

**REPORT of the COMMITTEE OF VISITORS  
Division of Astronomical Sciences  
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**COMMITTEE**

Dr. J. Craig Wheeler, *Univ. of Texas - Austin, Chair*  
Dr. Christopher G. De Pree, *Agnes Scott College*  
Dr. Ian P. Dell'Antonio, *Brown University*  
Dr. Matthew A. Greenhouse, *NASA Goddard Space Flight Center*  
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Dr. Colin Norman, *Johns Hopkins University*  
Dr. M. Sally Oey, *University of Michigan*  
Dr. Simon Plunkett, *Naval Research Laboratory*  
Dr. Keivan Stassun, *Vanderbilt University*  
Dr. James W. Truran, *University of Chicago*  
Dr. Robert V. Wagoner, *Stanford University*  
Dr. Charles E. Woodward, *University of Minnesota*

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## **I. Introduction and Executive Summary**

The Committee of Visitors (COV) to the Division of Astronomical Sciences (AST) met at NSF on 22-24 February 2005. The written charge to the COV had been given by Dr. Michael Turner, Assistant Director for Mathematical and Physical Sciences (MPS), and included the following topics to be addressed:

- The integrity and efficacy of processes used to solicit, review, recommend, and document proposal actions;
- The quality and significance of the results of the Division's programmatic investments;
- The relationship between award decisions, program goals, and Foundation-wide programs and strategic goals;
- The Division's balance, priorities, and future directions;
- The Division's response to the prior COV report of 2002; and
- Any other issues that the COV feels are relevant to the review.

In response to these charges, the COV found that the processes used to solicit, review, recommend, and document proposal actions were done with the highest level of integrity, both with respect to the sensitivities of the proposers and to the merit of the science. The committee took special note of the care with which thorough summaries of proposal evaluations and decisions were documented by the Program Officers.

The Division has supported some of the most exciting astrophysical research done in this especially active three-year period. The Division currently engages in a continuous rebalancing of its mission in response to community input and priorities. The COV enthusiastically endorses this dynamic allocation.

The Division has set high goals for scientific accomplishment within the AST program, in Foundation-wide programs and in complex new intra-agency and international initiatives. The COV found that the awards of the last three years were commensurate with supporting the present programs and those necessary to address the goals of the strategic plans of the Division.

The COV spent substantial time discussing the balance, priorities, and future directions of the Division. The primary recommendations in this regard are summarized here:

### **Management**

The COV was thoroughly convinced that the Division is doing an excellent job in an increasingly complex and challenging scientific and operational environment. The COV was impressed with the current leadership of the Division under the Division Director and the Executive Officer. As was the previous COV, this committee was deeply impressed by the complex array of responsibilities undertaken by each individual Program Officer.

*The COV recommends that the Division be given positions for additional scientific personnel in order to decrease the workload currently imposed on Division staff, to ensure adequate oversight and program management, and to allow progress on new programs and projects being generated in the community.*

### **Strategic Planning and Implementation**

The COV emphasizes that building the capacity of the astronomical community to realize the full scientific potential of new facilities is as important as building the facilities themselves. The COV thus recommends that, as the Division pursues the facilities priorities of the *Astronomy and Astrophysics in the New Millennium* (AANM) report, it respond with equal vigor to the capacity-building priorities that are also articulated therein. The COV agrees that the issue of future balance must be a principal goal of the proposed Senior Review.

*The COV strongly supports the planned Senior Review as the proper next step in the planning process.*

*The COV recommends that the Division continue to identify and lead development of appropriate joint interagency initiatives.*

*The COV recommends that the Senior Review focus on establishing a sustainable balanced program that is driven by science inquiry rather than the current wavelength-based structure.*

*The COV endorses the Division's new strategic plan to build a sustainable program using a community-based process that considers the scientific merits of extant facilities and programs as well as the advances that can be realized with new instruments and other initiatives.*

*The COV strongly concurs with the recommendation of the AANM report and the conclusion of the Division that the AST grants program (AAG) should be maintained at or above its current funding level despite the severe budget pressure presented by ALMA and other proposed large facilities.*

*The COV recommends that the Division continue to aggressively pursue its approach to the priority initiatives of the AANM report with a flexible, balanced response. This response should both advance the development of facilities and take advantage of opportunities associated with the scientific goals of those facilities to increase support for grants by means articulated in the AANM Decadal Survey and appropriate to the Division.*

*The COV encourages the Division to aggressively defend the spectrum allocations for scientific research and to expand efforts to keep the astronomical community apprised of critical issues.*

## **Education, Training, and Outreach**

The Division has been notably successful in leveraging the Foundation-wide CAREER, REU, and RUI programs to support education, training, and outreach. At the same time, other Foundation-wide programs for developing the capacity of graduate students to utilize new skills and techniques (e.g., IGERT) have gone completely unutilized by the AST community. The COV thus encourages active communication of the diverse array of available programs to the community.

*The COV recommends that the Division continue and expand its leadership role in fostering the next generation of scientists poised to take full advantage of new facilities.*

*The COV recommends that the Division continue to explore ways to unify and expand the EPO efforts within and across observatory enterprises.*

## **II. Schedule and Process**

In the absence of Dr. Turner, Dr. Judy Sunley, Executive Officer for MPS, welcomed the COV members to NSF and Dr. Wayne Van Citters, AST Division Director, reviewed the charge to the COV. Dr. Morris Aizenman (Senior Science Associate, MPS) briefed the COV on conflicts of interest and confidentiality, and introduced the COV reporting requirements, including the relation to the Government Performance and Results Act (GPRA). Dr. Eileen Friel, Executive Officer, AST, outlined the COV procedures. This was followed by an overview of the AST Division programs, organization, and staff by Dr. Van Citters.

The AST Grants Programs were described by Dr. Vernon Pankonin (Coordinator of the Research Grants Unit). The COV then moved to another location to review individual grants programs and activities in two consecutive sessions. The first session covered the four scientific themes of the Astronomy and Astrophysics Research Grants. The second session reviewed the variety of AST-specific and NSF- or MPS-wide special programs. Each session started with a series of brief introductions by the cognizant Program Directors, followed by the examination of proposal and award “jackets” in that program. The grant programs reviewed were:

- \* **Astronomy and Astrophysics Research Grants - thematic areas**
- \* Extragalactic Astronomy and Cosmology – Dr. Nigel Sharp,
- \* Stellar Astronomy and Astrophysics – Dr. Michael Briley,
- \* Galactic Astronomy – Dr. Randy Phelps,
- \* Planetary Astronomy – Dr. Vernon Pankonin,
- \* Education and Special Programs – Dr. Randy Phelps and Dr. Eileen Friel,
- \* Astronomy and Astrophysics Postdoctoral Fellowship Program - Dr. Dana Lehr
- \* Particle Astrophysics – Dr. Vernon Pankonin,
- \* Foundation-wide programs – Dr. Nigel Sharp,

**\* Instrumentation Programs**

- \* Advanced Technologies & Instrumentation/ Major Research Instrumentation – Dr. Andrew Clegg.
- \* Program for Research and Education with Small Telescopes – Dr. Craig Foltz

The review covered all proposal and award actions made during FY2002, 2003, and 2004. Sample proposal “jackets” for each of the AST program elements were examined in these sessions. The jackets had been screened by the Executive Officer to avoid conflicts of interest amongst COV members. A total of 318 jackets were reviewed, representing 12% of the proposal and award actions.

During a working lunch on the first day, Dr. Van Citters presented the AST strategic planning that is currently underway in the Division. He reviewed the many community recommendations for future facilities and programs and the resources needed to realize them, placed them in the context of the NSF planning process for large facilities and discussed AST-initiated community planning and roadmapping activities. The financial requirements for the construction and operation of future large facilities contrast sharply with the resources available in the current and projected NSF and AST budget. Dr. Van Citters introduced the COV to the “Senior Review” AST plans to carry out that will examine the current and future balance in the AST portfolio appropriate to making adequate progress on new facilities in the light of their impact on existing programs. He reviewed the process the Division planned to use in establishing the options for consideration by a senior review and the mechanisms to be used to obtain community input and invited the COV to comment on these plans.

The second day was devoted to review of the observatory facilities in the AST portfolio. An overview of each facility was presented by its Program Manager, and discussion with the COV followed. The morning focused on presentations of the radio facilities:

- \* University Radio Observatories – Dr. Richard Barvainis,
- \* National Astronomy and Ionosphere Center – Dr. Richard Barvainis,
- \* National Radio Astronomy Observatory – Dr. Andrew Clegg,
- \* Atacama Large Millimeter Array – Dr. Robert Dickman,
- \* Electromagnetic Spectrum Management – Dr. Tomas Gergely.

In the afternoon, the optical/infrared observatory facilities were reviewed:

- \* National Optical Astronomy Observatories – Dr. Craig Foltz,
- \* National Solar Observatory – Dr. Craig Foltz,
- \* Gemini Observatory – Dr. Wayne Van Citters.

Dr. Michael Turner joined the Committee for lunch and informal discussion on the second day of the meeting.

The third day was spent in committee discussion and preparation of a draft of this report. The COV met with members of the Office of the Assistant Director (Michael Turner,

Judy Sunley, Adriaan de Graaf) in the afternoon of the third day for a discussion of the Committee's primary conclusions and recommendations.

The COV was impressed with the work that had gone into preparing the materials and presentations for the meeting. The quality of the presentations and the enthusiasm with which they were presented were uniformly high. The staff were cooperative and flexible in responding to the needs and queries of the committee. The presentations outlined a great range of undertakings and accomplishments in terms of scientific development, new instrumentation, new facilities, and training and public outreach. The presentations also effectively communicated the challenges facing the Division. The exchanges with the Director, Executive Officer, and Program Officers were open and cooperative.

The COV was impressed with the openness and complexity of the NSF COV process and is convinced of the value of the process to both the NSF and the science community.

The following sections summarize the observations and recommendations from the COV review of the AST Division, including comments on the response of the Division to the 2002 COV report. The appended document contains the responses to the core questions and report template for FY2005 COV reviews provided by NSF.

### **III. Science Highlights**

The three years covered by this COV yielded an array of exciting scientific developments. Principal among these was the continued explosion of interest in the deep issues associated with the accelerating Universe and the presumed "dark energy" that drives it. The evidence for acceleration was first obtained by programs using NOAO facilities at KPNO and CTIO. CTIO continues to host one of the major follow-up programs that seek to better constrain the nature of the "dark energy." The observational basis for the acceleration has become ever more solid with a concordance model of a Universe filled about 2/3 with dark energy, about 1/3 with gravitating dark matter, and only a smattering of the baryonic matter that has been the traditional focus of astronomy, not to say human life. This concordance has arisen from joint observational studies of supernovae, the cosmic microwave background, and other techniques such as galaxy clustering and gravitational lensing, all of which the Division was instrumental in supporting. There is no explanation for this acceleration in the Standard Model of physics, so this issue is one that transcends a given field, and is of high import to basic physics as well as astronomy and cosmology. A recent response to the immense challenges of understanding the universal acceleration has been the formation by the Division of the multi-agency Dark Energy Task Force that will study the prospects for experimental and theoretical progress on this problem.

The Division supported the Cosmic Background Imager (CBI) experiment in Chile that was an important precursor to the WMAP satellite. The astounding results from measurements of the cosmic background radiation have not only added to the concordance model, but have strikingly confirmed the fundamental nature of slight

irregularities in the Universe that arose from primordial quantum fluctuations to develop all the large scale structure observed in the contemporary Universe. The Division is leading the CMB roadmap process that has recently produced a draft report.

The Sloan Digital Sky Survey and other large surveys enabled by Division investment revealed distant quasars showing that reionization was substantially complete by red shift of six, in striking contrast with the beginning of the process at a much larger redshift, as suggested by the WMAP data. These surveys also showed direct evidence for early and on-going galaxy mergers, a key aspect of galaxy evolution.

Black hole research has continued to be a dominant topic, from stellar mass black holes in binary systems to supermassive black holes in the centers of galaxies. Of especially great interest was the establishment of a link between the black hole mass and the velocity dispersion and the mass of the galactic bulge. This implies a deep connection between galaxy formation and the central black holes.

