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

March 15, 2006

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 Sherwood L. Boehlert, Chairman
Committee on Science
House of Representatives
Washington, DC 20515

The Honorable Ted Stevens, Chairman
Committee on Commerce, Science and Transportation
United States Senate
Washington, DC 20510

The Honorable Michael B. Enzi, Chairman
Committee on Health, Education, Labor and Pensions
United States Senate
Washington, DC 20510

Dear Dr. Bement, Dr. Griffin, Secretary Bodman, Chairman Boehlert, Chairman Stevens, and Chairman Enzi:

I am pleased to transmit to you the annual report of the Astronomy and Astrophysics Advisory Committee for 2005–2006.

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;
(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).

The attached document is the third such report. The executive summary is followed by the report, with recommendations for NSF, NASA and DOE regarding their support of the nation’s astronomy and astrophysics research enterprise, along with detailed recommendations concerning specific projects and programs.

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 Bart Gordon, Ranking Member, Committee on Science, House of Representatives
Senator Daniel K. Inouye, Ranking Member, Committee on Commerce, Science and Transportation, United States Senate

Senator Edward M. Kennedy, Ranking Member, Committee on Health, Education, Labor and Pensions, United States Senate
Senator Richard Shelby, Chairman, Subcommittee on Commerce, Justice and Science, Committee on Appropriations, United States Senate
Senator Barbara Mikulski, Ranking Member, Subcommittee on Commerce, Justice and Science, Committee on Appropriations, United States Senate
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Representative Alan B. Mollohan, Ranking Member, Subcommittee on Science, State, Justice and Commerce, Committee on Appropriations, House of Representatives
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Senator Bill Nelson, Ranking Member, Subcommittee on Science and Space, Committee on Commerce, Science and Transportation, United States Senate
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Representative Darlene Hooley, Ranking Member, Subcommittee on Research, Committee on Science, House of Representatives
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Dr. Robert Dimeo, Acting Assistant Director, Physical Sciences and Engineering, Office of Science and Technology Policy, Executive Office of the President
Dr. Jon Morse, Senior Policy Analyst, Office of Science and Technology Policy, Executive Office of the President
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Mr. David Trinkle, Program Examiner, NSF, The Office of Management and Budget
Ms. Amy Kaminski, Program Examiner, NASA, The Office of Management and Budget
Mr. Donovan Robinson, Acting Energy Branch Chief, The Office of Management and Budget
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Dr. Kathleen Turner, Program Manager, Office of High Energy Physics, U.S. Department of Energy
Dr. Charles Elachi, Director, Jet Propulsion Laboratory and Director of Advanced Planning, NASA Headquarters
Dr. Edward J. Weiler, Director, NASA Goddard Space Flight Center
Mr. David Goldston, Chief of Staff, Committee on Science, House of Representatives
Dr. Chuck Atkins, Minority Staff Director, Committee on Science, House of Representatives

Astronomy and Astrophysics Advisory Committee Members:
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Dr. John E. Carlstrom, (Vice-Chair) University of Chicago
Dr. Bruce Carney, University of North Carolina at Chapel Hill
Dr. Wendy Freedman, Observatories of the Carnegie Institute of Washington
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Dr. Robert P. Kirshner, Harvard University
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Dr. E. Sterl Phinney, California Institute of Technology
Dr. Catherine A. Pilachowski, Indiana University
Dr. Abhijit Saha, National Optical Astronomy Observatory

ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

MARCH 16, 2005 - MARCH 15, 2006

EXECUTIVE SUMMARY

Astronomy is in the midst of a period of extraordinary scientific discovery. The path ahead leads to the exploration of some of the most exciting aspects of our universe: the nature of dark matter and dark energy in the universe, the formation of galaxies at early times, the nature of massive black holes, the formation of stars and planetary systems, and the detection of planets like Earth around other stars. NASA, NSF, and increasingly DOE, together provide the opportunities for astronomical research that have allowed this nation to demonstrate its scientific and technological leadership worldwide. The framework that led to this leadership was established by the decade-long plan of the National Research Council (NRC) Astronomy and Astrophysics Survey Committee 2001 Decadal Survey, *Astronomy and Astrophysics in the New Millennium* (hereafter the "Decadal Survey"). The recommendations given in this report are intended to further the implementation of the Decadal Survey and of more recent NRC studies such as *Connecting Quarks with the Cosmos* (*CQC*). These NRC studies herald a decade of remarkable scientific opportunities.

The diverse approach to astronomical research offered by NASA, NSF and DOE is key to the scientific success and public visibility achieved in astrophysics over the last several decades, and this diversity remains a central aspect of the future success of astronomy. Joint programs among NASA, NSF and DOE, implemented within a healthy scientific research budget, are also 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 will realizes greatly enhanced value from its investment in astronomy.

In response to the need to address increasingly important interfaces among the agencies that support astronomy and astrophysics, the Astronomy and Astrophysics Advisory Committee (AAAC) was established in 2002 by the Executive Branch and Congress to: 1) assess, and make recommendations regarding, the coordination of astronomy and astrophysics programs of NSF and NASA; 2) assess, and make recommendations regarding, the status of the activities of NSF and NASA as they relate to the recommendations contained in the NRC Research Council's 2001 Decadal report, and the recommendations contained in subsequent National Research Council reports of a similar nature; and 3) issue an annual report to Congress and the agencies no later than March 15. This annual report is the third by the AAAC.

Many issues have arisen for the AAAC over the last year. The major cuts for the NASA Space and Earth Science budget in the FY 2007 budget request have dominated the Committee's attention recently, but we have been actively following developments at NSF and DOE as well. Our attention to the NSF has focused on the MREFC process and on the Senior Review in the Division of Astronomical Sciences (AST). We have devoted considerable attention to the question of "lifecycle" costing of major projects at NSF and the implications for the funding profile of large, high technology projects that are of critical importance to the future of astronomical research. 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), on developments in dark-energy and dark-matter searches, and on the task forces that have been assembled to evaluate the scientific approaches that will best enable progress in these latter areas. The Task Force on CMB Research (TFCR) submitted its excellent report last year, the Dark Energy Task Force (DETF) report is anticipated in the spring of this year, the Dark Matter Science Assessment Group (DMSAG) was recently chartered, and the AAAC has proposed the formation of an ExoPlanet Task Force (ExoPTF) to assess the options for extra-solar planet detection and characterization.

The NASA FY 2007 budget request was a great surprise to the science community, particularly given the Administrator's statements in September and October 2005. The challenge of putting together the NASA budget under the go-as-you-pay system has been widely recognized, but the real impact was seen this year. The balance that makes for a healthy space-science enterprise in Astrophysics and in the other Divisions of NASA's Science Mission Directorate (SMD) has been lost, and the prognosis is not good for the diversity of Astrophysics missions later this decade. The AAAC is very concerned that the NASA science program has become seriously imbalanced and that changes were made without extensive discussion with the science community, with Congress and, even more broadly, with an interested public.

The AAAC's strongest recommendation this year is that NASA's science funding be restored.

Recommendations for the Agencies

The AAAC's recommendations for the agencies are shown in bold below and discussed in detail in the report.

NSF

The AAAC was very encouraged by the NSF budget increase in the FY 2007 request as the first step towards the long-awaited budget "doubling." The AAAC is also encouraged by the continuing steps being taken to respond to the Brinkman report, *Setting Priorities for Large Research Facility Projects*. The release of NSB-05-77 provides more structure to the MREFC process, as does the release of the first Facility Plan. However, the value of the Facility Plan to current and potential MREFC projects would benefit from the inclusion of likely timelines, phasing and key milestones for each project. We recognize the challenges in establishing detailed procedures that will accommodate the agency's many different Directorates and disciplines, but we recommend that the NSF expeditiously complete and adopt a detailed plan for developing and managing MREFC projects.

Major projects are essential for progress in astronomy and astrophysics. An effective MRFEC process is thus of great interest to the astronomy community. The AAAC fully supports efforts to improve the MREFC process.

The AAAC also recommends that consideration be given to a "lifecycle" costing approach that recognizes the very different funding and management requirements of the different phases of a large, high technology project. Two key phases that are not well supported by the current Divisional and MRFEC approaches are identified. These are the pre-construction phase, in which key technologies and processes are demonstrated, and the immediate post-construction commissioning phase. By managing and funding these phases as an agency-level activity, the NSF should be able to reduce the risk of cost growth during construction and should ensure that high science returns are achieved more rapidly after construction ends.

The multi-stage process for major, high technology projects recommended by the AAAC will make the MREFC program more robust, lessen cost growth during construction and enhance science return during operations. The AAAC also advocates the development of approaches to project development and management that take advantage of the opportunities provided by international collaborations and/or significant levels of private funding. This is discussed in detail in §5.4.

The AAAC commends the proactive efforts of the NSF, MPS and AST in responding to the challenges of implementing and supporting ALMA and for moving ATST into the Readiness Phase of the MREFC process. The AAAC welcomes the support for technology development for projects prioritized by the Decadal Survey and CQC. We also commend AST for its willingness to take the difficult steps, such as the Senior Review, needed for the future vitality of the field.

NASA

The AAAC is deeply concerned that the NASA space science program has suffered a major blow. More than $3B has been removed from funding for the Science Mission Directorate (SMD) in the next 5 years, leading to a budget for science that is projected to decrease after inflation. Science has been the most visible and productive element of NASA. 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. NASA should reconsider the proposed budget and work to increase the funding for SMD—doing so for its scientific returns, for its inspirational value to the nation, and for its importance to NASA as a continual demonstration of NASA's value to the nation and to the world.

The cuts to the NASA science budget will severely impact Astrophysics and lead to a serious imbalance in the astronomy and astrophysics program. As noted above, the AAAC recommends that NASA's science funding be restored to its FY 2006 level.

For the past year the lack of an advisory structure for NASA—and for science at NASA—has been a deep concern for the community. By the time the new science advisory committees are selected, approved and assembled, a year will have passed without discussions on issues that are critical for the community and for NASA science. During that time, far-reaching decisions were made without any scientific input (e.g., the effective cancellation of SOFIA whose budget was reduced to $0 in FY 2007 and beyond without a review). The AAAC welcomes the creation of a new advisory structure. However, we and others are concerned that this structure may not be as effective as that previously employed. The lack of close coupling of the science subcommittees to the SMD leadership is likely to be a significant impediment. The AAAC has every hope that the new structure will work effectively and in a timely way by providing feedback to SMD quickly with minimal modification. However, if the structure is perceived by either party to be ineffective, the AAAC hopes that the Administrator and the Associate Administrator for Science will evolve the structure to better serve NASA and the community. These committees play an essential role in optimizing the science program within the programmatic and budgetary constraints faced by the agency and thus are of great value both to NASA and to the community.

The NASA advisory process has been a mainstay of a productive and mutually beneficial relationship with the space and earth science community, including the astronomy and astrophysics community. The AAAC considers effective advisory committees to be essential for developing consensus and support for an effective science program.

The last three Astronomy and Astrophysics Decadal Surveys have all emphasized the need for a balanced program of small, medium and large missions—and have given particular emphasis to the Explorer program and to a healthy program of research support. The cuts in the research and analysis budget have an immediate and significant impact and seem very inconsistent with the broad goals of the American Competitiveness Initiative (ACI). The very infrequent Explorer opportunities (six years between AOs) and the cuts and cancellations to Explorer missions in progress (NuSTAR and WISE) are indicative of a program in serious trouble. The R&A funds and smaller-scale missions each serve a critical role in supporting the broad fabric of research needed for realizing the science from future large missions and in enabling the development of the necessary personnel and skills.

The balance between small, medium and large programs in the NASA Astrophysics Division has been greatly undermined in the FY 2007 budget request. The AAAC strongly supports efforts to increase the funding and to rebalance the program.

As can be seen in the section of the report that summarizes major mission costs, most missions now have lifecycle costs that exceed $2B. The exceptions are the cost-capped programs like Discovery and Explorer. It is crucial that programs under consideration for implementation by the Decadal Survey process undergo a number of years of conceptual and technological development to reach an adequate level of maturity. Consistent support, even roughly at the $10M level, can make a significant difference for the robustness of both the missions and the Decadal Survey process. The cuts in the FY 2007 request in the development funds for the major missions in Beyond Einstein (Con-X, LISA) and in Navigator (TPF) mean that the projects will not meet even this modest goal.

Flagship missions happen rarely. Thus, it is crucial that the right choices be made in the Decadal Survey. For this to happen, a modest but consistent level of funding is needed for major programs to develop the required level of technical maturity and realistic cost estimates. The AAAC strongly recommends that the conceptual and technology development funding for missions such as Con-X, LISA, and TPF be increased to at least ~$10M per year.

With a substantial expenditure on HST servicing, increases in JWST's construction cost, and significant funding for SIM (despite its NET 2015/16 launch date), the Astrophysics program is overly biased towards large missions. The science return from such missions is not in doubt, but the lack of balance will impact future opportunities and the diversity of scientific investigations. As discussed in more detail in the report, substantial delays in the Shuttle availability for HST SM4, any further cost growth in JWST, and the funding profile for SIM are all issues that need to be considered. (SIM has a high lifecycle cost because of both current significant spending and an early ramp-up.)

NASA has sequenced the large Astrophysics missions as HST, JWST then SIM. Yet, the current SIM budget is high, and the funding profile is steep, for a mission that is 9-10 years from launch. As a result, lifecycle costs for SIM are several times the recent re-scope level of ~$1B. The AAAC strongly recommends increasing the overall budget for SMD, but if the increases are inadequate, some consideration should be given to a more appropriate, lower level of current support for SIM.

The sudden, dramatic cuts to the NASA science program will significantly impact the most visible and productive part of NASA. Because of the lack of a suitable advisory process and because of the overall dramatic impact on the scientific base in several very important areas as articulated by senior members of the community at recent Congressional Hearings, the AAAC recommends that the level of cuts be considered very carefully by NASA, Congress and the Administration, especially when the agency develops the FY 2008 budget.

As noted above, the AAAC's strongest recommendation this year is that NASA's science funding be restored.

DOE

The AAAC welcomes the involvement of DOE and the Office of Science, particularly the Office of High Energy Physics (HEP), with the AAAC in working to optimize the nation's astronomy and astrophysics enterprise. DOE is contributing in significant ways to projects that will address a number of basic questions of great interest to the astronomical and particle physics communities, with dark energy and dark matter being very important examples. The AAAC is encouraged by the good progress on GLAST, a joint NASA-DOE project. The AAAC appreciates HEP's support for the Task Force on CMB Research (TFCR), the Dark Energy Task Force (DETF) and the Dark Matter Science Assessment Group (DMSAG) and looks forward to the agency's response to these activities. The AAAC welcomes the effort at DOE to provide support for concept development for approaches to studying dark energy, in addition to continuing DOE support for SNAP. The AAAC expects that the DETF report will provide guidance for the optimization of near- and intermediate-term activities, as well as for JDEM and LST, and we hope that DOE, NASA and NSF will work together to utilize the DETF recommendations in their planning and review processes.

The AAAC is very encouraged by the DOE Office of High Energy Physics support for programs in the areas of dark energy and dark matter and for their increasingly active participation in programs at the interface of astronomy and particle physics.

Recommendations Related to the Astronomy and Astrophysics Decadal Survey and Other NRC Reports

We identify a number of programs that present particular opportunities and/or raise issues for the vitality of the nation's astronomy and astrophysics enterprise as carried out by NSF, NASA and DOE within the framework of the astronomy and astrophysics 2000 Decadal Survey and similar NRC reports (e.g., CQC). The rationale behind these recommendations and findings is given in the report.

5.1 Mission Operations and Data Analysis (MO&DA) and Research and Analysis (R&A)

The AAAC strongly supports an increase in R&A to offset the proposed FY 2007 cuts and to bring the level of support back to that in FY 2006. R&A complements mission data analysis support (in MO&DA) and is less than 1% per year of the investment in major missions. R&A trains the next generation of researchers and provides the scientific fabric for the space and earth science enterprise.

5.2 Hubble Space Telescope (HST)

The AAAC recognizes the scientific value of HST and the gains in capability that will be achieved through SM4; thus, we fully support a carefully managed program to maintain and upgrade HST. The AAAC recognizes the cost of preparing for SM4. If the Shuttle program suffers significant additional delays that continue into 2008 and if the HST servicing mission is delayed even further, the AAAC recommends that, in addition to seeking the advice of the NASA advisory committees, the NRC be asked to provide scientific guidance.

