survey; EVLA is the highest-ranked large radio project; and LSST is identified both in the Decadal Survey and CQC/Physics of the Universe. The EVLA upgrade is in progress with completion expected in 2010. ATST is likely to progress soon to a New Start soon within MREFC, but GSMT and LSST should be discussed within the context of the upcoming 2010 Decadal Survey since neither has started construction.

Progress on these projects is driven not only by Decadal Survey priorities, but also by technical readiness and funding scenarios that involve interagency activities, international partnerships or non-Federal private funding sources. The lifecycle cost issues, including the particular challenges of operations funding, also become especially significant with some of these large projects. Because NSF PHY and AST are gaining significant experience in dealing with large facility projects, it would be useful to discuss that experience and link it to some of the issues and questions raised with regard to the MREFC processes discussed above. The status of the individual projects, and of the processes associated with MREFC, are a key interest for the AAAC, and further discussion during this coming year would be valuable.

6.5.1 ALMA

ALMA, which is currently under construction, is a very high-priority program for the astrophysics community. We appreciate the continuing support of the NSF Director and the MPS Assistant Director for this impact project. The AAAC is looking forward to the first data from this important project, and its development into a facility that is readily accessible for a diverse range of research projects to researchers from across the astronomical community through its US-based science operations center. The largest projects that the astronomical community has dealt with to date have been space-based observatories like HST, Chandra and Spitzer, and the accessibility of the data from these missions should be a guide for ALMA.

6.5.2 ATST

ATST is a major astronomy project with a projected construction budget of ~$250M. Recent AAAC reports have noted that the Decadal Survey and the NAS study *The Sun to the Earth and Beyond*[27] gave strong emphasis to understanding the development of solar magnetic fields in space and time and to understanding how magnetic fields power flares and eruptive activity. Contemporaneous observations from the ground-based Advanced Technology Solar Telescope (ATST) and the space-based Solar Dynamics Observatory (SDO) would play a major role in meeting this scientific goal, but such overlap will not occur for many years. The AAAC applauds the progress that has been made on this important program and greatly appreciates the support from the NSF Director's Office in moving ATST forward. The declaration in 2007 by the NSB that the Advanced Technology Solar Telescope (ATST) was ready for inclusion within MREFC was very welcome news. This project is a powerful scientific facility ((see e.g., http://atst.nso.edu/science/), and was a medium scale recommendation as a $60M project (2000 dollars) from the 2000 Decadal Survey, and meets one of the goals laid out by the Senior Review, namely the focus of activities on new, more powerful facilities.

The AAAC has been disappointed by the lack of interest in the international community in forming partnerships to offset some of the cost of this major $252M program (over $400M in current dollars for lifecycle cost), but remains hopeful that some collaborations can be developed that will offset the construction cost and/or will contribute towards the ~$15M operations cost. Given the challenges of dealing with environmental and other issues at its Haleakala, ATST was not moved into a New Start in the FY09 budget request, as we had hoped in the 2007 AAAC report. However, there were two very positive aspects for ATST in the FY09 budget. First, ATST was explicitly identified within the MREFC account funding. Second, the identification of a new Design and Development component of the MREFC account for development at the crucial pre-construction phase on the program was an aspect of MREFC that had been advocated by the AAAC.

We have recommended in previous years (see above and Appendix A3) that the funding profile in MREFC include funds for projects to enhance their development in the critical year or two before construction begins to ensure that the project is mature technically and managerially, and that its costs are well understood before the funding level increase dramatically during construction. The AAAC appreciates these implementation of the D&D line. Unfortunately, the funding for the D&D line in MREFC was removed from AST's NSO budget, eliminating flexibility, and decreasing the long-term AST budget. This was not the goal of our recommendations regarding pre-construction D&D funding! In addition, we hope that in the likely event of a Continuing Resolution this year that the NSF can find ways to deal with maintaining the ATST project team as they work towards a New Start.

---

[27] http://www.nap.edu/catalog.php?record_id=10477

We understand that Final Environmental Impact Statement (FEIS) for ATST on Haleakala is being worked towards a likely late-spring publication. Based on that FEIS, the NSF will issue a record of decision. The AAAC hopes this leads to a positive outcome. A number of other steps remain, most of which involve negotiations and discussions, with groups and organizations in Hawaii. A key step in the final stages is the application for Conservation District Use Permit, which would allow construction to start. This aspect of the process likely will take 6 months. The AAAC is very supportive of this process moving forward expeditiously so as to allow construction to start on ATST. Where negotiations need to occur within the Executive Branch (for the FAA and the National Park Service), the AAAC encourages OSTP to help where it can in expediting those discussions. The budget impacts of a drawn-out process are significant. The AAAC is highly supportive of moving this project forward so that construction can begin.

6.5.3 LSST

LSST is a major ground-based 8-meter telescope project, whose goal is a deep survey of the sky accessible from Northern Chile. LSST was the third-highest-ranked large ground-based project (with estimated construction cost of $170M in 2000 dollars) in the Decadal Survey and would be a unique resource of data for the science community. LSST has an extremely broad range of exciting science goals, including deep galaxy surveys, measurement of dark matter and dark energy, time- resolved surveys, mapping of the Galaxy, and detection of Near Earth Asteroids and other Solar System objects. A central aspect of LSST is the rapid availability of data through a publicly-accessible archive of science-ready data products. The AAAC received a detailed presentation on LSST in fall 2006 from LSST Director Tony Tyson that was subsequently updated to reflect the project status when the proposal was submitted. The AAAC recognizes that the scientific case for LSST is very broad and very strong, and views LSST as a very exciting scientific project.

The LSST consortium submitted a construction proposal to NSF in February 2007 that is under review within the NSF AST. The project is making significant progress. The CoDR (conceptual design review) was completed in the late 2007. The primary mirror (with its embedded tertiary) will be cast in March 2008 at the Steward Mirror Lab. While NSF is the lead, this major project is a joint effort with the DOE Office of High Energy Physics (HEP). The DOE labs are involved in R&D (particularly for the wide-field camera) for pre-conceptual design. A key step for LSST in moving beyond the pre-conceptual phase at DOE is the review by P5 (a HEPAP subpanel) that will report in May on its recommendations for those projects and areas that HEP should concentrate on, given a variety of budget scenarios from flat funding at the Omnibus level through to doubling of the funding, as projected by ACI. NASA is also considering LSST as a ground-based option to fulfill Congressional requirements to catalog Near-Earth Objects.

The proposed funding for LSST is split between NSF, DOE and private funds, with efforts to identify international partners. The funding split in the proposal was NSF 63%, DOE 24% and private 13%, though the project has successfully raised another $30M over the last year, so that the private component is increasing. The total construction cost of LSST in the proposal submission was $390M in FY06 dollars, with ~$45M (FY06) of pre-construction spending (based on FY10 New Start), and an operations cost of $37M/yr (FY06 dollars; ~9% of pre-operations expenditure). For a 10 yr baseline survey lifetime this results in a total lifecycle cost of $805M. In actual expenditure year dollars, with 2.4% inflation, the lifecycle cost of this program for a 10 yr lifetime is ~$1.04B. The private (and potential international) contributions will offset a significant fraction of this, but the dominant contributions (currently ~75%) will come from the Federal government involvement.

The AAAC recommended in its 2007 report that LSST should be discussed in the 2010 Decadal Survey. The consensus of a wide range of committees has been that a zero-based approach is required in the new Decadal Survey for all missions or projects not into construction (e.g., GSMT, LSST, SKA, as well as the comparable space missions like Con-X, LISA and SIM, for example; see also §3.3). This is no reflection on the scientific merit of LSST; rather, it is a statement on responsiveness to Decadal Survey priorities and the need for an appropriate assessment by the community for such major projects. The Committee views the need for a robust, comprehensive and encompassing 2010 Decadal Survey as being of paramount importance to maintain the credibility of the astronomical community's strategic planning process. The likely timescale for a New Start designation in MREFC suggests that consideration of LSST by the 2010 Decadal Survey will not impact the LSST construction schedule.

LSST will be one of two the largest US-funded, ground-based astronomical project undertaken to date, being comparable to the US contribution to ALMA and its operations over a 10-yr period. As such, it will receive very close scrutiny by the Office of Large Facilities Projects, MPS, and the NSB, and by DOE HEP project management. Given this, along with the continuing refinements being applied to the MREFC process by the NSF and the NSB, the similarly rigorous project process at DOE HEP, and the current budget issues faced by both DOE and NSF, the likelihood that LSST will be able to move through all the steps in the MREFC process for declaration by the NSB as a New Start soon appears low (e.g., to be in the FY11 budget, all these activities must all be completed by fall 2009). A more likely timeframe is 2010, for an FY12 New Start. While there are significant uncertainties associated with the estimate, it does suggest, as mentioned previously, that consideration by the Decadal Survey can be carried out without impacting the LSST Project MREFC construction schedule. The AAAC recommends that the 2010 Decadal Survey give consideration to the role of LSST within the overall strategic plan that the Survey will develop.

6.5.4 GSMT

GSMT was identified as the highest ranked ground-based large project (and the second-highest behind JWST when considering both ground and space) in the 2000 Decadal Survey. Two concepts for this extremely large telescope surfaced, the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT), and both are maturing rapidly. Substantial private investments have been made in developing both the GMT and TMT concepts, with the potential for hundreds of millions of dollars of additional private investment. The TMT project recently was the recipient of a very large grant ($200M) from the Moore Foundation. In addition, international participation is also growing (Canada is already a member of the TMT and Australia is member of the GMT project.) The Federal role in GSMT remains very unclear, however. The mechanisms to link Federal processes (i.e., MREFC, operations planning and funding) to major private investments are not well developed. The opportunity is here for a top-ranked, scientific project to be funded largely privately (with an international component) at levels of $0.5-1B, but there is no obvious way to move towards the involvement of the Federal government as a significant partner. The issues are discussed extensively in Appendix A2.

Since GSMT somewhat unusually involved two projects, the expectation, as noted in the 2006 AAAC report, was for a competitive selection that would lead to one project moving forward as an MREFC project. This approach was derived from an earlier community report, *Strategies For Evolution of U.S. Optical/Infrared Facilities Recommendations* of the *OIR Long Range Planning Committee*[28] (OIR-LRPC). The OIR-LRPC report, from July 2005, involved extensive discussions and input that was developed for consideration by the NSF Senior Review committee and other planning groups. Such an approach, while not the only way forward, is certainly a normal one for government-funded science projects. Currently, however, GMT and TMT are moving ahead as distinct projects. What is the NSF role in this case? The good news is that the private funding may result in two major U.S. facility(s) of the 30-meter class to be constructed. The bad news is that this complicates the path forward and reduces the clarity of the discussion regarding GSMT. It is not obvious at this point how to move forward rapidly. The lack of clarity will bring challenges both in the Decadal Survey and for long-range planning at the Federal level, but the ultimate

[28] http://www.noao.edu/dir/lrplan/lrp-committee.html

outcome could well be two, large, somewhat different ELTs that are accessible to the U.S. community and that provide even larger scientific returns. A broad plan for how GSMT might develop would be particularly useful for the Decadal Survey. In the near-term the AAAC considers that the most valuable activity that could be undertaken is to explore the possible options and timescales for NSF support for GSMT so that discussion can occur within the 2010 Decadal Survey process towards ELT access for all US astronomers.

One possible option that the AAAC explored with the two groups last year was Federal involvement through an MREFC proposal for a set of instruments that are matched to each telescope's optimization. This could be a very effective mechanism for the national "GSMT" role, along with archive and operations support. However, the early commitment of operations support for the Federal partnership poses a challenge. The involvement of OMB and OSTP, and of committees in Congress, could help develop this unusual model. The role of the National Optical Astronomy Observatory (NOAO) as the national interface for GSMT is a welcome development. The AAAC also believes that continued dialog with the Europeans regarding their plans for an extremely large telescope (ELT) could be mutually beneficial as well. The AAAC recommends that NSF, AST and MPS, along with the projects, explore options for funding other aspects of GSMT, including major upgrades through MREFC (e.g., a set of second-generation instruments and archives). Developing mutually-beneficial approaches for funding operations could encourage progress on the projects with private donors, who will likely invest at least several hundred million dollars into GMT and/or TMT for construction. The AAAC recommends OSTP involvement because of the broad policy issues involved, and encourages Congressional support for alternatives if the current framework challenges the use of private funding.

