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Dear Wayne and Anne:

The National Astronomy and Astrophysics Advisory Committee (NAAAC) met 8-9 April, 2003 at the National Science Foundation in Arlington, Virginia. By this letter, I am forwarding to you our recommendations and observations. The Committee wishes to stress that the diverse approach to astronomical research offered by NASA and NSF is an essential part of the success achieved in our field over the last several decades. It remains the key to our future success. Cooperation, collaboration, and joint programs between NASA and NSF are appropriate and beneficial in many circumstances. The different strengths of the two agencies' approaches to achieving the science goals of our community enable us to accomplish much more than we otherwise would.

We strongly believe 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 NRC reports "Astronomy and Astrophysics in the New Millennium" and "Connecting Quarks with the Cosmos". We believe that these ventures would benefit from an integrated management approach. They are described briefly below and in more detail in Appendices A-C to this letter:

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. 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 in the FY2005 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, to perform wide-area supernova survey and cosmic gravitational lensing surveys. This exciting and

fundamental, but challenging, goal needs the broad capabilities of both LSST and the space mission operating on comparable timescales. LSST has also been identified in the 2002 NRC report "New Frontiers in the Solar System: An Integrated Exploration Strategy" as a key facility, not only for solar system science, but also for detecting solar system objects down to 300-m that are potentially hazardous to the Earth's biosphere. Given the broad interest in this program the NAAAC recommends a coordinated implementation effort between NSF and NASA (and other interested agencies).

3. Probing the temporal and structural development of solar magnetic fields and activity will require contemporaneous observations from the space-based Solar Dynamics Observatory (SDO) and the ground-based Advanced Technology Solar Telescope (ATST). The contemporaneous observations will only be realized if ATST can be put on a fast development track starting immediately.

4. Investigations of the polarization of the Cosmic Background Radiation (CMBR) with the objective of detecting the signature of inflation should be undertaken using a combination of facilities such as the Wilkinson Microwave Anisotropy Probe (WMAP) satellite, ground-based microwave telescopes operating from appropriate sites such as the South Pole Research Station, and Long Duration Balloon Flight payloads. We believe that this venture will benefit greatly from interagency collaborations because they are strongly motivated by mutual scientific and programmatic interests, and also by complementary technology capabilities. They are especially ripe for development now, and an effort should be made to identify elements of these programs that could be included in the NSF and NASA FY 2005 budget requests to expedite their early progress.

The Committee believes that the successful pursuit of the activities described above will depend upon the existence of a strong technical infrastructure that includes support for instrumentation development, computing, laboratory measurements, research and analysis (R&A) support, and the availability of large data bases through the National Virtual Observatory (NVO). We describe this requirement in more detail in Appendix D. 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 near-term existing priorities, all of which are subject to the appropriate peer review process. Nevertheless, we strongly encourage NSF and NASA to explore the implementation of our recommendations as soon as practicable.

We thank you for the information and assistance that you and your staff members provided in support of our deliberations.

Sincerely yours, on behalf of the Committee,

Robert D. Gehrz, Chair
Professor of Physics and Astronomy

Attachments: Appendices A, B, C, and D

APPENDIX A: DARK ENERGY AND THE SIGNATURE OF INFLATION

The "dark energy" driving the expansion of the universe is arguably the most important and unexpected discovery in basic physics of the last half-century. It is the first indication of "new physics," the discovery of a hitherto unknown force phenomenon demonstrating that the so-called standard model is incomplete. This astonishing result came from coupling ground-based optical observations of distant supernovae with precision mapping of the cosmic microwave background through NSF and NASA supported facilities and programs that share much of 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. As the road to larger, more powerful particle accelerators threatens to become too steep to follow, these new, ambitious programs to explore the structure and evolution of the universe itself as ultimate tests of the fundamental laws of nature capture both the imagination and the energy of our best scientists.

An unprecedented opportunity therefore exists to use the strengths of the NSF and NASA to push aggressively into this new area of research. The NRC report "Astronomy & Astrophysics in the New Millennium" 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 measuring the exact fraction of the dark energy component. Designs for proposed realizations of this facility - the Large Synoptic Survey Telescope - are presently underway. It's also important and exciting to remember that, as it scans the sky discovering supernovae, the LSST will at the same time 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 can and must play a crucial 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's part in this exciting scientific venture is complementary and equally strong. NASA's new "Beyond Einstein" theme (under the Astronomy & Physics Division, Structure & Evolution of the Universe) has identified in its strategic planning a "dark energy probe" that can take the next step to understand 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 so-called "equation of state" of the dark energy -- the evolution of the acceleration could well be the key step to understanding this genuinely new physics that apparently can only be detected on the vast scale of the universe.