5.3 James Webb Space Telescope (JWST)

The AAAC considers the science case for JWST to be extremely strong, as was recognized by the Decadal Survey committee in ranking JWST as the highest-priority Major Initiative. Cost growth in JWST, the disconnect between the current mission lifecycle costs and the budgets used in the previous Decadal Survey, and the budget cuts in SMD have all combined to result in a serious imbalance in NASA's program in astronomy and astrophysics. In the current plan, many smaller, very effective missions and programs are being curtailed in favor of a few, very large programs. The AAAC reaffirms the value of JWST, and more generally the value of "flagship missions" like JWST for the overall science program; in addition, the AAAC shares the view in the community, as reflected in the Decadal Survey, that a balanced program from R&A through moderate missions to "flagships" is essential.

5.4 Giant Segmented Mirror Telescope (GSMT)

The AAAC greatly appreciates that NSF-MPS and AST initiated and then supported a significant FY 2007 increase in GSMT technology development through funding the proposal from the two community groups, GMT and TMT. The AAAC recommends that the NSF evaluate its approach to major projects to see if incremental changes could allow it to take advantage of the opportunities provided by significant levels of private funding, provided that such programs meet the very high peer-review standards set for major projects. The involvement of OMB and OSTP, and of committees in Congress, could help to bring this about. The AAAC also believes that continued dialog with the Europeans regarding their plans for an extremely large telescope (ELT) could be mutually beneficial, especially if cooperation resulted in shared access for all-sky coverage in the north and the south for the next generation of ELTs.

5.5 The Explorer Program

The AAAC notes that the Explorer program has been identified as a high-priority activity in each of the last three Decadal Surveys. Yet, recent events involving a cancellation and a deferment, combined with infrequent announcements of opportunity (a gap from 2002 to 2008) indicate a program that is in serious trouble. The AAAC recommends that funding for the NASA Explorer program be restored with frequent announcements of opportunity to ensure its vitality and effectiveness.

5.6 The Beyond Einstein Program

The AAAC recommends that NASA look carefully at providing resources at the $10M or greater level for continuing a modest level of technology development for LISA and Con-X to ensure that they can be fairly evaluated, judged for technological readiness and provided with reliable cost estimates in the upcoming Decadal Survey. Conceptual development of the Einstein Probes program is also highly desirable before the next Decadal Survey.

5.7 Einstein/Origins Probes

The AAAC recommends that SMD and Astrophysics further the conceptual development of the Probes (~$600M missions) to where the concept could be presented to the next Decadal Review as a potential option for mid-scale missions between the small Explorer and Discovery-scale missions and the very infrequent flagship missions.

5.8 Major Mission Technology and Conceptual Development

The AAAC recommends that NASA look carefully at providing resources for ensuring a modest level of technology development for Major Initiatives identified in the 2000 Decadal Survey so their performance capabilities and cost envelopes are better defined in the 2010 Decadal Survey. This positions the missions for serious scientific evaluation in the upcoming Decadal Survey with more reliable and realistic cost estimates.

5.9 Stratospheric Observatory for Infrared Astronomy (SOFIA)

The AAAC was greatly concerned that a mission that was so close to flight demonstration was effectively cancelled ($0 in the five-year budget) without any review. The AAAC recognizes the cost and schedule issues with SOFIA, but any program should undergo a serious review before any major change in its status is announced. The upcoming SOFIA review is welcome, but any change in status now has broad budgetary implications for the remaining Astrophysics program, unless additional resources are identified.

5.10 Terrestrial Planet Finder (TPF): TPF-C and TPF-I

The AAAC was concerned in its 2005 report, as was the CAA, about the rapid acceleration of the TPF program following the announcement of the Exploration Vision. However, decreasing all technology and conceptual development to zero ($0 is allocated for TPF) is inconsistent with the Decadal Survey recommendation. To enable continuing development on this exciting but challenging program we recommend that TPF, like Con-X and LISA, should be funded at the $10M level or greater to allow a continuing level of conceptual and technology development.

Recommendations Related to Interagency Coordination

The programs and activities discussed here involve interagency coordination for DOE, NASA and NSF. The rationale behind these recommendations and findings is given in the report.

6.1 Research and Analysis (R&A)

The AAAC notes that a goal of the American Competitiveness Initiative (ACI) is to improve basic research in the physical sciences and in so doing excite and train young researchers and technologists. The cuts at NASA in R&A are exactly counter to that goal. The R&A funding in FY 2007 should be restored to the level in FY 2006 and inflated in subsequent years.

6.2 Gamma-ray Large Area Space Telescope (GLAST)

The AAAC is very encouraged that GLAST is moving forward towards a launch in late 2007 and that the LAT problems have been retired. A successful GLAST mission will bring great scientific progress, as well as provide a useful working model for future NASA-DOE partnerships

6.3 Giant Segmented Mirror Telescope (GSMT)—James Webb Space Telescope (JWST) Synergy

The AAAC reaffirms its view that operation of GSMT in the JWST era would provide major scientific synergies. The GSMT and JWST SWGs have prepared a report highlighting the scientific value of such synergy. The AAAC encourages NSF to be responsive to opportunities that would help GSMT move forward on a timescale to match that of JWST.

6.4 Advanced Technology Solar Telescope (ATST)—Solar Dynamics Observatory (SDO) Synergy

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 into the MREFC Readiness Phase. The AAAC recommends that the NSF move ATST quickly through the MREFC process to take advantage of scientific synergies that will arise from overlap with SDO following its launch in late 2008.

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

The AAAC accepted the final report from the CMB Task Force at its October meeting and commended the TFCR for its very comprehensive and valuable study. The AAAC expects that the report, with its prioritized program, and the response that will follow from all three agencies, will provide a basis for moving forward in this exciting area on a broadly based program for CMB polarization research towards the Beyond Einstein Inflation Probe CMBPOL and will provide invaluable guidance for the next Decadal Survey.

6.6 Dark Energy*:* The Dark Energy Task Force (DETF)

The AAAC supports a vibrant, wide-ranging program of investigations leading to understanding of the impact of dark energy on the Universe. The Dark Energy Task Force (DETF) was set up at our suggestion with the strong support of the agencies. The DETF report is nearly completed. The findings and recommendations from the DETF will be transmitted through the AAAC and HEPAP and will help to optimize a dark energy program that the science community and the agencies can utilize to make progress over the next decade quickly and cost-effectively.

6.7 Joint Dark Energy Mission (JDEM)

JDEM is proving to be an interesting vehicle for interagency cooperation, and the AAAC welcomes and appreciates the continuing willingness of the agencies to work towards overcoming some of the challenges that result from their different approaches to "doing business." The AAAC welcomes the plan at DOE to provide support for concept development for other approaches to studying dark energy, in addition to its continuing support for SNAP. The AAAC encourages NASA to complement the effort at DOE and to continue with its support of several potential implementations of JDEM.

6.8 Dark Matter Science Assessment Group *(*DMSAG)

The AAAC welcomed the request by DOE HEP and the NSF Division of Physics (PHY) and AST to jointly establish a Dark Matter Scientific Assessment Group (DMSAG) to advise the DOE HEP, PHY and AST concerning the U.S. dark-matter direct-detection research program. The DMSAG will report to HEPAP and to the AAAC.

6.9 ExoPlanet Task Force (ExoPTF)

The AAAC notes that substantial progress is being made on ground-based planet detection and that substantial activity has occurred in defining future space-based facilities. The AAAC recommends that the agencies consider the establishment of a task force to develop a roadmap 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. Such a report, as well as being a guide for agency planning, will also provide very valuable input to the Decadal Survey.

6.10 National Virtual Observatory (NVO)

The AAAC strongly encourages the NVO team to continue its excellent work, especially its efforts to fully involve the science community. The AAAC recommends that the agencies, NSF and NASA, expedite their plan to solicit proposals for the operation of the NVO and to implement that within the next year, and to discuss with DOE the possibility of DOE involvement in NVO.

6.11 Lessons-Learned Interagency Study

Following discussions with the agencies and OSTP over the last year, the AAAC asked the agencies to consider undertaking a “lessons-learned” activity for carrying out collaborative interagency projects. The AAAC, the agencies and OSTP agreed to have a more detailed discussion on the timetable, approach and nature of a lessons-learned report at the May 2006 AAAC meeting.

Synopsis: The NRC Decadal Survey and the NRC report CQC set out an exciting, viable program for astronomical research that we fully support. The diverse approach to astronomical research offered by NSF, NASA and DOE is an essential part of the scientific success and public visibility achieved in astronomy over the last several decades. By drawing on the different strengths of the three agencies, NSF, NASA and DOE, the nation will realize greatly enhanced value from its investment in astronomy and astrophysics.

COMMITTEE MEMBERS

Neta Bahcall, Princeton University
John E. Carlstrom, (Vice-Chair) University of Chicago
Bruce Carney, University of North Carolina at Chapel Hill
Wendy Freedman, Observatories of the Carnegie Institute of Washington
Katherine Freese, University of Michigan
Garth D. Illingworth, (Chair) University of California Santa Cruz/UCO/Lick Observatory
Robert P. Kirshner, Harvard University
Daniel Lester, University of Texas at Austin
Angela V. Olinto, University of Chicago
Rene A. Ong, University of California at Los Angeles
E. Sterl Phinney, California Institute of Technology
Catherine A. Pilachowski, Indiana University
Abhijit Saha, National Optical Astronomy Observatory

ACKNOWLEDGEMENTS

Over the last year the AAAC has met with many key people involved in the nation's astronomy and astrophysics enterprise. 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 DOE Office of Science Director Ray Orbach, NASA Administrator Mike Griffin and Associate Administrator for Science Mary Cleave, and NSF Deputy Director Kathie Olsen. The discussions with the OMB Examiners Amy Kaminski, David Trinkle and Joel Parriott are always fascinating for their insights into the complexity of the budget process. We greatly appreciate the interactions and support of OSTP scientists Rob Dimeo, Michael Salamon (before his return to NASA) and Jon Morse. They have provided a key interface and support for science in the Administration. We owe very special thanks to Pat Looney, who was at OSTP until his departure for Brookhaven last summer. Pat played a major role in helping the AAAC to get established and for his efforts to make our voice useful and relevant.

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 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.

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ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

MARCH 16, 2005 - MARCH 15, 2006

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ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

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1.0 Introduction

1.1 Charge to the Committee

The federal research enterprise in astronomy and astrophysics is a remarkably productive activity with great visibility to the public, both in the nation and worldwide. This visibility is a demonstration of U.S. scientific and technological vitality.

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. Support for this by the Executive Branch and Congress led to the establishment of the Astronomy and Astrophysics Advisory Committee (AAAC) under the National Science Foundation (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 2001 Decadal report, and the recommendations contained in subsequent National Research Council reports of a similar nature. (See Appendix A for the full language.)

The AAAC welcomed the formal inclusion of the Department of Energy DOE in its charge in March 2005. This reflected the increasing activities of the Office of High Energy Physics (HEP) in astronomy and astrophysics.

1.2 Context and Activities

The National Academy of Sciences (NAS) Decadal reports 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 2001 NAS Decadal Survey *Astronomy and Astrophysics in the New Millennium* (hereafter called the Decadal Survey) followed by the NAS report *Connecting Quarks with the Cosmos* (CQC) set out an exciting, viable program for astronomical research that the AAAC heartily endorses. The recent NAS report from the Committee to Assess Progress Toward the Decadal Vision in Astronomy and Astrophysics reaffirmed the vitality and relevance of the program outlined in the Decadal Survey. The AAAC fully concurs with the NAS 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."

The diverse approach to astronomical research offered by NASA and NSF, and increasingly by DOE, is an essential part of the scientific success and public visibility achieved in astrophysics over the last several decades. It remains a key aspect of future success in the field of astronomy. Cooperation, collaboration, and joint programs among NASA, NSF and DOE bring further benefits to astronomy and astrophysics. Each agency has its own approach to supporting research. While this brings challenges, it also enables more efficient use of national resources for science through synergistic approaches. It is essential that each agency, NSF, NASA and DOE, retain a healthy scientific research budget, even in times of fiscal constraint.

The attention given to the importance of basic physical research in the American Competitiveness Initiative (ACI) by the President in the State of the Union address was most encouraging. The increases requested as part of the implementation of ACI in the FY 2007 President's budget request for the NSF and DOE scientific enterprises were welcomed enthusiastically by the science community—though the good news here is offset for some communities by concerns regarding the impact of the changes for NASA science. The decreases (after inflation) that will occur in NASA's Science Mission Directorate in FY 2007 and the 5-year run-out budget are of great concern to the Space and Earth science communities.

The report of the NSF-NASA-DOE National Science and Technology Council (NSTC) working group, responding to CQC, was released early in 2004. This report, *Physics of the Universe* (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 several task forces, in conjunction with the High Energy Advisory Panel (HEPAP), to address tactical issues relating to specific important research areas in astronomy and astrophysics and in particle physics. These task forces will play a major role in guiding the agencies in their deliberations 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 is expected to be completed in the next three months; the Dark Matter Science Assessment Group (DMSAG), which will be formed in the near future and will report later this year; and the proposed ExoPlanet Task Force (ExoPTF), which will assess the opportunities for extra-solar planet detection and characterization on the ground and in space.

This report summarizes the findings and recommendations of the AAAC for the one-year period between 16 March 2005 and 15 March 2006. The AAAC held four meetings between 16 March 2005 and 15 March 2006. Face-to-face meetings were held at the NSF on 16-17 May 2005 and 11-12 October 2005 and at NASA Headquarters on 13-14 February 2006. A telephone conference was held to review the final report on 10 March 2006. 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 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.

2.0 National Science Foundation

***NSF**: The AAAC was very encouraged by the NSF budget increase in the FY 2007 request as the first step towards the long-awaited budget "doubling." The AAAC is also encouraged by the continuing steps being taken to respond to the Brinkman report, "Setting Priorities for Large Research Facility Projects." The release of NSB-05-77 provides more structure to the MREFC process, as does the release of the first Facility Plan. However, the value of the Facility Plan to current and potential MREFC projects would benefit from the inclusion of likely timelines, phasing and key milestones for each project. We recognize the challenges in establishing detailed procedures that will accommodate the agency's many different Directorates and disciplines, but we recommend that the NSF expeditiously complete and adopt a detailed plan for developing and managing MREFC projects. The AAAC also recommends that consideration be given to a "lifecycle" costing approach that recognizes the very different funding and management requirements of the different phases of a large, high technology project. Two key phases that are not well supported by the current Divisional and MRFEC approaches are identified. These are the pre-construction phase, in which key technologies and processes are demonstrated, and the immediate post-construction commissioning phase. By managing and funding these phases as an agency-level activity, the NSF should be able to reduce the risk of cost growth during construction and should ensure that high science returns are achieved more rapidly after construction ends. The AAAC commends the proactive efforts of the NSF, MPS and AST in responding to the challenges of implementing and supporting ALMA and for moving ATST into the Readiness Phase of the MREFC process. The AAAC welcomes the support for technology development for projects prioritized by the Decadal Survey and CQC. We also commend AST for its willingness to take the difficult steps, such as the Senior Review, needed for the future vitality of the field.*

The NSF plays a unique role in the Nation's science program. 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 results. Astronomy and astrophysics share in this approach to research. However, NSF is increasingly supporting major projects that are initiated from within the Divisions. Astronomy is one area where this has been traditionally the case. It is certainly the case in the current decade, when the extremely powerful Atacama Large Millimeter Array (ALMA) is a central element of the program of the Division of Astronomical Sciences (AST). The AAAC appreciates the efforts within the NSF Directorate for Mathematical and Physical Sciences (MPS) and in AST that have kept this important project on track through a year of challenges. The AAAC is also very encouraged by the NSF's decision to move the Advanced Technology Solar Telescope (ATST) into the Readiness Phase, a key step in the Major Research Equipment and Facilities Construction (MREFC) process. The NSF's response to the NAS Brinkman report "Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation" continues to be of great interest to the AAAC. The AAAC is very supportive of the agency's efforts to respond to Brinkman through improving the MREFC process and has some suggestions for how to further enhance this activity.

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 nation's research endeavor is one of its great strengths. The lack of any progress on the doubling for several years was disappointing, but we were delighted early this year when the President, in his State of the Union address, announced the American Competitiveness Initiative (ACI) and emphasized the importance of the physical sciences by stating, "I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years." Putting the NSF budget back on a track for significant growth is a key step in meeting the goals of ACI. The first step in that doubling, the 7.9% increase requested for NSF for FY 2007, was extremely welcome news for the scientific research community. Growth in the NSF's budget due to ACI will have a significant effect on the vitality of the research efforts across the nation, and particularly for researchers funded by the NSF in academic institutions who are closest to students and the community.

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 that is populated by objects from the time of its formation; 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 grow, and play an important role, as have the physics programs under NSF-MPS and the DOE Office of Science. However, NSF will remain at the heart of a broadly based ground-based program in astronomy and astrophysics.