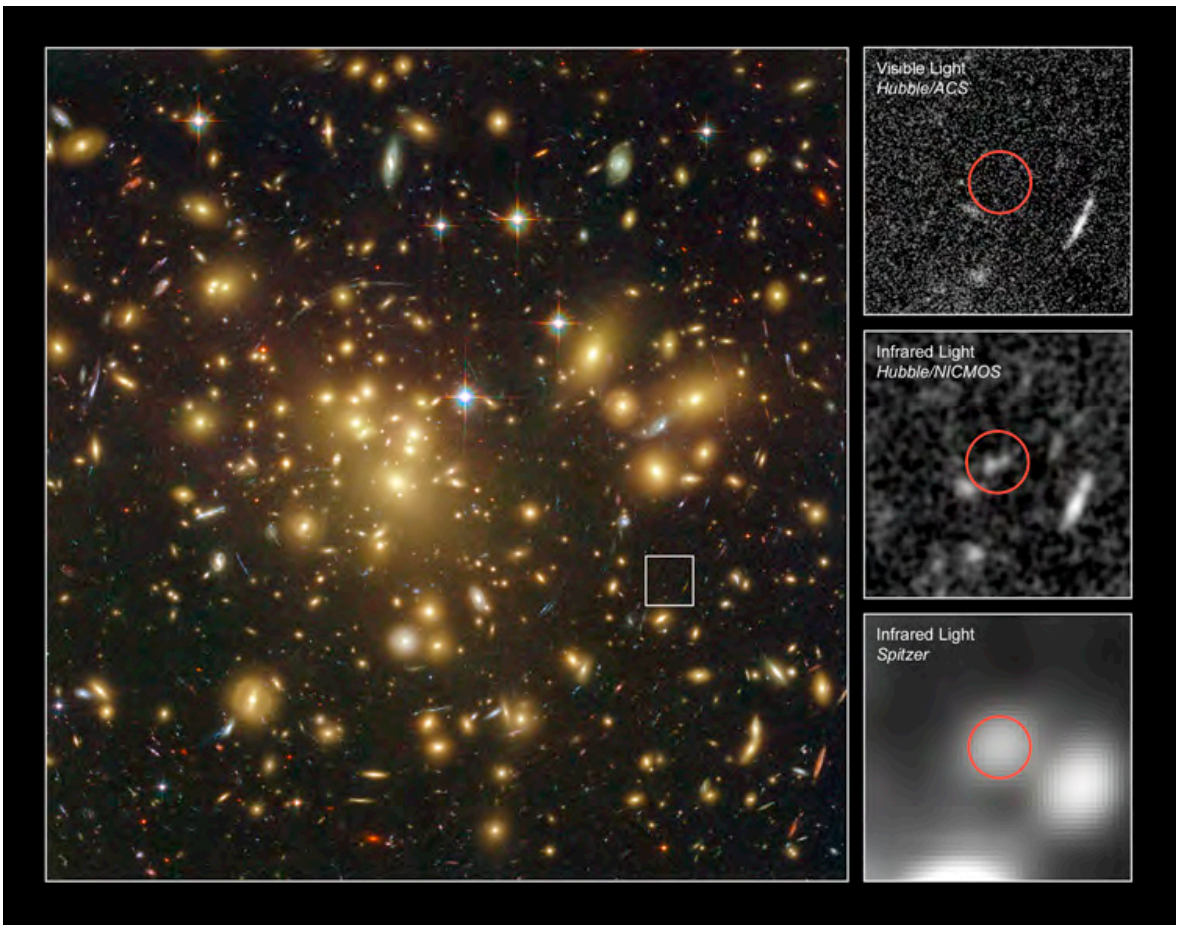
A larger version of an ELT is also under consideration by the Europeans through the European Southern Observatory (ESO). There is interest within the European Union (EU) astronomy community on moving forward on their own 42 m ELT (they use Extremely Large Telescope – ELT – for their telescope), given the great success of their Very Large Telescope (VLT, which consists of four 8-meter telescopes that are 100% EU-funded). Whether this proves practical is an open question at this time, just as the question remains here as to whether GSMT will be a fully U.S. venture (private plus Federal). Regardless of these uncertainties, their interest in extremely large telescopes (ELTs) around 40-meter apertures opens up the potential for future coordination or collaboration. The AAAC believes that continued dialog with the Europeans regarding their plans for an extremely large telescope (ELT) could be mutually beneficial. AST has convened a group of international funding agency representatives to explore cooperation on the next-generation telescopes. Continuing discussions with the European community could identify ways in which the two groups could develop their respective ELT facilities for mutual benefit (e.g., shared access and complementary instrumentation). This would be especially valuable if the result of these efforts is joint access to a next-generation, very large telescope in each of the northern and southern hemispheres, giving all-sky coverage. But, even if the telescopes are in the same hemisphere, the high cost of major instruments ($50M) indicates that significant advantages would accrue from shared access.

The AAAC has recommended that *all* projects not under construction be considered by the 2010 Decadal Survey. We fully expect that the Survey committee will be discussing the national role, the involvement of the broad community, and the priority of GSMT. The AAAC has become aware of the challenges of developing a Federal government support model that meets the needs of a very diverse set of players with different timescale and needs. The AAAC encourages the 2010 Decadal Survey committee and the appropriate Panel to consider the AAAC discussion here and particularly in Appendix A2. The AAAC recommends that the agencies alert the Decadal Survey committee of these issues and brings the GSMT discussion here to their attention.

6.5.5 GSMT/JWST Synergy

The AAAC emphasizes that operation of an ELT in the JWST era would provide major scientific synergies. Concurrent operations of the Hubble Space Telescope (HST) and of 8-m class ground-based telescopes has demonstrated that, working together, they synergistically provide scientific advances beyond even their enormous individual capabilities. At the request of the AAAC, the GSMT Science Working Group (SWG) worked with the JWST SWG to enunciate the science gains from overlapping operation in a two-page summary document[29] and a full report[30]. The report cover letter noted, "This report concludes that many of the most ambitious scientific goals of the next decades – for example, understanding the formation of galaxies and the chemical elements and the formation of stars and planets – can only be fully realized through construction of both GSMT and JWST and via their concurrent operation." The synergies outlined in this report remain as relevant today as they were in 2005 when the report was developed. The AAAC strongly encourages NSF to take advantage of opportunities that would help GSMT move forward expeditiously so that the GSMT/JWST synergies could be realized soon after the JWST launch in 2013.

HST identified an incredibly distant galaxy, formed within the first 5% of the age of the universe. It is likely one of the first generation of galaxies formed after the Big Bang. Observations with Spitzer confirmed that it was in the throes of rampant star formation. (Credit: NASA; ESA; HST; Spitzer; L. Bradley JHU; R. Bouwens UCSC; H. Ford JHU; and G. Illingworth UCSC).



[29] http://www.nsf.gov/attachments/103158/public/gsmt_jwst_synergy_handout_final.pdf
[30] http://www.nsf.gov/attachments/103158/public/gsmt_jwst_synergy_report_final.pdf

7.0 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA's extraordinary successes over the last decade have resulted in large part from its challenging, ambitious science missions, combined with continuing, broadly based research support that optimizes the science return from a diverse portfolio of programs. In astronomy and astrophysics, which is the purview of the AAAC, NASA has demonstrated remarkable scientific leadership by implementing missions that have dramatically changed our understanding of the universe – its origin, evolution and structure, the existence of massive black holes, when and how galaxies formed, and the birthplaces of star and planets. The excitement realized throughout the nation and the world from the Hubble Space Telescope (HST), the Mars Rovers, the very successful Explorer missions like the Wilkinson Microwave Anisotropy Probe (WMAP), the remarkable outer planet images in our Solar System from Cassini and Galileo, and from numerous other remarkable missions and projects has been seen as a demonstration of US technological leadership.

NASA science has provided the nation with two recent Nobel Prizes for COBE (Mather & Smoot, 2006) and for X-ray astrophysics (Giacconi, 2002), and could provide more. NASA has shown time and time again that technology, driven by great science goals, can dramatically expand our horizons and bring exploration of the cosmos within the reach of all.

NASA astrophysics has provided the nation with two recent Nobel Prizes for COBE (Mather & Smoot, 2006) and for X-ray astrophysics (Giacconi, 2002), and could provide more. NASA has shown time and time again that technology, driven by great science goals, can dramatically expand our horizons and bring exploration of the cosmos within the reach of all. The value of these science missions is widely recognized for generating enthusiasm for science and engineering and for stimulating the interest of the nation's youth.

7.1 The Challenge for NASA

NASA is being asked to do too much with too little. The challenges of transitioning within the current NASA budget to a new generation of space capabilities in the framework of the Exploration Vision, with no new funding, have become increasingly obvious over the last few years. Yet NASA's overall budget has remained essentially unchanged through the last four budget requests (FY06, FY07, FY08, FY09) with essentially the same amounts being requested or projected for FY08 ($17,309M), FY09 ($17,614M) and FY10 ($18,026M). The prospects are not better in the out-years beyond FY10. The balance among the needs of Space Shuttle (STS) operations and ramp-down, International Space Station (ISS) completion and operation, Exploration Systems development, and a robust Space and Earth Science program has come under great strain as the real costs of the transition to a new human spaceflight structure have been recognized. Yet no additional funds have been identified to carry out this transition.

The AAAC recognizes the constraints that the agency as a whole has to deal with. We are sympathetic to the problems that face the agency in its transition to a new human spaceflight capability. Nonetheless, it is our responsibility to comment on the impact that the budget requests and appropriated levels have on science, and particularly on astronomy and astrophysics through the Astrophysics Division. The impact of the removal of $3B from the 5-yr run-out budget from 2006 is still being felt. Science funding is still dropping in real terms, in inflation-adjusted dollars. The impact on science is large, both in the near-term and in the long-term. The entirety of the science community's planning was impacted by this sudden change in the budget slope. These budget changes were exacerbated by the realization that costs had been underestimated for a number of major programs. The resulting major restructuring of the long-term science program is a great concern to the science community, and will ultimately impact NASA's perceived value to the nation.

Dr. Griffin noted presciently before Congress in 2003 that NASA needed a $20B budget (in mid-decade dollars) if the agency were to transition out of its historic programs to develop new human space flight capability. This remains the case, especially if NASA is to retain a vibrant, diverse science program.

The leadership in the scientific and technological arena that NASA has shown – with the visibility that it brings to U.S. technological and scientific achievements – is clearly at risk in the coming years. We still lead the world, but the trend is a concern. The breadth and balance within NASA's science program is a major factor in this visibility. The substantial budget changes that are being implemented are resulting in a re-alignment between science and human spaceflight. We do not wish to condemn the agency to remain with outdated facilities and goals. We are supportive of moving ahead with changes to the human spaceflight and launch vehicle capability that will bring NASA into the 21st century. We recognize the stress that the agency is under. On several occasions before he became NASA Administrator, Mike Griffin noted presciently before Congress in 2003 that NASA needed a $20B budget (in mid-decade dollars) if the agency were to transition out of its historic programs to develop a new human space flight program. This remains the case, especially if NASA is to retain a vibrant, diverse science program.

The AAAC views the impact of the cuts on the scientific base to be a serious issue and would like to see the funding level increased by NASA, Congress and the Administration for the NASA Earth and Space Science enterprise. We are particularly concerned by the dramatic change that occurs within Astrophysics over the next 4 years – by 2012, the Astrophysics budget will be reduced by 30% in inflation-adjusted terms relative to FY07. We strongly urge Congress to support an increase in the NASA science budget as an investment in national innovation and competitiveness, in order to realize the longstanding plans and potential of the enterprise that has so often enthralled the nation over the last two decades. We urge the Administration to support this investment with a concomitant FY10 budget proposal for the agency.

7.2 ACI, America COMPETES and NASA

A major guiding force for the nation's research effort came into being as part of the FY07 budget request. The American Competitiveness Initiative (ACI) was announced by the President in his 2006 State of the Union Address, and was widely applauded for its recognition of the challenges faced by the nation in staying at the forefront of scientific and technological development. The 2005 Augustine report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*[31], consolidated widespread concern about our future competitiveness and catalyzed efforts to improve the situation. Research is a precursor to innovative activities and underpins a technologically competitive society. The Congressional commitment to competitiveness and the nation's science and technology capabilities were manifested through the H.R. 2272, *America Creating Opportunities to Meaningfully Promote Excellence in Technology and Science Act* (COMPETES) that was signed into law in August 2007. This bill specifically includes NASA as a key contributor to National excellence in science and technology, by endorsing the funding levels previously authorized for the agency.

The Augustine report also highlighted the importance of K-12 science education. HST has been the source of more news stories than any other science endeavor ever. Together with the other Great Observatories and the Mars missions like the Rovers, NASA science missions feature in science education and popular science news like no other. A future where such exciting results come infrequently is not good for NASA or the Nation.