A proposal that has arisen through scientists at DOE with that agency's support envisions a moderate-sized space telescope whose dedicated task will be to find many thousands of supernovae to great distances and with a precision not achievable from the ground. NASA is already cooperating with DOE scientists to advance the definition of this mission and plans, with sufficient support, to call for proposals and begin construction before the decade is out. In the meantime, NASA is also collaborating with ESA on a next-generation cosmic-microwave-background (CMB) satellite (PLANCK) and supporting the development of balloon-borne instruments that will refine this other path to precise measurements of the fundamental cosmological parameters. This will require measurements of CMB polarization, the first attempt with data from NASA's WMAP satellite, but taken to much greater precision by ground-based microwave experiments operating from appropriate sites such as the South Pole Research Station, with PLANCK, and with future long-duration balloon-borne experiments such as BOOMERANG. Together these new precision observations of supernovae and the CMB will crystallize the nature of this remarkable phenomenon.

Interestingly, both LSST and the dark energy probe 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 also ties directly into unknown particle physics, for example, as a manifestation of as-yet incomplete descriptions of the basic particles of our universe not as points but of string-like loops of energy that obey elegant rules of symmetry. Both LSST and the dark energy probe 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. It is indeed possible that the mysteries of dark matter and dark energy are clues to a common puzzle that we are at last beginning to solve. Through a coordinated, multi-threaded program at NSF, NASA, and possibly DOE, US scientists will begin a new era of exploration of nature's fundamental laws. The Turner report "Connecting Quarks with the Cosmos" rightly chose dark energy and dark matter as two of the great unexplained phenomena of our universe -- our major funding agencies for science are ready to pursue the answers to these defining questions. Their well-coordinated, complementary approaches are likely to lead to the most exciting discoveries in science by the
next decade.

APPENDIX B: 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 Extragalactic Distance Scale" used both HST and ground-based observations to lay to rest 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 bring similar such synergies. The most recent Astrophysics Decadal Survey "Astronomy and Astrophysics in the New Millennium" 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 Decadal Survey identified a number of scientific objectives that will need the complementary capabilities of GSMT and JWST (e.g., the high spatial resolution imaging and spectroscopic capability of GSMT combined with the mid-infrared sensitivity of JWST). One such example, a key science objective for this decade, 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. 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 put the formation of stars and the subsequent growth of planets 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 regions where planets are being formed, the disks around nearby young stars. 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, and so their ability to complement JWST will be limited.

With the selection of its prime contractor, JWST is moving towards a launch 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 NAAAC 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.

APPENDIX C: SOLAR ACTIVITY AND MAGNETIC FIELDS

The science goal identified in the Decadal Survey for solar astronomy is to achieve a thorough understanding of the whole of solar magnetism. This would require answers to many specific questions, including:

- How does the interaction of rotation and convection produce global structure in the solar interior?

- How does the solar magnetic dynamo work?

- How do magnetic fields structure the solar interior, surface, and atmosphere?

- How do 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 2007. Instrument teams are selected and Phase A is in progress.

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 natural size-scales at the solar surface.

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 full flight lifetime of SDO.

APPENDIX D: INFRASTRUCTURE AND TOOLS

To achieve the scientific goals defined in the current Decadal Survey for astronomy and astrophysics will require significant infrastructure that broadly spans specific missions and projects. These tools include the National Virtual Observatory (NVO) as well as continued funding for research and analysis programs, laboratory astrophysics programs, computing, and support of ground- based preparatory and follow-up observing programs which enable the full scientific return of missions and major facility projects such as a dark energy probe and LSST. Cooperative agency activities in support of the NVO will be particularly critical to the success of these scientific programs.

The LSST, DEP AND SDO efforts will produce unprecedented data volumes, with temporal information. For maximal scientific utilization, particularly as regards the temporal component, it is essential that the data be pipe-line 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 made note of this in our October 2002 report. But we also note with concern that the effort to establish a viable archiving system for the (relevant) ground-based data lags far behind such systems already available for space mission data through NASA.

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 publicly accessible archive of data from the Gemini telescopes that promises to increase the productivity and visibility of the Gemini Observatory. But that alone would not begin to address the archiving requirements for projects like LSST. An 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, is highly desirable. We encourage NSF to obtain adequate resources to accelerate their effort to address this situation by getting a prompt head start during FY2005.

Support of laboratory astrophysics investigations is also essential to the success of the scientific goals of the decadal survey. Improved atomic physics data will be essential, for example, to interpret infrared spectroscopic data from JWST and GMST. Laboratory astrophysics is funded both by NASA and NSF. NSF supports a broad range of investigations in laboratory astrophysics, while NASA funding is usually tied to mission-related needs, although the measurements made through NASA-funded research often have much broader utility than the specific mission for which they were made. Recent changes in federal support of laboratory astrophysics at other agencies may have critically impacted ongoing programs, and have strained the funding lines at both NASA and NSF. The support for laboratory astrophysics may benefit from a joint NASA/NSF solicitation guided by both mission requirements and the broader scientific goals outlined in the Decadal Survey. Maintenance of an appropriate level of funding for this essential tool should be a priority for both agencies.

Funding must also be provided for technology development programs that are essential to support the development of the LSST and other scientific programs identified in the Decadal Survey. An example is the development needed to produce large format focal plane detector arrays required by LSST and other projects. Such programs fall between the funding levels available through the MRI and MRE programs at the NSF. The Foundation has also recognized the broader need for a program to fill this gap across the disciplines. The committee urges the NSF to establish a new, mid- sized instrumentation program to meet these needs.