The NSF Division of Astronomical Sciences (AST) faces significant challenges in moving forward on the many high-priority projects advocated by the 2001 Decadal Survey and the 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. While the 7.7% requested increase in the AST budget in FY 2007 is very positive, the demands on AST resources over the next 5-7 years exceed likely increases. The Senior Review that is currently being undertaken by AST is key to utilizing the major new and extremely powerful facilities like ALMA that have been recommended through the Decadal Survey process, as is the need to provide funding opportunities in response to the Decadal Survey and to the programs outlined in the CQC and its companion report Physics of the Universe.

Below we address several key issues for NSF. In §2.1 we identify recommended changes to the agency's planning and management of large-scale projects funded by the Major Research Equipment and Facilities Construction (MREFC) account. In §2.2 we consider major Decadal Survey projects that are under construction or under consideration for construction during this decade, including the Atacama Large Millimeter Array (ALMA), the Advanced Technology Solar Telescope (ATST), the Giant Segmented Mirror Telescope (GSMT), the Extended Very Large Array Phase II (EVLA), and a Large Survey Telescope (LST). In this section we also discuss AST's stewardship of astronomy as well as the Division's initiation and implementation of a Senior Review process to evaluate the balance of its facilities portfolio and to identify funds both for new major initiatives and for its highest-priority existing facilities.

2.1 MREFC and Long-Range Planning at the NSF

The Major Research Equipment and Facilities Construction (MREFC) process is of great importance for astrophysics and is becoming of increasing importance to the agency. The major observatories and facilities constructed through MREFC provide dramatic advances in scientific exploration in astrophysics. Because of the long history of major projects in astrophysics 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 valuable insights to discussions of the MREFC process. The AAAC greatly appreciated the opportunity to discuss a number of questions and issues concerning MREFC with NSF Deputy Director Kathie Olsen during our October 2005 meeting.

The Brinkman report emphasized the need for a more open and transparent process for the funding of major research facility projects that are developed under the purview of the MREFC program. The NSF is responding to this report. Recently, the NSF and the National Science Board (NSB) have released the report "Setting Priorities for Large Research Facilities Projects Supported by the National Science Foundation" (NSB-05-77). The process outlined therein provides a framework for the steps required for a project to reach a level of maturity where it can be considered for MREFC and for the steps needed for a project to progress through to fruition. A key aspect of the recommended process is to offer an approach that is appropriate for the Foundation yet maintains sufficient flexibility to respond to the particular needs of different disciplines.

Key to an effective MREFC process, in addition to the steps to make the process much more transparent, is a Facilities Plan. 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 Facilities Plan should ensure that all stakeholders can 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 Facilities Plan was developed during 2005, though it remains incomplete in that it does not show likely timelines, phasing and key milestones for each project. The value of the Facility Plan to current and potential MREFC projects would benefit from the inclusion of these elements.

One cautionary note might be applied to the current process. The MREFC process consists of many steps, and it appears to have been structured with a rather narrow concept of what constitutes an "MREFC program." As the process increases 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 we discuss below.

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. "Lifecycle" is used to encompass the multiple, well-defined components in the realization of major projects: the conceptual development phase; a development and demonstration phase; the construction phase; a commissioning phase; and then the operations and science return phase. The envisaged approach, as in the past, is that the Divisions will usually find the resources internally for the two pre-construction phases and for the post-construction commissioning and operations phases, with construction being done through the MREFC process. There are, however, serious limitations to such an approach when the projects reach a certain scale. The "lifecycle" analysis and cost-profiling approach has become the norm at NASA 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.

Most major programs will have their pre-construction development phases and post-construction operations funding identified from within the appropriate division. However, some MREFC projects will likely be of a scale that, 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 level of risk of schedule slippage and cost growth than if adequate resources had been expended before the construction phase was entered. 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 where the key technologies and processes are actually developed and demonstrated. 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 is an activity that can be funded by the Divisions using current approaches. On major projects the second phase is unlikely to be done well with the resources available to the Divisions. Experience has shown that about 20% of the total construction cost might need to be spent in the second stage (Phase 2) for effective risk retirement. 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:

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;
2) a shorter, more focused and more tightly managed phase (that is inherently more costly) in which key technologies are demonstrated and reviewed and system-level issues are evaluated. This should be done under an agency-level activity that is very closely tied 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 skills and experience in the personnel, is intrinsically different to 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. Thus, to follow item 2) above we have:

3) the construction phase, as per current MREFC practice;
4) the commissioning phase, 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, during which the science is carried out. This is at a lower funding level than commissioning.

The steps, in short, are 1) low annual cost, modest duration, 2) moderate annual cost, short duration, 3) high annual cost, modest duration, 4) modest annual cost, short duration and 5) low modest cost, long duration.

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. It is this last phase wherein all the cost is "recovered" through science output. Inefficiencies at this time are not cost-effective.

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, as well as the commissioning phase, of major initiatives. Both phases should be supported with funding from within the Divisions and from MREFC.

2.2 Division of Astronomical Sciences

The primary driver for the AAAC's interest in MREFC has resulted, of course, from the needs of astronomy and of AST for the several MREFC projects recommended by the astronomy and astrophysics Decadal Survey.

A) Status of AST MREFC Projects: A major consideration for the AAAC concerns the timing of the major 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 Readiness Phase. A number of other projects remain under development, including the Giant Segmented Mirror Telescope (GSMT), a major upgrade to the Very Large Array (EVLA), and a Large Survey Telescope (LST). GSMT is the top-ranked ground-based project in the Decadal Survey; EVLA is the highest-ranked large radio project; and LST is identified both in the Decadal Survey and CQC/Physics of the Universe (as the Large Synoptic Survey Telescope LSST, which is now proposed as one possible implementation of those recommendations). Progress on these initiatives is driven not only by Decadal Survey priorities but also by both technical readiness and the availability of alternate funding scenarios that utilize non-federal sources. The status of the individual projects is a key issue for the AAAC.

ALMA, currently under construction, is a very high priority program for the astrophysics community. The cost growth in ALMA is a concern but reflects circumstances largely beyond the control of both the project and the Division. We greatly appreciated the risk taken by the agency during summer 2005 when the European partner encountered unexpected delays. We would like to thank the NSF Director, the MPS Assistant Director and the AST Division Director for their efforts to find a solution that enabled the U.S. side to move forward. Ultimately the European partner resolved their problem and contracted for antennas in fall 2005 (though an added complication arose when the vendors proved to be different between the two partners). We hope the NSF will move forward on this critically important project following the Director's review this spring.

The AAAC was very encouraged to see ATST move into the MREFC Readiness Phase last year. The AAAC has noted in its last two annual reports the importance of the overlap between this project and the NASA Solar Dynamics Observatory (SDO) mission. As the first astronomy project likely to go forward under the new MREFC process, ATST is a key pathfinder for the new process. The AAAC views positively the effort to include a significant component of international participation. Another positive aspect is the possibility of Air Force involvement, given the close relationship that will develop at the Haleakala site in Hawaii. ATST, along with the more immediate need for ALMA operations, also sets an important precedent for planning for future operations funding within current budget levels.

However, given the SDO timeline (late 2008 launch), the Committee is concerned that ATST move through the MREFC process as quickly as possible. Significant synergies accrue from overlapping operations. With a lifecycle cost of ~$830M, SDO reflects a substantial investment by the nation. NSF should consider any significant added value from having ATST overlap with SDO, especially from the perspective of cost-effective, interagency science return. If it appears that, by rigorously applying the newly developed MREFC guidelines to ATST, significant delays will be introduced into ATST's construction, the AAAC hopes that some offsetting actions will be taken to alleviate delays.

Of course, there is no suggestion inherent here that important technical and managerial milestones not be met—the issue is to find a way to move forward if the delays are caused by procedural issues that were unexpected during the conceptualization of the new MREFC process in NSB-05-77. Such fine-tuning is to be expected during implementation of new oversight processes, but it does carry a burden for the project. It would clearly be of substantial scientific benefit if the ATST project can be moved forward—without causing cost and risk changes—while procedural remedies for the MREFC process are addressed.

The AAAC was encouraged by the allocation of significant funding of $14M over a four-year period for technology development for the Large Synoptic Survey Telescope (LSST), one of the contenders for the LST project (also known as LSST in the Decadal Survey), and for the start of funding for GSMT technology development ($1M in 2005, ~$2M in 2006, but with a more significant increment to $5M in the FY 2007 request). While we recognize that the demands on MREFC over the next 5-7 years exceed resources, the slow pace of projects through the MREFC process adds significant cost, not only in dollars, but also in lost scientific opportunity and loss of synergy with space-based missions of limited lifetimes. Delays in ATST will limit its overlap with SDO as noted above. The Committee has also noted previously (in its 2004 and 2005 reports) that the synergy of JWST in space and GSMT on the ground is of particular scientific value, just as for HST and ground-based telescopes like Keck. The study commissioned by the AAAC in 2004 gave added clarity and emphasis to this recommendation (see §6.2). A significant challenge for both the astronomy community and the NSF, particularly for MPS and AST, is timely implementation of these highly ranked major projects.

B) Stewardship by AST: The AAAC would like to commend AST for its recognition of the importance of the NSF's role as a steward of astronomy. The Division has striven to maintain an appropriate balance among major initiatives, centers and individual investigators. The health of the discipline depends on maintaining a balance across telescope aperture size and wavelength, across facilities and individual investigators, and across existing programs and new initiatives. The Division is working well to respond to Decadal Survey priorities and to identify resources for major Decadal initiatives. The AAAC appreciates the Division's and the Foundation's continued support of ALMA, their attention to the complexities associated with international nature of the project, and their efforts to identify and ramp-up operations funding for the project.

C) AST Senior Review: A critical activity for AST has developed over the last year. The Division realized that if the astronomical community was going to achieve its goals of developing and operating major new facilities in the next decade, the Division must find a way to free up funding for both initial technology development and for operations. For example, operations funding for ALMA, which will begin to ramp up during 2006, will clearly stress the AST budget. It is clear that funds for the next-generation projects will have to come, at least in significant part, from existing facilities with their base of users. The Division recognized the critical steps that will be needed if the astronomical community and the nation are to benefit fully from the investment of the government's resources in major new projects. The AAAC strongly supports the Senior Review and commends the Division for its proactive stance towards long-range planning.

By beginning the process to identify funds for operations at an early stage, by being willing to take extensive input from the stakeholders, and by supporting the need for a thorough community-based review (the Senior Review), the AST leadership has rendered a remarkable service to the community. The Senior Review is designed to evaluate the distribution of funding within the Divisional portfolio and to identify strategies a) 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 LST, 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 has been initiated with clarity and simplicity. AST challenged the community to "free up" $30M per year, roughly 25% of the current budget for facilities. This process is still underway, and even when the recommendations are delivered in the near future, the Division will solicit further community input before making its final decisions about the timing of the recommended changes.

The AAAC would also like to commend the two long-range planning groups who developed framework documents and roadmaps in radio astronomy (*Report of the Radio, Millimeter and Submillimeter Planning Group*) and in optical/infrared ground-based astronomy (*Strategies for Evolution of U.S. Optical/Infrared Facilities*) for input to the Senior Review committee. It is never an easy task for a community to deal with the question of the downscaling or closure of facilities. Both committees had participation from a broad representation of the astronomical community. They developed guiding principles regarding the development of major new facilities recommended through the Decadal Survey, with some preliminary discussion of longer-term initiatives. These efforts also provided a broad, systemic view of how existing and upcoming facilities will support AST research activities. The roadmaps were a key input for the Senior Review.

There have been suggestions that the need for the Senior Review has lessened with the recent budget increase in the FY 2007 request. This budget increase is extremely welcome, and the Division and the community hope that AST benefits, as it should, from further growth in the NSF's budget as part of the ACI initiative. However, the scale of the future needs for the major projects that have been recommended from the Decadal Survey and CQC is such that, even with significant increases, a reevaluation of the facilities program is essential. As ALMA, ATST and other major programs come on line, AST's focus must of necessity change to reflect the needs of these new, powerful and very expensive facilities.

A number of projects or programs involving NSF are discussed in §5 and §6. Issues relevant to NSF occur in: §5.4 with regard to GSMT; in §6.3 for GSMT/JWST synergy; §6.4 for ATST/SDO synergy; §6.5 for the CMB Task Force (TFCR); §6.6 for the DETF; §6.8 for the DMSAG; §6.9 for ExoPTF; §6.10 for NVO; and §6.11 for the "Lessons-Learned" activity.

3.0 National Aeronautics and Space Administration

NASA: *The AAAC is deeply concerned that the NASA space science program has suffered a major blow. More than $3B has been removed from funding for the Science Mission Directorate (SMD) in the next 5 years, leading to a budget for science that is projected to decrease after inflation. Science has been the most visible and productive element of NASA. 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. NASA should reconsider the proposed budget and work to increase the funding for SMD—doing so for its scientific returns, for its inspirational value to the nation, and for its importance to NASA as a continual demonstration of NASA's value to the nation and to the world.*

For the past year the lack of an advisory structure for NASA—and for science at NASA—has been a deep concern for the community. By the time the new science advisory committees are selected, approved and assembled, a year will have passed without discussions on issues that are critical for the community and for NASA science. During that time, far-reaching decisions were made without any scientific input (e.g., the effective cancellation of SOFIA whose budget was reduced to $0 in FY 2007 and beyond without a review). The AAAC welcomes the creation of a new advisory structure. However, we and others are concerned that this structure may not be as effective as that previously employed. The lack of close coupling of the science subcommittees to the SMD leadership is likely to be a significant impediment. The AAAC has every hope that the new structure will work effectively and in a timely way by providing feedback to SMD quickly with minimal modification. However, if the structure is perceived by either party to be ineffective, the AAAC hopes that the Administrator and the Associate Administrator for Science will evolve the structure to better serve NASA and the community. These committees play an essential role in optimizing the science program within the programmatic and budgetary constraints faced by the agency and thus are of great value both to NASA and to the community.

The last three Astronomy and Astrophysics Decadal Surveys have all emphasized the need for a balanced program of small, medium and large missions—and have given particular emphasis to the Explorer program and to a healthy program of research support. The cuts in the research and analysis budget have an immediate and significant impact and seem very inconsistent with the broad goals of the American Competitiveness Initiative (ACI). The very infrequent Explorer opportunities (six years between AOs), and the cuts and cancellations to Explorer missions in progress (NuSTAR and WISE), are indicative of a program on life-support. The R&A funds and smaller-scale missions each serve a critical role in supporting the broad fabric of research needed for realizing the science from future missions and in enabling the development of the necessary personnel and skills.

As can be seen in the section of the report that summarizes major mission costs, most missions now have lifecycle costs that exceed $2B. The exceptions are the cost-capped programs like Discovery and Explorer. It is crucial that programs under consideration for implementation by the Decadal Survey process undergo a number of years of conceptual and technological development to reach an adequate level of maturity. Consistent support, even roughly at the $10M level, can make a significant difference for the robustness of both the mission and the Decadal Survey process. The cuts in the FY 2007 request in the development funds for the major missions in Beyond Einstein (Con-X, LISA) and in Navigator (TPF) mean that the projects will not meet even this modest goal.

With a substantial expenditure on HST servicing, increases in JWST's construction cost, and significant funding for SIM (despite its NET 2015/16 launch date), the Astrophysics program is overly biased towards large missions. The science return from such missions is not in doubt, but the lack of balance will impact *future opportunities and the diversity of scientific investigations. As discussed in more detail in the report, substantial delays in the Shuttle availability for HST SM4, any further cost growth in JWST, and the funding profile for SIM are all issues that need to be considered. (SIM has a high lifecycle cost because of both current significant spending and an early ramp-up.)*

The sudden, dramatic cuts to the NASA science program will significantly impact the most visible and productive part of NASA. Because of the lack of a suitable advisory process and because of the overall dramatic impact on the scientific base in several very important areas as articulated by senior members of the community at recent Congressional Hearings, the AAAC recommends that the level of cuts be considered very carefully by NASA, Congress and the Administration, especially when the agency develops the FY 2008 budget.

This last year has been a period of dramatic change within NASA. The budgets for science have been very dramatically impacted. The long-term impact of the cuts in the science program will be substantial. Other changes were more welcome. The new Administrator has brought a great depth of experience to the position, along with a clearer vision of what it takes to implement a major redirection of the agency. The Administrator also brought clarity of thought and an openness and candor that is not only refreshing, but also most likely essential given the technical and fiscal challenges that lie ahead. The AAAC appreciated an opportunity at its October 2005 meeting for a dialogue with Administrator Mike Griffin and Associate Administrator for Science Mary Cleave and was encouraged by the approach taken by Dr. Griffin to the role of science and its importance within NASA, especially at a time of great change for the agency. The AAAC welcomed the goal that the Administrator has set to transition the agency from being driven by the vestiges of its past program—one that was devised in the 1970s—into a new, forward-looking set of objectives. The challenges that face the Administrator became clearer over the ensuing months, however.

