REPORT of the COMMITTEE OF VISITORS
Division of Astronomical Sciences
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I. **INTRODUCTION**

The Committee of Visitors (COV) to the Division of Astronomical Sciences (AST) met at NSF on 2-4 April 2002. The charge to the COV was given by Dr. Robert Eisenstein, Assistant Director for Mathematical and Physical Sciences (MPS), and included the following topics to be addressed:

1) The integrity and efficiency of the processes used to solicit, review, recommend and document proposal actions, including such factors as
   a) The quality and effectiveness of merit review procedures;
   b) Selection of an adequate number of highly qualified, bias-free and conflict-free reviewers;
   c) The quality of the research and/or educational projects supported and their balance in terms of subject matter, size and duration of awards, and age, experience diversity and geographic distribution of principal investigators; and
   d) The overall technical management of the program.
2) Balance among activities such as funding for the National Centers, the University Radio Observatories, and awards to individuals.
3) Responsiveness of the Division operations and organization to evolving research trends.
4) The degree to which the award process supports the long-range goals and core strategies of the NSF as described in its FY2001-2006 Strategic Plan that addresses the Government Performance and Results Act of 1993 (GPRA).
5) Any other issues the COV feels are relevant to the review.

Dr. Morris Aizenman (Senior Science Associate, MPS) introduced the COV to the GPRA requirements and reporting, and Dr. Eileen Friel (Executive Officer, AST) outlined the COV procedures. This was followed by an overview of the AST Division programs and organization by Dr. Wayne Van Citters (AST Division Director).

The AST Grants Program was described by Dr. Vernon Pankonin (Unit Coordinator). The COV was then divided into three subgroups that reviewed the six elements of the grants program in two consecutive sessions. Each session started with a brief introduction by the cognizant Program Director. The six grant programs included

- Extragalactic Astronomy and Cosmology – Dr. Richard Barvainis,
- Stellar Astronomy and Astrophysics – Dr. Phillip Ianna,
- Planetary Astronomy and Particle Astrophysics – Dr. Vernon Pankonin,
- Galactic Astronomy – Dr. Vernon Pankonin,
- Education and Special Programs – Dr. Kathleen Eastwood and Dr. Eileen Friel,
- Advanced Technology and Instrumentation – Dr. James Breckinridge.

The review covered all proposal actions made during FY1999, 2000 and 2001. A sample of proposal 'jackets' for each of the AST program elements was examined by the subgroups. The jackets had been screened by the Executive Officer to avoid conflicts of interest amongst COV members. A total of 322 jackets were reviewed, representing 24% of the proposal actions. Notes were taken by appointed leaders of each subgroup, and were summarized to the full COV and discussed in an executive session.

Dr. Van Citters presented the AST strategic planning that is currently underway in the AST Division. He outlined the various projects that have been recommended by the recent NRC 'Survey of Astronomy and Astrophysics in the New Millennium', and reviewed their support requirements. He emphasized the need for a different process to implement the strategic plan than had been used in the past due to the large financial demands for these projects and the constraints of the AST budget.

On the second day, an overview of the Radio Astronomy Unit was presented by Dr. Robert Dickman (Unit Coordinator), and was followed by detailed descriptions of the unit elements by the cognizant Program Directors. This included:

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

In the afternoon, an overview of the Optical/Infrared Unit was presented by Dr.Van Citters (Unit Coordinator), and was followed by detailed descriptions of the sub-elements of the unit by the responsible Program Directors. This included:

- National Optical Astronomy Observatories – Dr. Daniel Weedman,
- National Solar Observatory – Dr. Daniel Weedman,
- Gemini Observatories – Dr. Wayne Van Citters.

The quality of all the presentations by the AST staff was uniformly excellent, and much care and attention were exercised by the staff in the preparations of the materials for the COV. The presentations showed a truly impressive array of accomplishments in scientific discoveries, innovative instrumentation development, and student education and training, as well as public outreach. The discussions between the COV and the Program Directors were open and frank, and all responses to questions asked by the COV were direct and unambiguous.

While the COV commends the AST staff for their professionalism and sound management, we were astonished to see the extent that each of the staff is spread amongst several major responsibilities in the Division. This can be readily deduced from the repetition of Program Director names amongst the various elements of the programs listed above.

The remainder of the COV meeting was spent in executive session, summarizing our observations and developing recommendations. Key inputs for the GPRA template were identified, and preparations of the report to the MPS Advisory Committee were initiated. A meeting with Dr. Eisenstein concluded our visit where our initial feedback on the COV primary observations and recommendations were outlined. It should be noted that all COV members were duly impressed with the openness of the NSF COV process and its value to both the NSF and the science community.

The following sections summarize the observations and recommendations from the COV review of the AST Division. The appended document contains the responses to the FY 2002 GPRA core questions and the COV evaluation according to the required GPRA template.