[31] http://www7.nationalacademies.org/cosepup/

Consistent with ACI, the FY07, FY08 and FY09 President's budget requests sought new investments leading to an eventual "doubling" of the budget for DOE science, the National Institute of Standards and Technology (NIST), and NSF. Cuts to the NASA science budget, on the other hand, that have occurred on the same timescale have had broad impact and are inconsistent with the broad goals of the ACI and the specific goals of America COMPETES. There is no question that NASA is a major source of science and technology funding, and the agency indisputably supports much basic research. This research contributes to the vitality of the national skill set in science and technology, has encouraged young people to move into science and engineering and has been shown to yield important, marketable spin-offs. We believe that the continued omission of NASA from research funding increases is inconsistent with the commitment to our competitiveness, and even shortsighted, given the visibility that the NASA science program has engendered for science and engineering across the nation. The Congressional interest in innovation and competitiveness enables a fresh look at the role of NASA science, and the AAAC strongly encourages Congress to enhance the support for science at NASA consistent with the explicit authorization in America COMPETES.

7.3 Future Launch Opportunities

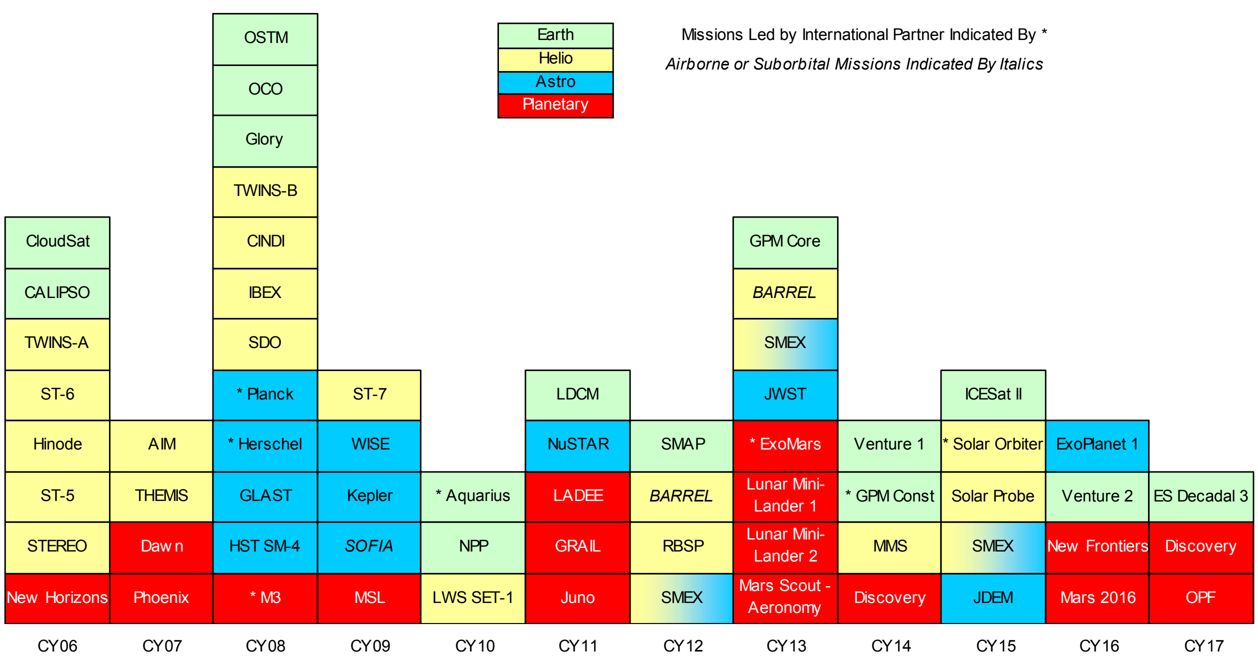
The large investment in a new human space flight program, including new crew vehicles and launchers, suggests opportunities for space astronomy. The new Ares V launch vehicle is of special interest in this regard, allowing very large payloads (both in mass and volume) to be lofted. Such a capability could open up entirely new opportunities for space astronomy, though the cost of such a launcher is likely to be high. The NRC's *Science Opportunities Enabled by NASA's Constellation System* panel has been chartered to identify such opportunities for the science community, and the AAAC looks forward to their report. These new launch capabilities are likely to offer real value for science missions, and so it will be important for the science community to identify aspects of the system which would be of benefit (such as very large shrouds, for example). Another aspect relates to human space flight. Astronauts have played a major role in the success of HST. However, for a science mission the added costs, and risks of schedule impact, of being coupled to human space flight are significant. Do the benefits of using humans in assembling, deploying and/or servicing large space telescopes justify the added cost and constraints? Or will robotic techniques largely supplant human involvement? The AAAC is interested in these issues given the potential new science capabilities that the Constellation system will bring.

7.4 Astrophysics – an overview

If one takes a near-term view, the mission mix in Astrophysics looks good. Over the next ~5 or so years Astrophysics will have a reasonably well-balanced program, i.e., one with a mix of small, medium and large missions in operation covering a diverse range of scientific areas. The launch of a mid-size multipurpose mission, the Gamma Ray Large Area Space Telescope (GLAST – in May 2008), a Discovery mission, Kepler (in 2009), a mid-sized Explorer (MidEx) mission, the Wide-Field Infrared Survey Explorer (WISE – in 2009), a small Explorer (SMEX), the Nuclear Spectroscopic Telescope Array (NuSTAR – in 2011), and participation in two powerful European Space Agency (ESA) missions Herschel and Planck (2008-9) strengthens the program. The Astrophysics Division is operating three Great Observatories, Chandra, Hubble and Spitzer, and providing significant funding for data analysis for those missions. The next Hubble Servicing Mission (SM4) and the instrument upgrades and repairs will rejuvenate Hubble. The Stratospheric Observatory for Far-Infrared Astronomy (SOFIA) is moving towards its first science demonstration in 2009 and full science operation in 2014. NASA is progressing on an extremely powerful Great Observatory-class mission, the James Webb Space Telescope (JWST). NASA Astrophysics and DOE HEP are planning for a medium-scale JDEM mission for launch in the middle of the coming decade in response to the recommendations of the BEPAC report. Planning is starting for a possible medium-scale ExoPlanet mission, with guidance from the upcoming ExoPlanet Task Force report, but not yet from the upcoming Decadal Survey.

So why is the astronomy and astrophysics community so concerned? And why is this concern reflected so strongly in the AAAC annual reports, and the reports and discussions of the NASA Advisory Council (NAC) Astrophysics Science Subcommittee, and the NRC committees (Space Studies Board – SSB; Board on Physics and Astronomy – BPA, Committee on Astronomy and Astrophysics – CAA)? The key concerns are (i) the mission frequency in the coming Decade in Astrophysics, and (ii) the lack of opportunities to respond to the upcoming 2010 Decadal Survey report. On (i), this concern is shown visually in the Figure below in which the blue boxes represent astrophysics missions. Between 2009 and 2018 the only broadly-based, observatory-like mission is JWST. There are two medium-scale missions (JDEM and an ExoPlanet mission), a PI-led SMEX (NuSTAR), and possibly an additional PI-led SMEX or two (they are shared with other Divisions and may or may not end up being Astrophysics missions; hence the partial blue boxes). These missions provide important focused science programs, but complement missions with broad capabilities. SMEX also are not as ideally-sized for Astrophysics as are the larger Explorers. JWST will be a very powerful observatory with a broad-ranging program for community access, but it is the only one in the foreseeable future.

Launches by Calendar Year



For (ii), as discussed above, the budget impacts greatly reduce the Astrophysics programs opportunities for initiating new projects in response to the Decadal Survey recommendations in 2010. This concern is demonstrated by the dramatic changes that occur in the budget in FY09 and beyond, where the Astrophysics budget falls by $203M from $1365.5M in FY08 to $1162.5M in FY09, and is then projected to continue to decrease over the next 4 years until it is only $1116.0M in FY13. We face these serious budget declines as we look ahead to the next Decadal Survey, and the prospect that new exciting missions it identifies will not be realizable.

How dramatically the budget decreases impact Astrophysics can be seen in the Table below. In real terms the Astrophysics Division suffers a precipitous decline in FY09 (down by 18% in constant dollars relative to 2007) that worsens in the out-years (down by ~30% in constant dollars relative to 2007). This large decline is with the recent OMB-mandated 2.4% inflation. It is clear that inflation is increasing, particularly for technology and construction projects, and so the loss in buying power will be even greater. Even though a number of important and productive missions will be operating into the next decade, the long lag between inception and launch will lead to a period with far fewer operating missions by the middle of the next decade, unless this budget trend is reversed.

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Actual Year $M	$1,357*	$1,364*	$1,163	$1,122	$1,057	$1,067	$1,116
% change**		0.5%	-14%	-17%	-22%	-21%	-18%
Inflation Adjusted***	$1,357	$1,332	$1,109	$1,045	$961	$948	$968
% change**		-1.8%	-18%	-23%	-29%	-30%	-29%

*operating plan #s **relative to FY07 ***in FY07 dollars with 2.4% annual inflation

Note that the FY07 and FY08 appropriated numbers have been corrected for the change from full cost accounting to direct costs to make them consistent with the numbers in the FY09 budget request.

The impact of any other cuts to the Astrophysics Division budget would clearly be devastating. Two such potential problems would be unfunded Congressional direction regarding the Alpha Magnetic Spectrometer (AMS) and SIM (discussed in §3.2). Direction that would force NASA to launch AMS on an ELV as an SMD-budgeted responsibility would have a very substantial impact on the Astrophysics Division budget at its likely cost of $0.57B-1B for an ELV launch (from the NASA Report to Committees on Appropriations regarding Alpha Magnetic Spectrometer – AMS – February 2008). Congressional direction to carry SIM into development would have an even larger and more dramatic impact. Doing SIM would preclude most new mission opportunities in Astrophysics for much of the coming decade, given its over $2B additional cost. This would wipe out any opportunities for new large or even medium scale missions. The AAAC has been undertaking the ExoPlanet Task Force at the request of the agencies (and with Congressional, OMB and OSTP interest in the outcome) to identify a synergistic ground- and space-based program of planet detection that could be used by the 2010 Decadal Survey to derive a cost-effective plan for new missions and facilities. The ExoPlanet Task Force recommends a narrow-angle astrometry mission later in the next Decade, but that is not SIM (see below). To force SIM into development now undercuts these two major community planning efforts. The AAAC is particularly concerned about the major impact on the Astrophysics Division budgets by being forced to do either of these missions, particularly just as the 2010 Decadal Survey is starting.

7.5 Lifecycle Mission Costs

Over the last two years the AAAC has emphasized in its annual report the need for a consistent approach to mission cost and advocated that the baseline be “lifecycle” costs. This was our response to the growing concern that the community did not understand what our missions really cost over the 10-15 years that it took for Decadal Survey recommendations to be implemented. The changing cost estimates of major science missions like JWST, SIM, SOFIA and the servicing mission costs of HST surprised many. The changes also led to concerns about what other potential mission “undercostings” (to use the NASA Administrator's very appropriate word) awaited us as other missions developed towards Phase B and even into Phase C/D. Unfortunately, the costs in the 2000 Decadal Survey were not consistently estimated, nor was independent cross-checking carried out. Fortunately, both NASA and the astronomy community have recognized the problem caused by the lack of attention to lifecycle costs and expect that they will be used in the upcoming Decadal Survey.

For many programs the bulk of the costs are not in construction (Phase C/D), but actually in Phase B and earlier activities, and then in Phase E (operations). An example of a mission for which operations is the majority of the cost is SOFIA which stands at $2.7B lifecycle (in constant 2007 dollars) for 20 yrs of operation (future operations cost sharing is expected to reduce the cost to NASA by roughly $17M/yr), but whose Phase C/D costs will probably be around $0.6-0.7B. Even for major missions such as JWST and SIM, the Phase C/D costs are about 30-40% of the total. For planning it is essential to develop reliable cost estimates and to use lifecycle costs (over the lifetime of the mission) in the discussions between NASA and the community. This will ensure that program planning within the Astronomy and Astrophysics Decadal Survey, and subsequent agency roadmaps, can be carried out within likely budgets over the 5-10 yr periods for which they are developed.

The Table below summarizes lifecycle mission costs (LCC) in constant 2007 dollars, with a summary of the caveats/comments appropriate for the derivation of these numbers. These numbers are from the NASA Science Mission Directorate (SMD). They were provided in response to Questions for the Record from testimony given by the AAAC Chair to the House Committee on Science and Technology's Subcommittee on Space and Aeronautics on May 2, 2007 at a hearing on *NASA's Space Science Programs: Review of Fiscal Year 2008 Budget Request and Issues*. Since these numbers were supplied by NASA, they can be considered baseline numbers for subsequent discussions of mission costs. Obviously taking costs from past missions done under very different accounting structures and converting them to present day structures will be uncertain, but they provide a very useful guideline for planning purposes and for setting the scale for missions under discussion. They are estimated as likely to be accurate to better than 10%, probably about ±5%. The NASA SMD AA's office provided these numbers and notes for a public response to a Congressional inquiry relating to Testimony in May 2007. The AAAC greatly appreciates that the agency made such costs available so that consistent costing is available as we go into the next Decadal Survey.