The community was quite shocked by the very substantial cuts (over $3B) in the FY 2007 5-year budget request and by the disconnect between the budget and the Administrator's goals for science as expressed in September and October 2005. The AAAC understands the pressures and challenges; but, the change of direction will have a substantial impact on the science community, and the change was made without any debate and consultation with the community and Congress. The issues raised by Chairman Boehlert of the House Science Committee in a press release regarding the FY 2007 Budget Request are ones with which members of the AAAC resonate. The Chairman noted, "Science funding should not be taking a back seat to operational programs that have much less impact." The cuts are damaging one of the most productive and visible parts of NASA.

The challenges of transitioning within the current NASA budget to a new generation of space capabilities in the framework of the Exploration Vision became dramatically obvious to all during February 2006. The balance among the needs of Space Shuttle operations and ramp-down, International Space Station (ISS) completion and operation, Crew Exploration Vehicle (CEV) development and a vibrant Space and Earth Science program has come under great strain. This became visible to all stakeholders when the FY 2007 President's Budget Request was released on 6 February 2006. The result has been a dramatic change in the budget for science at NASA, especially in the years beyond 2007, when science funding actually drops 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 is impacted by such sudden changes. Such changes are a great concern to the science community and also have the potential to significantly impact NASA's perceived value to the nation.

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. 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), from the Mars Rovers, from the very successful Explorer missions like the Wilkinson Microwave Anisotropy Probe (WMAP), and from numerous other remarkable missions and projects have been both a unifying force for the nation and a driving force for its people. NASA has demonstrated time and time again that technology, driven by great science goals, can dramatically expand our horizons. 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.

The sudden and dramatic change from a growing budget to one that is decreasing in inflation-adjusted dollars is causing deep disruption within the science community. While we recognize the challenge faced by NASA in phasing out the programs of the last generation (Shuttle/ISS) and in initiating the Exploration Vision (the CEV in the near-term), retaining a vibrant, broadly based Space and Earth Science program is a key aspect of national science leadership. Thus, we are deeply concerned about recent cuts to the science program budget. The continued remarkable scientific success and the positive image of NASA that has accrued from its science program are at risk. The FY 2007-11 budget request removes over $3B from the science program relative to the FY 2006 budget request total, which already was impacted relative to the FY 2005 budget with, for example, major hits to Explorers and to the Mars Exploration program. The careful planning that the science community has done on the basis of growth in a science program *planned together with NASA* has been thrown into serious disarray.

Furthermore, the process by which the cuts were made did not involve formal consultation with the science community. This has exacerbated the situation. We recognize the value of working together and of working for shared goals. We recognize that programmatic issues have arisen that constrain the agency. However, if the community is not involved, we lose the sense of a shared approach that has been built up through consultation between the agency and the science community, as reflected in the Decadal Survey and in subsequent agency Roadmaps. During a period when no advisory process was in place, the agency made major decisions that dramatically impacted the science program for the next decade, and it was done at the phase of the budget cycle when open discussion was embargoed! No matter how rational the decisions may be, nor how well based on programmatic issues, those persons most affected will be upset by the lack of their "day in court."

Cuts, cancellations and deferments are hard to accept at any time but threaten to destroy a carefully developed consensus when carried out essentially behind closed doors. The community has still not fully come to grips with the aftermath of the decision to effectively shut down HST two years ago that again was taken without consultation (under quite under different circumstances and for very different reasons). The outcome of this flawed process was 18 months of acrimonious and divisive debate that was ultimately settled in Congress, thus removing science planning from its normal orderly process between the community and the agency. The AAAC appreciated the clarity and decisiveness that the Administrator Mike Griffin brought to the issue of HST, especially given the AAAC's recommendation in its 2005 report—*that NASA carry out SM4 as originally planned as part of its overall effort to complete its current obligations and programs as the agency moves to focus on new capability as part of the Exploration Vision.* But, we are gravely concerned that the community turmoil of the last few weeks is reminiscent of 2004. It is our hope that we not embark on a repeat of such a process and that communication by the community with the Administrator and SMD becomes less acrimonious and much more productive.

Consensus can only arise through a consultative process; it is a two-way activity. Each of the stakeholders needs an opportunity to hear the problems, present their case, engage in constructive dialog, and give input on the alternatives. The resulting decisions may not be to their liking but are far more acceptable following a transparent and constructive planning process. When involved, the community can reach consensus. We discuss below some recommendations to help the agency and the community recover their balance and to begin working together again in ways that lead to a mutually beneficial and productive relationship. A key aspect of this is to get an advisory committee structure into place that is responsive to the needs of both the science community and NASA.

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 worldwide—is clearly even more at risk this year than last. The breadth and balance within NASA's science program is a major factor in this visibility. The recent, dramatic budget changes have resulted in the largest realignment in many, many years between science and human spaceflight and are inconsistent with the Administrators own statements just 5 months ago—effectively eliminating a long-held approach that science and human spaceflight each played a major role in the agency's objectives, and that science was "walled-off" from the Flight programs. We recognize the stress that the agency is under. Dr. Griffin noted before Congress on several occasions before he became Administrator that NASA needed a $20B budget if the agency were to transition out of its historic programs to undertake exploration while retaining a vibrant, diverse science program.

We are now seeing the problems of a "go-as-you-pay" approach when the "pay" is too small. The science program is now being cut with major consequences for the nation's preeminence in Earth and Space science. It is our hope—and that of the science community quite broadly, as reflected through discussions at recent Hearings and media reports—that Congress and the Executive find a viable solution that does not undercut one of the nation's most visible and productive scientific research enterprises—the NASA Space and Earth science program. If the Exploration Vision is to be taken seriously and implemented effectively, "go-as-you-pay" may not be viable without doing serious damage to science, realizing the fears of many, not only in the science community.

3.1 The Impact of the FY 2007 Budget Request on Science

The AAAC has been assigned a role of stewardship for the Decadal process through the requirement that the AAAC "assess, and make recommendations regarding, the status of the activities" of the agencies "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 AAAC also has a responsibility to coordinate "with other Federal advisory committees that advise Federal agencies that engage in related research activities." Beyond these requirements, the AAAC members also recognize that the advisory committees within each agency provide more detailed insight that complements the broader perspective and role of AAAC. Many of the AAAC members were chosen because of their involvement and experience in advisory committees, roadmapping committees or Science Assessment Groups. Such background brings insight into the activities of the agencies that has proven to be very useful for AAAC members. It also brings a great appreciation for the work of such committees, which is why we have chosen to highlight this area for NASA and its science program, and particularly for the Astrophysics program that is the focus of the AAAC's charge. In addition to the advisory process, we address a number of issues related to the FY 2007 budget request and its impact on Astrophysics.

A) The Importance of Consultation and an Effective Advisory Process: The last Space Science Advisory Committee (SScAC) meeting took place in March 2005. The lack of an advisory structure for science at NASA for the past year has been a deep concern for the community. By the time the new advisory committees are selected, approved and assembled, a year will have passed without discussions on issues that are critical for the science community and for NASA science. The current turmoil in the science community has been exacerbated by this lack of an advisory structure, and NASA has lacked the scientific input that helps to structure its program for the greatest science return. The AAAC and the science community of which we are part welcomes NASA's initiation of a new advisory structure. However, we and others are concerned that this structure may not be as effective as that previously employed.

It is useful to note how the previous structure operated. SScAC was a Federal Advisory Committee Act (FACA) committee that offered advice to the Office of Space Science (OSS) and to the Associate Administrator for Space Science, and later, when Space and Earth Science were combined, to the Science Mission Directorate and the AA for Science. During a short period, the SScAC and the Earth Science Advisory Committee (ESSAC) joined forces, but integration never really took place, and the joint operation was not fully realized. Subcommittees worked with each of the Divisions and provided detailed advice to the Divisions either directly to the Divisions (when the subcommittees were also FACA bodies), or through the SScAC (when their FACA status was rescinded). The Chair of SScAC was a member of the NASA Advisory Council (NAC) and brought strategic issues to the NAC for discussion. This process provided three levels of input and proved to be quite effective.

Each Division deals with a community whose scientific approach and mission structure differs, partly as a result of nature of the experiments and observational procedures, partly as a result of the "scientific culture" that has developed in each community, and partly as a result of the technical approaches needed for the missions. The subcommittees gave input and advice on rather detailed tactical issues that were of direct interest to the Divisions and their respective communities, but that were also of little interest beyond the relevant Division. However, the subcommittees also provided input to the SScAC on issues of a broader nature that had implications beyond the Divisions. (The subcommittee chairs were ex-officio SScAC members.) Acting as a broadly representative body of experienced space scientists, the SScAC's role was to advise the AA for Space Science on broader issues. A challenging aspect was dealing with cross-disciplinary issues. SScAC did provide an opportunity for several communities to come together, to hear the issues that the AA and the Science Directorate were addressing, to provide feedback and advice to the AA, and to be a conduit back to the community for the concerns and issues that the AA and the Science Directorate were addressing. This advisory process was not perfect, but there is broad consensus that overall it worked to the advantage of both NASA and the community.

There was an additional component of the process that also provided valuable guidance. Roadmapping groups were established to provide advice on the periodic refocus of the science program as part of the overall triennial NASA Strategic Plans. These groups provided invaluable input to the standing Division advisory subcommittees (often with significant overlap in membership) and to the SScAC.

The AAAC is encouraged that advisory committees are being reinstated but is concerned that the new structure may not be as effective as the previous one. The new structure echoes that of the old in that each Division will have a subcommittee to which reports and input will be given. As has been the case in the past few years, these will not be FACA committees and so will need to transmit their concerns and thoughts through a FACA committee. Under the new structure, this FACA committee will be the NAC—and particularly a six-member subcommittee of the NAC that will deal with science. The NAC reports to the Administrator. Thus, it is not at all obvious, how the often-detailed concerns of the subcommittees will be fed back to the AA for Science and the Science Mission Directorate and to the Division Directors and the Divisions. Nor is it apparent how the give-and-take will occur that is an essential part of establishing mutual understanding among the Directorate, the FACA committee members and the Division subcommittees. As before (above), strategic issues will still come before the NAC; but, the new advisory structure will likely overlook a large component of more routine issues that are of crucial concern to the community but that scarcely affect strategic thinking. Dealing with these issues at the NAC level could be inefficient and may lead to more serious problems because several levels exist in the advisory structure between the Divisions and the NAC.

A corollary, and potentially a very real problem, is that a small group—the six members of the NAC Science subcommittee—will be asked to address issues that spread across a very broad range of science topics, technical issues and “ways of doing business.” Regardless of the experience or commitment of those six NAC members, the breadth of the communities being covered will be a major challenge for six people. (The areas range from Earth Science, through Earth-Sun Environment, to all aspects of Solar System exploration, to the full gamut of missions for exploration of the Astrophysical universe.) There was a good reason why SScAC was a rather large committee of 18 members. The synthesis of the input by such a group was an important precursor before recommendations and advice were forwarded to the NAC. The synthesis was done with the involvement and concurrence of representatives across the broad communities that would be affected.

The AAAC has every hope that the new advisory structure will work effectively and in a timely way by providing feedback to SMD quickly and with minimal filtering. However, it is also the hope of the community that the Administrator and the AA for Science will evolve the advisory structure as needed if the structure does not fulfill the needs of both SMD and the science community. Such an evaluation is subjective, but we suspect that it will become apparent if the process is not working if both sides are willing to listen to the concerns and issues of the other. These committees play an essential role in optimizing the science program within the programmatic and budgetary constraints and thus are of great value both to NASA and to the community.

We recognize that it is not possible for the agency to discuss in detail with the community the budget issues under discussion with OMB during an embargo period. However, in the past, broad issues that could provide indirect feedback on issues relevant to the budget process have been discussed with the SScAC during its November meeting.

B) NASA and the American Competitiveness Initiative: Cuts to the NASA science budget have broad impact and seem very inconsistent with the broad goals of the American Competitiveness Initiative (ACI). In the FY 2007 budget, ACI has wisely justified new investments in DOE science and in the NSF that will result in clear benefits in national leadership in science and technology. There is no question that NASA is a major source of science and technology funding, and the agency indisputably supports even the most basic research. This research contributes to the vitality of the national skill set and has been shown to yield important, marketable spin-offs. We believe that the omission of NASA from the ACI plan is inconsistent and rather shortsighted given the visibility that the NASA science program has engendered for science and engineering across the nation and worldwide.

C) The Need for a Balanced Portfolio of Missions: Under the title “Ensuring the Diversity of NASA Missions” on page 7, the 2000 Decadal Survey stated:

“NASA should continue to encourage the development of a diverse range of mission sizes, including small, moderate, and major, to ensure the most effective returns from the U.S. space program.”

In its role as a steward of the Decadal Survey, the AAAC was encouraged in its discussion at its October meeting with the NASA Administrator and the Associate Administrator for Science that the Administrator was aware and very supportive of the recommendations of the Decadal Survey. Such recommendations include support for “flagship missions” as well as for smaller missions. There is no doubt that the “flagship” missions have provided remarkable scientific returns. The current situation where three Great Observatories—HST, Chandra and Spitzer—are all returning excellent science data makes this a unique time for astronomy and astrophysics. These have been the highest-ranked large programs over a number of decades. We welcome NASA’s support for the next generation mission JWST. This mission was the highest-ranked Major Initiative in the 2000 Decadal survey and promises to be both a remarkably powerful observatory and a very worthy successor to HST. However, our support is tempered with deep concerns about the cost growth in JWST, especially given how narrowly focused the program has become in the Astrophysics Division as a result of the budget cuts and the cost growth in the major programs. The 5-year budget run-out for the Universe/Astrophysics Division has dropped significantly in inflation-adjusted dollars (by ~25%) over the last couple of years.

While the science return is large from the major missions, as it would be from JWST, every Decadal Survey has also emphasized the scientific returns from NASA's smaller, quicker missions. The researchers involved in such programs are the ones who utilize the major facilities developed by NASA and who ultimately provide the science rationale and often the leadership for future missions. They, and their students and postdocs, need programs on which to develop the skills that make the larger scientific missions possible. It is no coincidence that every decadal survey for the last 30 years has emphasized the value of Explorer-class missions. It is also no coincidence that every survey has emphasized the importance of research support both for missions directly through Mission Operations and Data Analysis (MO&DA) and also for general research and analysis (R&A). R&A funds are not directed at specific missions but are used for a broad range of important research activities, including theory, multi-mission or archival data analysis, technology development and laboratory astrophysics programs that contribute to the interpretation of mission data. These funds support the broad fabric of research on which the mission-specific support can build. The mission-orientated research is identified under MO&DA, providing the support for the science return directly from the mission.

We recognize the budget challenges that face the agency. Nonetheless, we argue that there are three areas affected by the recent budget cuts (R&A, Explorers and R&D on future major missions) that will have major near-term as well as long-term impacts on the science community and on the strength and productivity of the science program at NASA. We consider these areas so important that we will argue that very careful and serious consideration should be given to the scale of the budget cuts for science, both by NASA during the Congressional action on the FY 2007 budget, and by the Executive branch, the agency, OMB and OSTP during the development of the FY 2008 budget. The balance of science and human spaceflight has undergone a very dramatic change that is inconsistent with what was being discussed just 4-6 months ago. The degree to which the balance has changed in just a few months exceeds what is good management practice, especially since the community was not at all involved in the process. Later in this report we will also indicate where a potential rebalancing might take place within the current budget envelope, but we consider this to be very much a second-tier alternative to applying less dramatic cuts.

D) R&A as a Critical Investment for Future Science: The R&A program represents research funding that is not explicitly associated with an operating mission. As a result, this budget line encourages creative extension of archived data, theoretical studies that can 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 initiatives. This budget line develops the fabric out of which new lines of astronomical research and new mission concepts evolve, and with its strong academic participation is a key factor in workforce training. The R&A budget has recently seen substantial cuts, and the 4-year run-out budget shows little opportunity for recovery. We recognize that these cuts have occurred across all divisions, with those in the Solar System Division being even more dramatic. Such cuts strike at the foundations of a strong science community and seem quite inconsistent with the broad goals of the American Competitiveness Initiative (ACI). Such cuts also have a dramatic and disproportionate impact on the future of the field—on the imaginative, hard-working young scientists. These young people, along with their guides, mentors and teachers among the more senior, experienced members of the community, constitute the nation's scientific human capital. Together they are the future of the field.

The R&A cuts that are causing such concern in the community are about $11M in the Universe/Astrophysics Division. The FY 2006 R&A program is about $65M. The proposed R&A program for FY 2007 and beyond is $54M. The AAAC strongly recommends 1) that NASA work with Congress so the R&A budget for FY 2007 is similar to that for FY 2006, and 2) that the agency increase the R&A funds in FY 2008 and beyond to reflect a baseline value at the inflation-adjusted 2006 level. Similar percentage cuts have occurred in the other science Divisions, with the exception of the Astrobiology program, which has been cut 50%. We would hope that similar steps would also be taken in those Divisions.

