March 15, 2004

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

Mr. Sean O'Keefe
Office of the Administrator
NASA Headquarters
Washington DC 20546-0001

Representative Sherwood Boehlert
Chair, House Science Committee
2320 Rayburn House Office Building
Washington, DC 20515

Senator Judd Gregg
Chair, Senate Health, Education, Labor and Pensions Committee
428 Dirksen Senate Office Building
Washington, DC 20510

Senator John McCain
Chair, Senate Commerce, Science and Transportation Committee
508 Dirksen Senate Office Building
Washington, DC 20510

Dear Dr. Bement, Mr. O'Keefe, Representative Boehlert, Senator Gregg, and Senator McCain:

I am pleased to transmit to you the first annual report of the Astronomy and Astrophysics Advisory Committee.

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;

(2) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration 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, 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 first such report. The Executive Summary is followed by the main body of the report, with recommendations for the key three agencies involved in astrophysics, and detailed recommendations concerning specific programs.

We will be glad to provide you with a personal briefing if you so desire.

Sincerely yours, on behalf of the Committee,

Robert D. Gehrz, Chair
Astronomy and Astrophysics Advisory Committee

Garth D. Illingworth, Chair-elect
Astronomy and Astrophysics Advisory Committee

Cc: Representative Bart Gordon, Ranking Member, Committee on Science, House of Representatives
Senator Ernest F. Hollings, 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 Christopher S. Bond, Chair, Senate VA-HUD-IA Appropriations Subcommittee
Senator Barbara Mikulski, Ranking Member, Senate VA-HUD-IA Appropriations Subcommittee
Representative James T. Walsh, Chair, House VA-HUD-IA Appropriations Subcommittee
Representative Alan B. Mollohan, Ranking Member, House VA-HUD-IA Appropriations Subcommittee
Senator Sam Brownback, Chairman, Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate
Senator John B. Breaux, Ranking Member, Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate
Representative Nick Smith, Chairman, Subcommittee on Research, Committee on Science, House of Representatives
Representative Eddie Bernice Johnson, Ranking Member, Subcommittee on Research, Committee on Science, House of Representatives
Dr. John Marburger, Director, Office of Science and Technology Policy, Executive Office of the President
Dr. Patrick Looney, Assistant Director, Physical Sciences, Office of Science and Technology, Executive Office of the President
Mr. David Radzanowski, Branch Chief, Science and Space Programs, The Office of Management and Budget
Mr. David Trinkle, Program Examiner, NSF, The Office of Management and Budget
Ms. Amy Kaminski, Program Examiner, NASA, The Office of Management and Budget
Dr. Joel Pariott, Program Examiner, DOE, The Office of Management and Budget
Dr. Michael S. Turner, Assistant, Director, MPS/AOD, The National Science Foundation
Dr. G. Wayne Van Citters, Division Director, Division of Astronomical Sciences, The National Science Foundation
Dr. Eileen D. Friel, Executive Officer, Division of Astronomical Sciences, National Science Foundation
Dr. Ed Weiler, Associate Administrator for Space Science, Office of the Associate Administrator, National Aeronautics and Space Administration Headquarters
Dr. Anne Kinney, Director, Division of Astronomy and Physics, National Aeronautics and Space Administration Headquarters
Dr. Paul Hertz, National Aeronautics and Space Administration Headquarters
Dr. Robin Staffin, Deputy Associate Director for High Energy and Nuclear Physics, Office of High Energy and Nuclear Physics, U.S. Department of Energy
Dr. Kathleen Turner, Program Manager, Office of Science, Division of High Energy Physics, U.S. Department of Energy

ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

MARCH 16, 2003 - MARCH 15, 2004

EXECUTIVE SUMMARY

CONTEXT: The organizational effectiveness of the federal research enterprise in astronomy and astrophysics 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 deal with the increasingly important interfaces between 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).

The AAAC fully supports the long-range plan of the NAS Astronomy and Astrophysics Survey Committee (AASC) 2002 Decadal Survey, "Astronomy and Astrophysics in the New Millennium". The recommendations given below are intended to further the implementation of the Decadal Survey, and more recent NAS studies, such as "Connecting Quarks with the Cosmos" (CQC).

With timely implementation of the decadal program, especially with regard to the congruent development of major facilities, the coming decade would further the extraordinary scientific productivity from the resources being made available to astronomy and astrophysics. With planned future observatories and enhancements to the facilities of today, some of the most exciting and challenging scientific issues of our time will be the subject of intense scrutiny. These include the nature of dark matter and dark energy, the formation of galaxies at the earliest times, and the formation of stars and planetary systems.