NASA SMD Lifecycle Costs for Science Missions (in constant 2007 dollars)

Mission (alphabetical)	$B (constant 2007 dollars)	Comments
Cassini	$3.9	Launch included
CGRO	$1.5	Launch included
Chandra	$4.0	Shuttle cost not incl. (IUS incl.)
Galileo	$3.2	Shuttle cost not incl. (IUS not incl.*)
HST	$12.8	Shuttle cost not incl.; Servicing mission costs incl.**
JWST	$4.4	2013 Launch; 10 yrs operations
SIM	$2.6	Nominal 2015/16 Launch; 10 yrs ops***
SOFIA	$2.7	Full science ops 2013; 20 yrs ops
Spitzer	$1.7	Launch included; Ops to 2009

All costs are lifecycle (LCC), adjusted for full cost prior to FY04 (full cost accounting used since FY04), and converted to constant 2007 dollars (rounded to nearest $0.1B). *Inertial Upper Stage (IUS) number too uncertain for inclusion (maybe $0.2B?); **ESMD funding of robotic servicing not included.
***Based on FY07 budget data; SIM-Lite under consideration.

As we go into the next Decadal Survey there has been widespread recognition that the Survey committee needs to utilize lifecycle costs over the decade so as to better match the recommended missions and projects to likely available funds. The BEPAC committee used this approach in its deliberations. The AAAC strongly supports using lifecycle costs, as it has done in its previous reports, and recommends that the 2010 Decadal Survey use the approach taken in the BEPAC study as a model.

7.6 ExoPlanet Task Force

Extra-solar planet discoveries have become commonplace. The field of exoplanet studies has been moving forward at a rapid pace, driven by advances in technology, in ground-based instrumentation, in facilities, and the unique utilization of current space assets like HST and Spitzer. With the upcoming launch of Kepler, and the recognition that some of the programs being considered for exoplanet studies were more costly and/or ambitious than could be realistically accommodated in a declining budget within the next Decade, the AAAC recommended that it would be an appropriate time to form an ExoPlanet Task Force (ExoPTF) to consider how to move forward on the ground and in space in this exciting but challenging area. This became timely given the challenges that were becoming apparent in moving forward with the TPF missions and SIM. The ExoPTF has submitted its report to the AAAC for review and it is expected that it will be completed and transmitted to the agencies this spring (2008). The refocusing of the Navigator/SIM into a new ExoPlanet initiative within the Astrophysics Division is a change that will allow a better response to the ExoPlanet Task Force and their suite of recommendations. The AAAC greatly appreciates the agencies' support for the ExoPTF, and particularly appreciates the efforts of the Chair Jonathan Lunine, the very considerable efforts and contributions of the Task Force members, and the very positive community response on the call for White Papers (with 85 received). Such a report, as well as being a guide for agency planning, will also provide very valuable input to the next Decadal Survey committee and to the Panels dealing with extra-solar planet detection. The ExoPTF is discussed further in §4.1.2.

The feedback from the AAAC has been positive, broadly endorsing a phased approach, separated into three time periods, 1-5 yrs, 5-10 yrs and 10-15 yrs. The recommended program is conservative in the near-term, becoming progressively more challenging in the middle and later phases. The recommendation for an astrometric mission explicitly focused on planet searches has been the source of much discussion, but any decision on this must await the review of the 2010 Decadal Survey and further assessment of the cost. *The astrometric mission recommended in the ExoPTF report is not SIM.* Equating this to the mission that has been discussed as SIM or even SIM-lite is premature, until an independent technical review and cost assessment is done. The ExoPTF explicitly recommended also that a detailed review of technology before embarking on its recommended narrow angle astrometry mission. The current SIM concept (and particularly SIM Lite) has *not* been reviewed by a Decadal Survey committee. The SIM that was transmitted by the 2000 Decadal Survey without extensive review was a very much cheaper mission (the AIM mission was costed at $250M in the 1990 Decadal Survey). The AAAC recommends that these astrometric missions (SIM, SIM Lite, ExoPTF astrometry mission) be considered by the 2010 Decadal Survey, consistent with our recommendation for other major missions.

The AAAC recommends that NASA (and NSF) use this report in developing their detailed plans for exoplanet research, in the context of the overriding recommendations of the 2010 Decadal Survey (who will also use this report as input for their deliberations and recommendations). In particular, given the pressure on the astrophysics budget and the limited opportunities post-2009, the AAAC recommends that any new medium class or larger ExoPlanet mission only proceed if it is prioritized to do so by the Decadal Survey.

7.7 BEPAC-JDEM

The AAAC has been concerned for some time that the Beyond Einstein program, with its missions from both the Decadal survey and Connecting Quarks with the Cosmos (CQC), and the potentially very rewarding Einstein Probes, has not been able to move forward. The Joint Dark Energy Mission (JDEM) has been one of the major programs of interest to DOE HEP within the Beyond Einstein program since CQC. The decision to carry out an NRC study through the Beyond Einstein Program Assessment Committee (BEPAC) to identify a mission for a potential funding opportunity ("wedge") was viewed very favorably by the AAAC. The BEPAC study[32] was carried out under the NRC's Board on Physics and Astronomy (BPA) and the Space Studies Board (SSB) by the *Committee on NASA's Beyond Einstein Program: An Architecture for Implementation.* Of particular interest to the AAAC was the decision by DOE HEP to share in the cost of the study.

The BEPAC committee was asked to assess the five Beyond Einstein missions (Constellation-X – Con-X, and the Laser Interferometer Space Antenna – LISA, and the smaller Einstein Probes, Inflation Probe – IP, the Joint Dark Energy Mission – JDEM, and Black Hole Finder Probe – BHFP) and recommend one mission as the first for development and launch. The committee assessed all five missions using criteria that addressed both potential scientific impact and technical readiness. A unique feature of this study was a rigorous assessment of the likely cost and readiness of each mission. The BEPAC committee consisted of a mix of astronomers, physicists and engineers. The broad experience base represented in the committee proved to be an invaluable asset as they dealt with the tradeoffs between the science potential, cost and readiness. The committee was also asked to assess each mission in sufficient detail to provide input for future decisions by NASA and for the next Astronomy and Astrophysics Decadal Survey regarding both the ordering of the remaining missions and the investment strategy for future technology development within the Beyond Einstein Program. Given its attention to science, cost and technical readiness, this NRC study was a pathfinder for the 2010 Decadal Survey, as well as providing a very detailed and informed input to the next Decadal on the missions that it assessed.

The BEPAC report recommended JDEM as the first mission to be done in the Beyond Einstein program, and provided additional recommendations regarding the other missions in its review that will feed into the Decadal Survey process. The enthusiasm of the BEPAC for the scientific potential of the missions in Beyond Einstein underscored the need for continued technology investments to try and find ways to reduce the high cost of many of the Beyond Einstein missions. The AAAC was very encouraged by the rapidity with which DOE HEP and NASA Astrophysics begun discussion on an agreement for JDEM, which was identified as a medium-scale, cost-capped, competitively-selected mission at the Einstein Probe scale, or roughly $600M-$800M.

The AAAC was very pleased to hear the subsequent discussions between DOE and NASA have led to an understanding that: (i) NASA and DOE will work towards a JDEM mission that will be a medium-class strategic mission with a competitively-selected, PI-led dark energy science investigation; (ii) they will partner in the fabrication and operation of instrumentation necessary to execute the science investigation; (iii) DOE's cost for the fabrication and operations phase is estimated at this time to be less than or up to $200M (FY08$), roughly 25% of the expected total lifecycle mission cost; (iv) the current planning schedule has a solicitation (AO) for a JDEM mission that would be released late in FY08 (after a draft in summer) and a particular concept selected in FY09 for conceptual design; and (v) that the planned launch is expected by the middle of the next Decade. These developments were viewed by the AAAC as a very important step in this major inter-agency project. The AAAC hopes that the appropriated budgets for FY09 and beyond can accommodate the timeline being worked by the two agencies.

[32] http://www7.nationalacademies.org/ssb/BeyondEinsteinPublic.html

7.8 Astrophysics Division Program

There are a number of significant changes in the structure of the Astrophysics program within SMD with the release of the FY2009 budget. In order to managerially emphasize the intellectual foundations of the program, the Astrophysics Division is being reorganized thematically. All exoplanet activities (e.g., the Navigator program, Kepler, SIM) will be combined under the Exoplanet Exploration theme. Navigator/SIM will be refocused into a new medium class Astrophysics initiative under this theme. The Cosmic Origins theme will now encompass HST, JWST, SOFIA and Spitzer. The Physics of the Cosmos theme will contain missions and programs like Beyond Einstein (JDEM, LISA, Einstein Probes), Chandra, GLAST, Con-X, XMM, Herschel/Plank, etc.

This restructuring brings a science-based framework that has value for the program. However, rigidity in the boundaries might work against implementation of the Decadal Survey recommendations if it proved very difficult to move funds in response to community priorities. One other change should be noted. Discovery missions will no longer be available to Astrophysics. Of the 10 Discovery missions to date only one has been an Astrophysics mission, and that is Kepler, which is slated for launch in 2009. Given the growing interest in exoplanet studies this is potential future loss if Astrophysics could have successfully competed for these funds. An increase in funding for R&A and the solicitation for Small Explorer (SMEX) missions was welcomed by the AAAC (the SMEX budget transfers from Heliophysics if an astrophysics SMEX is chosen), but the concerns regarding the overall budget weighed very heavily on us. The substantial drop in funding experienced by Astrophysics from FY09, with a continuing effective decline in the out-years (a drop of about $200M/yr from the current budget), indicates that the future opportunities are very limited.

7.8.1 R&A and MO&DA

NASA supports scientific research directly through funding for mission operations and data analysis (MO&DA), and also for broadly-based research and analysis (R&A). R&A and MO&DA are key elements of NASA's support for research within the community. Indeed, DA and R&A support are the primary mechanisms by which NASA's investments in mission development and operations are alchemized into the cutting-edge scientific results that the community and the nation have come to expect from SMD. The AAAC strongly welcomes the FY09 budgetary emphasis on, and commitment to, R&A and MO&DA within SMD and within the Astrophysics Division and hope they are sustained through the appropriation process.

The designation of a Senior Advisor for Research and Analysis (SARA) within the SMD AA's office to be the "point person" was very warmly received within the community. The SMD AA Alan Stern announced recently that a number of important steps are being taken: "These include establishing a Research and Analysis Management Operations Working Group to identify R&A process improvements. We are also working to improve our practices for conduct of panel reviews of proposals to improve transparency and provide additional guidance to R&A program managers. We are also working to restore funding cuts from prior years. To better evaluate the need for funds in specific scientific disciplines, we are developing 'demand metrics' that help us guide funds to areas with the strongest scientific interest, and therefore with the strongest proposal pressure."

Significant improvements have been made of which a few highlights are: Decreased the time from peer review to proposal status notification; Increased the number of four year grant programs; Adopted new policy to send regular email updates regarding program status; Streamlining constraints which inhibited financial processes (ongoing); Set up SARA email communication with the science community; Removed the bottleneck in No-Cost Extensions; Reduced unnecessary internal NASA reporting requirements. The net result has been that SMD has taken important steps to enhance R&A funding, functioning and support. The broad concerns about the budget levels will take longer to rectify, but the AAAC was greatly encouraged that the downward trending budgets for R&A appear to have been arrested and the trend is for slow but definite improvements in funding levels. However, these increases need to be realized through the Congressional appropriation process and sustained by the agency and OMB into the future. Since the R&A budget was $65M just 3 years ago, it will take several years before we reach the same level in inflation-adjusted terms.

The dominant contribution to the overall research funding pool that is distributed to the community is actually the mission-specific science data analysis funds (MO&DA). These funds are an important aspect of NASA's missions that has resulted in great science return, benefiting both NASA and the science community. The total of the MO&DA and R&A budgets was $213M in FY07, of which $50M was in the R&A pool, $88M was in mission-specific data analysis, $75M was for science teams. If the FY09 budget request is reflected in the appropriation, $61M will be available in FY09 for R&A. The recognition that it is the total of the MO&DA and R&A budgets that sustains the research enterprise in Astrophysics and elsewhere, brought additional concerns that the future may portend significant decreases in MO&DA as our Observatory-class programs (Chandra, HST, Spitzer) missions become more narrowly focused, or capabilities are lost. The total DA budgets for these missions are comparable to the total R&A budget. The relative desert of new missions in the first half of the Decade will inevitably translate into lower levels of science research funding on that timescale. This is an additional impact of the lower Astrophysics budget run-out as projected from 2009; if there are few operating missions there will be a substantial reduction in data analysis funding and a significant reduction in the support that is so vital for preparing and sustaining the next generation of scientists (thereby running counter to the goals of ACI and America COMPETES).