E) Involving the Community—Explorers: Explorers are a key component of the scientific community's "hands-on" involvement with space science missions. The Explorers have been remarkably productive scientific missions; the COBE and WMAP missions are excellent examples. As noted above, Explorers have been strongly supported in the last three decadal surveys. The recent 2000 Decadal Survey noted, "NASA's Great Observatories have revolutionized understanding of the cosmos, while the extremely successful Explorer program provides targeted small-mission opportunities for advances in many areas of astronomy and astrophysics. The committee endorses the continuation of a vigorous Explorer program. There are now fewer opportunities for missions of moderate size however, despite the enormous role such missions have played in the past."

The decision two years ago to remove a large component of funding from Explorers ran counter to the very strong recommendations of the Decadal Survey. This program needs to be recovered and made healthy as soon as practical. Concerns about the program have been exacerbated by the recent decision to cancel, for budgetary reasons, the Nuclear Spectroscopic Telescope Array (NuSTAR), a small Explorer that was within two months of undergoing a key review. Despite a recent "favorable" confirmation review, budget cuts for another Explorer, the Wide-field Infrared Survey Explorer (WISE), have also put that program at risk by deferring confirmation and in all likelihood driving up the overall cost. The last Explorer announcement of opportunity (AO) was in 2002, and the next is anticipated for 2008. This indicates a program that is in serious jeopardy and is not what the community considers to be a viable program, let alone "vigorous".

F) Prioritizing Future Major Missions: With the support of the agencies, the astronomy and astrophysics community intends to convene in the next few years a broadly based Decadal Survey study that reconsiders and prioritizes our goals for the next decade. It is very obvious to all that almost none of the high-priority initiatives from the last Decadal Survey will be completed. There is a widespread view that the next Decadal Survey will have to re-assess and re-prioritize each and every program that remains unfinished if it is to develop a viable program for the next decade. It will not be appropriate to just pass through those unfinished programs, given how incomplete progress has been on the previous recommendations. Given this, it is crucial that we go into that next Decadal Survey with adequate technology and conceptual development in hand for the many missions or programs that will be considered in the 2010 Decadal Survey. Otherwise, the Survey discussions will be devoid of solid technical underpinning and will be saddled with unreliable cost estimates. As has been noted by many across the community, the underestimates in the mission budgets in the 2000 Survey have caused significant problems, and the AAAC would very much like to see the cost estimates improved.

The space-based missions that would presumably be included in the discussion would be those from the 2000 Decadal Survey that have been the recipient of funding over the last few years: the major initiatives like NGST/JWST and Constellation-X (Con-X); those designated for initial technology development like the Terrestrial Planet Finder (TPF); the moderate initiatives that are under development like the Laser Interferometer Space Antenna (LISA), as well as those carried over from the 1990 Decadal Survey like the Space Interferometry Mission (SIM). JDEM and the Einstein Probes, which grew out of the CQC report and Physics of the Universe, would also likely be included. While this does not encompass all the programs likely to be discussed in the next Decadal Survey, these will be part of the discussion. A modest level of funding in each of these over the next ~3-4 years would make a big difference to the future robustness of the missions chosen for the next decade through the Decadal Survey process—and for the robustness of the process leading to the recommended pool of missions.

Currently these programs are inadequately funded to fulfill the goal of adequate maturity at the time of the Decadal Survey. The total funding in the Beyond Einstein program will only be ~$21M per year in FY 2007 and FY 2008, and overheads reduce what is available for mission studies below this total. Consequently, Con-X, LISA and the Einstein Probes/JDEM have been provided significantly less than $20M per year in the Beyond Einstein program, while TPF now has $0 in the Navigator program. [This summary excludes, for example, the Single Aperture Far-Infrared Observatory (SAFIR), which was recommended in the Decadal Survey for technology investment, but has been essentially unfunded this decade.] While the committee is not in a position to judge in detail the funding levels required, it appears from recent experience that flagship missions need about $10M/yr to be at a critical mass for any useful conceptual and technical development. A smaller amount (a few $M per year?) would be appropriate for missions at the scale of the Einstein Probes, which are ~$600M missions.

G) Cost Credibility for Major Missions: The recent cost estimates of major science missions like JWST have surprised many in the community and have led to questions about cost growth and "how did we get it so wrong" in reference to the Decadal Survey cost estimates. Unfortunately there was a period during the late 1990s and earlier in this decade when the use of unrealistic cost estimates was very common within NASA, and these costs were reflected in the 2000 Decadal Survey. The community has recognized the problem that this has caused, and a change is under discussion for how to cost missions for consideration in the next Decadal Survey.

Two additional factors have led to significant difficulty in assessing and comparing costs among current, past and future missions. First, it has often been unclear whether the cost estimates refer to Phase C/D construction costs or to the lifecycle costs (pre-Phase A through E) that include technology development through operations over the mission lifetime. Second, NASA's recent transition to full-cost accounting has added significantly to the actual cost of a mission (since civil service labor was not previously included for those NASA centers that have a civil servant workforce—e.g., GSFC and MSFC do, JPL does not).

To put the current program into context with the historical program, we note here the estimated lifecycle costs of a number of ongoing and future major programs. These estimates have significant uncertainty, given both the very different situations under which they were carried out and the uncertainties inherent in projects, but as the economist John Maynard Keynes noted, "it is better to be roughly right than precisely wrong"—and to which we might add, "it is better to be roughly right than have no idea at all." We would encourage NASA to refine these numbers if changes occur in mission structure. With the caveat that changes do occur, we note the lifecycle costs in current dollars in a full-cost accounting environment (including design and technology, construction, launch and operations) for a range of past, present and future missions: HST— ~$7.5B (assuming SM4 will occur in December 2007 plus 5 years of added operations); Chandra— ~$2.8B (with 15 years of operations); Spitzer— ~$1.3B (with operations through 2011); Cassini— ~$3B (including ESA and DOE contributions); JWST— ~$4.5B (assuming 2013 launch and 10 yrs of operations); SIM— ~$3.4B (or more, depending on launch date, with 12 yrs of operations); SOFIA— $2.6B (with 20 yrs of operations). They clearly indicate the need, noted above, for better cost estimates by both NASA and the Decadal Survey (AXAF/Chandra was $500M in the 1980 survey; SIRTF/Spitzer was $1.3B in 1990; SOFIA was $230M in 1990; AIM/SIM was $250M in 1990; NGST/JWST was $1B in 2000).

These lifecycle cost estimates also suggest why the astronomy community so values the Explorer and Discovery missions. At ~$300M and ~$420M they can occur more frequently. It also suggests why the concept of $600M-scale missions like Einstein Probes, New Horizons and Origins Probes has been extensively discussed (and implemented as in the case of New Horizons) because of a scale that is intermediate between the small missions and the rare flagships.

H) Funding the Changes: Last year the AAAC was very careful in its report to attempt to be budget neutral in its recommendations, with the exception of Explorers, where we recommended an increase after a particularly large decrement was made to support activities related to the Exploration Vision and to Return-to-Flight (RTF). The level of cuts this year is so large that we are unable to take such an approach. We feel that the program has become seriously imbalanced and that changes were made without extensive discussion with the science community, with Congress and, even more broadly, with an interested public. We hope that because of the lack of a suitable advisory process, and because of the overall dramatic impact on the scientific base in several very important areas as articulated by senior members of the community at recent Congressional Hearings, the level of cuts will be considered very carefully by NASA, Congress and the Administration and increased funding found for the NASA Earth and Space Science program, particularly for Astrophysics.

As noted above, there is considerable concern about the reality of a "go-as-you-pay" approach when major changes in direction are being undertaken. But, if an overall substantial increase in NASA's budget is impractical, we think that abolishing the traditional "firewall" between science and human spaceflight is quite unwise. We would strongly advocate reconsideration of the recent balance within the agency between the four major elements of the overall NASA program. We do not wish to condemn the agency to remaining with outdated facilities and goals. We are supportive of moving ahead with changes to the human spaceflight program that will bring it into the 21st century. However, cutting science—the agency's most consistently productive and visible program—while continuing a high level of support for programs conceived in the 1970s appears to be shortsighted. Our first recommendation is that NASA work with Congress to provide a rebalance in the FY 2007 budget, and that NASA respond in the FY 2008 budget process to sustain that rebalance.

While this is our preferred approach, we also recognize the scale of the changes that have been thrust upon us and would like to discuss the possibilities for rebalancing, assuming that there are no new funds. We are reluctant to do this because nothing comes for free. In this case the rebalancing would have to come from the major or Flagship missions. But let us consider them and consider the impacts.

1) HST: Congress has directed the agency to update and repair HST, if it can safely be done. In a very clear statement early last year, the Administrator decided that the only viable approach was through a shuttle servicing mission, and that such a mission would be undertaken if the first two Shuttle flights were successful. As noted above, the AAAC strongly supported HST servicing in its 2005 report, and continues to do so, but the AAAC also recognizes that if the Shuttle issues and delays continue into 2008, it would be wise to consider a re-evaluation of whether HST servicing should be carried out. About $130M/yr of additional funding is being spent preparing to service HST in late 2007 or in 2008. Any such change should involve discussion with the science community through advisory committees and through the NRC, particularly given the importance and visibility of HST.

2) JWST: JWST is the highest-ranked space-based Major Initiative in the Decadal Survey. It is a successor to HST yet is substantially more powerful, reflecting the technological advances that have occurred over the more than two 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. However, JWST has become more costly than expected, though the underestimates by NASA in the last decade that came to be reflected in the Decadal Survey have not helped. (The NASA Administrator has used the word "undercosted.") Nor did the lack of a decision on the launch vehicle by the previous NASA Administrator, which ultimately drove the largest component of the cost increase in 2005 (~$500M). The current plan is for JWST to enter Phase C/D or construction early in 2007 and to track through for launch in 2013. Should JWST be slowed and some of its current funding be diverted to other programs? From a budgetary and programmatic viewpoint, this is unwise. Schedule delays are costly because of the “marching army” problem. While visiting the AAAC, the Administrator framed this issue well when he said that missions should move quickly through Phase C/D and shouldn’t take more than six years, regardless of size, if the technological risks have been properly retired before the start of Phase C/D. The upcoming cost review for JWST plus the confirmation review at the end of the year will clarify whether JWST is ready to go. If it is, then there will have to be very good reasons why it should not move forward expeditiously, given the programmatic advantages in doing so.

3) SIM: While originally on a schedule for launch circa 2010-11, SIM’s launch date has been moved to no earlier than (NET) 2015/16. This is far longer than expected from the original recommendation in the 1990 Decadal Survey when SIM was known as AIM and recommended as a moderate $250M mission. This additional delay raises questions about whether a reassessment is appropriate in the light of much greater understanding of planet search and characterization issues. SIM has also undergone substantial cost growth twice in the last 5 years and has met new cost targets through project de-scopes. The phasing of SIM vis-à-vis JWST has been the subject of some speculation during the past year, again without advisory committee participation. The agency made the decision to move forward on JWST and to defer SIM to NET 2015/16. A consequence of this might have been a reevaluation of the SIM budget profile to match the new launch date. This did not seem to happen. SIM is budgeted to spend ~$1B from FY 2007 through FY 2011 and $117M in FY 2006. Since about $500M has been spent to date, this suggests a Phase A-B-C/D cost that exceeds $2B. For a program whose C/D costs were re-scoped to be less than $1B recently, this suggests a significant mismatch between the funding profile and the new launch date. Since the other elements of the Navigator program have been cut severely (TPF to $0, for example), an assessment to balance more broadly the planet search and characterization activities within Navigator is due. The AAAC recommends that this be one of the issues before the new Astrophysics advisory committee.

The current Astrophysics budget is stressed by the cuts to the SMD budget in FY 2007 and beyond. The balance among the major missions and the other aspects of the program is not optimal. We have argued that additional funds are badly needed for R&A, Explorers and technology development for future major missions. The AAAC strongly recommends that the large cuts to the science budget be reversed. If not, the AAAC would support consideration of a more appropriate, lower level of current support for SIM. With a NET 2015/16 launch date the current high funding level ($117M in FY 2006), plus a rapid ramp-up over the next five years, drives the lifecycle cost of the mission to over $3B. Reduced near-term funding for SIM should not impact its ability to be launched since the mission was re-baselined to a $1B program last year and ramp-up for construction need not happen for several more years.

The issues highlighted in this report need continuing discussion. We would hope that the new NASA Advisory committees would discuss and evaluate such issues. In addition, the 2005 NASA Authorization Act explicitly requested that NASA request the NRC to undertake a series of studies to assess the progress towards meeting the recommendations of the Decadal Survey in each of the SMD Divisions. It is the understanding of the AAAC that the first such Division to be so assessed will be Astrophysics. The committee established to review the Astrophysics Division would presumably also provide guidance on the implementation of the programs in the Decadal Survey for the remainder of the decade before the next Decadal Survey is completed.

Summary: There are great concerns about the potential impact of the recent cuts on NASA’s ability to remain pre-eminent in the longer-term. There are positive developments that we welcome: the progress on reaching very high technology readiness levels (TRL6, i.e., flight readiness level) for JWST, the highest-ranked, large space-based program in the Decadal Survey; the progress on GLAST, the highest-ranked moderate-size program in space; and the continuing scientific productivity and public visibility of the three Great Observatories, HST, Chandra and Spitzer. However, we are deeply concerned that smaller missions have been cut—the Explorer program is in deep trouble—and that R&A has also been cut. The balance that makes for a healthy space-science enterprise in Astrophysics (and in the other Divisions) has been lost, and the prognosis is not good for a diversity of missions later in the decade. There are great opportunities for NASA and U.S. science to lead the world in exploring the great science questions of our time like dark energy, dark matter, the cosmos at its earliest times, planets around other stars, and the ubiquity of life. But can we take advantage of these opportunities? We discuss many of these in more detail below and note our concerns regarding some particularly important programs: the impact on Explorers, the slow ramp-up of the Beyond Einstein program, and the overall challenge in technology and conceptual development for major projects when funds are minimal or zeroed out.

A number of projects or programs involving NASA are discussed in §5 and §6. Issues relevant to NASA occur in: §5.1 and §6.1 with regard to R&A; §5.2 for HST; §5.3 for JWST; §5.5 for the Explorer program; §5.6 for Beyond Einstein; §5.7 for Einstein/Origins Probes; §5.8 for Major Mission Technology and Conceptual Development; §5.9 for SOFIA; §5.10 for TPF; §6.2 for GLAST; §6.3 for GSMT/JWST synergy; §6.4 for ATST/SDO synergy; §6.5 for the CMB Task Force (TFCR); §6.6 for the DETF; §6.7 for JDEM; §6.8 for the DMSAG; §6.9 for ExoPTF; §6.10 for NVO; and §6.11 for the “Lessons-Learned” activity.

4.0 Department of Energy (DOE)

DOE Office of Science: *The AAAC welcomes the involvement of DOE and the Office of Science, particularly the Office of High Energy Physics (HEP), with the AAAC in working to optimize the nation’s astronomy and astrophysics enterprise. DOE is contributing in significant ways to projects that will address a number of basic questions of great interest to the astronomical and particle physics communities, with dark energy and dark matter being very visible examples. The AAAC is encouraged by the good progress on GLAST, a joint NASA-DOE project. The AAAC appreciates HEP’s support for the Task Force on CMB Research (TFCR), the Dark Energy Task Force (DETF) and the Dark Matter Science Assessment Group (DMSAG) and looks forward to the agency’s response to these activities. The AAAC welcomes the effort at DOE to provide support for concept development for approaches to studying dark energy, in addition to continuing DOE support for SNAP. The AAAC expects that the DETF report will provide guidance for the optimization of near- and intermediate-term activities, as well as for JDEM and LST, and we hope that DOE, NASA and NSF will work together to utilize the DETF recommendations in their planning and review processes.*

This year marks the start of the formal involvement of DOE in the AAAC’s advisory role, as a result of language signed into law in December 2004. The AAAC welcomes this change. The U.S. Department of Energy (DOE) Office of High Energy Physics (HEP) under the Office of Science is becoming increasingly involved in research efforts related to astronomy and astrophysics. DOE 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 and particle physics communities, with dark energy and dark matter being very visible examples, as highlighted in CQC and in the Physics of the Universe (POU) report. The AAAC has discussed developments and issues with HEP routinely over the last year and has greatly appreciated the involvement of DOE in the Nation’s astronomy and astrophysics enterprise. The AAAC also met with the DOE Office of Science Director Ray Orbach in May 2005 and welcomed his very optimistic assessment of the opportunities for the future—an optimism that was realized when the FY 2007 Budget Request was recently released with a 14% increase for the DOE Office of Science (and an 8% increase for HEP).