The Committee wishes to stress that the diverse approaches to astronomical research enabled by NASA, NSF and DOE have been essential to the scientific success and public visibility of astrophysics over the last several decades. This diversity will increase in importance in the future as we develop even more technically challenging facilities for analyzing the universe. For the agencies we note:

> NSF: To keep the US pre-eminent in ground-based astronomy, and to respond to the evolving nature of the field, careful planning and adjustments in the NSF Astronomy program are required. A pro-active approach is needed in order to ensure successful developments of the top recommended projects (such as the Giant Segmented Mirror Telescope - GSMT). NSF and the Astronomy Division should continue development of innovative approaches to the NSF planning process, and implement its plans to manage such a process of technology development and concept definition using a model appropriate for ground-based projects. For example, large future instrumentation facilities such as

GSMT and Adaptive Optics call for immediate funding for technological studies, planning for long-term construction funding, and funding for instrumentation and operations.

NASA: The committee is encouraged by the continued strong support for the James Webb Space telescope (JWST) and the increased commitment to a 2011 launch in a time of major change for the agency. However, we are seriously concerned about the scientific impact of canceling SM4 for HST and the impacts resulting from the decreases in the run-out budgets for the Structure and Evolution of the Universe and Sun-Earth Connection themes. These proposed changes could significantly unbalance a carefully-crafted science program defining the highest-priority space missions in the NAS AASC Decadal Survey and the NAS report "Connecting Quarks with the Cosmos".

DOE: The agency is contributing significantly to both space-borne and ground-based projects that explore a variety of cosmological and astrophysical phenomena. The committee recognizes and applauds the increasing role that DOE is playing in key astrophysical research areas. Inter-agency collaboration is already playing an important role in a number of programs of interest to DOE, and we support the continuance, and expansion where appropriate, of these efforts because of the value it brings in so many key areas.

RECOMMENDATIONS: Our primary recommendations deal with three major pairs of projects whose effective implementation depends on timely and related development at NASA and NSF, and DOE in the case of LSST/JDEM. We believe that there is compelling evidence that these ventures would benefit from a coordinated management approach. Our recommendations are:

GSMT/JWST: The two highest-ranked programs in the AASC Decadal Survey were the 30-m class ground-based telescope GSMT and the infrared Next Generation Space Telescope NGST (now JWST). The ambitious science goals, which include understanding the formation of galaxies and the chemical elements within just the first one billion years of the Big Bang, and the formation of stars and planets, will only be fully realized through operational overlap of the facilities, as HST and large-ground based telescopes have demonstrated over the last decade. 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 FY06 budget.

LSST/JDEM: Determining the nature of the dark energy and dark matter in the universe will require both a ground-based telescope as well as an orbiting observatory (the decadal survey recommended the Large Synoptic Survey Telescope - LSST - as the ground-based facility, while the orbiting observatory under consideration is the NASA/DOE effort on the Joint Dark Energy Mission - JDEM). Both facilities need to be operational on comparable timescales - neither covers the full parameter space needed to resolve these challenging questions. LSST has also been identified in the 2002 NAS report "New Frontiers in the Solar System: An Integrated Exploration Strategy" as a key facility for solar system science and for the detection of potentially hazardous earth-intersecting objects as small as 300-m. The AAAC recommends a coordinated implementation effort between NSF, NASA and DOE to ensure timely development of these facilities.

ATST/SDO: 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). SDO is well into development. The proposal for construction of ATST has been received by NSF. Contemporaneous observations will only be realized if ATST proceeds through construction at a brisk pace.

Two other areas where we felt that interagency cooperation would have an impact on scientific progress were highlighted.

The first concerns investigations of the polarization of the Cosmic Microwave Background Radiation (CMBR). We believe that this venture will benefit greatly from interagency collaboration. The agencies are strongly motivated by mutual scientific and programmatic interests, and also bring complementary technology capabilities to the CMBR studies. An effort should be made to identify elements of these programs that could be included in the NSF, NASA and DOE FY06 budget requests.

Second, the Committee believes that the achievement of the top priority science goals of the current decade will depend upon enabling technologies identified in the Decadal Survey, such as theory, laboratory astrophysics, and a National Virtual Observatory (NVO). We encourage the agencies, through their appropriate peer review processes, to explore the implementation of our recommendations in this broad area.

SUMMARY: The AASC Decadal Survey for the current decade, "Astronomy and Astrophysics in the New Millennium" and the recent NAS report "Connecting Quarks with the Cosmos" set out an exciting, viable program for astronomical research that we heartily endorse. 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 astrophysics over the last several decades. Such diverse approaches remain the key to the future success of astronomy and astrophysics, and consequently we are concerned about recent changes in emphasis within the NASA program. Cooperation, collaboration, and joint programs between NASA and NSF, and DOE when appropriate, are of great benefit to science. By drawing on the different strengths of the agencies' approaches to achieving the science goals of the astronomical community, the nation will realize greatly enhanced value from its investment in astronomy.