On a smaller scale, but also with attendant great scientific excitement, the field of extrasolar planets continued to progress on both observational and theoretical fronts. The Division supports the major U.S. planet-searching teams. Well over 100 planets have been identified. The quest is now to find lower mass planets with terrestrial mass planets that could host life being the ultimate goal. Discovering multiple planets in single solar systems is a forefront topic as is research to understand the dramatic departures of the extra-solar systems from our own Solar System in terms of the mass, the distance distribution, and eccentricities of the planets.

#### **IV. AST Division Management**

##### *A. General Comments*

By the end of the meeting, the COV was thoroughly convinced that the Division is doing an excellent job in an increasingly complex and challenging scientific and operational environment. Attention to management of the staff and their duties has yielded a very efficient enterprise with the staff involved in many interrelated tasks that they accomplish with great energy and commitment. There is concern that the staff is not sufficiently large for the tasks now and certainly for the planned future growth of facilities and the science to be done with them. The Division is doing an excellent job of trying to foresee and manage that growth, but there are great challenges coming, as we address below.

##### *B. Management of the Division*

The COV was impressed with the leadership of the Division under the Division Director and the Executive Officer. The Division has taken great steps to maximize the efficiency and effectiveness of the staff. The Division leadership has reorganized and refocused the staff effort to respond to the evolving needs of the community. Internal staff working groups for grants, facilities and instrumentation have been organized to more fully utilize

all the talent in the Division and to coordinate uniform treatment of management issues. The COV takes this as good evidence of the proactive efforts of the Division. Even in advance of NSF-wide implementation of the recommendations of the Booze-Allen report, the Division has planned for and implemented changes in the management of the program that are necessary for handling the increasingly varied Division portfolio. In addition, the Division Director laid out a clearly defined management plan and a vision for future evolution of the organizational structure from a traditional linear structure to one in which there are efficiently over-lapping areas of interest and responsibility.

### *C. Staffing Issues*

This COV, like the one in 2002, and the one before that, notes that the Division is understaffed. The Division has made important progress in filling positions that were vacant at the time of the 2002 COV, but the problem remains severe. The Division is unique within NSF in that a large fraction of the Division funding (of order 2/3) and staff-hours are related to the oversight of four major research facilities and two international partnerships (Gemini, ALMA). The increased complexity, cost, and international nature of facilities now supported within the Division, combined with requirements for enhanced assessment activities associated with the individual grants programs, places great strain on the staff's ability to manage the portfolio effectively. During this period, the implementation of the electronic jacket and other business tools effectively shifted many administrative tasks to the Program Officers. Program Officers have multiple assignments and limited travel funds. The COV noted that these conditions limit the degree of direct oversight of facilities through site visits to a less than optimum value. The high quality of current oversight of grants and facilities has only been due to the dedication and significant hard work of the current staff, which has remarkably high morale given their workload. This workload threatens to have a negative impact on the quality of management and scientific output of the facilities.

***The COV recommends that the Division be given positions for additional scientific personnel in order to decrease the workload currently imposed on Division staff, to ensure adequate oversight and program management, and to allow progress on new programs and projects being generated in the community.***

## **V. Strategic Planning and Implementation**

### *A. General Comments*

Because of the long, successful history of astronomy decadal surveys, the strength of the astronomy strategic planning is recognized within the NSF. The Division is proceeding with the assumption that strategic planning must be driven by the science and that well-enunciated, potentially transformational science will sell the program. The Division recognizes that rational decisions about implementations require an understanding of the complex trade space that involves capability, cost, time-to-realization, and risk. The Division understands that substantial investment must be made to characterize this trade



space and that this investment must be made with no commitment to proceed with a given project. The COV endorses this approach to strategic planning.

The Director was assiduous in laying out his strategy for future planning. In his presentation on this topic, he outlined the context of the *Astronomy and Astrophysics in the New Millennium* (AANM, the most recent decadal survey) report that presents scientific priorities derived from wide community consultation. No other scientific division in the NSF is so strongly guided by this community-based, prioritized input. The Division then works closely with the National Research Council Committee on Astronomy and Astrophysics (CAA) to implement the report recommendations. Recently, the Division has also been guided by the strategic plan for combined federal research in physics and astronomy as summarized in the Office of Science and Technology Policy (OSTP) *Physics of the Universe* report. The Astronomy and Astrophysics Advisory Committee (AAAC) was formed to oversee this multi-agency initiative to coordinate first NSF, NASA, and OSTP involvement and then, effective March 15, 2005, DOE.

This sets the context for the strategic planning of the Division: it must respond to the priorities of the science and community-driven AANM report in the context of a multi-agency coordinated effort. From the Division's perspective, a program that is sustainable for the long term must be built on community support, be suitably ambitious with the promise of transformational science at reasonable cost, be able to maintain community support for periods exceeding a decade, and be commensurate with NSF processes, shaping them if necessary and possible.

The Director also outlined the challenges facing the Division that need to be addressed in the context of this strategic planning. He raised the issue of the degree to which a twenty-year strategy is required to guide more near-term plans for new large optical and radio facilities. A particular challenge will be the means to respond to the growing demand for funds to both operate and do science with large, expensive new facilities. To address issues of current scientific balance, the ambitions of the community, and the budget outlook, the Director proposes to convene a Senior Review that, with appropriate community input, will seek to set clear goals and define a process of evaluation that can produce attainable results based on clearly-defined criteria.

***The COV strongly supports the planned Senior Review as the proper next step in the planning process.***

#### *B. Implementing Community Initiatives*

The NSF Astronomy Division has done a commendable job in the past three years incorporating the long-range vision of the astronomical community (the AANM report) and the astronomy/physics community (*Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century*; the *Physics of the Universe* report) into the long-range strategic plan of the division. The majority of initiatives in the AANM report are either funded, or in the design/development phase. The Division has actively engaged in

a number of creative funding approaches including shared private funding (GSMT) and international partnerships (e. g. Gemini, ALMA). Inter-division coordination for some of these projects is required, and the Division has taken very active steps in advancing these projects. The Division led the chartering and implementation of the Astronomy and Astrophysics Advisory Committee (AAAC). The COV regards this to be a major accomplishment. The establishment of the AAAC is a crucial step toward the development of an integrated strategy among NSF, NASA, and DOE for enabling astrophysical research.

The COV examined portions of the portfolio involving interagency cooperative programs. The COV found that the Division has been creative and has provided leadership in establishing new processes and mechanisms to ensure programmatic success while guarding the interest of the Division and the astronomical community.

***The COV recommends that the Division continue to identify and lead development of appropriate joint interagency initiatives.***

### *C. Balance*

The Division currently engages in a continuous rebalancing of its mission in response to community input and priorities. The COV enthusiastically endorses this dynamic allocation. Balance of funding remains a key issue among and within the Astronomy and Astrophysics Grants (AAG) program, the other Research and Instrumentation Grants programs, and the Facilities programs. These issues of balance will become even more acute in the future as major new facilities are undertaken. The division of resources tied to facilities has an historical basis. This division of resources needs to be reviewed and, if necessary, corrected periodically by community input followed by a senior review, as recommended by the AANM report. The COV agrees that this issue of future balance must be a principal goal of the proposed Senior Review.

The Division endorsed the recommendation of the AANM report that the optical/IR facilities be viewed as an integrated system in which the NOAO/Gemini telescopes and private university telescopes are viewed as part of an integral whole in terms of capabilities. The COV appreciated the work of the Division staff to make NOAO and the TSIP/ATI/MRI/PREST instrumentation programs part of an integrated system in terms of national research priorities. The COV encourages the Division to develop a plan to assess how this integrated system is meeting scientific and education goals.

Approximately two-thirds of the Division's budget goes toward the operation of the national optical/IR, radio, and solar facilities and university radio observatories. The remaining one-third provides support for the research and instrumentation programs and the Division's participation in NSF-wide initiatives. There are currently no transparent scientific criteria to show that this funding profile adequately reflects the relative impact of science that is carried out in the grants program and by facilities. The COV supports the plans of the Division to task the Senior Review to address this issue of balance to

ensure that funding is allocated among the national facilities in a way that ensures optimum scientific return from, and peer-reviewed access to, these valuable assets.

***The COV recommends that the Senior Review focus on establishing a sustainable balanced program that is driven by science inquiry rather than the current wavelength-based structure.***

#### *D. The Challenge of New Facilities.*

The AANM report recommended several new high priority facilities with very high construction and operating costs. Within NSF, facility construction appropriations do not include funds for operation of the proposed facility. These operations costs are dominated by maintenance costs that are typically incurred long before science activities begin at the new facility. The operations costs cannot be funded by the MREFC facility development appropriation and thus fall to the Division. This process thus generates an operations lien on the Division with every new facility start. ALMA is one immediate and notable example. The COV supports the Division's practice of developing accurate operations costs early in a project and continually assessing them as the project progresses as an essential component of program management and planning.

The demands for technology development and for the design and operation of ALMA and other planned facilities such as ATST, GSMT, LSST, and SKA must be a principal consideration of the Senior Review. The COV notes that the estimated operations budget for ALMA is comparable in size to the AAG grants program, the budget for NOAO, or the budget for NRAO. It is difficult to understand how operation and maintenance resources could be obtained by re-allocating funds freed up by closure or re-scoping current Division-supported facilities without severely impacting the commitment of the Division to fulfill NSF goals. While budget problems have been faced throughout the history of the Division, the COV notes that the projected US portion of operating costs for ALMA presents an exceedingly difficult challenge. The problem cannot be solved by closing single instruments, but with a flat budget projection may require more substantial facility closures. The COV supports the request made by the Division to the optical/IR and radio/mm/sub-mm communities to address these challenges under the assumption of a flat budget.

The Division's plan to meet this challenge and that associated with other proposed large facilities is to re-balance its overall program to yield cost reductions in other less value-added program areas and to seek growth in the overall program. This planning activity is now among the Division's most pressing issues, both from a budget perspective and in terms of communication of the issues to the science community. The Director will present the Senior Review panel with multiple options, drafted in consultation with the Division staff and the Observatory directors. The latter will be charged to consult with the broader community through user's groups and other mechanisms.

***The COV endorses the Division's new strategic plan to build a sustainable program using a community-based process that considers the scientific merits of extant facilities***

***and programs as well as the advances that can be realized with new instruments and other initiatives.***

*E. The AAG Grants Program*

The unrestricted AST Division AAG grants program is unique among those of other agencies and yields the only funding “eco-niche” for unrestricted, inquiry-based initiatives that is available to the US astronomy community. The AAG program is also the primary source of tangible research results (“nuggets”) that pique the interest of the taxpayers who invest in that research.

***The COV strongly concurs with the recommendation of the AANM report and the conclusion of the Division that the AST grants program (AAG) should be maintained at or above its current funding level despite the severe budget pressure presented by ALMA and other proposed large facilities.***

*F. Responding to the Challenge*

New facilities are intended to address compelling scientific goals. To meet those goals, astronomers must be able to take full advantage of the facilities. Maximizing the scientific promise of new facilities requires substantial complementary activities including broadly based multi-wavelength observing programs, innovative theoretical research to both motivate the facilities and interpret their output, and development of instrumentation to take advantage of new technologies, instrument design, and computational power. To quote from the AANM report “*Starting construction without an overall budget in hand for a complete program can spell lost opportunities for researchers who could capitalize on the powerful new capabilities; bare-bones instrumentation efforts unable to move forward with technology developments; and operations funds inadequate to realize the scientific potential of the facility.*”

The COV emphasizes that building the capacity of the astronomical community to realize the full scientific potential of new facilities is as important as building the facilities themselves. The COV thus recommends that, as the Division pursues the facilities priorities of the AANM report, it respond with equal vigor to the capacity-building priorities that are also articulated therein. Special attention should be paid to the training of the new generation of scientists who will be needed to make maximum use of the new facilities. The issue is how to meet the pressing need for the AAG program to maintain rough parity with the facilities budgets.

The Division needs to develop the overall program in consonance with the enormous appeal of the scientific goals outlined in the AANM and *Physics of the Universe* reports. The Division may have the opportunity to grow the unrestricted AAG grants programs through participation in compelling national science initiatives as enunciated in those reports. Opportunities that could be associated with new programs are funds in the AAG program to dynamically respond to proposals motivated by new facilities and “theory challenges” to explore the scientific prospects for a proposed facility with the intent of

guiding the design of the facility and its instrumentation. The Division should have the flexibility to respond to new opportunities according to the goals and means of implementation outlined in the AANM report.