The AAAC has also played a key role in initiating and guiding two activities of great interest to that DOE Office of Science, namely the Task Force on Cosmic Microwave Background (CMB) Research (TFCR) and the Dark Energy Task Force (DETF), which have reported jointly to both the AAAC and the High Energy Physics Advisory Panel (HEPAP). DOE will also be involved in the Dark Matter Science Assessment Group (DMSAG), which will also report jointly to HEPAP and the AAAC. As examples for 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), while DOE involvement in the Large Synoptic Survey Telescope (LSST) is under consideration. 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 late 2007, with many of the issues that most concerned the AAAC in its 2005 report having been resolved.

The continuing support of HEP for dark energy programs is very welcome. The increase in the FY 2007 request for DOE Office of Science includes an increase in SNAP R&D in FY 2007 of $4.6M and provides another $5M in dark energy R&D funds that will be competitively awarded. Ground- and space-based concepts will be able to apply for these funds. The AAAC is very pleased that DOE HEP appreciates the need for support for other concepts and is working towards minimizing disparities while also supporting the SNAP program. Coordinating this effort with NASA would be of mutual benefit. The AAAC expects that the DETF report will provide guidance for the optimization of near- and intermediate-term activities, as well as for JDEM and LST, and we hope that DOE, NASA and NSF will work together to utilize the DETF recommendations in their planning and review processes.

Because many of these programs are some of the first examples of major interagency collaborations in a number of areas, 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. We have recommended to the agencies that a “Lessons-Learned” activity might be a very useful step to take at this time to provide guidance for the future. The agencies and OSTP are beginning discussions on how this activity might be structured and have indicated that they will give the AAAC an update on their thinking on this at its May 2006 meeting. The AAAC applauds this interagency collaboration and hopes that DOE can continue to build on its collaborations with NSF and NASA in a number of areas.

A number of projects or programs involving DOE are discussed in §5 and §6. Issues relevant to DOE occur in: §5.6, §5.7, §5.8 and §6.7 with regard to JDEM and Dark Energy; in §6.5 for the CMB Task Force (TFCR); in §6.6 for the DETF; in §6.8 for the DMSAG; §6.9 for NVO; and in §6.10 for the “Lessons-Learned” activity.

5.0 Decadal Survey and NRC Reports Status

The following sections deal with specific projects that raised issues and/or concerns for the AAAC during its deliberations over the last year. These programs have all grown out of Decadal Survey recommendations, and so we address these under the broad heading of the status of the missions in the Decadal Survey and like NRC Reports (e.g., CQC). 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.

5.1 Mission Operations and Data Analysis (MO&DA) and Research and Analysis (R&A)

R&A/MO&DA: The AAAC strongly supports an increase in R&A to offset the proposed FY 2007 cuts and to bring the level of support back to that in FY 2006. R&A complements mission data analysis support and is less than 1% per year of the investment in major missions. R&A trains the next generation of researchers and provides the scientific fabric for the space and earth science enterprise.

NASA supports scientific research directly through funding for mission operations and data analysis and research and data analysis programs. One aspect of this funding 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 MO&DA funding is about $70M for the flagship missions like HST, Chandra and Spitzer.

A second component of community support is R&A. This is broader in nature, providing support that nurtures and trains a scientific community with the goal of making it able to effectively and efficiently derive exquisite scientific results from the operating missions. The R&A program represents research funding that is not explicitly associated with an operating mission. As a result, this budget line encourages creative extension of archived data, theoretical studies that can 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 initiatives. This budget line develops, as a result, the fabric out of which new lines of astronomical research and new mission concepts evolve, and with a strong academic emphasis, is a key factor in workforce training.

The R&A budget was about $65M in the Universe Division in 2006 but is projected to be cut substantially to $54M. Such cuts strike at the foundations of a strong science community, and the run-out budget shows little opportunity for recovery. The investment in missions like HST, Chandra and Spitzer, plus a number of smaller missions, is ~$10B for development, construction and launch. The funds for the development of most missions, and especially the large ones, of course go primarily to the industrial contractors and NASA Centers and thus help only a small fraction of the community directly. However, NASA missions are science missions, and the ultimate metric of success will be from the science returned—and that takes active, knowledgeable, trained and involved scientists with longer-term support. They are the human capital on the science side. Thus, spending ~1% per year to ensure high science return is a good value. The AAAC, like so many in the community since the FY 2007 budget was released, are very deeply concerned about the R&A cuts. We recommend that NASA work with Congress to redress the balance in the near term for FY 2007 and that NASA consider changes for FY 2008 that will continue any revision into the future.

5.2 Hubble Space Telescope (HST)

HST: The AAAC recognizes the scientific value of HST and the gains in capability that will be achieved through SM4; thus, we fully support a carefully managed program to maintain and upgrade HST. The AAAC recognizes the significant cost of preparing for SM4. If the Shuttle program suffers significant additional delays that continue into 2008 and if the HST servicing mission is delayed even further, the AAAC recommends that, in addition to seeking the advice of the NASA advisory committees, the NRC be asked to provide scientific guidance.

The AAAC recommended last year *that NASA carry out SM4 as originally planned as part of its overall effort to complete its current obligations and programs as the agency moves to focus on new capability as part of the Exploration Vision.* We applaud the Administrator for resolving the question of what to do with the HST servicing program. Congress has directed the agency to update and repair HST if it can safely be done. In a very clear statement early last year, the Administrator decided that the only viable approach was through a Shuttle servicing mission and that it would be done if the first two Shuttle flights were successful. About $130M/yr of additional funding has been directed at preparing to service HST in late 2007 or 2008. If a return to routine shuttle flight does not happen in the next couple of years, there is the possibility of problems developing on HST itself or of further delay. At that point there should be a mechanism by which the agency can obtain advice from the community on whether to continue preparations for a servicing mission, or whether HST servicing preparations should be discontinued and those funds used elsewhere in Astrophysics. This should certainly include the NASA advisory committees, but given the visibility of this mission, it would be appropriate to seek NRC advice.

5.3 James Webb Space telescope (JWST)

JWST: The AAAC considers the science case for JWST to be very strong, as was recognized by the Decadal Survey committee in ranking JWST as the highest-priority Major Initiative. Cost growth in JWST, the disconnect between the current mission lifecycle costs and the budget estimates used in the previous Decadal Survey, and the budget cuts in SMD have all combined to result in a serious imbalance in NASA's program in astronomy and astrophysics. In the current plan, many smaller, very effective missions and programs are being curtailed in favor of a few, very large programs. The AAAC reaffirms the value of JWST, and more generally the value of "flagship missions" like JWST for the overall science program; in addition, the AAAC shares the view in the community, as reflected in the Decadal Survey that a balanced program from R&A through moderate missions to "flagships" is essential.

JWST is the highest-ranked, large space mission 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 technological advances that have occurred over the more than two 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 has become more costly than expected, though the underestimates by NASA in the last decade that came to be reflected in the Decadal Survey have not helped. (The NASA Administrator has used the word "undercosted.") The costs quoted in the Decadal Survey were largely C/D costs, and these were "undercosted" by about a factor of two (correcting to current dollars with inflation and full-cost accounting). JWST is not alone in suffering from this problem, nor is the problem peculiar to the 2000 Decadal Survey. In the 1990 Decadal Survey, SIM and SOFIA were costed as moderate $250-$230M missions. The community has recognized that we need to find a mechanism that will provide better cost estimates in the next Decadal Survey. The lack of a decision in 2004 on the launch vehicle during the tenure of the previous NASA administrator also did not help to contain the cost, ultimately driving the largest component of the cost increase in 2005 (~$500M). The current plan is for JWST to enter Phase C/D or construction early in 2007 and to track through for launch in 2013.

There is little doubt that JWST will be a remarkably powerful scientific facility with huge gains in capability. The issue that is being discussed in the community, particularly since the release of the FY 2007 budget request, concerns the impact of the cost of JWST on the broad suite of missions in the Universe/Astrophysics Division. As noted above in the discussion of major mission costs, the cost for such missions is now very high. Should we not do such missions? It would be reasonable to consider at our experience with HST. HST has delivered a long series of remarkable results and stunning images that have become synonymous with both NASA and astronomy. How much of the growth in the Universe/Astrophysics budget is due to the visibility of HST? Could Astrophysics sustain a budget of ~$1.5B long term without a “flagship” that brings consistent visibility to the program and its accomplishments? It is difficult to answer such questions, but they do provide a framework for thinking about the role of such large missions. Nonetheless, the reason that the last three decadal surveys have emphasized the value of a broad suite of activities is because such a range of missions is considered to be scientifically effective. Thus, it is crucial that JWST be done within a program that reflects more balance between small, medium and large than the current program, and which also enables development for the future major missions that will follow JWST.

The AAAC understands that a major cost review will occur in the next few months. In a discussion at the last AAAC meeting, Deputy AA for Science Colleen Hartman, GSFC Director Ed Weiler and JWST Program Scientist Eric Smith discussed with the AAAC various aspects of the status of the JWST project. Particular emphasis was given to the level of technological readiness that JWST has now achieved in its core technologies. It was very encouraging to hear that they are now at or close to the technology readiness level (TRL) appropriate for flight, i.e. TRL6.

The AAAC understands some of the unfortunate history of the recent cost increases, particularly the impact of the delayed decision regarding the launch vehicle. The cuts in the science budget and the cost growth in JWST have combined to generate a significant level of concern in the community and have led to a serious imbalance in the NASA science program in astronomy and astrophysics. We have recommended above some actions to alleviate this concern and to restore more balance to the overall Astrophysics program, but the AAAC is concerned that any future substantial changes in the cost of JWST could have a major impact on the JWST program.

5.4 Giant Segmented Mirror Telescope (GSMT)

GSMT: The AAAC greatly appreciates that NSF MPS and AST initiated and then supported a significant FY 2007 increase in GSMT technology development through funding the proposal from the two community groups, GMT and TMT. The AAAC further recommends that the NSF evaluate its approach to major projects to see if incremental changes could allow it to take advantage of the opportunities provided by significant levels of private funding, provided that such programs meet the very high peer-review standards set for major projects. The involvement of OMB and OSTP, and of committees in Congress, could help to bring this about. 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, especially if cooperation resulted in shared access for all-sky coverage to the next generation of extremely large telescopes in the north and the south.

A giant 30-m 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-m class telescopes.

Significant efforts towards realizing GSMT have begun in the 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. As demonstrated for JWST and for other large programs, the ideal approach in light of the technological challenges is to support technology development to the point where the projects can submit proposals from which a selection can be made that will allow the NSF to move forward with a single project for a major investment through the Major Research Equipment and Facilities Construction (MREFC) process.

The astronomy community came together with a joint proposal to the NSF for GSMT technology development. The AAAC is highly supportive of the GSMT program and was delighted when some funds were made available from NSF AST for technology development (~$1M in FY 2005, $2M in FY 2006, and $5M requested in FY 2007).

There is another quite unusual aspect of the GSMT program that provides great opportunities for bolstering the research funding available to the nation as a whole, but which brings with it some interesting policy issues. The two candidate projects (at this point in time), the GMT and the TMT, expect to bring at least several hundred million dollars of private funding into the project from private foundations, individuals and universities. International partners are also likely. (Canada is already a member of one 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. At first glance such investments, when combined with funding from the Federal Government, appear that they might solve a long-standing issue for privately funded facilities—namely, the problem of funding operations. Private foundations have shown a preference for supporting major construction expenditures over a limited period, with significantly less willingness 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. Could procedures be found that would allow the agency, in this case the NSF, to make longer-term commitments for 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 the 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. Could an NRC study be initiated that would address the development of a strategy that would be mutually satisfactory to the agency, OMB, Congress and private foundations, to see what could be achieved in finding a way to utilize private resources at the level of $300M-$500M for funding very highly-ranked science projects? 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.

A larger version of GSMT is also under consideration by the Europeans through the European Southern Observatory (ESO). A recent review in November 2005 identified a telescope of about 40 m as the focus of their development efforts. Their interest in extremely large telescopes (ELTs) 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.

5.5 The Explorer Program

Explorers: The AAAC notes that the Explorer program has been identified as a high-priority activity in each of the last three Decadal Surveys. Yet, recent events involving a cancellation and a deferment, combined with infrequent announcements of opportunity (a gap from 2002 to 2008) indicate a program that *is in serious trouble. The AAAC recommends that the NASA Explorer program be restored to a level of support adequate to ensure its vitality and effectiveness with frequent announcements of opportunity.*

The AAAC continues to be very concerned by the low level of funding for the Explorer program. The Explorer line has provided many of NASA's most successful missions. The remarkable cosmological results from the Wilkinson Microwave Anisotropy Probe (WMAP) exemplify the power of Explorer missions. 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. The focused investigations enabled by Explorers provide early technology demonstration 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 can see 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 build the larger missions in NASA's future.

The funding shortfall for the last two years has caused a substantial delay in the announcement of the next Explorer opportunity. The next announcement will occur in 2008, six years after the previous announcement in 2002. The reduced rate of new missions under the current Explorer program limits the opportunities to exploit new technologies and scientific opportunities and to support the science goals of the Decadal Survey. Explorers have been identified as playing a key role in the last three decadal surveys. The recent 2000 Decadal Survey noted, "NASA's Great Observatories have revolutionized understanding of the cosmos, while the extremely successful Explorer program provides targeted small-mission opportunities for advances in many areas of astronomy and astrophysics. The committee endorses the continuation of a vigorous Explorer program. There are now fewer opportunities for missions of moderate size however, despite the enormous role such missions have played in the past."

In the meantime, the Nuclear Spectroscopic Telescope Array (NuSTAR), a small astrophysics Explorer that was proceeding to its interim confirmation review this month, was cancelled last month for budgetary rather than technical reasons. Furthermore, another astrophysics Explorer mission, the Wide-field Infrared Survey Explorer (WISE), which was rated as "favorable" on its confirmation review, did not enter into construction but was deferred at reduced funding. A concern in deferring a mission at this stage is that the delay will drive up the overall cost, leading to fiscal difficulties and potential cancellation in the future. The AAAC is deeply concerned about the future of the Explorer program. As noted, it has been listed as very high priority in each of the last three Decadal Surveys, yet missions are now extremely infrequent.

5.6 The Beyond Einstein Program

Beyond Einstein: The AAAC recommends that NASA look carefully at providing resources for continuing a modest level of technology development for LISA and Con-X to ensure that they can be fairly evaluated, judged for technological readiness, and provided with reliable cost estimates in the upcoming Decadal Survey. Conceptual development of the Einstein Probes program is also highly desirable before the next Decadal Survey.

In our 2004 and 2005 reports the AAAC highlighted our concern that a major aspect of the space science program for astronomy and astrophysics at NASA, the Beyond Einstein program, was progressing very slowly. This program includes initiatives from both the Decadal Survey and from *Connecting Quarks with the Cosmos* (CQC). The major areas of concern were with the gravitational wave detector, the Laser Interferometer Space Antenna (LISA), the next-generation X-ray mission Constellation-X (Con-X), and the Einstein Probe program. We were pleased, therefore, to hear that the Beyond Einstein Formulation Authorization Document was signed in late 2004, formalizing the Beyond Einstein program, that LISA has been given Phase A status, and that some funding for Con-X was restored in the FY 2006 budget request after its absence in the FY 2005 budget. However, the impact of the FY 2007 budget request has been dramatic. Con-X had a launch date last year of NET 2018 but is now indefinitely deferred. LISA changed over the last year from NET 2013 to "indefinitely deferred."

Overall, the Beyond Einstein initiative remains severely underfunded, even though it is based on a science program that defined some of the highest-priority space missions in the Decadal Survey and in the CQC report. The NAS Report from the *Committee to Assess Progress Toward the Decadal Vision in Astronomy and Astrophysics* raised similar concerns: "The Beyond Einstein roadmap (currently being updated), is an excellent implementation and synthesis of the Decadal Survey and CQC. For the program to fulfill its promise, support for the Beyond Einstein projects needs to be sustained."

More specifically, the effect is substantial on the future viability of the major missions currently in the Decadal survey list and in CQC. In Beyond Einstein, Con-X, LISA and Einstein Probes/JDEM are dealing with very modest funding. (The program is budgeted at ~$21M in FY 2007 and FY 2008, but overheads reduce what is available for mission studies.) While the Committee is not in a position to judge the detailed funding levels required, it appears from recent experience that flagship missions each need about $10M/yr each to be at a critical mass for any useful conceptual/technical development. For missions at the scale of the Einstein Probes, i.e., for the ~$600M missions, something smaller would help conceptual development significantly.