The fragility of the current budget process and the potential for future problems with sustaining R&A funding has left the AAAC cautious about the trends, as encouraging as they appear at the moment. Thus we kept our rather thorough discussion of the rationale for R&A and its importance not just to the science community but also for NASA and put it into an Appendix (A1). We encourage OMB and OSTP and others to use this appendix as a resource if questions arise as to the value of R&A.

7.8.2 Sub-Orbital

A continuing concern for the science community has been the ability to train young researchers in the complexities and details of space science missions. This has traditionally happened through the suborbital programs (rockets and balloons most typically for Astrophysics) and through the Explorer-class missions. However, the Explorer-class missions, even small Explorers (SMEX), happen rarely, involve long timescales from proposal to fruition (typically 5 years or more), and are now at cost levels (~$300+M for an Explorer and >$100M for a SMEX) that makes student and postdoctoral involvement challenging. The suborbital programs appear to be the best mechanism for doing these "training" activities because of the timescales and the relative ease with which students and postdocs can be involved. The suborbital program is distinguished by being inexpensive (relative to orbital missions). The FY07 appropriation budget lines for sounding rockets, balloons and aircraft at Wallops are $32M, $22M and $10M, respectively. These are modest programs in NASA terms, but still a significant item in a shrinking budget for the part of the program that is paid by Astrophysics (balloons). The flight opportunities for rockets and balloons are typically ~20 per year. A typical rocket or balloon mission is thus very low cost, being in the million-dollar range ($1-2M). The research from the suborbital program has played a significant role in a large number of Ph.D. theses and publications in peer-reviewed journals. The increase in the FY09 budget in these programs by about 15% from the FY08 numbers represents an expansion of training opportunities that the AAAC welcomes.

7.8.3 Explorers

The Explorer program has been identified as a high-priority activity in each of the last three Decadal Surveys. The Explorer line has provided many of NASA's most successful missions, as exemplified by the remarkable cosmological results from the Cosmic Background Explorer (COBE) and the Wilkinson Microwave Anisotropy Probe (WMAP). One of the Explorer program's key features has been the ability to respond rapidly to new scientific opportunities with state-of-the-art technology by offering a route for small and midscale mission concepts that focus on specific science questions. The focused investigations enabled by Explorers also provide technology precursors and scientific pathfinding for future missions. The rapidity with which they are developed allows for young scientists and technologists to develop leadership skills on a mission that they are involved in from inception to conclusion. The competitive selection of Explorers, and their modest scale, provides an essential step in training the scientists and engineers who will be involved in the conceptualization and construction of the larger missions in NASA's future.

There remains strong community support for small-to-moderate scale programs within Astrophysics, and so the decision in 2006 to identify added funding for the Wide-Field Infrared Survey Explorer (WISE), along with the reinstatement of NuSTAR in 2007 was appreciated. While Astrophysics has traditionally benefitted most from the larger Explorers, the opportunity afforded by the call for proposals last year for Small Explorers (SMEX) was warmly welcomed. The AAAC views the recent efforts to provide Explorer-class opportunities as a very positive move by the new SMD AA, and one that we had strongly recommended over the past three years. A larger Explorer-class solicitation would be a very welcome addition for the astronomy community.

7.8.4 Astrophysics "Frontiers" Missions

Mid-scale \$600-700M missions (similar to the New Frontiers program in the Planetary Science Division) would lie in cost between the ~\$300M Explorer missions and the very infrequent flagship missions, and can address scientific questions that cannot be done within the cost envelope of the smaller Explorer missions. The AAAC was encouraged to hear that the Astrophysics Division was beginning to plan for missions of this scale. In the near-term both JDEM and an ExoPlanet mission have been identified as falling in this category. This already allocates most of the likely mission slots in the first half of the coming decade for such missions. Since these are likely to be a significant component of the Astrophysics Division's total program in the coming Decade, we would encourage the Division to actively solicit feedback for science priorities for medium-scale missions during their discussions with the NRC and during their interactions with the Survey committee and its Panels.

7.8.5 Future Mission Concept and Technology Development

Over the last few years the AAAC has been particularly concerned that inadequate funding was being allocated for technology development for future missions. The AAAC recommended in both its 2006 and 2007 reports that NASA provide resources for continuing a modest level of technology development for Major Initiatives identified in the 2000 Decadal Survey and CQC that are expected to be discussed in the 2010 Decadal Survey. We recognized the challenges of the SMD and the Astrophysics budget but were greatly concerned that future mission opportunities were being mortgaged by not allocating funds for technology and mission concept development. A useful level of such support was estimated to be about \$10M/yr. This would enable a much better understanding of the technological readiness and the likely performance, as well as improve cost estimates. The missions identified for this support were three that were identified in the 2000 Decadal Survey and/or CQC: Constellation-X (Con-X), the Laser Interferometer Space Antenna (LISA) and the Terrestrial Planet Finder (TPF). These are all potentially large or very large missions, and, given the recent cost history, are all likely to have lifecycle costs that are in the range \$2-4B.

The AAAC is very encouraged to see that the Astrophysics Division plans support in the FY09 budget for further mission concept and technology development for Con-X, LISA and for an ExoPlanet mission. The AAAC fully supports this mission development funding, and recommends that they be continued through to the completion of the next Decadal Survey when it will become clear what missions have been selected for the next decade. The Astrophysics Division also solicited proposals for Astrophysics Strategic Mission Concept Studies last year. These are up to ~$1M studies aimed at understanding the technology requirements for a large suite of medium and large concepts on a longer timescale than is expected for Con-X, LISA and SIM. Nineteen were chosen. The AAAC is very supportive of this forward-looking effort. Similarly, the AAAC supports funding for mission development at the medium scale. The funding provided to the three JDEM concept studies is an excellent first step in helping develop missions at the medium ("Probe") level.

An area which continues to be underfunded is technology development. This was one of the areas that was lost when the science budgets were cut so dramatically two years ago. The AAAC would like to remind SMD of the importance of this area, and recommend that some consideration be given to implementing a significant technology development effort focused on the research community. This would mesh well with the goals of ACI and America COMPETES.

7.9 Large Missions and Observatories

Three of the Great Observatories are still operating and returning remarkable data. SOFIA is moving towards its first science demonstration in 2009. JWST is poised to undergo two major reviews, the PDR and the NAR, in April 2008. Spitzer is in its last full year of operation and preparing for the first year as a "warm" mission. HST is operating but awaiting a major upgrade in its capabilities in SM4 later in 2008. The future operations of both Spitzer ("warm") and Chandra are now being considered as part of a broadly-based Senior Review. Such reviews are an important activity for all missions (as we have noted for the NSF AST Senior Review) and the AAAC expects that HST and SOFIA will also undergo such reviews in the future.

7.9.1 HST

The AAAC has consistently supported a servicing mission SM4 for HST, guided by the very clear recommendations of the 2004 NRC Lanzerotti committee report *Assessment of Options for Extending the Life of the Hubble Space Telescope*[33]. We applaud the NASA Administrator for resolving the question of what to do with the HST servicing program. Based on the Lanzerotti committee recommendations, Congress directed the agency to update and repair HST if it can safely be done. In a very clear statement early in 2006, the Administrator decided that the only viable approach was through a shuttle servicing mission. With the successful completion of several shuttle flights, the Administrator announced in fall 2006 that SM4 would be scheduled for mid-2008. We welcomed this announcement. The recent successful shuttle flights to the International Space Station (ISS) are paving the way forward for the Shuttle launch to Hubble. We look forward this year to a very successful servicing mission with its two powerful new instruments Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS), and the potential repair of two of its other instruments, Advanced Camera for Surveys (ACS) and the Space Telescope Imaging Spectrograph (STIS).

7.9.2 JWST

JWST is the highest-ranked Major Initiative in the 2000 Decadal Survey (listed there as the Next Generation Space Telescope, NGST). It is a successor to HST, yet is substantially more powerful, reflecting the

[33] http://www.nap.edu/catalog.php?record_id=11169

technological advances that have occurred over the three decades since HST was designed. JWST will address some of the most important questions in astrophysics (the state of universe in its earliest years, the buildup of galaxies, the birth of stars and planetary systems) and, like HST, will have remarkable capabilities for exploration and discovery. JWST underwent a very challenging period several years ago as a result of a substantial cost increase. The successful Technology Non-Advocate Review (T-NAR) early in 2007 and the identification of added contingency for JWST indicated a more stable path to launch and gave reassurance that the project had successfully surmounted some serious hurdles. Further insight into the readiness of the project to move into construction lies just ahead. Two major milestones, the overall Preliminary Design Review and the Non-Advocate Review, will be held this April.

The AAAC reaffirms the high scientific value of JWST that led to its Decadal Survey ranking, and more generally the value of "flagship missions" like JWST for the overall science program. There is little doubt that JWST will be a truly remarkably powerful scientific facility with huge gains in capability over our current missions. The goal now is to ensure that JWST moves through development and construction without further cost growth, to continue the efforts to balance between small, medium and large missions, and to enable development for the future major missions that will follow JWST

7.9.3 SOFIA

SOFIA has had a troubled and costly development history, but the objective is for it to begin its initial science operations in 2009. However, it is likely not to reach full science operations until 2014, well over 15 years after the project began. SOFIA was recommended as a moderate-scale $250M mission in the 1990 Decadal Survey to replace the Kuiper Airborne Observatory (KAO). SOFIA started its development in the late 1990s. By offering access to a 2.5-meter telescope aboard a modified Boeing 747 aircraft above most of the water vapor in the Earth's atmosphere, this observatory is designed to provide visibility in broad, critical infrared wavelength regimes that are otherwise inaccessible from the ground. Access to these regions would provide key insights to star and galaxy formation and to the astrophysics and evolution of molecular gas in the cosmos.

SOFIA is, in reality, a major mission, with a lifecycle cost for 15 years of operations that exceeds $2B. From FY09 on its yearly cost is estimated to be about $73M, and then drops to $60M if additional support can be found from an international partner. This cost is broadly comparable to HST operations costs and similar to that expected for JWST. When fully operational, SOFIA is estimated to provide ~960 hours of on-target time per year for science observations. (For comparison, low earth-orbit programs like HST provide ~2400 hrs, while missions in high earth orbit, drift-away or L2 locations like Chandra, Spitzer and JWST can provide ~6000 hrs per year). While the amortized on-target cost-per-hour on SOFIA is larger than for space observatories, SOFIA offers instrument development and refinement opportunities that are unavailable for space missions. In this context, it is crucial that the SOFIA program has extremely efficient operational models given the limited on-target hours, utilizes forefront instruments, and fully involves the science community to provide high scientific returns. The AAAC is looking forward to the first science demonstrations in 2009.

7.10 Advisory Process

The AAAC recognizes that a number of committees offer advice and/or feedback to the agencies on a variety of issues, and it is most useful and effective for all concerned if the enunciated messages are similar and synergistic. We were very encouraged when the new NASA advisory committees were established in 2006 after nearly a year in hiatus. From a broad agency perspective, the path for formal advice to the agency is simplified and clearer, with the only path through the NAC to the Administrator. The new structure does differ from that used previously, particularly regarding the interface with the Science Mission Directorate

(SMD). The new structure has lost a valuable role that was once provided by the Space Science Advisory Committee (SScAC), which encouraged dialogue between SMD and the science community on broad-ranging issues that cut across the SMD divisions. Such a group can act both to provide feedback to SMD on ideas that might be under discussion (in the sense of "what impact will this have?" or "how is the community likely to react to…?") as well as provide a means of disseminating issues of concern to SMD that require an informed group to discuss with the community. By virtue of a large number of committee members, representing different science disciplines, assessing and reviewing efforts across all of these disciplines, the SScAC fostered an interdisciplinary sense of cooperation that is no longer as evident in the agency. In his meeting with us, the Administrator noted the need for such a spirit of interdisciplinary cooperation. This dialogue proved to be valuable to the Divisions like Astrophysics also, since it provided a much larger experience base than is represented on the more narrowly focused activities within the Division-specific subcommittees.

The 2006 report of the congressionally requested NAPA committee (*A Performance Assessment of NASA's Astrophysics Program*[34], by the NASA Astrophysics Performance Assessment Committee (NAPA) under the NRC Committee on Astronomy and Astrophysics – CAA) study noted in its Recommendation 2 that "NASA should consider changes in its advisory structure to shorten the path between advisory groups and relevant managers so as to maximize the relevance, utility, and timeliness of advice as well as the quality of the dialogue with advice givers. Clear communication between stakeholders and the agency is critical to a strong partnership for successfully implementing national priorities and realizing community science aspirations." The concern that we outlined above has parallel arguments in this recommendation.

The Administrator has noted that he is willing to consider changes to the advisory structure. One area for consideration would be an improved interface with SMD. The importance of an "integrating body" for NASA science, as discussed above, underscores the continued need for such changes. It would be in the best interests of both NASA and the science community to restore this important two-way communication link that has contributed to the success of NASA science in the past. The current NAC Science committee does not represent the breadth of the SMD science community. The AAAC recommends that a cross-divisional committee like SScAC be convened so that broader issues can be discussed in an interdisciplinary forum, even if the formal reporting path is through the NAC.