*The COV recommends that the Division continue to aggressively pursue its approach to the priority initiatives of the AANM report with a flexible, balanced response. This response should both advance the development of facilities and take advantage of opportunities associated with the scientific goals of those facilities to increase support for grants by means articulated in the AANM Decadal Survey and appropriate to the Division.*

## **VI. Programs**

### **A. Research Programs**

#### *General Discussion*

The grants program is the prime example of the Division's practice of dynamic balancing in response to proposal pressure. By going to a common proposal deadline for AAG proposals, the Program Officers are able to convene review panels not according to some set prescription, but in accord with the distribution of proposal topics actually submitted. The COV strongly endorses this flexible approach. The Program Officers are managing this process with evident efficiency and zeal. The FASTLANE and electronic jacket systems seem to be functioning very well.

The COV supports the plan of the Division to consider a solicitation for all proposals to better establish the rules and expectations for the large variety of programs sponsored by the Division. The PREST program currently requires management plans, but most programs do not. A solicitation might, for instance, spell out at what level of cost and complexity proposals to the Advanced Technologies and Instrumentation program should include a management plan. The COV notes that the selection panel for proposals for large, multi-year hardware development should include a skill set appropriate for the non-science aspects of these proposals to enable assessment of technical and management risk as part of the selection process.

There is concern about the considerable required Division investment in non-dynamically allocated grant programs external to the Division, in particular those for which opportunities and interest are essentially negligible in the astronomy community. Examples are ACT and BE. The COV notes that Division funds could be used more efficiently and directed to our community if the Division could determine the level of financial involvement in interdisciplinary or Foundation-wide activities based on how well matched they were to the interests of the astronomical community. The Math Science Priority Area and ITR are examples where the Division was able to set the level of Division involvement.

There is a good balance in the research grants program between experienced PIs and new PIs. The COV closely examined the rates of funding and the size of the grants for women and minorities. The COV is satisfied that no substantial discrepancies exist in this regard, and encourages the Division to continue to monitor this issue closely.

### **Planetary Astronomy (PLA)**

The planetary astronomy program provides funding for theoretical, observational, and laboratory studies of the solar system, ranging from small bodies (comets, asteroids, Kuiper belt objects, and dust) to planets and their satellites, and the origins and evolution of the solar system. Most of the active awards at the end of FY2004 (31 out of 52) are in the area of planets and satellites. Theoretical investigations account for 27 of the 52 active awards, and 18 awards were for purely observational studies. Only two active awards are in the area of laboratory investigations.

The number of proposals and the budget for planetary astronomy both doubled in the three-year period reviewed by the COV. This indicates that the planetary astronomy program is in a healthy state, and that available funding is keeping pace with demand from the community. Based on a review of a random sample of proposal jackets, the COV concluded that the proposal review process for planetary astronomy is working well, and that review panels contain an appropriate breadth of expertise. Given the broad range of topics and techniques that fall within the purview of planetary astronomy, it is important that the expertise of the review panels should be complemented by external reviews when appropriate.

Planetary astronomy offers special opportunities for cooperative programs with NSF-ATM and NASA that are not generally available to other disciplines in astronomy. There were no such collaborative programs in the period under review, although discussions are underway to establish such programs. The COV encourages the development of these collaborative programs as a way to maximize the return on investment in planetary astronomy research by the AST Division.

### **Stellar Astronomy (SAA)**

The Stellar Astronomy and Astrophysics Program (SAA) includes Panels addressing five broad categories: (1) Star Formation and Extrasolar Planets; (2) Compact Objects; (3) Properties of Stars; (4) Stellar Evolution, Massive Stars, and Supernovae; and (5) Fundamental Astronomy and Astrophysics. The distribution of FY02-04 proposals awarded in these five subject areas - 28%, 17%, 19%, 19%, and 17%, respectively - was viewed by the COV as reflecting a very balanced SAA program. Research supported in SAA includes theoretical, observational, and laboratory investigations pertaining to solar astronomy, stellar atmospheres and interiors, stellar evolution and planetary nebulae, massive stars and supernovae, star and planet formation, extrasolar planets, compact objects, and binary stars and accretion-driven phenomena.

The slightly greater emphasis on studies of Star Formation and Extrasolar Planets is a measure of the current level of interest and excitement associated both with progress in the very fundamental problem of star formation and with recent discoveries of extrasolar planets. In response to this increased level of interest and activity, the first panel devoted solely to extrasolar planets (searches, properties) will become active in FY05.

### **Galactic Astronomy (GAL)**

The Galactic Astronomy Program (GAL) encompasses the five main subtopics of (1) Interstellar Medium, (2) Laboratory/Fundamental Astrophysics, (3) Clusters, Stellar Populations, and Abundances, (4) Galactic Structure, and (5) Nearby Galaxies. The subtopic of Nearby Galaxies was added to GAL immediately prior to the previous COV report, and we note that proposals in this area now represent roughly 20% of the awards in GAL. As modern instrumentation enables studies of nearby galaxies at a level of detail previously only possibly in the Milky Way, we find the addition of this subtopic to the GAL program to be appropriate. Indeed, comparative studies of the astrophysics of the Milky Way and other nearby galaxies are imperative to advancing our understanding of the Universe as well as our very own Galaxy.

Of the five main subtopics in GAL, the least proposal pressure (and consequently the lowest fraction of awards) is in the area of Laboratory/Fundamental Astrophysics, with 9% of the total GAL awards in FY02-FY04 (this does not include awards administered through CHE or PHY that are co-funded with AST funds). The committee expressed some concern for maintaining active research in this area, and concern that the community should be mindful that expertise in laboratory astrophysics does not become extinct.

Within the GAL program, 26% of the awards are to female PIs (as voluntarily self identified), which is significantly above the AST average of 16%. We also note that 8% of the awards in GAL are to institutions that qualify as RUIs.

### **Extragalactic Astronomy and Cosmology (EXC)**

EXC supports research on galaxies -- both “normal” and active -- on gamma-ray bursts, and on the large-scale structure and evolution of the universe. The number of proposals to EXC has increased by about 10% since FY2001 to an FY2004 total of 136, the largest among the AST programs. Of the 180 grants that were active in FY04, 44% were observational in nature, 46% theoretical, 8% a combination, and 2% were classified as laboratory astrophysics.

Projects supported within EXC include the following themes, with some overlap across themes. (1) Galaxies and clusters of galaxies: observations across the electromagnetic spectrum, basic theory, and computer modeling, including N-body and smoothed-particle hydrodynamical simulations of galaxy and cluster formation and evolution; (2) Quasars and other active galactic nuclei and gamma-ray bursts: monitoring of brightness variations and of changes in radio images on both long and short time scales, rapid-

response observations of gamma-ray burst afterglows, and hydrodynamical and magnetohydrodynamical simulations of relativistic jets; (3) Cosmology, including the Cosmic Microwave Background and the Sunyaev-Zel'dovich effect and theoretical models of the evolution of the universe; (4) Techniques such as spectral synthesis, plasma processes, and atomic physics.

Reviews of many of the EXC proposal jackets by COV members indicated that the selection of panels was appropriate, and that both panel decisions and final decisions by the program officer were well reasoned and explained. The awards spanned a wide range of topics, seniority of investigators, and emphasis on observation, theory, education, and dissemination of information to the public.

The EXC program faces a number of issues that require careful attention. These include the maintenance and mining of extensive databases from large surveys, an increasing number of projects that require longer duration and stability than has been common in the past, multi-institutional collaborative groups, increased need for computer code development, and inter-panel, inter-division, and inter-agency projects. The recent appointment of a permanent Program Officer for EXC should bring the stability needed to monitor the evolution of these complications and to guide their development such that they become assets rather than liabilities.

### **Education and Special Programs – AAPF, CAREER, REU, RUI**

Education and Special Programs deserve special mention for their success in increasing the visibility and accessibility of astronomy at all levels of the educational system. Of particular note are popular grants and programs that foster attention to astronomy research and education proceeding hand-in-hand (e.g., CAREER Grants, Research Experience for Undergraduates).

The RET program at Green Bank (NRAO) called RARECATS is an example of the impact that relatively small programs can have on fostering observational and research skills in high school teachers who then pass that interest and enthusiasm on to students. The long term success of astronomy in the coming decades will require that attention be paid not only to students at the undergraduate and graduate level, but to the younger K-12 students who feed into those systems and to their teachers. The Division has done a commendable job in highlighting the funding opportunities in ESP to astronomers at AAS meetings.

The AAPF postdoctoral fellowship program is also a great success. The COV supports the current NSF-wide re-examination of the allocation of funding for Fellows' benefits in order to make this process easier and more cost effective for the host institutions and Fellows to implement. The COV encourages the Division to continue their efforts to lead the community in setting appropriate salary and benefits levels for postdoctoral scholars.



*The COV recommends that the Division continue and expand its leadership role in fostering the next generation of scientists poised to take full advantage of new facilities.*

### **Particle Astrophysics**

The Division has successfully coordinated large, interdisciplinary, multi-agency programs like VERITAS for which complete management plans, report plans and joint review of progress has been instituted. The structure of the VERITAS Joint Oversight Group (JOG) is a model mechanism to facilitate complex interactions between community investigators, funding sources, and multi-agency oversight of cooperative agreements.

### **Instrumentation Programs – ATI/MRI, PREST**

Approximately 15% of the Research and Instrumentation program grants were awarded through the instrumentation programs ATI and PREST during FY04. ATI funding grew modestly over this period, and the PREST program was created in FY2004. The ATI program includes advanced technology development for science instruments and their key enabling technologies across all wavelength regions. This research area is key to both maintaining the effectiveness of current Division research facilities and enabling long lead-time development of future facilities. The recent discovery of seven edge-on planet-forming disks around nearby stars by an AAG-funded PI using an ATI funded multi-object spectrometer at NOAO facilities serves as an excellent example of the desired interplay between technology development and effective facility science.

A diverse set of projects were funded by the ATI during this report period at levels spanning a range of roughly \$100,000 – \$1,500,000. A review of randomly selected ATI proposal jackets revealed that the Division's standard review process and associated detailed record keeping extends to proposals in this category. The COV finds that this process is both of high quality and integrity with respect to general science research proposals such as those in the AAG themes.

The popularity of the PREST program is especially noteworthy and an excellent example of a modest investment having enormous impact on the productivity of small college and university-based telescopes.

### **B. National Observatories**

#### *General comments*

The COV reviewed the portfolio of major research facilities currently funded by the Division through cooperative agreements with organizations, including NRAO, NOAO, NSO, Gemini, and NAIC, and grants to universities for the funding of the URO's, including CARMA. Based on presentations by Division staff and extensive discussion,

the committee was pleased with the return on investment that these facilities were providing to the astronomical community

The EPO and PIO offices of the national observatories coordinate their activities to a significant degree. The COV encourages the Division to continue to explore ways to unify these EPO efforts. The COV notes that funds for EPO compete directly with those for research programs and facilities and that balance needs to be continually assessed.

***The COV recommends that the Division continue to explore ways to unify and expand the EPO efforts within and across observatory enterprises.***

The Visitor Centers at the national observatories continue to attract large numbers of visitors. The COV was especially impressed by the 120,000 visitors per year that trek to Arecibo. In addition, NRAO hosts over 60,000 visitors per year to all their sites. NOAO and NSO together host well over 100,000 per year. The Visitor Centers at NSF-sponsored observatories provide a valuable forum in which to educate the general public as well as capture their interest in science and astronomy. It is imperative that these centers be well maintained and kept up-to-date.