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COMMITTEE MEMBERS

Robert D. Gehrz (Chair), University of Minnesota
Garth D. Illingworth, (Chair Elect) University of California Santa Cruz/UCO/Lick Observatory
John Carlstrom, (Vice-Chair Elect) University of Chicago
Neta Bahcall, Princeton University
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TABLE OF CONTENTS

ANNUAL REPORT

ASTRONOMY AND ASTROPHYSICS ADVISORY COMMITTEE

MARCH 16, 2003 - MARCH 15, 2004

1.0 INTRODUCTION

The Astronomy and Astrophysics Advisory Committee (AAAC), established under the National Science Foundation (NSF) Authorization Act of 2002 (see Appendix A), held four meetings between 16 March 2003 and 15 March 2004. Face-to-face meetings were held 8-9 April 2003 at the National Science Foundation in Arlington, Virginia and 5-6 February 2004 at the National Aeronautics and Space Administration (NASA) Headquarters in Washington, DC. Telephone conferences were held to review issues arising (3 November 2003) and to review the final report (8 March 2004). We thank 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 February 2004 meeting was the first formal face-to-face meeting of the full Committee as established by the enabling legislative act. The Committee established a three year term for its members, with the option of one renewal. The Chair and Vice-Chair will be chosen by its members in an annual election and would serve for no more than two consecutive terms. The intent is to provide balance between continuity and the appropriate leadership for the issues under consideration.

The AAAC stresses the importance of the National Academy of Sciences (NAS) decadal reports in evaluating and setting priorities for the nation's astronomy and astrophysics program funded by NASA and NSF. The recent NAS Decadal Survey "Astronomy and Astrophysics in the New Millennium" (AASC) followed by the NAS report "Connecting Quarks with the Cosmos" (CQC) set out an exciting, viable program for astronomical research that we heartily endorse. The diverse approach to astronomical research offered by NASA and NSF is an essential part of the scientific success and public visibility achieved in astrophysics over the last several decades. It remains the key to future success in the field of astronomy. Cooperation, collaboration, and joint programs between NASA, NSF and the Department of Energy (DOE) are beneficial to astronomical science. The different strengths of the agencies' approaches to achieving the science goals of the astronomy community enable astronomers to accomplish much more than they otherwise would.

We await the report of the NSF-NASA-DOE National Science and Technology Council (NSTC) working group whose charge is to respond to the NAS study "Connecting Quarks with the Cosmos". We felt that this appeared to be an excellent example of a process for dealing with initiatives which were of mutual interest to several agencies.

2.0 THE STATUS OF ASTRONOMICAL RESEARCH AT THE NSF

Astronomical explorations using ground-based telescopes have yielded some of the most exciting discoveries in astronomy 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 - 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 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. To keep the US at the discovery frontier and preeminent in ground-based astronomy, and to respond to the evolving nature of the field, careful planning and adjustments in the NSF Astronomy program are required. We are pleased with the NSF vision and plans in this direction as reported to us at our recent meeting and outlined below, and look forward to discussing the plans at future meetings. We commend the increase in the FY05 budget requested for the Division of Astronomical Sciences at the NSF (NSF/AST). Recognizing the challenge of enabling high priority projects advocated by the 2001 AASC Decadal Survey and the CQC report, we believe that the NSF Division of Astronomical Sciences is pursuing reasonable plans and instituting effective approaches in responding to these reports.

Based on our review of the current plans, we make the following recommendations to the NSF for astronomy and astrophysics:

1. Continue development of innovative approaches to the NSF planning process as laid out, for example, in the NAS Brinkman report ("Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation"). A pro-active approach is needed in order to ensure successful developments of the top recommended projects. The technological development necessary to implement large projects, i.e. the Giant Segmented Mirror Telescope (GSMT) and its associated Adaptive Optics (AO) system, calls for a coherent long-term planning process, such as a roadmap, that outlines the necessary steps to achieve the long-term goals set out by the AASC Decadal Survey and the CQC report. NSF/AST should proceed with its plans to manage such a process of technology development and concept definition using a model appropriate for ground-based projects.

2. Large future instrumentation facilities such as GSMT and AO call for immediate funding for technological studies, planning for long-term construction funding, and funding for instrumentation and operations. As recognized by NSF/AST, the required attention to large, high-priority projects should be carefully integrated with healthy funding of the proposal-driven NSF base program. We agree that a mix of mechanisms should be developed to deal with different sizes and types of projects and programs. In addition, partnership between NSF, NASA, DOE and science funding from the private sector should be encouraged and carefully implemented in order to insure the success of the overall scientific program.

3. As part of the NSF road-mapping process for large projects, as called for in the Brinkman Report, NSF/AST should regularly re-evaluate how changes at NASA and other agencies affect the planned activities at the NSF Astronomy program, in order to maximize the

highest-priority research in astronomy for the nation. For example, GSMT and the James Webb Space Telescope (JWST) should be developed on congruent schedules to reap, once again, the benefit of matching capabilities on the ground and in space that led to such a rich harvest with HST and the large ground-based telescopes of the 1990's. Furthermore the NSF should consider how NASA's decision to cancel the Hubble Space Telescope (HST) Servicing Mission Four (SM4) might affect the directions to be taken in ground-based astronomy. The AAAC is looking forward to hearing from the NSF about progress in these plans at our future meetings.

3.0 THE STATUS OF ASTRONOMICAL RESEARCH AT NASA

The President's current budget proposal includes a significant increase in the budget of the NASA Office of Space Science for the '05 fiscal year and beyond. Much of this increase supports the President's new exploration initiative, "A Renewed Spirit of Discovery", that focuses on the Moon and Mars. The AAAC regards the scientific component of this initiative as crucial to its success. In particular, we were encouraged by the continued strong support for JWST and the increased commitment to a 2011 launch.