A particular concern continues for the Einstein Probes program. This aspect of Beyond Einstein is discussed in §6.7 in the context of the study of dark energy for one of its missions, the Joint Dark Energy Mission (JDEM). The Einstein Probes include several potential missions of great interest, namely the Inflation Probe, the Black-Hole Finder and the Dark Energy Probe. While the Probe program is still identified as part of the Beyond Einstein initiative, the only activity thus far has been an AO for JDEM studies. The situation for the Einstein Probes mirrors that of the Beyond Einstein program as a whole: it has yet to receive significant fiscal traction.

5.7 Einstein/Origins Probes

Einstein/Origins Probes: The AAAC recommends that SMD and Astrophysics further the conceptual development of the Probes (~$600M missions) to where the concept could be presented to the next Decadal Review as a potential option for mid-scale missions between Explorer and Discovery-scale missions and the very infrequent flagship missions.

The high cost of missions of the flagship class (HST, JWST, Spitzer, Chandra, SIM, SOFIA) has highlighted the need for missions at the $600M level that are intermediate between Explorers and flagships (somewhat like GLAST, which is around ~$750M). The AAAC recommends that NASA continue to develop the Einstein and Origin Probes concept, and to discuss those within the advisory process as the Astrophysics analog of New Frontiers. The NASA Astrophysics subcommittee could assist in developing the concept of Probe-class mission to where they could be subsequently discussed by the Decadal Survey.

5.8 Major Mission Technology and Conceptual Development

Conceptual Development for Flagship Missions: The AAAC recommends that NASA look carefully at providing resources for continuing a modest level of technology development for likely Major Initiatives identified in the 2000 Decadal Survey so they are positioned for serious performance evaluation with reliable, realistic cost estimates.

With the support of the agencies, astrophysics intends to convene a broadly based Decadal Survey study in the next few years that reconsiders the community's goals and priorities for the next decade. It is very obvious to all concerned that almost none of the high-priority recommendations from the last Decadal Survey will be completed. There is a widespread view that the next Decadal Survey will have to re-assess and re-prioritize each and every unfinished if it is to develop a viable program for the next decade. Given the incompleteness of the previously recommended program, it will not be appropriate to just pass through those unfinished programs. Consequently, it is crucial that we go into the next Decadal Survey with adequate technology and conceptual development in hand for the many missions or programs that will be contestants in the 2010 Decadal Survey. Otherwise, the Survey discussions will be devoid of solid technical underpinning and will be saddled with unreliable cost estimates. The underestimates in the mission budgets in the 2000 Survey have caused problems. A particular concern arises for the Major Initiatives since, given recent cost history, these missions are likely to all have lifecycle costs that are in the few-to-several $B class (i.e., $2-4B). This class would include those missions like LISA, Con-X, and TPF that have received some funding this decade, and which we have argued should be the recipients of a modest level of funding in each of these areas over the next ~3-4 years. Such funding (at the level of ~$10M) would make a big difference to the future robustness of the missions chosen for the next decade through the Decadal Survey process and for the robustness to the process leading to the recommended pool of missions.

The $600M-class of missions (the Einstein Probes, of which JDEM is one, along with the Origins Probes) would also benefit from some funding to help characterize the cost envelope. As has been seen with Discovery missions, as well as with Explorers, cost growth has become a significant issue even for missions where the cost constraints are given high weight and visibility. The Probes are likely to suffer the same cost-growth problems. The next step in evaluating the reality of the cost cap for some of the concepts being discussed will be to provide some funds for mission studies.

One of the Decadal Survey Major Initiatives recommended for technology and conceptual development this decade was the Single Aperture Far Infrared (SAFIR) mission. This 10-m class cryogenic observatory would complement ALMA by exploring the infrared universe by taking advantage of the extraordinarily dark sky between the peaks of the zodiacal and the CMB emission. SAFIR would build upon architectural elements being developed for JWST, and so it might be appropriate to begin considering an assessment of the technology issues as the Decadal Survey approaches, particularly given the technical maturity of JWST.

5.9 Stratospheric Observatory for Infrared Astronomy (SOFIA)

SOFIA: The AAAC was greatly concerned that a mission that was so close to flight demonstration was effectively cancelled ($0 in the five-year budget) without any review. The AAAC recognizes the cost and schedule issues with SOFIA, but any program should undergo a serious review before any major change in its status is announced. The upcoming SOFIA review is welcome, but any change in status now has broad budgetary implications for the remaining Astrophysics program.

SOFIA was recommended as a moderate-scale mission in the 1990 Decadal Survey to replace the Kuiper Airborne Observatory (KAO). SOFIA started its development in the late 1990s. This observatory, by offering access to a 2.5m telescope aboard a modified Boeing 747 aircraft above most of the water vapor in the Earth's atmosphere, 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 allows such measurements to be made relatively economically with instrumentation that is routinely accessible, upgradeable, and repairable and that allows the science to take advantage of the steep trajectory of infrared sensor improvements that technology development efforts are providing. While this mission is significantly over budget and behind schedule, this airborne astronomical observatory is now approaching completion. It came as a complete surprise to the community, therefore, that SOFIA was zeroed out in the FY 2007 budget, a change that effectively terminates the project.

A review is now scheduled to assess cost and schedule credibility for both completion of development and the eventual operations plan, presumably to evaluate the potential impact of recovering the program. The AAAC is aware of the problems that have beset the SOFIA program and that the project has not yet demonstrated that it can fully achieve its scientific objectives. The very substantial growth in the project lifecycle cost now places SOFIA within the category of Major Initiatives. But, to cut a major program with a strong international component that is nearing its first flight without any consultation dispenses with well-established processes. The lack of a "day in court" for the program is clearly going to elicit a very strong reaction. The announcement that there will be a serious review is welcome. The scientific impact deserves to be fully aired and discussed, as do different operational models and lifetimes, with the scientific return being assessed versus the cost of using different approaches. We do recognize, however, that without an increase in the SMD budget, other programs would be impacted substantially. Thus, any change in SOFIA's status has broader implications that should be addressed by the appropriate science committees, since reinstatement now impacts a program that is already constrained for funds and does not have the balance desired by the community.

5.10 Terrestrial Planet Finder (TPF): TPF-C and TPF-I

TPF: The AAAC was concerned in its 2005 report, as was the CAA, about the rapid acceleration of the TPF program following the Exploration Vision announcement. However, decreasing all technology and conceptual development to $0 is inconsistent with the Decadal Survey recommendation. To enable continuing development on this exciting but challenging program we recommend that TPF, like Con-X and LISA, should be funded to allow a continuing level of conceptual and technology development.

The scientific potential of TPF led to a recommendation for technology development in the Decadal Survey. TPF is an exciting mission scientifically, with its goal of detecting and characterizing earth-like planets around other stars. Following the announcement of the Exploration Vision in 2004, the TPF program was expanded into two major missions (TPF-C, a near-term, large optical space telescope with an optical coronagraph—the "C" in TPF-C—and TPF-I, an infrared interferometer—the "I"—with TPF-I planned for longer-term implementation). An accelerated development and implementation schedule was set for TPF-C, leading to a launch in 2015 and necessitating passage in Phase A, and even Phase B, before the next Decadal Survey.

The NAS Committee on Astronomy and Astrophysics (CAA) was asked to provide a letter report on this change, which involved a significant departure from the Decadal Survey recommendations. The Decadal Survey recommendations were to initiate technology development for TPF and to establish the science framework based on missions like SIM and others (e.g., the Discovery mission Kepler) with the expectation of a comprehensive evaluation in the 2010 Decadal Survey. The CAA-led *Panel to Review the Science Requirements for the Terrestrial Planet Finder* raised concerns about the move to a very aggressive schedule for TPF-C, given both the lack of scientific maturity (at that time Kepler and SIM launch dates were around 2008 and 2011, respectively) and the potential impact of the technical and fiscal challenges on the priorities of the Decadal Survey. The CAA letter report noted that TPF is an exciting mission scientifically, but that, as a mission of at least the cost of the James Webb Space Telescope (JWST), significant impact could well occur on other highly-ranked missions in the Decadal Survey. The AAAC supported the concerns of the CAA. While significant technological developments had occurred in the last few years, TPF-C remains a highly challenging mission. Thus, the risk to other programs is enhanced because of the potential for cost growth through the lack of technical maturity. The AAAC thus recommended in its 2005 report *that the development of the TPF-C mission be the subject of a comprehensive independent review of both its scientific and technical readiness by the National Academy of Sciences before decisions are made to move TPF-C forward as a flight project.*

However, the situation for FY 2006 and in the FY 2007 request has oscillated to the other extreme. The budget for the TPF program was reduced to $0 in the FY 2007 request, after a substantial reduction in the FY 2006 appropriation to about $10M. We, as with the CAA, felt that a longer period of technology development and risk mitigation and retirement would be appropriate given the challenges of planet detection and characterization. An FY 2007 (and beyond) budget of $0 is not consistent with this view. Moreover, planet searching and characterization is an area of great scientific interest, with a developing community of very active researchers, including very many young researchers. A workshop at the Aspen Center for Physics last year turned out to be one of the largest winter workshops organized by the Center. A modest level of continued support for technology development and community involvement in conceptual development, even comparable to that in FY 2006 (about $10M), would enable progress in this important area to continue.

6.0 Interagency Coordinated Programs

The following sections deal with specific projects or activities that came before the AAAC during its deliberations over the last year in the areas of interagency cooperation and future return from initiatives that will be the focus of more than one agency.

6.1 Research and Analysis (R&A)

R&A: The AAAC notes that a goal of the American Competitiveness Initiative (ACI) is to improve basic research in the physical sciences and in so doing excite and train young researchers and technologists. The cuts at NASA in R&A are exactly counter to that goal. The R&A funding should be restored to the level in FY 2006.

As discussed in §5.1, R&A plays a key role in the community's ability to be productive and effective users of facilities that have been developed with very considerable investments. We strongly encourage NASA and SMD in particular to re-evaluate the cuts to R&A and to restore funding. (We recognize that these cuts have occurred across all divisions, with those in the Solar System Division being even more dramatic.) Cuts in R&A 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. These young people, along with their guides, mentors and teachers among the more senior, experienced members of the community, constitute the scientific human capital. Together they are the future of the field.

Even if NASA is largely excluded from ACI, NASA indisputably supports basic research, and to cut R&A at NASA while advocating increases elsewhere (NSF, DOE, NIST) is counter-productive. The net gain may be zero or even negative given the scale of the R&A activities at NASA. The breadth of the scientific investigations that are supported through R&A is also an investment for the future. 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.

The R&A cuts that are causing such concern in the astrophysics community are about $11M in Universe/Astrophysics. The FY 2006 R&A program is about $65M. The proposed R&A program for FY 2007 and beyond is $54M. The AAAC strongly recommends 1) that NASA work with Congress so the R&A budget for FY 2007 is similar to that for FY 2006, and 2) that the agency increases the R&A funds in FY 2008 and beyond to reflect a baseline value at the 2006 level and to inflate the numbers so R&A does not decrease in real terms. Similar percentage cuts have occurred in the other science Divisions, with the exception of the Astrobiology program, which has been cut 50%. We would hope that similar steps would be taken in those Divisions also.

6.2 Gamma-ray Large Area Space Telescope (GLAST)

GLAST: The AAAC is very encouraged that GLAST is moving forward towards a launch in late 2007 and that the LAT problems have been retired. A successful GLAST mission will bring great scientific progress, as well as provide a useful working model for future NASA-DOE partnerships.

The Committee was pleased to learn that the Gamma-ray Large Area Space Telescope (GLAST) is now in the construction phase and is progressing towards a launch date of September 2007. GLAST is a very important gamma-ray space mission. It is the highest ranked space mission in the “moderate” category in the Decadal Survey. The primary instrument on GLAST, the Large Area Telescope (LAT), has been built in partnership between DOE and NASA. GLAST is the first such major program to be developed in partnership between the two agencies, and the AAAC is particularly interested in how it develops. It is a pathfinder for future, even larger, joint efforts such as the Joint Dark Energy Mission (JDEM).

The LAT instrument had encountered schedule and cost overruns, but these problems have been overcome with some additional funding from NASA and DOE. The GLAST project is moving forward towards launch. Indeed, the full array of the sixteen towers of the tracker and calorimeter that comprise the heart of the LAT instrument has now been completed and is undergoing testing at the Stanford Linear Accelerator Center (SLAC). Following environmental testing it will be integrated with the spacecraft. A successful GLAST mission will bring great scientific progress, as well as provide a useful working model for future NASA-DOE partnerships.

Being more than an order of magnitude more sensitive than the earlier Compton Gamma Ray Observatory, GLAST will have a major impact on our understanding of the astrophysics of sources that emit high-energy radiation. Specifically, it is expected that GLAST will discover thousands of new high-energy sources, many of which will require detailed, correlated observations using instruments at longer wavelengths. We note that a relatively comprehensive multi-wavelength program will be needed to fully capitalize on the GLAST mission, and that much of this program will be carried out using ground-based facilities supported by NSF.

6.3 Giant Segmented Mirror Telescope (GSMT)—James Webb Space Telescope (JWST) Synergy

GSMT/JWST Synergy: The AAAC reaffirms its view that operation of GSMT in the JWST era would provide major scientific synergies. The GSMT and JWST SWGs have prepared a report highlighting the scientific *value of such synergy. The AAAC encourages NSF to be responsive to opportunities that would help GSMT move forward as JWST proceeds to launch.*

As noted above, GSMT and JWST are the highest ranked large programs in the Decadal Survey on the ground and in space, respectively. We have commented above on each of these missions and on the central role that they will play in cutting-edge science in the coming decade. There is another aspect of these programs that deserves particular attention. The experience of HST and the current generation of 8-m class ground-based telescopes have demonstrated that, working together, they synergistically provide scientific advances beyond even their enormous individual capabilities. This opportunity for enhanced synergistic capabilities led to the recommendation in the 2004 AAAC report: "Progress on these scientific objectives is heavily dependent on GSMT being developed on the same timescale as JWST. This requires initiation of an aggressive technology development program, ramping up if possible in 2005, with particular support in the FY 2006 budget". This did not happen, but the AAAC is encouraged by the ramp-up in funding for GSMT technology development that is in the FY 2007 request.

To provide a more detailed scientific case for the synergies from concurrent operation of GSMT and JWST, the AAAC asked the GSMT Science Working Group (SWG) to develop in collaboration with the JWST SWG a document that would enunciate the science gains to be made with overlapping operation. The two SWG's agreed to do so, and their report has been completed and accepted by the AAAC at its May 2005 meeting. Copies of a two-page summary (a "handout") and the full report can be found at:
http://www.nsf.gov/attachments/103158/public/gsmt_jwst_synergy_handout_final.pdf
http://www.nsf.gov/attachments/103158/public/gsmt_jwst_synergy_report_final.pdf

Another aspect of the synergy between ground and space has surfaced as a result of developments over the last year. The focus at NASA on the search for other planets at NASA (see the TPF §5.10) has highlighted the scientific and public interest that is developing in the search for planets around other stars, their characterization and the broader issue of planetary system formation and evolution. Recent developments in adaptive optics (AO—and particularly the potential of what is now called Extreme AO—ExAO) have led many researchers into thinking about the great potential of large telescopes in the GSMT-class for tackling these problems in the upcoming decade. The high resolution available in the infrared with 30-m class, AO-equipped telescopes enables observations of some planets and disks closer to other stars than can be done with space telescopes with their smaller mirrors. Again, these ground-based capabilities will complement the space observatories under discussion and allow synergistic approaches to investigating how planetary systems develop around stars. See §6.9 for a discussion of the AAAC recommendation that the agencies form an ExoPlanet Task Force to evaluate the approaches to planet detection and characterization on the ground and in space.

6.4 Advanced Technology Solar Telescope (ATST)—Solar Dynamics Observatory (SDO) Synergy

ATST: 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 into the MREFC Readiness Phase. The AAAC recommends that the NSF move ATST quickly through the MREFC process to take advantage of scientific synergies that will arise from overlap with SDO.

In both the 2004 and 2005 reports, the AAAC reiterated one of the central findings of the Decadal Survey, and of the NAS study *The Sun to the Earth and Beyond*: understanding the development of solar magnetic fields in space and time, and understanding how magnetic fields power flares and eruptive activity will require contemporaneous observations from the space-based Solar Dynamics Observatory (SDO) and the ground-based Advanced Technology Solar Telescope (ATST).

In this past year, both NASA and NSF have made steady progress toward this goal. SDO continues towards launch in 2008, having being placed in Phase C/D following its Confirmation Review in June 2004. ATST was moved into the Readiness Phase in the MREFC process.

The AAAC was very pleased to see ATST move into the MREFC Readiness Phase and views positively the effort to include a significant component of international participation. The project did not achieve its goal of a new start, but the AAAC hopes that NSF will move ATST expeditiously into a new start in the MREFC queue. The lag of ATST relative to SDO remains a concern of the AAAC. Site-specific planning for the chosen site on Haleakala on Maui in Hawaii is moving forward. Given the siting of ATST on Haleakala, collaboration between the Air Force and ATST would be an obvious benefit, and it is hoped that this will be formalized. A strong international component would add significant value to the program, both in the near-term development and construction and in the long-term scientific effectiveness of the Observatory.