APPENDIX A

Appendix A.1 Research and Analysis (R&A) and Mission Operations and Data Analysis (MO&DA) at NASA

R&A and MO&DA are key elements of NASA's support for research within the community. NASA supports scientific research directly through funding both for mission operations and data analysis (MO&DA), and also for broadly-based research and analysis (R&A). In a very real sense, the scientific results enabled by DA and R&A funding represent the ultimate return on the nation's investments in SMD missions. The cuts that occurred in 2006 in NASA SMD had a major impact on the science community. The AAAC has discussed the role of R&A and MO&DA in its previous reports and that material is updated and continued here (expanding on the discussion on NASA §7). The renewed commitment with SMD to R&A since AA Alan Stern arrived is very encouraging, but we also recognize the fragility of these programs given the pressures on SMD and on the agency. These arguments are presented here in case of discussion arises regarding the importance of R&A and MO&DA.

[34] http://www7.nationalacademies.org/bpa/caa.html

MO&DA is directed for support of the operating missions. This component is very important for the community and for NASA since it directly funds the science from the operating missions; that is, it enables the direct return on the capital investment. Current science data analysis funding totals ~$60M for the flagship missions like HST, Chandra and Spitzer. This funding is crucial for returning the science results from operation missions that represent a huge investment for Federal dollars. The science community greatly appreciates that NASA explicitly and directly recognizes the value of science data analysis funding for its missions and ensures that such funding receives priority along with mission operations support.

A second component of community support is R&A. The R&A program represents research funding that is not explicitly associated with an operating mission. However, this does not mean that R&A isn't targeted at areas of particular value for NASA. It typically has been. While the focus at NASA is on missions and mission-related data analysis, *there is a crucial need for a broader-based program that is in NASA's best interest to fund.* Even at a mission-focused agency there are essential research and development needs that must be supported if NASA is to have cutting-edge future missions. The R&A line is at the heart of this need, enabling creative extension of archived data, theoretical studies that cross traditional disciplinary boundaries, laboratory studies that develop chemistry and physics with which astronomical data can be interpreted, and new instrumentation and sensor technologies that pave the way for new science missions. This budget line develops the fabric out of which new areas of astronomical research and new mission concepts evolve. With its strong academic participation, R&A is a key factor in workforce training. This broader funding trains scientists to effectively and efficiently derive exquisite scientific results from the NASA missions. Thus, R&A has significant direct value to NASA and its future flight opportunities, as well as to the science return from current missions. The AAAC, like so many in the science community, is very deeply concerned about the long-term impact of the R&A cuts on future mission opportunities and the science return from the current missions.

The impacts of any reductions in R&A funding extend to a wide range of activities, most of which have long timescales. A break in funding can impact our readiness for scientific mission opportunities, or technology developments, or theoretical modeling, or analysis and archiving techniques. For example, if we fail to develop a particular technology to flight readiness (TRL-6), it may preclude a whole class of missions. Coronagraphic planet detection techniques, with their exquisite and extraordinarily challenging optical requirements, are an example where progress is necessarily slow. Detectors are a perennial problem, and it is rare for a program not to find their baseline detectors on the critical path. Stopping efforts in areas like these can have a major impact when funding does again become available – the mission suites will be limited if a long-term development program has been interrupted.

R&A can make a substantial difference in many areas, for example, by: (1) targeting low-flight-readiness technology, at a point where high risk, high payoff activities are low in cost (e.g., sensor development); (2) encouraging investment in specialized test and characterization equipment and implementation expertise in a low-cost lab environment; (3) encouraging applied physics research that can lead to novel hardware solutions, as well as to new software systems; (4) developing new and innovative data analysis approaches that leverage a huge investment in major facilities; (5) carrying out low-cost, suborbital proof-of-concept (technology and science) demonstrations for flight hardware; (6) enabling end-to-end student projects in academia that develop skills in experiment planning, design, and execution; (7) exploring theoretical models with the goal of understanding the results from multiple-missions datasets; (8) developing sophisticated numerical modeling techniques, implementing them on computer arrays and interpreting the results over the many years it takes to put these systems into place; and (9) enabling measurement through laboratory astrophysics of parameters that are essential for deriving scientific results from missions.

We were interested to note that our own views about R&A were similar to those who developed the Universe (now Astrophysics) Division roadmap in 2005, namely: "The theory, laboratory astrophysics, ground-based observation, archival research, and technology development components, together with the suborbital program described above, constitute the seed corn from which major NASA missions grow. It is the R&A program that supports creative, high-risk, novel ideas and the initial development of new detectors and instrument concepts. Support of new ideas at an early stage is the lifeblood of progress across the radiation spectrum from radio to gamma rays, cosmic rays, neutrinos, and gravitational waves. A stable, long-term program of basic research in detector development and supporting research and technology is essential for the future development of large space missions. The opportunities for hands-on training with cutting edge technologies and relatively modest R&A projects is equally critical for supporting and nourishing the scientists, technicians, engineers, and managers who will be responsible for the scientific priorities and flagship missions of the future. While the R&A program supports future developments needed to sustain the Roadmap, it also provides scientists the opportunity to do cutting-edge science: The recent Hubble observations of the oldest known planet, a Jupiter-sized body orbiting around a sun-like star in a globular cluster 5600 light years from Earth, was supported by R&A. Likewise, the Spitzer observation of the youngest planet observed outside the Solar System, the BOOMERANG balloon-borne studies of the cosmic microwave background, and the observations of prompt optical flashes from gamma ray bursts were supported by R&A."

While we recognize that the new AA Alan Stern has made substantial steps to reverse the cuts to R&A from the FY07 budget, the budget challenges for NASA SMD are substantial. We remained concerned that pressure on the R&A could surface in the future, and we want to note that R&A cuts at any of the agencies have broad impact and seem very inconsistent with the broad goals of the American Competitiveness Initiative (ACI). Such cuts have a dramatic and disproportionate impact on the future of the field – particularly on the imaginative, hard-working young scientists. They are largely supported at universities from small research grants that are the province of the R&A program, and so are amongst the first to feel the cuts because they are not as established and recognized as the more senior members of the community. These young people, along with their guides, mentors and teachers among the more senior, experienced members of the community, constitute the scientific human capital. They constitute the future of the field.

Even if NASA is largely excluded from ACI, NASA indisputably supports basic research, and any cuts to R&A at NASA while funding increases elsewhere (NSF, DOE, NIST) could lead to no net gain or even overall cuts, given the scale of the R&A activities at NASA. R&A support for theory, for technological development and for multi-mission analysis all add substantial breadth to the science program and provide the framework for future missions. In many respects, the R&A program seeds the ideas and training for the next generation of programs and missions.

An example of the programs that R&A supports was brought to the AAAC's attention in its May 2006 meeting during a presentation regarding a recent workshop on Laboratory Astrophysics. The results from laboratory astrophysics research underpin the interpretation of a wide range of astronomical phenomena, and so it is a small but very important component of the overall research enterprise in astronomy and astrophysics. The funding needs of researchers such as these who benefit a much wider community are met through R&A programs. Cuts in R&A programs significantly impact these broadly-beneficial research undertakings. This is but one of many examples where the science returns, future capabilities and future science productivity for a broad range of science investigations can be damaged by cuts.

The Decadal Survey explicitly recognized that the R&A and grants programs at NASA and NSF are the means by which the community undertakes the professional development needed for missions and programs by "ensuring the creation of the next generation of instrumentalists… and establishing expertise in computational techniques, data-mining and algorithmic skills" through "postdoctoral training, NASA's [Long-Term Space Astrophysics (LTSA)] program, and the participation of women and minorities". These themes are reinforced in the AST Senior Review's second principle, *Optimizing the Workforce*: "The development and operation of next-generation astronomical facilities requires concomitant investment in the development of next-generation personnel and the retention of key individuals with highly specialized skills and abilities."

Appendix A.2 Extremely Large Telescope (ELT)/Giant Segmented Mirror Telescope (GSMT)

A giant 30-meter-class telescope, identified as a Giant Segmented Mirror Telescope (GSMT), was the highest-ranked ground-based large project in the Decadal Survey. GSMT can play a major role in some of the most ambitious scientific goals of our time, namely understanding both the formation and evolution of galaxies within the first 1-2 billion years after the Big Bang and the formation of stars and planets. Just as the current generation of large telescopes has heralded unexpected discoveries through the breadth of their capabilities, so would a telescope with ~10 times the light gathering power of our current 8-meter-class telescopes. The discussion in this appendix represents the result of several years of consideration of the challenges of implementing GSMT as a Federal project in a partnership with GMT and/or TMT. The experience and thinking that went into this summary is expected to be valuable for the upcoming Decadal Survey and for further discussions regarding the development of GSMT. This section also provides background to the discussion in the NSF section on GSMT (§6.5.4).

The US is not alone in its interest in such a telescope. The European astronomical community, through the European Southern Observatory, has begun a very systematic approach to their 42-m ELT, and expect to give its implementation priority as the ALMA project moves towards completion.

Significant efforts towards realizing GSMT have begun in the US community. Two concepts have surfaced. One, the Giant Magellan Telescope (GMT), uses a small number of large segments for the mirror. The other, the Thirty Meter Telescope (TMT), uses a large number of small segments. These groups came together with a joint proposal to the NSF for GSMT technology development. The AAAC is highly supportive of the GSMT program and was very encouraged that some funds were made available from NSF AST for technology development (~$1M in FY05, $2M in FY06, and $5M in FY07, originally $5M but now TBD in FY08 because of the Omnibus funding level, and with further support requested in FY09). Given the scale of these projects, these funds have not constituted a significant contribution towards GSMT, but the FY07, FY08 and FY09 funding would be a valuable resource for the projects. The AAAC has noted on several occasions its hope that the R&D funding grows to match the originally requested $39M total for GMT and TMT. A key area for GSMT is adaptive optics (AO), and support for AO system technology development and on-the-sky demonstrations that are directed towards capabilities needed by GSMT could also be a valuable contribution for both concepts.

The usual approach with major projects has been to prepare and submit a construction proposal for Major Research Equipment and Facilities Construction (MREFC) funding once the concept and early technology development phase is completed. This was the case for the Atacama Large Millimeter Array (ALMA) and the Advanced Technology Solar Telescope (ATST), and was recently done for the Large Synoptic Survey Telescope (LSST). Based on this, the expectation was for a path forward that led to a GSMT construction-funding request through the MREFC program. Since GSMT somewhat unusually involved two projects, the expectation, as noted in the 2006 AAAC report, was for a competitive selection that would lead to one project moving forward as an MREFC project. This approach was derived from an earlier community report, *Strategies For Evolution of U.S. Optical/Infrared Facilities Recommendations* of the *OIR Long Range Planning Committee*[35] (OIR-LRPC). The OIR-LRPC report, from July 2005, involved extensive discussions and input that was developed for consideration by the NSF Senior Review committee and other planning groups. Such an approach, while not the only way forward, is certainly a normal one for government-funded

[35] http://www.noao.edu/dir/lrplan/lrp-committee.html

science projects. JWST, for example, supported technology development to the point where the competing projects submitted proposals for construction. In the case of GSMT a selection would have been made that would allow the NSF to move forward with a single project for a major investment through the MREFC process for the national share of the construction costs. Unfortunately the current timescale for reaching a "new start" as an MREFC project is many years. (For ATST the lag from Readiness to New Start could be as long as 5-6 years.) This is a very long period for projects like TMT and GMT that have significant momentum for private funding. The challenge is compounded also by the different development stages for GMT and TMT.

This private funding is a quite unusual aspect of the GSMT program. The two candidate projects expect to bring at least several hundred million dollars of private funding into the project from private foundations, individuals and universities. The TMT Project recently announced a gift of $200M from the Moore Foundation. International participation is also growing. (Canada is already a member and a major partner of the TMT project, and Australia is member of the GMT project.) Clearly investments of this scale for projects of very high priority in the Decadal Survey are of significant value to the nation's research enterprise. It provides great opportunities for bolstering the research funding available to the nation as a whole, but also brings with it some interesting policy issues. How can the funding for such projects be developed so as combine the constraints, interests and approach of private foundations and donors with those of the Federal government and its agencies and Congressional oversight?

The difference between the MREFC approval process timescale (up to 5-6 years as noted above) and the private funding timescale presents a clear problem for moving ahead. Both projects are likely to want to move forward more rapidly once they identify their major private funding sources. Given this, it is very unlikely that MREFC can be used for the initial construction phases of GSMT. This is unfortunate since MREFC involves a well-defined process for Federal involvement and funding of a major project.