The committee is seriously concerned, however, about the scientific impact of canceling SM4 for HST and the delays that would be introduced by the lack of growth in the budgets for the Structure and Evolution of the Universe and Sun-Earth Connection themes. These proposed changes could significantly unbalance a carefully-crafted science program defining the highest-priority space missions in the AASC Decadal Survey and the CQC report.

3.1 The Scientific Impact of the HST SM4 Cancellation

NASA's decision to cancel the Hubble Space Telescope (HST) servicing mission SM4 will cause the premature death of a national treasure, an event that will have sweeping ramifications. HST, the most productive scientific mission ever flown by NASA, has been a pivotal research tool for advancing our understanding of the origin and evolution of the universe. It has made fundamental contributions to our understanding of the nature of dark energy and dark matter, the formation of galaxies, the history of star formation in the Universe, the production of the chemical elements that are the building blocks of life and the planets, and the existence and nature of nearby planets. HST results have conveyed the excitement of scientific research and exploration to the public worldwide. The results from HST have inspired several generations of students to pursue scientific and technical careers to the great benefit of our national interest.

The premature demise of HST will end virtually all space-based ultraviolet spectroscopy and high spatial resolution visual imaging. SM4 would have extended the life of HST beyond 2010 and greatly enhanced its capabilities by installing two instruments that have already been built: the Cosmic Origins Spectrograph (COS), a high efficiency UV spectrograph and the Wide Field Camera 3 (WFC3), a state-of-the art UV-Visible-IR panchromatic camera. The loss of COS and WFC3 will end scientific investigations in many areas. There are no future missions presently planned to fill this gap.   JWST is not designed to perform in the ultraviolet and visible parts of the spectrum. A continued HST mission with COS and WFC3 would have laid a strong foundation for JWST and the Joint Dark Energy Mission (JDEM). It would have maximized the scientific return from discoveries made by other NASA/NSF funded facilities including space-based telescopes such as the Advanced X-Ray Astrophysics Facility (AXAF; now Chandra), Space Infrared Telescope Facility (SIRTF; now Spitzer), and the Galactic Evolution Explorer (GALEX), and ground-based telescopes such as Gemini, Keck, and the Atacama Large Millimeter Array (ALMA).

A compelling case for continuing HST through 2010 with SM4 has been made by the 2001 AASC Decadal Survey, by the 2003 “HST-JWST Transition Panel” (the Bahcall Committee") that evaluated HST refurbishment options, and the NASA Space Science Advisory Committee (SScAC) and its subcommittees.. If the SM4 mission is not carried out, other approaches for providing the capabilities expected for the post-SM4 HST should be considered. For example, the instruments built for SM4 may have useful applications in some mission. We strongly recommend that other options be evaluated to recover the science that has been lost if SM4 does not occur.

3.2 Funding for the SEU and SEC Themes.

NASA's ability to implement recommendations from NAS studies (the AASC, CQC and the “The Sun to the Earth – and Beyond: A Decadal Research Strategy in Solar and Space Physics” report from the Solar and Space Physics Survey Committee (SSPSC)) will be impacted by the lack of growth in the funding level for the Structure and Evolution of the Universe (SEU) and Sun-Earth Connection (SEC) themes within NASA's Office of Space Science.   This situation is negatively impacting several high priority mission lines: Einstein Probes in SEU and Solar-Terrestrial Probes in SEC. These mission lines are required to realize the science goals set for NASA by the NAS studies and the NASA road maps. The committee is deeply concerned about the delay in the Laser Interferometer Space Antenna (LISA) to 2013 and the delay in the high throughput X-ray astronomy facility, Constellation-X (Con-X), to at least 2016, and hopes that these programs can be restored to their original schedule. The indefinite delay in the implementation of the "Einstein Probes" program is of particular concern. Given the continuing investment by DOE in research and technology necessary for the Joint Dark Energy Mission (JDEM) and by NASA to mission concept studies for JDEM, the Committee hopes that funding can be provided to allow NASA and DOE to jointly realize this high priority science mission. A delay of at least five years in beginning JDEM, as is proposed in the President's FY05 budget submission for JDEM and the other Einstein Probes, would fail to effectively realize the investments that NASA and DOE are currently making in JDEM. A similar delay in the implementation of the Solar-Terrestrial Probe missions, as proposed in the FY05 budget, will negatively impact the recommendations of the AASC and the SSPSC in their respective decadal surveys.