### **National Optical Astronomy Observatory (NOAO)**

The COV is pleased to see the Division's pro-active adaptation to NOAO's evolving role in the community. The NOAO/NSO cooperative management agreement was completed in 2001, with AURA retaining management. The explicit role of NOAO defined by the new agreement specifically includes: data dissemination, development of facilities and data analysis tools, and implementation of institutional partnerships to further its objectives. These are in addition to: providing forefront observing facilities and support, scientific research by staff, and education and training programs. Integrating these multi-faceted responsibilities with continuing appropriate balance is a challenge that has been admirably addressed by the Program Manager. In particular, the NOAO oversight structure is functioning smoothly, with observatory Users' Committees and various Gemini advisory committees reporting to NOAO, the Observatories Council reporting to AURA, and an overall NOAO Program Review Panel reporting to NSF/AST. The latter is chartered by the new cooperative agreement and is providing valuable guidance directly to the Division. NOAO has also developed a highly successful Program Plan and improved communication with the community regarding their activities. The COV notes the formation of the NOAO Program Review Panel that reports directly to the Division as an innovative approach to providing programmatic advice.

The young TSIP program has proven a great success in facilitating development of PI instruments on 6-m class telescopes, with community access provided as a condition for grant funding. A first example is set by the OSIRIS spectrometer that will shortly be commissioned at the Keck Observatory, in exchange for which nights have already been offered to the community through NOAO. This program complements the Major Instrumentation Program (MIP) for NOAO facility instruments. A third program, the AODP, addresses the AANM report recommendation to provide funding for adaptive



optics technology. The previous COV report recommended that vital instrumentation programs for 4-m class telescopes be maintained. In response, NOAO and the Division have worked together to expand the TSIP program to include 3 to 6-m class telescopes. NOAO has also established institutional partnerships through the MIP to develop instrumentation for NOAO 4-m class telescopes, for example, the NEWFIRM IR imager and the proposed Dark Energy Camera, in collaboration with, respectively U. Maryland and Fermilab. These programs also demonstrate the potential success of institutional partnerships, which are mandated by the new management agreement.

Addressing the responsibility for data dissemination and archiving, NOAO sponsors the Data Products Program. This program oversees the NOAO Data Archive and supports certain NOAO data reduction pipelines and NVO-compatible data and software tools. The program is also appropriately planning for LSST data management. The COV emphasizes that data management has, and must increasingly become, a major NOAO responsibility.

The previous COV expressed concern regarding the net reduction of peer-reviewed community telescope time at NOAO, and the changing role and management of small telescopes. We commend the Division for increasing community access to new instrumental capabilities through the above institutional partnership programs, yet caution that the erosion of the total available competitively allocated community nights on extant NOAO telescopes continues. The PREST program has also proved a great success at restoring some community access to small telescopes for a modest financial investment. We note that proportionally the greatest loss in community telescope time has been on the smallest aperture telescopes, which will most strongly affect education and training efforts. In view of the difficult balance issues outlined above, which are greatly compounded by financial constraints, the COV feels that Division management in this area is appropriate. Overall, the number of available nights on all telescopes allocated through national peer-reviewed processes supported by Division funds declined by 20% during the period 2002-2004. This decline was precipitated by the implementation of cost-effective management models at NOAO. Division initiatives through PREST and TSIP may stabilize the total number of nights available to the community that are not pre-committed to various programs.

Substantial NOAO involvement in planning for LSST and GSMT continues, with institutional consortia and Science Working Groups established. Extremely large telescopes (20 to 40-m class) are necessarily inter-institutional, and even international, undertakings. The COV commends the Division's initiative and leadership in sponsoring an international agency meeting to address the science case and planning for such projects. The COV strongly shares the Division's concern that the community must fully address the enormous financial, scientific, technical, and societal consequences and responsibilities entailed by projects of this scale. We emphasize that this is a primary concern to be addressed by the Senior Review. These issues should also be at the forefront of those directly communicated by the Division to the community.

## **Gemini**

Gemini operates two twin 8-m telescopes, atop Mauna Kea (Hawaii) and Cerro Pachon (Chile). The Division provides funding for the U.S. share of operations and instrumentation. The observatory operates a broad suite of optical and infrared instruments available to the astronomical community. These currently include at Gemini North -- Altair, a natural guide star adaptive optics system, GMOS, an optical multi-object spectrograph, Michelle, a mid-IR imager and spectrograph, and NIRI, a near-IR grism spectrograph; and at Gemini South - GMOS, optical multi-object spectrograph, GNIRS, a near-IR spectrograph, Phoenix, a high-resolution near-IR spectrograph, T-ReCS, a mid-IR imager and spectrograph, and Hokupa'a-85, an adaptive optics system. Instruments to be commissioned over the next 14-month period include NIFS, a near-IR integral field spectrograph, and NICI, a near-IR dual-channel coronagraphic imager with an integrated adaptive optics bench. In addition, the Gemini Observatory is rapidly moving forward with the deployment of a Laser Guide Star upgrade for Altair, as well as implementing the initial stages of a Multi-Conjugate Adaptive Optics (MCAO) system to exploit unique science opportunities enabled by AO correction over large fields of view (2.5-5 arcminute) in the focal plane of the telescope. Development of the advanced AO capabilities on Gemini has benefited from the exchange of expertise between the Observatory and the Center for Adaptive Optics (CfAO), an NSF funded center.

With these “first-generation” instruments and new AO capabilities, Gemini is now the premier facility available through a peer-reviewed telescope time allocation process to the general U.S. community to conduct optical/IR observations with an 8-m class telescope. User support is therefore a mission-critical component of the facility. This includes a fully-documented and easily-navigable website with detailed specifications for all facility instruments, exposure time calculators, easy-to-use proposal preparation tools, visitor support services, science support personnel, and frequently updated data-reduction software for IRAF. The NOAO Gemini Science Center (NGSC, a division of NOAO) provides these services to the community as well as advocating the United States astronomical community’s scientific needs and aspirations within the international partnership. The proactive role that the Division Director, the Executive Officer, and the Program Manager for the NOAO facilities portfolio have played in the maturation of the NGSC and its activities have benefited the community and assisted in the realization of an internationally competitive 8-m class observatory first envisaged as a high national priority by the decadal survey process.

The facility maintains a number of performance metrics that include number of nights available for science, image quality statistics, basic telescope performance (e.g., pointing and tracking accuracy), and number of publications arising from Gemini data.

On the whole, the COV was positively impressed with the Gemini facility, its performance relative to established metrics, and the early impact of its science output. An active public relations component appears to be successfully communicating Gemini science to the public. In addition, the recent Aspen Workshop, which brought together individuals broadly representing the astronomical community in the Gemini partnership,

is a good model of community-based dialog providing direction to the facility's science and instrumentation plans.

The Division provides a critical leadership role in the governance of the observatory, serving as the Executive Agency of the Gemini partnership, and providing oversight of Gemini's managing organization, AURA. This leadership role provides strong positioning for the U.S. community in this multi-national project. Indeed, such positioning may be critical to advancing community priority initiatives that increasingly require such large-scale, multi-partner facilities. The role of the Division generally and its program officers specifically in participating in facility governance is an essential aspect of the Division portfolio.

The COV concluded that the Division's active leadership in guiding the Gemini partnership through the telescope commissioning and initial operational phases was key to maintaining the partnership and realizing a successful and internationally competitive Observatory.

### **National Solar Observatory (NSO)**

The NSO operates solar telescopes at two major facilities: Kitt Peak in Arizona and Sacramento Peak in New Mexico. In addition, NSO operates the Global Oscillations Network Group (GONG), a network of telescopes distributed at six sites around the world for the study of solar oscillations.

The telescopes at Kitt Peak and Sacramento Peak have been the backbone of solar astronomy for many years. Both low- and high-order adaptive optics systems are now in routine use on the 76-cm Dunn Telescope at Sacramento Peak and the 150-cm McMath/Pierce telescope at Kitt Peak. These systems have significantly improved the image quality that can be obtained with these telescopes, and they have increased the available observing time at both facilities.

NSO also operates SOLIS (Synoptic Optical Long-Term Investigations of the Sun), a new suite of three telescopes co-located on the Kitt Peak Vacuum Tower. SOLIS will provide long-term observations that will help to address some of the major outstanding problems in solar astronomy, including the cause of the solar cycle, the origin of explosive eruptions on the Sun, and the sources of variability in the solar radiative output. NSO is leading the ground-based effort to develop the Virtual Solar Observatory (VSO), with the first version released for public use in FY2004.

NSO has completed the concept design for the Advanced Technology Solar Telescope (ATST), a 4-m off-axis system that will replace existing major solar facilities when it becomes operational. ATST will provide major improvements over existing solar telescopes in both resolution and light-gathering power. It will also provide excellent polarization measurements and low-scattered light performance that will permit coronagraphic observations in the IR. ATST will allow solar astronomers to observe the Sun at a spatial resolution comparable to the fundamental length scales of many physical

processes in the solar atmosphere. The ATST site selection has been completed with the recommendation of Haleakala, HI as the location for the telescope. The proposal for construction of the ATST is under review, although it appears unlikely that construction will begin in 2006 as planned.

Solar astronomy has particular relevance to society, both for the enormous public interest in detailed images of our nearest star, and for the influence of solar activity on the near-Earth space environment (space weather). The COV recognizes the vigorous program that NSO is pursuing to advance solar astronomy in the 21<sup>st</sup> century, both in the enhancement of existing facilities and in the development of new capabilities. NSO faces a significant challenge in funding ATST until construction begins. NSO is also facing the issue of consolidation of existing facilities when ATST is operational. It is important that construction of the ATST should commence as soon as possible, both to enable these issues to be resolved and to enable the science return from ATST to be realized in a timely manner.

### **National Astronomy and Ionosphere Center (NAIC)**

NAIC operates one site (plus remote offices at Cornell) at Arecibo, Puerto Rico, home of the 305-m radiotelescope. NAIC supports radio and radar astronomical observations and atmospheric science research and hosts a heavily utilized education and outreach center. NAIC is the smallest of the national centers operated by the Division, with a total budget of just over \$12 million. The facility has been jointly funded by the AST Division in conjunction with the ATM Division and NASA; however, the small NASA contribution is being phased out, leaving approximately 80% of the support from AST.

During the period under review by this COV, there were significant changes in the management of NAIC. Most importantly, in 2004 the operation of NAIC was re-competed for the first time since the Division took over operations of NAIC. The re-competition results will be presented to the NSB in March 2005. Additionally, the Division has undertaken to increase the oversight of NAIC operations at Arecibo and will form an NSF task force to monitor the management of NAIC. The COV noted that the Division's Program Manager has proactively established new progress reporting, program plan assessment, and observatory management mechanisms to improve accountability and facilities stewardship. The COV commends the Division for the smooth handling of the recompetition and for its efforts in improving the oversight of this facility.

The COV was also encouraged that improved management and operational efficiency of NAIC may result from moving the Director's office in Puerto Rico. We encourage the Division to continue to identify processes and mechanisms to enhance the return from the current NAIC investments (i.e., user-friendly single dish reduction software, remote and queue operations, exploitation of higher frequencies perhaps to 10 GHz) to the radio and radar communities.

The observatory report to the COV highlighted the challenges faced by the observatory. The COV notes particularly the difficulty the observatory has in retaining staff members, given the remote and undeveloped location of the site.

The major operational improvements to NAIC over the 2002-2004 period resulted from the deployment of the (Australia-built) ALFA 7-beam correlator array. This instrument, made possible by the Gregorian feed installation, dramatically speeds the sky coverage of the radiotelescope for surveys, and re-affirms the viability of the telescope for cutting-edge research. As a confirmation of the importance of the facility, the COV notes the nearly 40% rise in the number of users over the period under review, as well as the near-doubling of PhD student users. The development of remote observing interfaces has served to further expand the user base for the telescope. NAIC has engaged its user community to establish team collaborations to conduct large surveys with ALFA. The COV notes that these consortia have a significant involvement of foreign investigators and encourages the Division to explore mechanisms to identify resources and partnering arrangements that support NAIC activities from foreign agencies and institutes that support these scientists.

The COV was particularly impressed with the functioning of the Angel Ramos NAIC Visitor Center. The 120,000 visitors annually to the site exceed those for other Division facilities, despite the remote site of the observatory. The Ramos Center represents a model for other visitor centers.

### **National Radio Astronomy Observatory (NRAO)**

The NRAO currently operates four astronomical centers around the country, located in (1) Charlottesville, VA, (2) Green Bank, WV, (3) Socorro, NM and (4) Tucson, AZ. As a result of the closing of the 12-meter telescope, NRAO plans to close the Tucson office in 2006. Staff currently working on the ALMA project will be moved to Charlottesville to be part of the ALMA operations center, now under construction.