However, there may well be other approaches to utilizing MREFC for GSMT. For example, the telescope construction may be initiated by the project(s) and the telescope facility largely funded through private sources, but other aspects could be funded separately. The instruments for a 30-meter telescope (the baseline GSMT in the Decadal Survey) are very challenging and expensive items. The typical cost is expected to be $50M or more, possibly significantly more for a very complex system like a major AO planet-detection system. Several instruments may then approach $200M. A MREFC proposal could well include a mix of instruments optimized for GSMT, i.e., to match the particular strengths of GMT and TMT if both projects go ahead. If both are built, the "system" approach will be key to their effective utilization – that is, an approach that optimizes and provides complementary capabilities, and not overlapping capabilities. In addition, an archive that meets National Virtual Observatory (NVO) standards for data access could also be part of such an MREFC proposal. Together (instruments and archive) these may well constitute a MREFC proposal that provides a significant investment at the Federal level and is timed to match better the telescope construction and operation. The construction could start with private funding for the observatory with an initial set of instruments, leaving the major instruments as an MREFC proposal.

Regardless of the outcome of proposals to use MREFC funding, there remains a separate clear path for the involvement of the Federal government in GSMT. This would involve funding operations. Private foundations have shown a preference for supporting major construction expenditures over a limited period, with significantly less ability to fund long-term operations. The agencies, while unable to make long-term commitments explicitly, have in fact been able to fund long-term operations in programs that are consistently returning high-value science results. Clearly one approach to a national facility would be for the NSF to come in as a partner by funding operations, while allowing the private foundations to bear the brunt of the early development and construction costs. Such arrangements may enable a project with a high level of private support to move more expeditiously once they have satisfied their readiness and review requirements.

The policy aspects of such an arrangement between the private and public sectors could be of interest to those in the agencies, OMB and Congress. The appropriate review and management mechanisms would need to be implemented on all sides, but to do this successfully would be "win-win" for all concerned. While discussions could be held among the interested parties, one mechanism might be a study that would address the development of a strategy that would be mutually satisfactory to NSF, OSTP, OMB, Congress and private foundations, to see what could be achieved in finding a way to utilize private resources at the level of $300-500M for funding very highly ranked science projects. The mechanism for this is not obvious – could OSTP coordinate such an effort?

Over the last few years the options for GSMT broadened from the initial TMT 30-meter project as the GMT 24.5-meter project was developed. The Senior Review gave considerable attention to the role of the National Optical Astronomy Observatory (NOAO) and recommended a number of significant changes for NOAO, as noted in §6.3.3. In particular, it came to be recognized during this process that the focus of activities at NOAO on TMT was not optimal from a national perspective. As a result, NSF-AST has asked AURA/NOAO[36] to act as NSF's "Program Manager" for GSMT development. This is a broad and important role that will facilitate progress on the national component of GSMT. With this new role NOAO will be expected to understand and champion national needs for a GSMT, establish appropriate, symmetrical interfaces with TMT and GMT, and promote development at a pace that recognizes both private and Federal timescales. These broad goals encompass a very extensive range of activities that are still being discussed between NSF-AST, GMT, TMT and AURA/NOAO. The AAAC viewed this development very positively since it provided a clearer structure for dealing with the two projects, and noted an interest in the detailed plan for NOAO's role that is currently under development.

A larger version of GSMT is also under consideration by the Europeans through the European Southern Observatory (ESO), as noted above. There is interest within the European Union (EU) astronomy community on moving forward on their own ELT, given the great success of their Very Large Telescope (VLT), which consists of four 8-meter telescopes that are 100% EU-funded. Whether this proves practical is an open question at this time, just as the question remains as to whether GSMT will be a fully U.S. venture (private plus Federal). Regardless of these uncertainties, the European interest in extremely large telescopes (ELTs) around 40-meter apertures opens up the potential for future coordination or collaboration. AST has convened a group of international funding agency representatives to explore cooperation on the next-generation telescopes. Continuing discussions with the European community could identify ways in which the two groups could develop their respective ELT facilities for mutual benefit (e.g., shared access and complementary instrumentation). This would be especially valuable if the result of these efforts is joint access to a next-generation, very large telescope in each of the northern and southern hemispheres, giving all-sky coverage. But, even if the telescopes are in the same hemisphere, the high cost of major instruments ($50M) indicates that significant advantages would accrue from shared access.

An interesting question that remains unresolved then is "What is GSMT?" Is it TMT? Is it GMT? Is it access to some combination of GMT and TMT if private funds are found for both? Does it involve some combination of the above along with the ESO ELT? Will GMT and TMT combine into a single project? The level of private funding required is large, and so this may be the only practical way forward. This is a complicated option set. What is the NSF role in these different options? The good news is that the private funding may allow at least one, but possibly two, major U.S. facility(s) of the 30-meter class to be constructed. The bad news is that this complicates the path forward and reduces the clarity of the discussion regarding GSMT. This uncertainty surrounding the Federal role may impact the speed at which GSMT moves ahead, and the concurrent operation with the James Webb Space Telescope (JWST), as discussed in §6.5.5. It is not obvious at this point how to move forward rapidly. The lack of clarity will bring challenges

[36] The Association of Universities for Research in Astronomy (AURA) is the management organization for NOAO.

both in the Decadal Survey and for long-range planning at the Federal level, but the ultimate outcome could well be two, large, somewhat different ELTs that are accessible to the U.S. community and that provide even larger scientific returns. A broad plan for how GSMT might develop would be particularly useful for the Decadal Survey. In the near-term the AAAC has recommended (and does so again in §6.5.4) that the most valuable activity that could be undertaken is to explore the possible options and timescales for NSF support for GSMT so that planning for them can begin both within the projects and at NSF-AST.

In summary, the AAAC appreciated that NSF MPS and AST continue to support GSMT technology development through funding for the two community groups, the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT). The next step is less clear. The 2010 Decadal Survey will clearly evaluate the prospects for an ELT, but the broad issues outlined here will likely remain as we move into its implementation if an ELT receives similar priority as in the 2000 survey. The options for Federal involvement in the GSMT project are unclear given both the potentially different timescales for GMT and TMT and the likely need for construction funding for either project more rapidly than can be provided through the MREFC process. TMT and GMT and their private donors are likely to be ready to commit hundreds of millions of dollars to construction well before an MREFC New Start could be reached. Federal involvement through an MREFC proposal for a set of instruments that are matched to each telescope's optimization could be a very effective mechanism for the national "GSMT" role, along with archive and operations support. The early commitment of operations support for the Federal partnership poses a challenge. The involvement of OMB and OSTP, and of committees in Congress, could help develop this unusual model. The role of the National Optical Astronomy Observatory (NOAO) as the national interface for GSMT is a welcome development. The AAAC also believes that continued dialog with the Europeans regarding their plans for an extremely large telescope (ELT) could be mutually beneficial as well. The AAAC has recommended (and does again) that NSF, AST and MPS, along with the projects, explore options for funding other aspects of GSMT, including major upgrades through MREFC (e.g., a set of second-generation instruments and archives). Developing mutually-beneficial approaches for funding operations could encourage progress on the projects with private donors, who will likely invest at least several hundred million dollars into GMT and/or TMT for construction, as the Moore Foundation has done. The AAAC recommended OSTP involvement because of the broad policy issues involved, and encourages Congressional support for alternatives if the current framework challenges the use of private funding (as in §6.5.4).

Appendix A.3 MREFC and Long-Range Planning at NSF

Over the last several years the AAAC has been particularly interested in changes and improvements under discussion for the Major Research Equipment and Facilities Construction (MREFC) activity. We have moved the section detailing our thinking on this to an appendix for continuity, thereby providing the background to the comments that remain in the main body of the report in §6 under the NSF. The committee welcomed the approach taken in the FY09 Request budget for ATST, where funds were identified within MREFC to support immediate pre-construction development. This will ultimately strengthen the project and add robustness to its final construction budget and timescale (though we were concerned that in doing so, AST's budget was impacted, which was not the intention of our recommendation!).

The MREFC process is of great importance for astrophysics and is becoming of increasing importance to NSF. The major observatories and facilities constructed through MREFC provide dramatic advances in scientific exploration in astrophysics. Because of the long history of major astronomy projects, and because our future is so interwoven with MREFC, it is an aspect of the NSF's funding to which we pay particular attention. Based on our long experience with major facility construction and operation, we can also bring what we hope are valuable insights to discussions of the MREFC process. The MREFC process has become more open and transparent. The key to an effective MREFC process is that it be appropriate for the NSF's oversight responsibility, yet maintain sufficient flexibility to respond to the particular needs of different disciplines.

A Facility Plan is an essential component of program such as MREFC. Such a plan provides guidance for the agency and all stakeholders. Concerns about the rigidity of such plans can be alleviated by periodic reassessment so that the plan is responsive to changing circumstances. Together, the process and Facility Plan should ensure that all stakeholders understand the status, timescale and progress of large projects. The process should also provide opportunities for negotiation with potential international, multi-agency or private partners. Such complexities have become the norm for major astronomy projects, and recognition is needed that procedures and timelines should allow private and/or international partnerships to be folded into the planning and approval processes. The AAAC supports the broad direction outlined in NSB 05-77, though several questions and possible concerns remain. The AAAC was encouraged to see that a Facility Plan was developed, though it remains incomplete in that it does not show likely timelines, phasing and key milestones for each project, as is done for plans at other agencies where large projects are undertaken. The value of the Facility Plan to current and potential MREFC projects would benefit from the inclusion of these elements, and the AAAC hopes that the next version of the Facility Plan is more complete in these areas.

One cautionary note might be applied to the current process. As the process has increased in complexity, we are concerned that MREFC may become unable to respond effectively to opportunities for interagency, public-private and international projects aligned with Decadal Survey priorities. It would be very useful to do a timeline and step-by-step walk-through of the current MREFC process with a project that involves international cooperation and private donors, all of whom have different timescales, management constraints and funding processes. We suspect it would challenge the present approach. With a more nimble and responsive process, scientific opportunities can be optimized for the greatest benefit from the investment of Federal and private resources. This is of particular importance for large 20- to 30-m telescope projects, where the potential exists for very substantial private contributions, as discussed in §6.5.4 and Appendix A2.

An important aspect for astronomical projects is that they inevitably utilize forefront technologies. This imposes significant challenges for a major construction project and leads to substantial upfront costs for technology development so that major areas of risk are retired before the construction phase. The implications of this are addressed in the next section.

Lifecycle Costing of MREFC Projects

An important aspect of the MREFC process will be the need to understand and identify the "lifecycle" aspects of major projects and their associated costs. The AAAC discussed these issues in some detail in its previous reports, and the Senior Review committee stressed these same issues in Finding (3) of their report, where they noted that "realistic life cycle costing for the observatories that are under construction or consideration is an essential part of planning." The term "lifecycle" is used to encompass the multiple, well-defined components in the realization of major projects: the conceptual design and preliminary development phase (Phase 1); a development and demonstration phase (Phase 2); the construction phase (Phase 3); a commissioning phase (Phase 4); and the operations and science return phase (Phase 5). In addition, there is a final end-of-life stage, which is de-commissioning the facility. The recent Senior Review discussions have highlighted the possibly very significant costs associated with this last stage.

The "lifecycle" analysis and cost-profiling approach has become the norm at NASA and DOE and other agencies from their long experience with major projects, and it may be useful for NSF to look at the experiences of other agencies to determine what aspects might be appropriate for the NSF environment. The mapping of Phases 1-5 onto DOE's CD-0 through CD-4 and NASA's pre-Phase A through Phase E is not one-to-one, but has many parallels.

Lifecycle budgeting was addressed in the 2003 NSB report, *Science and Engineering Infrastructure for the 21st Century*[37], (NSB 02-190) from the Committee on Programs and Plans Task Force on Science and Engineering Infrastructure. Under their Recommendation (4): "Strengthen the infrastructure planning and budgeting process through the following actions," they note in item (3): "Develop and implement budgets for infrastructure projects that include the total costs to be incurred over the entire life-cycle of the project, including research, planning, design, construction, commissioning, maintenance, operations, and, to the extent possible, research funding."

The importance of developing a "lifecycle" approach to project conceptual development through construction to operations becomes particularly important as the scale of projects increases. In particular, the importance of careful evaluation of the funding level of operations and science return during the operations period cannot be understated. Both science operations and upgrades (e.g., new instruments) are key factors during this period. It is this last phase wherein all the cost is "recovered" through science output. Inefficiencies at this time are not cost-effective. The challenges associated with operations have been noted above, namely that a $1B project with a typical 10% annual budget for operations, maintenance and upgrades would alone consume ~50% of the AST budget. The need for added operations funding for these next-generation facilities is clear.