4.0 DEVELOPMENTS IN ASTROPHYSICAL RESEARCH AT DOE

The AAAC is pleased to acknowledge the involvement of the Department of Energy (DOE) Office of High Energy Physics under the Office of Science in research efforts related to astronomy and astrophysics. These efforts address basic questions of great interest in high energy physics, such as the unification of forces, mechanisms of particle acceleration, the predominance of matter over antimatter, and the nature of dark matter and dark energy. DOE is contributing in a significant way to both space-borne and ground-based projects that will explore a variety of cosmological and astrophysical phenomena. Currently supported projects include those in cosmology and large-scale structure (Supernova Cosmology Project, Nearby Supernova Factory, and the Sloan Digital Sky Survey - SDSS), in high-energy gamma rays (Gamma Ray Large Area Space Telescope - GLAST – and the Very Energetic Radiation Imaging Telescope Array System - VERITAS), in cosmic rays (Pierre Auger and the Alpha Magnetic Spectrometer - AMS), and in dark matter (Cryogenic Dark Matter Search - CDMS - and the Axion Search - AXION-I). DOE is supporting R&D funding for the SNAP concept that could be a proposal for the JDEM. DOE involvement in LSST is under preliminary consideration. All of these efforts have resulted from inter-agency collaboration; we applaud this and we hope that NASA, NSF, and DOE will continue this fruitful collaboration by keeping these programs on track.

5.0 OPPORTUNITIES FOR NSF/NASA COOPERATION

We reiterate the AAAC's strong belief, first stated in our 23 April 2004 report to NASA and NSF, that the NSF and NASA should immediately begin to cooperate, through coordinated tactical planning, research and analysis, and technology development, on four exciting ventures that respond to the scientific objectives of the current long-range plan of the astronomical community as stated in the NAS AASC Decadal Survey and the CQC report. These cooperative ventures are described in detail in Section 6. Our rationale was that there was compelling evidence that these ventures would benefit from a coordinated management approach. We note with pleasure that NSF and NASA have made significant strides in pursuing several of these areas. At the same time we are concerned that the impact on these plans caused by major changes in the NASA mission as a result of the President's exploration initiative have yet to be fully assessed. The pursuit of science should remain a top priority within NASA.

The state of progress by NASA and NSF on the four key ventures as the Committee finds it as of 15 March 2004 is described under items 1-4 below. We discuss the state of the infra-structure programs in item 5.

1. Understanding the formation and chemical evolution of galaxies within 1 billion years of the Big Bang, and the formation of stars and planets are two of the most ambitious scientific goals of our time, requiring the space-based James Webb Space Telescope (JWST) and a Giant Segmented Mirror Telescope (GMST) on the ground (see Section 6.1). Progress on these scientific objectives is heavily dependent on GSMT being developed on the same timescale as JWST, requiring an aggressive technology development program being initiated, ramping up if possible in 2005, and with further significant support in the FY06 budget.

2. Determining the nature of the dark energy and dark matter in the Universe will require a ground-based Large Synoptic Survey Telescope (LSST), as well as an orbiting observatory (such as the Joint Dark Energy Mission - JDEM), to perform high redshift supernova surveys, and cosmic gravitational lensing surveys (see Section 6.2). This exciting and fundamental, but challenging, goal needs the broad capabilities of both LSST and the space

mission operating on comparable time scales. LSST has also been identified in the 2002 NAS report "New Frontiers in the Solar System: An Integrated Exploration Strategy" as a key facility for solar system science, with the capability to detect solar system objects down to 300-m that are potentially hazardous to the Earth's biosphere. Given the broad interest in this program the AAAC recommends a coordinated implementation effort between NSF and NASA (and other interested agencies).

3. 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). These programs are described in Section 6.3. SDO has passed several major milestones and is into development. The proposal for construction of ATST has been received by NSF. Contemporaneous observations will only be realized if ATST proceeds through construction at a brisk pace.

4. The goal of probing the first instants of the universe and testing inflation by definitive measurements of the polarization of the Cosmic Microwave Background Radiation (CMBR) should be aggressively pursued jointly by NSF, NASA and DOE. The definitive, i.e., foreground limited, CMBR polarization measurement will require an all sky survey over several frequency bands with sensitivity several orders of magnitude higher than ever achieved. This is the goal of the Inflation Probe of NASA's "Beyond Einstein" theme. A broad program supporting new technologies, techniques and observing facilities should be put in place to work toward achieving this fundamental and ambitious goal (see Section 6.2). This venture will benefit greatly from interagency collaborations because the agencies have a strong motivation from their mutual scientific and programmatic interests. They also bring complementary technology capabilities. We enthusiastically support the effort led by NSF to develop a joint NSF-NASA-DOE roadmap for the definitive measurements of the CMBR and look forward to its report. The field is especially ripe for development now, and an effort should be made to identify elements of these programs that could be included in the agencies FY06 budget requests.

5. The Committee believes that the achievement of the top priority science goals of the current decade will depend upon enabling technologies identified in the Decadal Survey, including theory, laboratory astrophysics, and a broadly inclusive National Virtual Observatory (NVO). We describe this requirement in more detail in Section 6.4. The order of these recommendations does not imply their relative priority. We recognize that the joint efforts that we suggest must be reconciled with on-going programs at the two agencies (and with efforts at DOE) and near-term existing priorities, all of which are subject to the appropriate peer review process. Within this framework, we strongly encourage the agencies to explore the implementation of our recommendations as soon as practicable.