Green Bank, WV operates the Green Bank Telescope (GBT), now in early scientific operations, and the 40-foot telescope used for education and training with summer schools. The GBT has produced impressive scientific results and has the acquired funds needed to resolve structural issues with its track. The Green Bank site also has a newly expanded visitor's center, with a rich variety of educational programs that benefit K-12 students, high school teachers, and amateur radio astronomers.

The Array Operations Center (AOC) in Socorro, NM is responsible for the operation of the Very Large Array (VLA) and the Very Long Baseline Array (VLBA). These two radio interferometers are unique world-class facilities that attract astronomers from around the globe. Staff in Socorro have begun the transition to the Expanded VLA (EVLA), and plan to be able to effect the transition gradually, achieving a minimum of down time for the array. According to current plans, the number of VLA telescopes available may dip to 23 during the telescope upgrade (in 2005-2006). The VLA data archive system has been modernized, and VLBA operations anticipate a change to disk-

based recording (as a transition from the current tapes). Raw VLA archival data are available in a transparent manner to users.

NRAO headquarters are located in Charlottesville, VA, as is the Central Development Lab (CDL). The Charlottesville site will see an infusion of new staff with the construction of the national ALMA operations center. Some current staff from the Tucson office (to be closed) will move to Charlottesville, and other new staff will be hired.

The COV was impressed with the high quality of scientific results and with the scientific and operations staff within the National Radio Astronomy Observatory. With over 1000 observers from nearly 250 institutions authoring over 400 papers in 2003, the NRAO clearly has a large impact on the astronomical community. NRAO has taken an active approach in Education and Public Outreach.

### **Atacama Large Millimeter Array (ALMA)**

ALMA is a global project for which the Division represents NSF as the lead agency. This instrument should address a multidisciplinary set of issues from the origin and evolution of stars and planets to the origin and evolution of galaxies. The ALMA project broke ground in the fall of 2003, and as of September 2004 has added a new partner in the National Astronomical Observatory of Japan (NAOJ). Site work is underway, but no construction has started. The project is suffering some of the consequences of the global increase in material costs since budgeting in 1999.

As befits a complex global project, the organization and management are a special challenge. The COV commends the Division for its leadership role in this regard. The Division represents the NSF on the ALMA Board and appoints five North American members to the ALMA Management Advisory Committee (AMAC) and to the ALMA Science Advisory Committee. While a single Executive Agency (the NSF) and a single Executive Intermediary (AURA) were possible with Gemini, no single Executive Agency is possible with ALMA because of the complex partnerships. The result has been the invention of unique organizational structure in which the NSF participates in the ALMA Board. The Board acts as an oversight committee, but must not preempt U.S. government prerogatives, especially regarding the budget. Achieving this balance and satisfying the needs of the U. S. astronomical community requires a strong role for the NSF and thus for the Division.

Daily responsibility for this critical and complex management task currently falls to a single member of the Division, the ALMA Staff Associate. The COV was once again deeply impressed by the range of responsibilities of this single individual and the quality of the work being done. The need for expanded staffing in this area was, once again, clear.

While the project has excellent managerial and scientific leadership, it faces significant challenges in terms of cost, scope, and the intricacies of the international collaboration.



ALMA will face challenges in terms of management. Since observatories in coming decades are increasingly likely to be international collaborations, these are issues that the astronomical community will have to face, and in which the Division has already shown early leadership.

### **University Radio Observatories (URO)**

UROs, including OVRO, BIMA, FCRAO, and CSO, have an annual combined budget from the Division of roughly \$11M, with each observatory receiving approximately \$2-3M each year. The COV noted that the CARMA project (combining of the Owens Valley and BIMA facilities) was progressing well with assistance from the Division.

The Division needs to rigorously monitor the community access to these facilities to ensure that an appropriate fraction of observing time is used by “outside” observers, as determined by the home institution of the Principal Investigators. The COV cautions that mechanisms must be identified to ensure that competitive access is maintained and properly supported for users outside of the major consortium members commensurate with the investment by the Division of public resources.

### **Electromagnetic Spectrum Management (ESM)**

As our society becomes more dependent on communications technology, the wavelength windows available to carry out astronomical observations are becoming increasingly contaminated and threatened. Historically, this problem has primarily affected observations at radio wavelengths; however, optical and infrared bands are increasingly threatened by government and commercial use of space-based laser communications. As the technology becomes feasible at mm-wavelengths these windows will become increasingly popular with commercial users. A particularly difficult problem is the increasing number of Non-Geostationary Orbit satellites, some of which are above the horizon and provide interference at all times. At present, the ESM program within the Division bears most of the responsibility for defending spectrum allocations, although other Divisions are also directly impacted by spectrum management (including Polar Programs, Atmospheric Research, and Oceanography).

The COV commends the efforts to coordinate policies relating to ESM with the both the government and private sector. In particular, the COV is pleased with their effort to work with the FCC to protect the areas around observatories from transmitters. Much of the spectral range covered by ALMA will be considered at the 2010 World Radiocommunications Conference (275-1000 Ghz), and the Division needs to proactively lay the groundwork for that conference. In addition, spectrum allocation issues are becoming increasingly international, particularly with the development of ALMA, and there is an urgent need to coordinate with Latin American countries (particularly Chile, Argentina, and Brazil). We encourage the Division to aggressively defend spectrum allocations for scientific research, and to expand their efforts to keep the astronomical community informed, for example via the summer schools in spectrum management in which they already participate.

*The COV encourages the Division to aggressively defend the spectrum allocations for scientific research and to expand efforts to keep the astronomical community apprised of critical issues.*

## **VII. Response to the COV Report of 2002**

The COV is charged with reviewing the response of the Division to the prior COV report. Here we briefly summarize the main recommendations of the 2002 COV report and address the Division's response to each in the context of the concerns and recommendations of the current COV.

The 2002 report of the AST COV included seven specific recommendations. Following that report, the AST Division issued a formal response and, in January 2005, Director Van Citters issued a follow-up report summarizing the Division's progress on the 2002 COV's seven recommendations.

The specific recommendations of the 2002 AST COV were that:

1. Most urgently, the AST Division increase its staff.
2. The AST Division develop an implementation plan with funding requirements to the end of the decade to support the various initiatives that have been identified and prioritized by the astronomical community in the Decadal Survey, and that the Division actively engage the community on a continuing basis in the planning effort.
3. The AST Division explore new ways to enhance the astronomy community's response to the "broader impacts criterion" in the review process by emphasizing its importance, clarifying its meaning and usefulness, and illustrating its application. Review panels should also be encouraged to pay closer attention to this criterion and to give credit to investigators who fulfill it well.
4. The AST Division maintain a vital instrumentation program for the 4-m class telescopes to which the national community has access.
5. The AST Division help clarify information disseminated to the astronomical community about various NSF-wide opportunities such as MRI, RUI and other similar programs, by providing simplified descriptions of goals and requirements for these programs. The Division should also encourage additional proposals for these programs from the community.
6. Consider establishing new UROs in the future as the closing of older facilities provides new funding opportunities, but without impacting the support for research grants to individuals.
7. The AST Division devote more than the one FTE position to ESM activities.

The AST Division has shown a high degree of responsiveness to these recommendations. The COV is, on the whole, positively impressed with the Division's serious and proactive

approach to responding to the previous COV's concerns. Evidence of the Division's responsiveness includes (organized by the seven recommendations above):

1. The Division has expressed its strong agreement with the need for additional staff. The Division has since filled vacant positions, has reorganized the allocation of its existing FTEs to better meet the demands of the Division, and has even identified creative solutions such as the creation of a Senior Policy Fellowship program that would serve to attract more members of the astronomical community to serve as Visiting Scientists at AST. The total number of FTEs within the Division has not increased, and the proposed Senior Policy Fellowship program has not been implemented; recruitment of members of the astronomical community to serve as rotators continues to be a challenge.
2. The Division has been extremely active in developing an implementation plan with detailed funding requirements that responds directly to the priorities articulated in the AANM report and in complementary reports (e.g., *The Physics of the Universe* and *Connecting Quarks with the Cosmos*). The Division's overall budget has shown impressive growth since the 2002 COV, with concomitant growth in the funding available to the research and instruments grants programs and facilities. Critically, the overall outlook for the growth of the Division budget has changed significantly since the 2002 COV. Specifically, flat or declining budgets may be expected for the next five years, with significant implications for the ability of the Division's portfolio to rise to the ambitions of the AANM report. The Division plans to convene a Senior Review to specifically address this issue.
3. Review by the COV of the proposal review process during FY 2002-04 showed clear evidence of improvement in the quality of the astronomical community's response to NSF's merit review Criterion II (i.e., "broader impacts"). The AST Division has been particularly proactive in educating the community about the importance and meaning of this criterion, and in illustrating its application. The creation of the AAPF postdoctoral fellowship program and, impressively, the new PREST program for the development of small telescopes for research and education, have provided creative new mechanisms for the community to effectively respond to the broader impacts criterion.
4. The Division has been actively engaged in the development of a vital instrumentation program for the 4-m class telescopes. Specific examples include the full suite of instruments for the SOAR telescope and the WIYN one-degree imager. Importantly, through engagement with the NOAO-led "System" committee, the successful TSIP program, formerly limited to telescopes with apertures greater than 6-m, has been modified to include telescopes in the 3 to 6-m aperture range (i.e., the 4-m class telescopes). Beyond this, the role of the Division in furthering the recommendation of the AANM report for the development of the ground-based optical/IR "observing system" is noted as a success of the period reviewed by the COV.
5. AST Division staff have responded actively to the 2002 COV call for enhanced outreach to the community with respect to NSF-wide funding opportunities. Indeed, the commitment of the Division's staff to frequent and personalized communication with the community is exceedingly evident. This includes:

- a. Semi-annual presentations/discussions with the NRC Committee on Astronomy and Astrophysics (CAA).
- b. Semi-annual presentations/discussions with the NRC Board on Physics and Astronomy (BPA).
- c. Four meetings annually of the Astronomy and Astrophysics Advisory Committee (AAAC) - joint NSF/NASA (and now DOE) advisory committee.
- d. Semi-annual town meetings at AAS meetings.
- e. Attendance of scientific and administrative staff at all AAS meetings and presence at a booth in the exhibit hall.
- f. Typically 3-6 “outreach” visits annually to individual colleges, universities to present seminars on how NSF works, provide information on funding opportunities, and to have informal discussions with faculty, students, and administrators.
- g. Regular contributions to the AAS newsletter, announcing funding opportunities, providing updates on activities, explaining changes in NSF requirements and guidelines for funding (including guidance regarding the “broader impacts” criterion).
- h. “How NSF Works” special sessions at AAS meetings.
- i. Regular invitations to the community for requests for visits by AST staff, either in person or virtually (e.g., via video-conferencing).

Unfortunately, the astronomical community’s utilization of AST staff, particularly with respect to items (h) and (i) above, has been limited. In addition, several NSF-wide opportunities that appear to have applicability to the astronomical community (e.g., IGERT and others) continue to be under-utilized.

6. In FY 2002 the Division carried out a competitive review for UROs, and is planning another competition for FY 2006.
7. The Division has assigned a program officer to the role of addressing ESM issues. In FY2002, there was already a full time position dedicated to ESM issues. Since then, several other program officers have taken on some responsibility for ESM, and when a currently advertised position is filled, an additional 0.5FTE will be devoted to ESM activities.

Remaining concerns from the 2002 COV report (organized by the seven recommendations above):

1. The COV commends the Division for identifying creative solutions to the ongoing problem of staffing shortages; however, it is distressing to this COV that this issue persists, despite strongly worded recommendations from two prior COVs. The AST Division manages an impressive and increasingly complex portfolio of facilities, programs, and community engagement activities. This portfolio is unique in many respects as compared to the portfolios of other MPS divisions. Adequate staffing for careful stewardship of the public’s investments in astronomy remains a critical priority.