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

CMB Task Force: The AAAC accepted the final report from the CMB Task Force (TFCR) at its October meeting and commended the TFCR for its very comprehensive and valuable study. The AAAC expects that the report, with its prioritized program, and the response that will follow from all three agencies, will provide a basis for moving forward in this exciting area on a broadly based program for CMB polarization research and will provide invaluable guidance for the next Decadal Survey.

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. 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 the NSF that led to the recent spectacular success of the NASA Wilkinson Microwave Anisotropy Probe (WMAP) Explorer satellite mission.

As profound as these results have been, it has become clear that the minute variations in the polarization properties of the CMB radiation over large scales may allow us to probe directly the first instants of time and test the inflation theory for the origin of our universe. Such a measurement would be one of the crowning scientific achievements of the century and of the utmost importance for our understanding of fundamental physics. This ambitious goal of probing the first instants of the universe and testing inflation by definitive measurements of the polarization of the CMB was highlighted in CQC and POU. It builds directly on the remarkable progress in the last few years from observations of the CMB anisotropy (such as WMAP). The definitive, foreground-limited, CMB polarization measurement will require an all-sky survey over several frequency bands and with sensitivity several orders of magnitude higher than ever achieved. That is the goal, and the great challenge, of the CMB Inflation Probe (CMBPOL) of NASA’s Beyond Einstein theme. A broad program supporting new technologies and techniques will need to be put in place to work toward achieving the definitive CMB polarization measurements. At the required sensitivity levels, systematic uncertainties will be difficult to control, and contamination from astronomical foregrounds will be severe. Several independent experiments using a variety of techniques will have to be explored. This will require the active involvement all three agencies. A challenge remains in setting the timescale and identifying the funding for the NASA mission that would be the culmination of this effort, namely CMBPOL.

The AAAC enthusiastically supported the effort to develop a joint NSF-NASA-DOE roadmap leading to definitive measurements of the CMB polarization. The Task Force on CMB Research (TFCR) was set up early in 2004 and submitted its report last year to both the AAAC and HEPAP. The AAAC discussed the draft TFCR report during its February 2005 meeting with the TFCR chair and were very impressed with the comprehensive nature of the study. The number and breadth of the TFCR-recommended activities in the current funding environment were noted as a potential issue for its timely implementation, and so the AAAC asked that the task force prioritize programs and areas for emphasis to help guide the agencies if the full program could not be initiated in the near to intermediate term. The TFCR responded, using external reviewers to also give feedback on the report. The final report was submitted to HEPAP and to the AAAC in fall 2005. The AAAC commended the task force on its very comprehensive study. 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.

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

Dark Energy: The AAAC supports a vibrant, wide-ranging program of investigations leading to understanding of the impact of dark energy on the Universe. The Dark Energy Task Force (DETF) was set up at our suggestion with the strong support of the agencies. The DETF report is nearly completed. The findings and recommendations from the DETF will be transmitted through the AAAC and HEPAP and will help to optimize a dark energy program that the science community and the agencies can utilize to make progress over the next decade quickly and cost-effectively.

The discovery of dark energy at the end of the 1990’s is one of the great 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 HST. A number of complementary approaches, such as weak gravitational lensing, the evolution of galaxy clusters, and the growth of structure in the matter of the Universe, as well as distant supernovae, are now being utilized for their potential in narrowing down 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—namely a ground-based program now generically called the Large Survey Telescope (LST) and a space-based mission known as the Joint Dark Energy Mission (JDEM). JDEM was developed as a joint effort by DOE and NASA, reflecting the increasing interest by DOE HEP in astrophysical programs of interest to the physics community. JDEM is unlikely to be launched until well into the next decade (see §6.7). Two ground-based projects are moving forward as potential implementations of LST.

A pilot project called the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) is moving ahead in Hawaii with the goal of demonstrating that wide-area surveys for dark energy studies, along with other science goals such as asteroid detection, can be done with a number of small, very wide-field telescopes operating together. Another project, the Large Synoptic Survey Telescope (LSST), is taking a comparably ambitious approach using a single large 8-m class ground-based telescope with similar goals. The LSST consortium has received NSF funding for technology development ($14M over 4 years) and is collaborating with DOE investigators who are working to develop the camera. The consortium is also pursuing a significant component of private funding. The adopted approach for LST will be determined by technological readiness, presumably through a peer-reviewed selection. The likely timescale for completion of the construction of this project is also early in the next decade (2012?), given the remaining technology development and the steps involved in moving through the NSF MREFC process.

However, a number of projects both within the U.S. scientific community and internationally are actively being developed to address dark energy. 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 a Dark Energy Task Force (DETF) that is reporting to the AAAC and to the High Energy Physics Advisory Panel (HEPAP). DETF will establish a framework and provide guidelines that will help in the subsequent peer-reviewed choice of dark energy projects but will not prioritize individual projects. The initiatives that will occur under the framework established by the DETF will then set the stage for LST and JDEM. The DETF has been meeting this past year and will have a report available during spring 2006.

The DETF findings already 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 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 already 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 one of the four science techniques considered by the DETF (baryon oscillations, clusters, supernovae, and weak lensing). Such feedback will prove immensely valuable to the field and to the agencies that will fund the developments.

6.7 Joint Dark Energy Mission (JDEM)

JDEM: JDEM is proving to be an interesting vehicle for interagency cooperation, and the AAAC welcomes and appreciates the continuing willingness of the agencies to work towards overcoming some of the challenges that result from the different approaches to "doing business." The AAAC welcomes the plan at DOE to provide support for concept development for other approaches to studying dark energy, in addition to its continuing support for SNAP. The AAAC encourages NASA to complement the effort at DOE and to continue with its support of several potential implementations of JDEM.

One of the initial agency responses to dark energy was the development of an interagency agreement to carry out a DOE-NASA Joint Dark Energy Mission (JDEM). One particular implementation of JDEM, the Supernova Acceleration Probe (SNAP), has been supported at DOE for some time, and so the AAAC was encouraged by the effort undertaken by the Universe/Astrophysics Division to initiate funding for a competitive evaluation of mission concepts for JDEM. The AAAC has recognized that the agencies' different approaches to funding conceptual development activities has led to the DOE HEP-supported program being funded at a higher level than other mission concepts. SNAP also began at an earlier stage, and so it is more mature. While the Universe/Astrophysics Division is to be commended for its effort to provide funding for a range of concept studies, the differential funding is becoming larger between the DOE supported effort (SNAP) and other concepts for JDEM that have proposed to NASA. This will significantly impact the approach of a competitive selection since the playing field will not be seen as level for all. Given the support for SNAP and other concepts in the DOE FY 2007 request it is important for NASA to adequately fund conceptual development to help balance the playing field. The increase in SNAP funding is balanced by the new R&D investments that DOE is planning for the span of dark energy measurement approaches (see below). The Lessons-Learned activity, recommended by the AAAC this last year might usefully discuss the impact of the different approaches.

Along these lines, an interesting example of the challenges of doing a balanced interagency program occurred recently during the budget process. The opportunity presented by the recent ACI-driven budget increase for DOE science during the FY 2007 budget process led to the DOE HEP and OMB jointly agreeing to increment the SNAP budget by $4.6M in FY 2007. The increased support for mission development is welcome, but it further differentiated the current DOE–supported project SNAP from the other projects that are looking to NASA for support. The AAAC discussed this with the agency representatives and the OMB Examiners during a discussion at the AAAC February 2006 meeting. Ideally, OSTP and the OMB Examiners would have noted this imbalance and discussed possible re-balancing with NASA and DOE. Since the agency budget activities are quite "stovepiped" at that time, it appears that the burden for this probably falls on the OMB Examiners and OSTP (nor can any interaction and discussion take place on the budget outside the Executive branch—normally this would be another way in which such issues are identified). However, the time pressures are considerable during this phase of the budget process, and it is not clear how the necessary interactions would to take place, though this may be a situation where OSTP could help.

In addition to the planned increase in SNAP R&D in FY 2007 of $4.6M, the DOE FY 2007 budget request also provides for another $5M in dark energy R&D funds that will be competitively awarded. Ground- and space-based concepts will be able to apply to get these funds. The AAAC is very pleased that DOE HEP appreciates the need for support for other concepts and is working towards minimizing disparities. Coordinating this effort with NASA would be of mutual benefit. The AAAC also expects that the DETF report will provide guidance for the optimization of JDEM and hopes that NASA and DOE HEP will utilize the DETF recommendations in their assessment of the program and in reviews.

6.8 Dark Matter Science Assessment Group (DMSAG)

DMSAG: The AAAC welcomed the request by DOE HEP and the NSF Division of Physics (PHY) and AST to jointly establish a Dark Matter Scientific Assessment Group (DMSAG) to advise the DOE HEP, PHY and AST concerning the U.S. dark matter direct-detection research program. The DMSAG will report to HEPAP and to the AAAC.

Great interest has developed in the detection and understanding of the mysterious dark matter that dominates the mass of the universe. This is a scientific area that is of importance 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 PHY, AST and the DOE HEP 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* that was produced under the auspices of the OSTP.

6.9 ExoPlanet Task Force (ExoPTF)

ExoPTF: The AAAC notes that substantial progress is being made on ground-based planet searches and that substantial activity has occurred in defining future space-based facilities. The AAAC recommends that the agencies consider the establishment of a task force to develop a roadmap 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. Such a report, as well as being a guide for agency planning, will also provide very valuable input to the Decadal Survey.

Interest in planet searches, in the characterization of planets, and in the broader scientific issues encompassing planet formation is rapidly growing in the community. 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 HST and Spitzer, are being used to address the scientific questions with several missions planned or under discussion for the future, including Kepler, SIM, TPF-C, TPF-I, and Darwin. The science case for current and future large ground-based telescopes with innovative (and very challenging) AO capabilities includes programs that are contributing to this topic or are planned to do so. Given this great interest in the field of ExoPlanet research, and the challenges and high cost of both ground- and space-based experiments and missions, it would be very timely and valuable to undertake a study similar to what has been done recently for the CMB and for dark energy. The results of such a study would also be very valuable input for the next Decadal Survey. Given the dramatic changes that have occurred at NASA in the last two years with regard to planet searching, the recommendations of such a group could also provide a more stable framework under which a planet search/characterization program could be developed. The AAAC recommends that the agencies consider establishing such a task force this year. Once started, this activity would likely take over a year, and so the availability of a report late in 2007 or early in 2008 would allow the community to build on its findings and recommendations in time for the next Decadal Survey later this decade.

6.10 National Virtual Observatory (NVO)

NVO: The AAAC strongly encourages the NVO team to continue its excellent work, especially its efforts to fully involve the science community. The AAAC recommends that the agencies, NSF and NASA, expedite their plan to solicit proposals for the operation of the NVO and to implement that within the next year, and to discuss with DOE the possibility of DOE involvement in NVO.

The joint NASA-NSF supported National Virtual Observatory (NVO) effort was recommended by the Decadal Survey and will provide a “virtual sky” based on the enormous data sets being created now and on the even larger ones proposed for the future. The NVO will enable a new mode of research for professional astronomers and will provide to the public an unparalleled opportunity for education and discovery. The NVO will 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, infra-red to radio wavelengths. Such data sets are orders of magnitude larger, more complex, and more homogeneous than in the past. The NVO provides the ability to match and correlate data from such vastly different sources and thus empowers astronomers to mine the data archives to maximum benefit. The NVO is a key technology that will maximize the scientific productivity of both existing and new facilities and programs.

The NVO provides access and tools for maximally utilizing data archives, but is not itself an archive. NVO provides the tools that enable astronomers to collate material from all existing sources, which in turn increases the value of a single archive by placing it in the joint context of other archives. The AAAC hopes that the capabilities of the NVO will encourage and stimulate more widespread archiving of data by institutions and organizations that do not already have roadmaps to do so.

NSF and NASA are working together to create a joint program for implementing and managing the NVO by developing a memorandum of understanding (MOU) for a joint solicitation for establishing the operations and management of a Virtual Astronomical Observatory (VAO). The expectation is that the VAO will be operated as a distributed center, and proposals for operation of the VAO will likely come from collaborations and consortia of institutions. Once the MOU is cleared in both agencies, the process for clearance of the solicitation itself will begin, and the deadline for proposals for operation of the VAO will be due 90 days after the solicitation is announced. The goal is to reach a selection by the end of the year. Support for NVO activities will continue through this year to sustain the project until a solicitation can be announced, proposals can be received and reviewed, and a selection can be made. Progress on the NVO has been excellent, and cooperation between the agencies is good, but the process for clearance of the MOU between the agencies seems to work slowly.

The AAAC hopes that progress can be accelerated so as to expedite the solicitation. The AAAC would also be interested in seeing discussions develop with DOE regarding their future involvement in NVO.

6.11 Lessons-Learned Interagency Study

Lessons-Learned: Following discussions with the agencies and OSTP over the last year, the AAAC asked the agencies to consider undertaking a "lessons-learned" activity for carrying out collaborative interagency projects. The AAAC, the agencies and OSTP agreed to have a more detailed discussion on the timetable, approach and nature of a lessons-learned report at the May 2006 AAAC meeting.

After discussion at several meetings over the last year, the AAAC recently sent a letter to the agencies noting an interest in a "lessons-learned" activity that would provide a guide 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. Since time is passing, and the key players in some of the activities will move on to other responsibilities, the AAAC suggested that it would be valuable to carry out a "lessons-learned" effort in 2006, and to produce a report that captures the experience and wisdom of the current players. It was noted that it would also be valuable to enhance this effort so it also covers 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 at this time. Though we recognize that the nature of the cooperation on joint projects will depend both on the project and the agencies involved, the report could capture such differences. There is no "one-size-fits-all" approach. 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 learnt to date.

The AAAC recommended to the agencies that they consider 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. The AAAC, the agencies and OSTP agreed to follow up on the initial discussion on this effort at the February 2006 meeting with a more detailed discussion at its May 2006 meeting

APPENDIX A: 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 2001 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 B: 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
AO	Adaptive Optics
AO	Announcement of Opportunity
AST	NSF Division of Astronomical Sciences
ATST	Advanced Technology Solar Telescope
AXAF	Advanced X-ray Astrophysics Facility (now known as Chandra)
BPA	Board on Physics and Astronomy
CAA	Committee on Astronomy and Astrophysics
CEV	Crew Exploration Vehicle
Chandra	Chandra X-ray Observatory (formerly known as AXAF)
CMB	Cosmic Microwave Background
CMBPOL	CMB Polarization Mission
COMRAA	Committee on Organization and Management of Research in Astronomy and Astrophysics
Con-X	Constellation X-Ray Observatory
CQC	Connecting Quarks with the Cosmos (2004 NAS report)
DETF	Dark Energy Task Force
DMSAG	Dark Matter Science Assessment Group
DOE	U.S. Department of Energy
ELT	Extremely Large Telescope
ESA	European Space Agency
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
GLAST	Gamma-ray Large Area Space Telescope
GMT	Giant Magellan Telescope
GSFC	Goddard Space Flight Center
GSMT	Giant Segmented Mirror Telescope
HEP	DOE Office of High Energy Physics
HEPAP	High Energy Physics Advisory Panel
HST	Hubble Space Telescope
ISS	International Space Station
JDEM	Joint Dark Energy Mission
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope (formerly known as NGST)
KAO	Kuiper Airborne Observatory
LAT	Large Area Telescope
LISA	Laser Interferometer Space Antenna
LST	Large Survey Telescope
LSST	Large Synoptic Survey Telescope

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
MSFC	Marshall Space Flight Center
NAC	NASA Advisory Council
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NET	No Earlier Than
NIST	National Institute of Standards and Technology
NGST	Next Generation Space Telescope (now known as JWST)
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
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
Pan-STARRS	Panoramic Survey Telescope and Rapid Response System
PHY	NSF Division of Physics
R&A	Research and Analysis
R&D	Research and Development
RTF	Space Shuttle Return to Flight
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)
SLAC	Stanford Linear Accelerator Center
SM4	HST Servicing Mission 4
SMD	NASA Science Mission Directorate
SNAP	Supernova Acceleration Probe
SOFIA	Stratospheric Observatory for Infrared Astronomy
Spitzer	Spitzer Space Telescope (formerly known as SIRTF)
SScAC	Space Science Advisory Committee
SWG	Science Working Group
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
TRL	Technological Readiness Level
VAO	Virtual Astronomical Observatory
VERITAS	Very Energetic Radiation Imaging Telescope Array System
VLA	Very Large Array
WISE	Wide-field Infrared Survey Explorer
WMAP	Wilkinson Microwave Anisotropy Probe