6.0 DETAILED RECOMMENDATIONS:

6.1 The Formation and Evolution of Galaxies, Stars and Planets

A decade of complementary observations with ground-based telescopes and several of the Great Observatories, notably HST, has demonstrated a powerful scientific synergy. For example, the "Hubble Space Telescope Key Project on the Extra-galactic Distance Scale" used both HST and ground-based observations to bring to convergence nearly forty years of controversy over the value of one of the most important cosmological parameters, the Hubble Constant. Similarly, ground-based telescopes and HST (through the Hubble Deep Field, for example) together have allowed us to explore back more than 12 billion years, to within 1-2 billion years of the Big Bang, mapping out when the stars in today's galaxies were built up from the dispersed baryons in the universe. The 30m Giant Segmented Mirror Telescope (GSMT) and the James Webb Space Telescope (JWST) will provide similar synergies. The most recent Astrophysics Decadal Survey from the AASC identified these missions as the number one priority in space (JWST) and on the ground (GSMT), and recognized that they were highly complementary -- much as the Atacama Large Millimeter Array (ALMA) and GSMT are seen as scientifically complementary. In particular, the AASC Decadal Survey identified a number of scientific objectives that will need the complementary capabilities of GSMT and JWST (for example, the high spatial resolution imaging and spectroscopic capability of GSMT combined with the mid-infrared sensitivity of JWST).

A key science objective for this decade is one such example. This is to look back into the young universe at the formation of the first stars and galaxies, and the buildup of massive black holes that we now know must go with that formation. To do this, by tracing the assembly of dark matter and baryonic matter into galaxies, and the concurrent buildup of heavy elements, from the earliest times to the present day is one of the outstanding questions of our time. Another example lies not, as above, at the earliest times and greatest distances, but right on the doorstep of our own solar system. The Decadal Survey has identified the need to ensure that our understanding of the formation of stars and the subsequent growth of planets is put on a much firmer scientific footing. The extraordinary capabilities of JWST and GSMT, particularly the high spatial resolution offered by an adaptive optics-equipped GSMT, provides unique opportunities to investigate the disks around nearby stars where planets are formed. Meeting these diverse objectives, and many more identified in the Decadal survey and its panel reports, requires the capabilities of both GSMT and JWST. JWST's observational capability will far outstrip the capabilities of even the most powerful of today's 8-10m telescopes, so their ability to complement JWST will be limited.

Following the decision to cancel SM4, there has been increased focus on launching JWST in 2011. Presently, however, GSMT is lagging substantially behind JWST, and the committee is concerned that the investment in JWST will not be fully realized without GSMT. The committee is aware of recent developments to establish a public-private partnership for GSMT, in recognition of the benefit that such partnerships bring (as recommended in the Decadal Survey). We were also happy to hear about the joint discussions that are planned to take place this year between the JWST and GSMT Science Working Groups (SWG). These important activities, however, need to be supplemented by more concrete developments for GSMT. The AAAC recommends that NSF take the necessary steps to align GSMT with JWST by providing adequate support for an aggressive technology development program that will result in the timely implementation of GSMT.

6.2: Dark Energy, Dark Matter, and the Signature of Cosmic Inflation

Observations have driven astronomers to a surprising new view of the universe. Measurements of distant supernovae, the glow from the big bang itself, galaxy clustering, and other strands of evidence converge on a new picture in which the universe underwent a brief initial "inflation" phase when it was expanding faster than the speed of light, followed by an era in which "dark matter" slowed cosmic expansion while building up dense structures in the universe, shifting to the present when the expansion of the universe is accelerating due to a mysterious "dark energy" that makes up 2/3 of the energy density of the universe. All of these ideas are schematic - we don't really know what happened in the inflation era, we do not know the identity of the dark matter, and we do not know what the dark energy is. But each of these is within our grasp through astronomical observations, using a combination of ground-based and space-based facilities, and the experience of all three agencies. Cooperation between NSF, NASA and DOE on these exciting and fundamental topics would be highly effective for the technical challenges ahead.

The dark energy driving the expansion of the universe is a remarkable and unexpected discovery in basic physics. It is a powerful indication of "new physics" that is not accounted for by the Standard Model for fundamental particles and fields. This astonishing result came from coupling ground-based optical observations of distant supernovae with precision mapping of the cosmic microwave background. Facilities and programs supported by NSF, NASA and DOE share the credit. The tremendous excitement of this discovery that the universe is not just expanding but accelerating promises not only to revolutionize cosmology but also to invigorate theoretical and experimental work in particle physics. These new, ambitious programs to use the evolution of the universe itself as the ultimate test of fundamental laws of nature captures the imagination and the energy of our best scientists.