Implementation Phases of MREFC Projects

Most major programs will have their pre-construction development phases and post-construction operations funding identified from within the appropriate Division. There are, however, serious limitations to such an approach when the projects reach a certain scale. For these large MREFC projects, even with substantial commitment of resources from the Division, the pre-construction developments may not allow the risk retirement that is the primary goal of such pre-construction efforts. If the project goes ahead, the agency as a whole assumes a larger risk of schedule slippage and cost growth than if adequate resources had been expended before entering the construction phase. The identification of two phases of pre-construction development, as noted above in the "lifecycle" costing approach, is a well-understood approach to risk retirement. The first phase demonstrates conceptual reality and usually endeavors to assess the main technological hurdles while also evaluating the likely facility performance and the resulting scientific capabilities. This is a crucial step, but one which takes time and only modest levels of funding, with review as appropriate. The next pre-construction step is when the key technologies and processes are demonstrated to be in place and when much more detailed and realistic costing can be done. This step is intrinsically more expensive, is run under much tighter management constraints and is the subject of key reviews to ensure that the risks are understood and retired before going into construction.

The first phase (Phase 1) is an activity that can be funded by the Divisions using current approaches. On major projects the second phase (Phase 2) is unlikely to be done well with the resources available to the Divisions. Experience has shown (depending on the project) that about 20% of the total construction cost needs to be spent in the second stage for effective risk retirement, though it could well be more for a very technically-challenging project. The NASA James Webb Space Telescope (JWST) is likely to spend ~40% of its total budget before going into construction (Phase C/D). Because risk retirement is in the best interest of the agency as a whole (particularly because the whole agency bears the downside of major problems during the construction phase), the agency should work to develop a process in which the Phase 2 activity is either funded under the MREFC account or budgeted at the agency level rather than at the Division level.

To summarize, the AAAC recommends that the NSF consider an approach which differs from the current one in that the pre-construction activities are clearly separated into:

[37] http://www.nsf.gov/nsb/documents/2002/nsb02190/nsb02190.pdf

1) a long but modest level of effort funded by the Divisions, wherein the conceptual design, required technologies, expected performance and scientific capabilities are developed (Phase 1);
2) a shorter, more focused and more tightly managed phase (that is inherently more costly) in which key technologies are demonstrated and reviewed, system-level issues are evaluated and the detailed costs are established (Phase 2). This should be done under an agency-level activity that is closely linked to the MREFC process.

To further develop this approach, the AAAC recommends the involvement of experienced project managers and program officers in the formulation of procedures and processes for MREFC-scale projects.

A similar two-phase structure exists on the back-end of projects, following construction. As construction is completed, the project transitions to the commissioning phase. This phase, which involves different mixes of personnel skills and experience, is intrinsically different from operations and again requires a different level of support. This is an important aspect of taking a "lifecycle" planning approach to major projects. It is obviously undesirable to make a major investment in a program and then have that project not reach its design level of scientific return because the funding was too low for effective and timely commissioning of the project. Since commissioning can be funded from MREFC we consider that it would be good practice to budget this where appropriate. Thus, to follow item 2) above we have:

3) the construction phase (Phase 3), as per current MREFC practice;
4) the commissioning phase (Phase 4), with its overlap with the engineering resources from construction and with the technical expertise that will handle operations. The commissioning phase needs higher overall resources than the operations phase, and again should be viewed as an agency-level activity that is closely tied to the MREFC process;
5) the operations phase (Phase 5), during which the science is carried out. This is at a lower funding level than commissioning.

Finally there is:

6) a de-commissioning activity whose funding is very project dependent, but could be quite significant.

The impact and timescales of these steps are, in summary:
Phase 1) conceptual development: low annual cost, moderate to lengthy duration;
Phase 2) system-level assessment and detailed costing: moderate-high annual cost, short duration;
Phase 3) construction: high annual cost, moderate duration;
Phase 4) commissioning: moderate-significant annual cost, short duration;
Phase 5) operations: moderate cost, long duration;
and 6) de-commissioning: variable but a sometimes significant cost activity

In summary, a funding base for large initiatives that includes both Division- and agency-level contributions during critical project lifecycle phases would: expedite the later phases of the design and development process; lower the risk of cost growth; achieve science goals more reliably and quickly; and reduce serious impacts on ongoing research infrastructure within the discipline, including human resources. The AAAC urges the consideration of new approaches for funding the design and development phase of major initiatives. Both the design and development phase and the commissioning phase should be supported with funding from within the Divisions and from more agency-wide approaches, possibly linked to MREFC.

APPENDIX B – CHARGE

ESTABLISHMENT OF THE AAAC UNDER THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT OF 2002 AND ITS SUBSEQUENT MODIFICATION TO INCLUDE DOE

NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT OF 2002, Public Law 107-368, Dec.19, 2002

An Act To authorize appropriations for fiscal years 2003, 2004, 2005, 2006, and 2007 for the National Science Foundation, and for other purposes.

SEC. 23. ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE.

(a) Establishment. – The Foundation and the National Aeronautics and Space Administration, and the Department of Energy shall jointly establish an Astronomy and Astrophysics Advisory Committee (in this section referred to as the "Advisory Committee").

(b) Duties. – The Advisory Committee shall

(1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy;

(2) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration, and the Department of Energy as they relate to the recommendations contained in the National Research Council's 2000 report entitled ``Astronomy and Astrophysics in the New Millennium'', and the recommendations contained in subsequent National Research Council reports of a similar nature; and

(3) not later than March 15 of each year, transmit a report to the Director, the Administrator of the National Aeronautics and Space Administration, the Secretary of Energy and the Committee on Science of the House of Representatives, the Committee on Commerce, Science, and Transportation of the Senate, and the Committee on Health, Education, Labor, and Pensions of the Senate on the Advisory Committee's findings and recommendations under paragraphs (1) and (2).

(c) Membership. – The Advisory Committee shall consist of 13 members, none of whom shall be a Federal employee, including –

(1) 4 members selected by the Director;
(2) 4 members selected by the Administrator of the National Aeronautics and Space Administration;
(3) 3 members selected by the Secretary of Energy; and
(4) 2 members selected by the Director of the Office of Science and Technology Policy.

(d) Selection Process. – Initial selections under subsection c shall be made within 3 months after the date of the enactment of this Act. Vacancies shall be filled in the same manner as provided in subsection c.

(e) Chairperson. – The Advisory Committee shall select a chairperson from among its members.

(f) Coordination. – The Advisory Committee shall coordinate with the advisory bodies of other Federal agencies that engage in related research activities.

(g) Compensation. – The members of the Advisory Committee shall serve without compensation, but shall receive travel expenses, including per diem in lieu of subsistence, in accordance with sections 5702 and 5703 of title 5, United States Code.

(h) Meetings. – The Advisory Committee shall convene, in person or by electronic means, at least 4 times a year.

(I) Quorum. – A majority of the members serving on the Advisory Committee shall constitute a quorum for purposes of conducting the business of the Advisory Committee.

(j) Duration. – Section 14 of the Federal Advisory Committee Act shall not apply to the Advisory Committee.

APPENDIX C – ACRONYMS

AA	Associate Administrator
AAAC	Astronomy and Astrophysics Advisory Committee
ACI	American Competitiveness Initiative
AIM	Astrometric Interferometry Mission (now known as SIM)
ALMA	Atacama Large Millimeter Array
America COMPETES	H.R. 2272, America Creating Opportunities to Meaningfully Promote Excellence in Technology and Science Act
AMS	Alpha Magnetic Spectrometer
AO	Adaptive Optics
AO	Announcement of Opportunity
AST	NSF Division of Astronomical Sciences
ATIC	Advanced Thin Ionization Calorimeter
ATST	Advanced Technology Solar Telescope
AUGER	Pierre Auger Observatory
AURA	Association of Universities for Research in Astronomy
AXAF	Advanced X-ray Astrophysics Facility (now known as Chandra)
BEPAC	Beyond Einstein Program Assessment Committee
BESS	Balloon-borne Experiment with Superconducting Spectrometer
BHFP	Black Hole Finder Probe
BPA	Board on Physics and Astronomy
CAA	Committee on Astronomy and Astrophysics
Cassini	Cassini-Huygens Mission to Saturn and Titan
CDR	Critical Design Review
CEV	Crew Exploration Vehicle
CGRO	Compton Gamma Ray Observatory
Chandra	Chandra X-ray Observatory (formerly known as AXAF)
CMB	Cosmic Microwave Background
CMBPOL	CMB Polarization Mission
COBE	Cosmic Background Explorer
COMRAA	Committee on Organization and Management of Research in Astronomy and Astrophysics
Con-X	Constellation X-Ray Observatory
COROT	COnvection, ROtation and planetary Transits
CQC	Connecting Quarks with the Cosmos (2004 NAS report)
COS	Cosmic Origins Spectrograph
CREAM	Cosmic Ray Energetics And Mass
CTIO	Cerro Tololo Inter-American Observatory
DETF	Dark Energy Task Force
DMSAG	Dark Matter Science Assessment Group
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
ELT	Extremely Large Telescope
ELV	Expendable Launch Vehicle
EPP2010	Elementary Particle Physics in the 21st Century
ESA	European Space Agency

ESMD	Exploration Systems Mission Directorate
ESO	European Southern Observatory
EVLA	Expanded Very Large Array
ExAO	Extreme Adaptive Optics
ExoPTF	ExoPlanet Task Force
FACA	Federal Advisory Committee Act
FY	Fiscal Year
Galileo	Galileo Jupiter Mission
GLAST	Gamma-ray Large Area Space Telescope
GMT	Giant Magellan Telescope
GONG	Global Oscillation Network Group
GSMT	Giant Segmented Mirror Telescope
HEP	DOE Office of High Energy Physics
HEPAP	High Energy Physics Advisory Panel
HST	Hubble Space Telescope
ILC	International Linear Collider
IP	Inflation Probe
ISS	International Space Station
JDEM	Joint Dark Energy Mission
JWST	James Webb Space Telescope (formerly known as NGST)
KAO	Kuiper Airborne Observatory
LAT	Large Area Telescope
LHC	Large Hadron Collider
LISA	Laser Interferometer Space Antenna
LST	Large Survey Telescope
LSST	Large Synoptic Survey Telescope
LTSA	Long-Term Space Astrophysics
MIE	Major Item of Equipment
MO&DA	Mission Operations and Data Analysis
MOU	Memorandum of Understanding
MPS	NSF Directorate for Mathematical and Physical Sciences
MREFC	Major Research Equipment and Facilities Construction
MRI	Major Research Instrumentation
NAC	NASA Advisory Council
NAIC	National Astronomy and Ionosphere Center
NAS	National Academy of Sciences
NAPA	NASA Astrophysics Performance Assessment Committee
NASA	National Aeronautics and Space Administration
NEO	Near-Earth Object
NET	No Earlier Than
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NIST	National Institute of Standards and Technology
NGST	Next Generation Space Telescope (now known as JWST)
NOAO	National Optical Astronomy Observatory
NRAO	National Radio Astronomy Observatory
NRC	National Research Council
NSB	National Science Board
NSF	National Science Foundation
NSTC	National Science and Technology Council

NuSTAR	Nuclear Spectroscopic Telescope Array
NVO	National Virtual Observatory
OIR-LRPC	Optical-IR Long Range Planning Committee
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
Pan-STARRS	Panoramic Survey Telescope and Rapid Response System
PDR	Preliminary Design Review
PHY	NSF Division of Physics
R&A	Research and Analysis
R&D	Research and Development
S&E	Salaries and Expenses
SAFIR	Single Aperture Far-Infrared Observatory
SDO	Solar Dynamics Observatory
SIM	Space Interferometry Mission (formerly known as AIM)
SIRTF	Space Infrared Telescope Facility (now known as Spitzer)
SKA	Square Kilometer Array
SLAC	Stanford Linear Accelerator Center
SM4	HST Servicing Mission 4
SMD	NASA Science Mission Directorate
SMEX	Small Explorers
SNAP	Supernova Acceleration Probe
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPIRES	Stanford Public Information REtrieval System
Spitzer	Spitzer Space Telescope (formerly known as SIRTF)
SPT	South Pole Telescope
SScAC	Space Science Advisory Committee
STIS	Space Telescope Imaging Spectrograph
STS	Space Transportation System (a.k.a. Space Shuttle)
SWG	Science Working Group
TDRSS	Tracking and Data Relay Satellite System
TFCR	Task Force on CMB Research
TMT	Thirty Meter Telescope
TPF	Terrestrial Planet Finder
TPF-C	Terrestrial Planet Finder-Coronagraph
TPF-I	Terrestrial Planet Finder-Interferometer
T-NAR	Technology Non-Advocate Review
TRL	Technological Readiness Level
VAO	Virtual Astronomical Observatory
VERITAS	Very Energetic Radiation Imaging Telescope Array System
VLA	Very Large Array
VLBA	Very Long Baseline Array
VLT	Very Large Telescope
WFC3	Wide-Field Camera 3
WISE	Wide-field Infrared Survey Explorer
WMAP	Wilkinson Microwave Anisotropy Probe