2. The AST Division is entering a time of increasing pressures due to the combination of the current budget outlook and the continued demands for new initiatives (particularly with respect to operations for new facilities) from the community. The COV is concerned that the astronomical community may not be as fully aware as it should about this issue, despite proactive efforts on the part of Division staff to conduct outreach to the astronomical community (see above).
3. There is evidence from examination of proposals submitted during the FY 2002-04 period of some idiosyncrasies in the reviewers' application of the "broader impacts" criterion. Specifically, some reviews received during this period simply do not address Criterion II at all, while in other cases reviewers identified broader impacts on behalf of proposers who did not explicitly address this criterion in their proposals. Obtaining proper balance within the written narrative of proposals is integral to the integrity of the peer-review process.
4. None.
5. Continued education within the astronomical community of opportunities to apply for NSF-wide programs is needed. To this end, utilization of the Division's website for providing information about these programs is encouraged. At the same time, the astronomical community must assume greater responsibility in making fuller use of the Division staff for education about these opportunities.
6. None.
7. None.

**FY 2005 REPORT TEMPLATE FOR  
NSF COMMITTEES OF VISITORS (COVs)**

<b>Date of COV</b>	<b>Feb 22-24, 2005</b>		
<b>Program/Cluster:</b>			
<b>Division:</b>	<b>AST</b>		
<b>Directorate:</b>	<b>MPS</b>		
<b>Number of actions reviewed by COV<sup>1</sup>:</b>	<b>Awards: 227</b>	<b>Declinations: 92</b>	<b>Other: 0</b>
<b>Total number of actions within Program/Cluster/Division during period being reviewed by COV<sup>2</sup>:</b>	<b>Awards: 1411</b>	<b>Declinations: 1105</b>	<b>Other: 0</b>
<b>Manner in which reviewed actions were selected: Initial randomly by program, supplemented by jackets pulled to ensure all review panels were sampled</b>			

**PART A. INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT**

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, and withdrawals) that were *completed within the past three fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

**A.1 Questions about the quality and effectiveness of the program's use of merit review procedures.** Provide comments in the space below the question. Discuss areas of concern in the space provided.

<b>QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCEDURES</b>	<b>YES, NO, DATA AVAILABLE, or NOT APPLICABLE<sup>3</sup></b>
1. Is the review mechanism appropriate? (panels, ad hoc reviews, site visits) Comments:	<b>YES</b>

<sup>1</sup> To be provided by NSF staff.

<sup>2</sup> To be provided by NSF staff.

<sup>3</sup> If "Not Applicable" please explain why in the "Comments" section.

<p>2. Is the review process efficient and effective? Comments:</p>	<p><b>YES</b></p>
<p>3. Are reviews consistent with priorities and criteria stated in the program's solicitations, announcements, and guidelines? Comments: <b>There are concerns with respect to the consistency with which merit review Criterion II (i.e., "broader impacts") is being applied in the review panels. COV members found examples in their review of the jackets of reviewers who injected broader impacts rationale where this rationale was not provided explicitly in the proposal.</b></p>	<p><b>YES</b></p>
<p>4. Do the individual reviews (either mail or panel) provide sufficient information for the principal investigator(s) to understand the basis for the reviewer's recommendation? Comments: <b>Broader impacts criterion sometimes not explicitly addressed in individual reviews.</b></p>	<p><b>YES</b></p>
<p>5. Do the panel summaries provide sufficient information for the principal investigator(s) to understand the basis for the panel recommendation? Comments: <b>Additional information to PIs regarding context of funding decision is desirable. There were some cases of disconnects between the individual reviews and panel summaries as documented.</b></p>	<p><b>YES</b></p>
<p>6. Is the documentation for recommendations complete, and does the program officer provide sufficient information and justification for her/his recommendation? Comments: <b>The COV felt that in general this was done very well, and points to the quality of stewardship by the Division of the review process. We noted an improvement during the time period reviewed by the COV, reflecting an increase in AST staff devoted to this important task.</b></p>	<p><b>YES</b></p>
<p>7. Is the time to decision appropriate? Comments: <b>Cases in which the 6-month goal of time to decision was not met were highly correlated with staffing shortages within the Division.</b></p>	<p><b>YES</b></p>
<p>8. Discuss any issues identified by the COV concerning the quality and effectiveness of the program's use of merit review procedures:</p>	

**A.2 Questions concerning the implementation of the NSF Merit Review Criteria (intellectual merit and broader impacts) by reviewers and program officers.** Provide comments in the space below the question. Discuss issues or concerns in the space provided.

IMPLEMENTATION OF NSF MERIT REVIEW CRITERIA	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE <sup>4</sup>
1. Have the individual reviews (either mail or panel) addressed both merit review criteria? Comments: <b>Examples were found where the broader impacts were not addressed.</b>	YES
2. Have the panel summaries addressed both merit review criteria? Comments:	YES
3. Have the <i>review analyses</i> (Form 7s) addressed both merit review criteria? Comments:	YES
4. Discuss any issues the COV has identified with respect to implementation of NSF's merit review criteria.	

<sup>4</sup> In "Not Applicable" please explain why in the "Comments" section.



**A.3 Questions concerning the selection of reviewers.** Provide comments in the space below the question. Discuss areas of concern in the space provided.

<b>SELECTION OF REVIEWERS</b>	<b>YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE<sup>5</sup></b>
1. Did the program make use of an adequate number of reviewers? Comments: <b>Sometimes minimum of three.</b>	<b>YES</b>
2. Did the program make use of reviewers having appropriate expertise and/or qualifications? Comments:	<b>YES</b>
3. Did the program make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups? Comments:	<b>YES</b>
4. Did the program recognize and resolve conflicts of interest when appropriate? Comments:	<b>YES</b>
5. Discuss any issues the COV has identified relevant to selection of reviewers.	

<sup>5</sup> If “Not Applicable” please explain why in the “Comments” section.

**A.4 Questions concerning the resulting portfolio of awards under review.**

Provide comments in the space below the question. Discuss areas of concern in the space provided.

<p><b>RESULTING PORTFOLIO OF AWARDS</b></p>	<p><b>APPROPRIATE, NOT APPROPRIATE<sup>6</sup>, OR DATA NOT AVAILABLE</b></p>
<p>1. Overall quality of the research and/or education projects supported by the program. Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>2. Are awards appropriate in size and duration for the scope of the projects? Comments: <b>The priority of fully funding meritorious proposals was recognized. Among the AAG programs, there is no evidence of systematic differences in funding levels among women or minority PI's. The trend, if any, is in the sense that women and minorities receive slightly larger grants than average.</b></p>	<p><b>APPROPRIATE</b></p>
<p>3. Does the program portfolio have an appropriate balance of:  <ul style="list-style-type: none"> <li>• High risk projects?</li> </ul> Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>4. Does the program portfolio have an appropriate balance of:  <ul style="list-style-type: none"> <li>• Multidisciplinary projects?</li> </ul> Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>5. Does the program portfolio have an appropriate balance of:  <ul style="list-style-type: none"> <li>• Innovative projects?</li> </ul> Comments:</p>	<p><b>APPROPRIATE</b></p>

<sup>6</sup> If “Not Appropriate” please explain why in the “Comments” section.

<p>6. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Funding for centers, groups and awards to individuals?</li> </ul> <p>Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>7. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Awards to new investigators?</li> </ul> <p>Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>8. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Geographical distribution of Principal Investigators?</li> </ul> <p>Comments: <b>EPSCoR is being utilized.</b></p>	<p><b>APPROPRIATE</b></p>
<p>9. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Institutional types?</li> </ul> <p>Comments: <b>Noted lack of HBCUs and MSIs among awarded institutions.</b></p>	<p><b>APPROPRIATE</b></p>
<p>10. Does the program portfolio have an appropriate balance of:</p> <ul style="list-style-type: none"> <li>• Projects that integrate research and education?</li> </ul> <p>Comments: <b>This was noted as a particular strength.</b></p>	<p><b>APPROPRIATE</b></p>
<p>11. Does the program portfolio have an appropriate balance:</p> <ul style="list-style-type: none"> <li>• Across disciplines and subdisciplines of the activity and of emerging opportunities?</li> </ul> <p>Comments:</p>	<p><b>APPROPRIATE</b></p>
<p>12. Does the program portfolio have appropriate participation of underrepresented groups?</p> <p>Comments:</p>	<p><b>APPROPRIATE</b></p>

<p>13. Is the program relevant to national priorities, agency mission, relevant fields and other customer needs? Include citations of relevant external reports.  Comments:  <i>Astronomy and Astrophysics in the New Millennium; Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century; the Physics of the Universe</i></p>	<p><b>APPROPRIATE</b></p>
<p>14. Discuss any concerns relevant to the quality of the projects or the balance of the portfolio.</p>	

**A.5 Management of the program under review.** Please comment on:

<p>1. Management of the program.  Comments: <b>The Management has done an excellent job responding to complex, rapidly evolving scientific goals and managing intra-agency and international collaborations.</b></p>
<p>2. Responsiveness of the program to emerging research and education opportunities.  Comments: <b>The Division has developed a flexible and dynamic means of responding to community input and proposal pressure.</b></p>
<p>3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.  Comments: <b>The Division has responded to community input and scientific challenges to effectively set priorities and institute a long-range strategic planning process.</b></p>
<p>4. Additional concerns relevant to the management of the program.  <b>The Division is understaffed for the complex and growing work load.</b></p>

## **PART B. RESULTS : OUTPUTS AND OUTCOMES OF NSF INVESTMENTS**

**B.1 OUTCOME GOAL for PEOPLE: Developing “a diverse, competitive and globally engaged workforce of scientists, engineers, technologists and well-prepared citizens.”**

Comments: See examples and award numbers below

**B.2 OUTCOME GOAL for IDEAS: Enabling “discovery across the frontier of science and engineering, connected to learning, innovation, and service to society.”**

Comments: See examples and award numbers below

**B.3 OUTCOME GOAL for TOOLS: Providing “broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation.”**

Comments: See examples and award numbers below

**B.4 OUTCOME GOAL for ORGANIZATIONAL EXCELLENCE: Providing “an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices.”**

Comments: See examples and award numbers below

**Examples in support of the above :**

### **B.1 People**

#### **Teacher Leaders**

NOAO’s Teacher Leaders in Research Based Science Education (TLRBSE) program successfully wrapped up its first on-line distance learning course on astronomy content, pedagogy and leadership skills for teachers. This unique 15-week course with intensive interaction with instructors and among the participants served as a prelude to a busy, highly successful two-week research experience. At the workshop, teachers received specialized training on mentoring and leadership as well as science education content in order to work more effectively with their learning colleagues. One group conducted

research at Kitt Peak National Observatory and the other at the National Solar Observatory's Sacramento Peak facility. The task before them is to bring the research, and their renewed excitement for it, into the classroom; in addition, each of the teacher leaders are to mentor three other teachers new to the field in an effort to retain them in the teaching ranks.

**NSF Award Numbers: 0132798**

**Award Title: AURA Management and Operations of the National Optical Astronomy Observatory and the National Solar Observatory**

**PI Name: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

### **The Big Bang Happened Here**

NSF Astronomy and Astrophysics Postdoctoral Fellow Kim Coble and her co-authors have filled a perceived gap in educational resources for nonscientists by writing a textbook that guides introductory science students to an understanding of the key insights of modern scientific cosmology. While popular cosmology books and advanced texts for physics and astronomy majors are in no short supply, this text may be singular in its intended audience as introductory cosmology courses for non-majors become increasingly popular. While emphasizing the stunning observations of modern cosmology, the book seeks to connect the most important scientific concepts and findings with the reader's personal worldview of humans and our cosmic origins.

**NSF Award Numbers: 0104465**

**Award Title: An Integrated Program of Cosmological Research and Education**

**PI Name: Kimberly Coble**

**Institution Name: University of Chicago**

### **Gemini StarsTeachers Exchange**

The children and teachers of Hawai'i and Chile were the first to benefit from a novel educational program made possible by Gemini Observatory's new high-speed Internet link that connects the twin telescopes on both hemispheres. The Gemini StarTeachers Exchange Program links teachers in Hilo and its Sister City of La Serena, Chile - the two host communities of Gemini Observatory. The goal of the StarTeachers Exchange Program is to foster scientific, educational and cultural understanding through the use of Gemini's latest net-based, audio-visual conferencing technology. Gemini sponsors this opportunity for three teachers from each community to exchange visits and interact using the Internet with their students back in their home schools. The Chilean Ministry of Education has recognized the impact of the Gemini StarTeachers program. For the first time, the Gabriela Mistral Medal for excellence in education has been awarded outside of Chile. The medal, named for the famous Nobel-Prize winning poet Gabriela Mistral, was awarded in October to the Gemini Observatory in celebration of its outstanding efforts in international astronomy education through the StarTeachers exchange program.