There exists an unprecedented opportunity to use the combined strength of the agencies to push aggressively into this new area of research. The AASC Decadal Survey recognized that a specially constructed ground-based telescope capable of sweeping the whole sky in a matter of days would have extraordinary leverage in refining the technique of using supernovae as cosmic surveyors and in measuring the fraction of the dark energy component. Designs for realizations of this facility - the Large Synoptic Survey Telescope - are presently underway. As it scans the sky discovering supernovae, the LSST will also measure the dark matter of the universe through weak gravitational lensing. LSST will also identify and track asteroids down to 300-m in size - 30 times less massive than those detected by any other survey, but still a substantial threat to life on earth.
The NSF plays a central role in (1) bringing the LSST into operation, (2) supporting the detector development that allows the mining of vast areas of sky simultaneously, (3) developing the tools to process unprecedented quantities of digital data, and (4) distributing these data through the National Virtual Observatory for universal scientific access and to the general public (over the Internet) for novel educational opportunities inside and outside the classroom. NASA and DOE both have interest in LSST because of its relevance to some of their key science objectives. We recommend that the agencies explore opportunities to jointly bring LSST to fruition.

Given the wide range of scales in the universe over which the effects of dark energy become apparent, both ground-based and space-based facilities are needed. NASA's part in this exciting scientific venture is complementary and equally strong. NASA's new "Beyond Einstein" theme has identified in its strategic planning a "dark energy probe" that can take the next step to understanding the nature of the dark energy. Is it the "cosmological constant" that Einstein envisioned, or an even more exotic manifestation of the meta-structure of our universe that controls its most basic forces? The key to answering this question will be measurements of the history of cosmic expansion. That history will constrain the nature of the dark energy by showing how it changes over cosmic time. Only astronomical observations on the largest scale can lead us to an understanding of this genuinely new part of physics. Due to the high priority of dark energy in both the DOE and NASA programs, the agencies have worked out a plan for a Joint Dark Energy Mission (JDEM), a spaced-based mission to determine the nature of dark energy. As an example of the interest at DOE, one concept for a space-based mission (the SuperNova/Acceleration Probe, SNAP) has arisen through scientists funded by DOE with that agency's R&D support.

Interestingly, both LSST and JDEM are well placed to advance our understanding in complementary ways of the other major mystery in astrophysics, the "dark matter" that dominates the mass and gravity of the universe but whose exact nature remains unknown. It is probable that dark matter ties directly into unknown particle physics: the dark matter could be the lightest super-symmetric particle, the neutralino, being sought in direct detection experiments, and through work at accelerators. Both LSST and JDEM will provide extensive, deep maps of the sky that will provide a detailed picture of the dark matter through the technique of weak gravitational lensing. The mysteries of dark matter and dark energy may be clues to a common puzzle. The NAS CQC report rightly chose dark energy and dark matter as two of the great unexplained phenomena of our universe. A well-coordinated complementary approach by the agencies will be key to exciting discoveries in the future.

Observations of the Cosmic Microwave Background Radiation (CMBR) anisotropy have led to remarkable progress in improving our understanding of the universe in recent years. The challenge ahead is to use CMBR to probe the inflationary period in the history of the universe. Inflation theory predicts the presence of primordial gravitational waves. These waves will imprint a unique polarization pattern on the CMBR. If detected, the polarization pattern would provide a direct probe of the first instants of the universe, test a key prediction of the inflation model and set the energy scale of inflation. The signal is likely swamped by other polarization signals, which do not arise from inflation, as well as a number of sources of foreground polarization emission. The ultimate sensitivity of CMBR polarization measurements will therefore be limited by our ability to separate the gravitational wave induced polarization from other sources.

The definitive, foreground-limited, CMBR 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 of the Inflation Probe of NASA's "Beyond Einstein" theme. In addition to detecting or setting stringent upper limits to the level of gravitational waves, the CMBR polarization data can be used to determine the mass of the neutrino and constrain the equation of state of the dark energy; fundamental and compelling goals in their own right. A broad program supporting new technologies and techniques should be put in place to work toward achieving the definitive CMBR polarization measurements. At the required sensitivity levels, systematics will be difficult to control and contamination from astronomical foregrounds will be severe. Several independent experiments using a variety of techniques should be explored using a combination of facilities such as the Microwave Anisotropy Probe (WMAP) and Planck Surveyor and future satellites, ground-based microwave telescopes operating from appropriate sites such as the high Chilean plateau and the South Pole Research Station, and Long Duration Balloon Flight payloads. This venture will benefit greatly from interagency collaborations that are strongly motivated by mutual scientific and programmatic interest, and by complementary technology capabilities. We enthusiastically support the effort led by NSF to develop a joint NSF-NASA-DOE roadmap for the definitive measurements of the CMBR.

6.3: Solar Activity and Magnetic Fields

The science goal identified in the AASC Report for solar astronomy is to achieve a thorough understanding of the whole of solar magnetism. In addition, the recent report "The Sun to the Earth - and Beyond, A Decadal Research Strategy in Solar and Space Physics" reemphasizes the central role of magnetism in the study of the Sun and its impacts. Both reports focus on the synergy that will occur from the coordinated development of the flagship solar facilities by NASA and NSF in this decade.