**NSF Award Numbers: 0084699**

**Award Title: Gemini 8 Meter Telescope**

**PI Name: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

### **Guide to the Best Spanish Language Astronomy Materials**

The staff of the educational outreach group at the National Optical Astronomy Observatory often hears the question, “Where can one find the best advice on the most engaging astronomy-related books and teaching materials in Spanish?” This is not surprising given that NOAO is based in Tucson, Arizona, a city with many Spanish-speaking residents located only 100 kilometers from Mexico. NOAO received a small supplemental grant from the NSF astronomy division in late summer 2002 to pursue a solution and the resulting NOAO Spanish Language Astronomy Materials Education Center site is now on the Web. The NOAO team has created an expanding library of reviewed materials and a Web-based catalog of generally available Spanish-language astronomy materials for all grade levels. Published in both English and Spanish, these evolving Web pages are meant to provide a user-friendly way to find grade level-appropriate astronomy education materials.

**NSF Award Numbers: 0132798**

**Award Title: AURA Management and Operations of the National Optical Astronomy Observatory and the National Solar Observatory**

**PI Name: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

### **Extragalactic Research with the National Virtual Observatory**

An example of the effectiveness of the Special Focus Grants Programs administered within AST is the SGER grant to initiate an extragalactic HI node in the context of the National Virtual Observatory. It involves conversion of an Arecibo survey of extragalactic HI into a catalog that is accessible on the NVO. The broad impact involves the large community of users of the NVO, the tools for access to a wide range of research, and the training of a significant number of graduate students.

**NSF Award Numbers: AST-0435697**

**Award Title: An Extragalactic HI Node within the National Virtual Observatory.**

**PI Name: Riccardo Giovanelli**

**Institution Name: Cornell University**

## **B. 2 Ideas**

### **The Very First Signs of Stars**

Large surveys are playing an increasingly important role in astronomy, as shown by programs such as the Galactic Ring Survey being carried out at Boston University. Their map of molecular carbon monoxide (CO) emission of our Galaxy has allowed the determination of the properties of numerous dark clouds seen in the Galactic plane. They find that these clouds have large masses and small sizes which, when coupled with their high densities of molecular gas, indicate that they are precursors to not just individual stars, but large star clusters. Apparently these dark clouds condense from much larger giant molecular clouds and have just begun to fragment into the clumps that will become a cluster of massive stars. They then represent a very important class of objects, and represent the very first stages of the formation of stars and clusters. This work involves many undergraduate students and the results show the power of large, coherent, systematic surveys.

**NSF Award Numbers: 0098562**  
**Award Title: The Galactic Ring Survey**  
**PI Name: James Jackson**  
**Institution Name: Boston University**

### **Why So Much Carbon?**

The oldest stars in our Galaxy play a special role in illuminating the story of how the elements that make up our world form. The oldest stars we see are also among the most deficient in ‘metals’, the elements heavier than hydrogen and helium, because they formed before the exploding stars of supernova could make and distribute newly created elements throughout space. Recent studies of the most metal-deficient stars show that many of them are extremely and unexpectedly rich in carbon, which is difficult to understand from our current models of supernovae and chemical evolution. It appears now that most of these carbon-rich stars were members of binary star systems and obtained their carbon from a long-dead companion. The results have far-reaching implications for the kinds of stars that formed in the early galaxy, suggesting that many more high mass stars formed then than do today.

**NSF Award Numbers: 0098549, 0205815**  
**Award Title: The Nature of Metal-Poor Carbon-Enhanced Stars in the Galaxy**  
**Award Title: Collaborative Research: Fundamental Properties of Local Subdwarfs**  
**PI Name: Timothy Beers**  
**Institution Name: Michigan State University**

### **New Windows on Birth and Death in the Galaxy**

David J. Helfand of Columbia University has led a team of graduate students and collaborators in the creation of a survey of radio and X-ray images of dozens of new star birthsites and stellar mortuaries which promise to provide a complete census of the most massive stars in the Galaxy. For astronomers studying such diverse subjects as the formation of black holes, the chemical enrichment of the Galaxy, and the continuous transformation of gas to stars and back again, the new images and catalogs offer important new constraints on models for the Galaxy's ecosystem and the evolution of its constituents. The new survey of the Milky Way -- the most sensitive ever conducted -- is using the Very Large Array, coupled with the European Space Agency's XMM-Newton Observatory. The violent events surrounding the formation and death of stars generate a great deal of radiation in the radio and X-ray bands, making these wavelengths particularly well-suited for a census of birth and death in the Galaxy.

**NSF Award Numbers: 0206055**  
**Award Title: Through the Gas Darkly: Birth and Death in the Milky Way**  
**PI Name: David Helfand**  
**Institution Name: Columbia University**

### **Pulsar Bursts From Beachball-Sized Structures**

In a major breakthrough for understanding what one of them calls “the most exotic environment in the Universe,” a team of astronomers has discovered that powerful radio bursts in pulsars are generated by structures as small as a beach ball.

Tim Hankins led a research team that studied the pulsar at the center of the Crab Nebula using Arecibo Observatory. Some extremely powerful pulses contain subpulses that last



no longer than two nanoseconds. They interpret this to mean that the regions in which these subpulses are generated can be no larger than about two feet across. This fact, the researchers say, is critically important to understanding how the powerful radio emission is generated.

**NSF Award Numbers: 9809484**

**Award Title: Operation of the National Astronomy and Ionosphere Center**

**PI Name: Robert Brown**

**Institution Name: Cornell University**

### **Watching How Our Galaxy Formed**

One of the competing theories of how our galaxy formed is that it has been built up primarily by the agglomeration of many smaller pieces. Dr. Kathryn Johnston of Wesleyan University has been using her CAREER grant to focus on this process by creating computer simulations of how this might have happened. In her simulations, stars from sub-galactic “chunks” are stripped off by the tidal gravitational field of the Milky Way nucleus. Stars from many different pieces can be added together in the computer and show how a whole galaxy might have been built. If a realistic number of merging events are included, it is possible to build up something that looks similar to the stellar halo of our own Galaxy. Dr. Johnston and her co-workers are currently comparing these simulated halos to surveys of our Galaxy to determine to what extent this model of galaxy formation is compatible with the real Universe.

**NSF Award number: 0133617**

**Award Title: CAREER: Simulating the Universe from the Bottom Up**

**PI Name: Kathryn Johnston**

**Institution Name: Wesleyan University**

### **A New Galaxy**

Case Western Reserve University astronomers have announced the discovery of a new, nearby galaxy, named Andromeda VIII. The new galaxy is so widespread and transparent that astronomers did not suspect its existence until they mapped the velocity of stars thought to belong to the well-known and nearby large Andromeda spiral galaxy and found them to move independently of it. Theory has predicted for decades that galaxies are assembled in a “bottom-up” process, forming first as small galaxies that later merge to form large ones. The newly found galaxy provides support for this picture now in our nearest galactic neighbor. And VIII is being stretched and torn apart by the gravitational pull of the larger Andromeda galaxy and leaving trails of stars in the way a jet’s contrail shows its route. This work made use of telescopes at Kitt Peak National Observatory. The research was funded by an Early Career Development Award.

**NSF Award Numbers: 9624542, 0132798**

**Award Title: Astronomers Discover a New Galaxy Orbiting Andromeda**

**PI Name: Heather Morrison, William Smith**

**Institution Name: Case Western Reserve University, AURA/NOAO**

### **Galactic Building Blocks**

A team of astronomers using the Robert C. Byrd Green Bank Telescope (GBT) has made the first conclusive detection of what appear to be the leftover building blocks of galaxy

formation -- neutral hydrogen clouds -- swarming around the Andromeda Galaxy. This discovery may help explain why certain young stars in mature galaxies are surprisingly bereft of the heavy elements that their contemporaries contain.

**NSF Award Numbers: 0223851**

**Award Title: Byrd Radio Telescope Discovers Galactic Building Blocks**

**PI Name: Riccardo Giacconi**

**Institution Name: AUI, NRAO**

### **Colliding Galaxies**

Arcs of blue stars in the radio galaxy Centaurus A are the signatures of galactic cannibalism, with the main elliptical galaxy consuming an interloper according to work completed by E. Peng (Johns Hopkins U., NSF award 0098566).

**NSF Award Numbers: 0098566**

**Award Title: The Halos of Post-Merger Galaxies: A Detailed Study of NGC 5128 (Centaurus A)**

**PI Name: Eric Peng**

**Institution Name: Johns Hopkins University**

### **Formation of Globular Clusters**

Andrey Kratsov has done numerical simulations of galaxy and cluster formation that include the relevant physical processes more accurately than in previous work. The simulations show how globular clusters could have formed within the first 2 billion years of the universe and explain the correlation between the mean density of gas and rate of star formation.

**NSF Award Numbers: 0206216**

**Award Title: Galaxy and cluster formation with feedback**

**PI Name: Andrey Kratsov**

**Institution Name: University of Chicago**

### **Ionizing the Universe**

Xiaohui Fan has detected the Gunn-Peterson absorption trough in the spectrum of a quasar at a redshift of 6.4. This demonstrates that the intergalactic medium completed its transition from neutral to an ionized state around a redshift of 6, about 800 million years after the Big Bang.

**NSF Award Numbers: 0307384**

**Award Title: Probing the Cosmic Evolution**

**PI Name: Xiaohui Fan**

**Institution Name: University of Arizona**

### **Black Hole at the Galactic Center**

Recent work by Andrea Ghez has solidified the case for a massive black hole at the center of our Galaxy. Over several years, with NSF support, she has used the orbits of stars near the center of the galaxy to infer the density of the dark mass at the Galactic core. Most recently, using adaptive optics, and with a 7-year baseline, she has been able to follow the detailed orbits of a larger sample of fainter stars. One of these stars passes a mere 60 astronomical units from the central dark mass at a velocity of 9000 km/s. The

orbit of this star increases the constraints on the density of the dark mass by four orders of magnitude over her previous estimates, and eliminates several remaining alternatives to a supermassive black hole. Our own galaxy has now become the strongest case for a normal galaxy containing a supermassive black hole.

**NSF Award Numbers: 9988397**

**Award Title: A Diffraction-Limited View of the Galaxy's Central Parsec**

**PI Name: Andrea Ghez**

**Institution Name: University of California-Los Angeles**

### **Colliding Black Holes**

David Merritt and collaborator Ron Ekers explain the appearance of X-shaped radio sources as the result of the merging process of two supermassive black holes following an encounter between the galaxies that originally harbored the beasts.

**NSF Award Numbers: 0071099**

**Award Title: Colliding Black Holes**

**PI Name: David Merritt**

**Institution Name: Rutgers University**

### **Feeding Black Holes**

C. Gammie has produced computer simulations of the flow of gas being swallowed by a black hole. His work involved three undergraduate students.

**NSF Award Numbers: 0093091**

**Award Title: Theory of Black Hole Accretion Flow**

**PI Name: Charles Gammie**

**Institution Name: University of Illinois**

### **Jets from Black Holes**

Alan Marscher and S. Jorstad obtained clues regarding the process by which accreting black holes shoot energy down jets that extend out to intergalactic space. Dips in X-ray flux from the accretion-disk area of the radio galaxy 3C 120 precede the appearance of new bright spots in the jet moving at speeds that appear (via an illusion) to be faster than light.

**NSF Award Numbers: 0098579**

**Award Title: Compact Nonthermal Jets in Active Galactic Nuclei**

**PI Name: Alan Marscher**

**Institution Name: Boston University**

### **Quasar Feedback**

Mitch Begelman has calculated that such jets can deposit so much energy into the environment of a galaxy that gas is prevented from falling in. This can control the inflow of gas and therefore the growth of a galaxy containing a supermassive black hole.

**NSF Award Numbers: 9876887**

**Award Title: Outflows from Accreting Black Holes in Active Galactic Nuclei**

**PI Name: Mitchell Begelmann**

**Institution Name: University of Colorado**

### **The Magnetic Structure of Solar Flares**

The large solar flares of October 2003 were observed in exquisite detail by scientists at the National Solar Observatory. The sharpest ever images of the magnetic structures involved in flares were recorded using the adaptive optics system on the Dunn Solar Telescope. These flares and associated coronal mass ejections led to some of the largest space weather impacts of the current solar cycle.

**NSF Award: 0132798**

**Award Title: AURA Management and Operations of the National Optical Astronomy Observatory and the National Solar Observatory**

**PI Name: William Smith**

**Institution: AURA/NOAO**

### **The First Planet Discovered by Transit**

Optical Gravitational Lensing Experiment (OGLE) showed very low amplitude periodic decreases in their apparent brightness which is caused by periodic transits of a small dark object in front of a star. This star - planet system, OGLE TR 56, has the shortest known orbital period of only 30 hours. The planet is the hottest known "Jupiter-like" object. This is the first detection of a new planetary system with the candidate object identified photometrically. OGLE is one of two dozen teams searching for periodic transits, and the first to report a successful candidate. The success of the OGLE project illustrates the scientific benefit of making large datasets immediately available to the community.

**NSF Award: 0204908**

**Award Title: Optical Gravitational Lensing Experiment**

**PI Name: BOHDAN PACZYNSKI**

**Institution: Princeton University**

### **Modeling Planet-Scale Collisions**

Robin Canup, Southwest Research Institute, and Erik Asphaug, University of California at Santa Cruz, are studying collisions that shaped the Solar System. In particular, the "Giant Impact" theory has been developed in which the Moon formed from debris ejected when Earth collided with a Mars-sized body about 4.5 billion years ago. These researchers have also produced a model in which the Pluto-Charon system formed from a grazing impact between like-sized objects. Dr. Canup is scientific advisor to the American Museum of Natural History in New York for the creation of a new Rose Center show titled "Cosmic Collisions". The show will use actual simulation data of Moon-forming impacts. The show has an anticipated audience of 2 million.

**Award number: AST-0076643**

**Award Title: Planetary Collisions**

**PI Name: Robin Canup**

**Institution Name: Southwest Research Institute**

### **Asteroid Moon**

The smallest known moon of an asteroid, a 4-km moon orbiting the 189-km asteroid (130) Elektra, was discovered using observations made at the Keck Observatory by W. Merline and C. Chapman of the Southwest Research Institute.

**NSF Award: 0407352**

**Award Title: Search for Asteroidal Satellites Using Adaptive Optics**

**PI Name: William Merline**

**Institution: Southwest Research Institute**

### **B. 3 Tools**

#### **Planet-forming Disks**

The recent discovery of edge-on planet-forming disks around seven stars using an ATI funded multi-object spectrometer under a NSF research award to an independent astronomer using NOAO facilities serves as an excellent example of the above interplay between technology development and facility science.

**NSF Awards: 9731180, 0204976**

**Award Title: Toward a Complete Near-IR Spectroscopic Survey of Giant Molecular Clouds**

**PI Name: Elizabeth Lada**

**Institution: University of Florida**

#### **The Promise of the National Virtual Observatory**

A new approach to finding undiscovered objects buried in immense astronomical databases has produced an early and unexpected payoff: a new instance of a hard-to-find type of star known as a brown dwarf. Scientists working to create the National Virtual Observatory (NVO), an online portal for astronomical research unifying dozens of large astronomical databases, confirmed discovery of the new brown dwarf. The star emerged from a computerized search on millions of astronomical objects in two separate astronomical databases. Thanks to an NVO prototype, that search, formerly an endeavor requiring weeks or months of human attention, took approximately two minutes. NVO researchers emphasized the tantalizing hint this discovery offers to the potential of NVO. The discovery came at a stage when organizers were simply hoping to use NVO to confirm existing science, not make new findings.

**NSF Award Numbers: 0122449**

**Award Title: ITR/IM: Building the Framework of the National Virtual Observatory**

**PI Name: Alexander Szalay**

**Institution Name: Johns Hopkins University**

#### **An Extragalactic Atlas**

The Digital Universe project of the Hayden Planetarium announced the release of its Extragalactic Atlas on January 8, 2004. Available to teachers, researchers and the public via download from the World Wide Web, the interactive software package offers anyone with a personal computer the opportunity to navigate through accurate, colorful representations of the universe which represent the cutting edge of current scientific knowledge. The visualization tool allows users to plot stars, constellations and distant galaxies—and then to travel through them at speeds exceeding the speed of light. NSF Astronomy and Astrophysics Postdoctoral Fellow Eric Gawiser worked with Hayden staff to add data to the atlas from the Sloan Digital Sky Survey and the 2 Degree Field

Survey, which illustrate the locations of over 200,000 galaxies and quasars stretching out to the edge of the observable universe.

**NSF Award Numbers:0201667**

**Award Title: A Square-Degree Survey of Galaxies at  $z = 3-5$**

**PI Name: Eric Gawiser**

**Institution Name: Johns Hopkins University**

#### **Faintest Spectra Ever Raise Glaring Question**

A multinational investigation, called the Gemini Deep Deep Survey (GDDS), used technique known as 'nod and shuffle' to probe a redshift regime that has been excluded from ground-based observations because of interference from telluric features. A team using the Frederick C. Gillett Gemini North Telescope has shown that many galaxies in the young Universe appear to be more fully formed and mature than expected at this early stage in the evolution of the Universe. A large fraction of the stars in the Universe are already in place when the Universe was quite young, a surprising result that prompts a re-examination of the early epochs of galactic evolution.

**NSF Award Numbers: 0084699**

**Award Title: Gemini 8 Meter Telescope**

**PI Name: William Smith**

**Institution Name: AURA/National Optical Astronomy Observatories**

#### **Robotic Telescope for the Sun**

SOLIS, a new robotic telescope for solar observations over a long time frame that is funded by the NSF and designed and built by the NSO, has seen first light. SOLIS will provide unique observations of the Sun on a continuing basis for several decades using state of the art techniques. These long-term studies of the astronomical object most important to humanity will provide fundamental data to understand the solar activity cycle, sudden energy releases in the solar atmosphere, and solar irradiance changes and their relationship to global change.

**NSF Award: 0132798**

**Award Title: AURA Management and Operations of the National Optical Astronomy Observatory and the National Solar Observatory**

**PI Name: William Smith**

**Institution: AURA/NOAO**

### **B. 4 Organizational Excellence**

The Division is doing an excellent job in an increasingly complex and challenging scientific and operational environment. Attention to management of the staff and their duties has yielded a very efficient enterprise with the staff involved in many interrelated tasks that they accomplish with great energy and commitment. There is concern that the staff is not sufficiently large for the tasks now and certainly not for the planned future growth of facilities and the science to be done with them. The Division is doing an excellent job of trying to foresee and manage that growth in the face of future challenges.

## **PART C. OTHER TOPICS**

### **C.1 Please comment on any program areas in need of improvement or gaps (if any) within program areas.**

There are no perceived gaps in the scientific programs.

### **C.2 Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.**

### **C.3 Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.**

The COV notes that public relations is the responsibility of the NSF Office of Legislative and Public Affairs (OLPA). There is a single person in OLPA who handles not just astronomy, but physics, math, materials science, chemistry and other areas within NSF. The COV is concerned that having a single person in this critical position can scarcely keep the public apprised of the excellent and stimulating science produced under the auspices of the AST Division, never mind the other productive divisions.

The COV expressed concern about the required Division investment in grant programs external to the Division such as ACT and BE for which opportunities and interest are essentially negligible in the astronomy community. The COV notes that Division funds could be used more efficiently if the Division could determine the level of financial involvement in interdisciplinary or Foundation-wide activities based on how well they matched the interests of the astronomical community.

### **C.4 Please provide comments on any other issues the COV feels are relevant.**

### **C.5 NSF would appreciate your comments on how to improve the COV review process, format and report template.**

#### **SIGNATURE BLOCK:**

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For the COV for the NSF/MPS Division of Astronomical Sciences  
J. Craig Wheeler  
Chair

## Commonly Used Acronyms

AAAC – Astronomy and Astrophysics Advisory Committee (joint NSF/NASA/DOE committee)

AAG – Astronomy and Astrophysics Research Grants

AANM – Astronomy and Astrophysics in the New Millennium (the NRC Decadal survey report)

AAPF – Astronomy & Astrophysics Postdoctoral Program

AAS – American Astronomical Society

ACT – Approaches to Combat Terrorism

ALMA – Atacama Large Millimeter Array

AODP – Adaptive Optics Development Program

AST – Division of Astronomical Sciences

ATI – Advanced Technologies and Instrumentation

ATM – Atmospheric Science Division (in GEO directorate)

ATST – Advanced Technology Solar Telescope

AUI – Associated Universities, Inc

AURA – Association of Universities for Research in Astronomy

BE – Biocomplexity in the Environment

BIMA – Berkeley-Illinois-Maryland Array

BPA – Board on Physics and Astronomy

CAA – NRC Committee on Astronomy and Astrophysics

CAREER – Faculty Early Career Development Program

CARMA – Combined Array for Research in Millimeter Astronomy

CDMS II – Cryogenic Dark Matter Survey

CHE – Division of Chemistry (MPS)

CMB – Cosmic Microwave Background

CSO – Caltech Submillimeter Observatory

CTIO – Cerro Tololo InterAmerican Observatory (part of NOAO)

DOE – Department of Energy

EPSCoR – Experimental Program to Stimulate Competitive Research

ESM – Electromagnetic Spectrum Management

ESP – Education and Special Programs

EVLA – Expanded Very Large Array

EXC – Extragalactic Astronomy and Cosmology

FCRAO – Five College Radio Astronomy Observatory

GAL – Galactic Astronomy

GBT – Robert C. Byrd Green Bank Telescope

GONG – Global Oscillations Network Group

GPRA – Government Performance and Results Act

GSMT – Giant Segmented Mirror Telescope

HBCU – Historically Black Colleges and Universities

IGERT – Integrative Graduate Education and Research Traineeship

IRAF – Image Reduction and Analysis Facility (software produced by NOAO)

ITR – Information Technology Research

KPNO – Kitt Peak National Observatory (part of NOAO)



LST – Large Survey Telescope or Large Synoptic Telescope  
LSST – Large Synoptic Survey Telescope  
MIP – Major Instrumentation Program (an NOAO program)  
MPS – Mathematical and Physical Sciences Directorate  
MPSAC - Mathematical and Physical Sciences Advisory Committee  
MREFC – Major Research Equipment and Facility Construction  
MRI – Major Research Instrumentation  
MSI – Minority Serving Institution  
MSPA – Math Sciences Priority Area  
NAIC – National Astronomy and Ionosphere Center  
NASA – National Aeronautics and Space Administration  
NOAO – National Optical Astronomy Observatory  
NRAO – National Radio Astronomy Observatory  
NRC – National Research Council  
NSB – National Science Board  
NSO – National Solar Observatory  
NVO – National Virtual Observatory  
OSTP – Office of Science and Technology Policy  
OVRO – Owens Valley Radio Observatory  
PHY – Physics Division (MPS)  
PLA – Planetary Astronomy Program  
PREST – Program for Research and Education with Small Telescopes  
RET – Research Experiences for Teachers  
REU – Research Experiences for Undergraduates  
RUI – Research in Undergraduate Institutions  
SAA – Stellar Astronomy and Astrophysics Program  
SGER – Small Grant for Exploratory Research  
SKA – Square Kilometer Array  
SOAR – Southern Astrophysical Research Telescope  
SOLIS – Synoptic Optical Long-Term Investigations of the Sun  
TMT – Thirty-Meter Telescope  
TSIP – Telescope Systems Instrumentation Program  
URO – University Radio Observatory  
VERITAS – Very Energetic Radiation Imaging Telescope Array System  
VLA – Very Large Array  
VLBA – Very Long Baseline Array  
VSO – Virtual Solar Observatory  
WIYN – Wisconsin Indiana Yale NOAO telescope  
WMAP – Wilkinson Microwave Anisotropy Probe