These facilities would provide a coordinated attack on a number of key problems, including questions as wide-ranging as how the interaction of rotation and convection produces global structure in the solar interior; how the solar magnetic dynamo work; how magnetic fields structure the solar interior, surface, and atmosphere; and how magnetic fields produce thermal heating, mass ejections, and acceleration of high energy particles in the solar chromosphere and corona.

NASA's Solar Dynamics Observatory (SDO) will provide a unique global context for answering many of these questions. It will trace magnetic fields from the solar interior through the surface into the corona and the solar wind. SDO is approved for launch in 2008.

The National Solar Observatory's (NSO) proposed Advanced Technology Solar Telescope (ATST) will provide a powerful, complementary diagnostic capability for answering the science questions. It will quantify the magnetic fields in the corona and measure the magnetic and thermodynamic fields down to the small size-scales at the solar surface that need to be studied to answer the above questions.

Because these phenomena are dynamic, progress toward understanding solar magnetism depends on simultaneous observations with SDO and ATST. The value of such joint observations greatly exceeds that of disjoint individual observations. We recommend that NSF and NASA focus on this synergy and work together to ensure that ATST is operational during the flight lifetime of SDO.

6.4: Enabling Technologies

To achieve the scientific goals defined in the current Decadal Survey for astronomy and astrophysics will require significant investment in enabling technologies that broadly encompass the diverse range of specific missions and projects. These tools include the National Virtual Observatory (NVO) as well as sustained and adequate funding for laboratory astrophysics and theory. Cooperation among the NSF, NASA, and other agencies as appropriate can assure that these investments target the priorities outlined for the decade and meet the needs of our highest priority science programs.

The LSST, JDEM and SDO efforts will produce unprecedented data volumes, especially including information on the time variability of astronomical sources. For maximal scientific utilization, particularly as regards the temporal component, it is essential that the data be pipeline-processed and served to the community with minimum delay. The facilities to do this must be developed on a parallel timescale with the hardware. Joint support by NSF and NASA will encourage rapid development of the NVO to support the large array of new space- and ground-based observatories that are coming online over the next few years. The NVO has been identified as a top priority for both NASA's and NSF's astronomical science programs. We applaud the agencies' decision to collaborate in the immediate pursuit of this concept, and noted important progress in developing a viable archiving system for the relevant ground-based data.

Ideally, we would like to see the archive know-how at NASA propagated into the ground-based community effectively through pilot programs. One example is the recently released and publicly accessible prototype archive of data from the Gemini telescopes that promises to increase the productivity and visibility of the NSF-supported Gemini Observatory. Another example is the Virtual Solar Observatory (VSO) prototyping effort (with teams at universities, NASA and NSF Centers) to provide integrated access to ground-based and space-based data. We are encouraged to see interest at NASA in participation in the data pipeline and archive for the high volume of data yielded by the LSST project. We recommend the development of a detailed implementation plan with joint NASA and NSF participation, which shows how to achieve an NVO that serves the science expectations from the LSST and other high priority projects.

Support of laboratory astrophysics investigations is also essential to the success of the scientific goals of the Decadal Survey. The recent Laboratory Astrophysics White Paper highlights the various areas for which improved data are needed to support current and planned NASA missions, and ground-based programs funded by NSF also require improved laboratory astrophysics data. Improved atomic physics data will be essential, for example, to interpret infrared spectroscopic data from JWST and GMST. Both agencies support laboratory investigations, and we urge the relevant program directors to work together to assure that appropriate funding levels are sustained at a level of research activity necessary to meet the needs of the high priority projects identified in the Decadal Survey and in the CQC (Physics of the Universe) Report. The specific needs of such a program remain to be defined, although the scientific requirements are clear. Support to the laboratory astrophysics community from other NSF Divisions and from agencies such as NIST and the DOE should also be monitored to assure that a balanced program that meets the needs of planned, high priority programs is carried out. We further recommend that access to laboratory astrophysics data and databases be incorporated into the structure of the National Virtual Observatory.

The success of the science program outlined in the Decadal Survey and the CQC Report also relies on a successful and coordinated theory program. An important recommendation of the Decadal Survey was the incorporation of theory support into NASA missions at all phases, from initial Phase A studies through completion of the mission as an integral part of the mission itself.

Specifically, theory challenges for major and moderate size programs should identify theory challenges that are ripe for progress, relevant to the planning and design of the mission, and essential to the interpretation and understanding of its results in the broadest context. Such an approach has already proven successful on many NASA astrophysics missions. We urge that support for theory continue to be integrated into all phases of NASA missions. At the NSF, theory support needed for major projects cannot be incorporated directly into projects within the Major Research Equipment and Facilities Construction (MREFC) program, but a path must be found through the grants program to enable support of theory required to guide the scientific requirements of major projects and to support their scientific goals.

APPENDIX A: ESTABLISHMENT OF THE AAAC UNDER THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT OF 2002

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 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;

(2) assess, and make recommendations regarding, the status of the activities of the Foundation and the National Aeronautics and Space Administration 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, 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) 5 members selected by the Director;

(2) 5 members selected by the Administrator of the National Aeronautics and Space Administration; and

(3) 3 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, such as the Department of Energy, which may 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.