II. EXPANDING OUR UNIVERSE: HIGHLIGHTS FOR 1999-2001

In the last three years, the frontiers of the exploration of the universe have been greatly expanded through the advent of new instrumentation, observations, and theory. Remarkable discoveries have been made and they have changed and challenged our conventional views of the universe. These discoveries have further enriched our appreciation of astronomy, and have been fostered through various collaborative research and educational efforts. We summarize some of these highlights here under the broad themes of the NSF goals: *Ideas*, *Tools*, and *People*. Details of these and other examples are included in Part B of the GPRA template.

IDEAS: Scientific discoveries and advances

- A large number of new planets were detected orbiting around other stars using innovative techniques that measure the small gravitational effects that the planets exert on the star *(Butler, Carnegie Institution of Washington, Marcy and Fischer, UC Berkeley, Vogt, Lick Observatory, AST-9988087; Cochran and Hatzes, U. Texas, AST-9808980).*

- The surface and atmosphere of Jupiter's moon Europa were observed and investigated *(Brown, California Institute of Technology, AST-9973151),* and a satellite was discovered around an asteroid *(Merline, Southwest Research Institute, AST-9802030).*

- Images of the emission from the cosmic microwave background were created using a variety of experimental techniques, and constraints on the density parameter and cosmological constant were established based on the data *(Readhead, Caltech, AST-982989 and AST-0098734;Ruhl, UCSB, AST-9813920; Jaffe, UC Berkeley, AST-9872979; Carlstrom, Univ. Chicago, AST-0096913).*

- Advances were made in computational models to trace the evolution of the cosmic structure in the universe to its current lumpy state *(Loeb and Hernquist, Harvard, AST-0071019).*

- Constraints on the jets of energy released during gamma ray bursts were set based on observations at the Very Large Array *(Kulkarni, Caltech, AST-0098676 and AST-9803157).*

- Precise measurements of the velocities of stars near the center of the Milky Way resulted in the first detection of accelerations and provided the strongest evidence for the existence of a black hole at the center of our Galaxy with a mass of 2.6×10^6 M_{sun} *(Ghez, UCLA, AST-9988397).*

- The structure of the molecular gas in the inner Milky Way was mapped with high resolution at the FCRAO radio telescope *(Jackson, Clemens, Heyer, and Bania, Boston U., AST-9800334).*

- Advances were made in our understanding of the physical processes such as magnetic fields associated with the formation of stars *(Boss, Carnegie Institution, AST-9983530)*, and of stellar evolution including processes of supernovae explosions *(Mezzacappa, U. Tennesee,, AST-9877130).*

- White dwarfs were detected in the Galactic halo, accounting for 2% of the dark matter *(Saumon, Vanderbilt U., AST-9731438).*

- Synoptic seismic imaging of active regions on the far side of the Sun was achieved using SOHO *(Braun & Lindsey, Solar Physics Research Corp. & Northwest Research Assoc., AST-9987286).*

TOOLS: Major Instrumentation

- Construction of the 8-meter Gemini North (Hawaii) and South (Chile) telescopes was completed. The telescopes saw 'first light' in early 1999 and 2000 respectively, and are currently operational.

- Construction of the 100-m Green Bank Telescope was completed at the National Radio Astronomy Observatory, and is being commissioned through early science operations.

- The Arecibo Telescope returned to full operation following completion of the Gregorian upgrade.

- The design and development phase of the Atacama Large Millimeter Array (ALMA) was completed through an international partnership between the U.S. and Europe, and this has led to the approval of the start of the construction phase in FY 2002 under the MRE program.

PEOPLE: Education, training and outreach

- The Astronomy & Astrophysics Postdoctoral Fellowship Program (AAPF) was initiated in 2001 to provide outstanding recent PhD recipients with 3 years of support to pursue a coordinated research and educational program at the institution of their choice. Ten fellowship awards out of 51 applications were made *(AST Divisional Report, FY2001, pg 2).*

- Graduate student education in astronomy is vibrant. A total of ~300 students are supported annually by the AST Division, primarily under research grants to individuals at colleges and universities. Training opportunities in instrumentation at national and university facilities serve to develop technological expertise and represent an important investment in future leadership.

- Integration of education and research at the undergraduate level is promoted through a highly-successful REU program in astronomy at 14 sites, supporting ~125 students annually. Roughly 50% of these students are women, and 15% are from under-represented minorities. Examples:
  - Students participating in the REU program at NRAO carried out a collaborative observing project using the Very Large Array in which they discovered the first radio emission ever detected from a brown dwarf. The students' paper was published in *Nature*, and is forcing experts to rethink their theories about brown dwarfs *(Giacconi, AUI, REU AST-9731795).*
  - Students participating in the REU program at Cal State L.A. found that a recently-discovered asteroid is actually a new comet. This program, dedicated to providing research opportunities to minority students, is arguably the AST Division's most successful initiative towards creating a workforce that reflects America's diversity. *(Gregorich, Cal State LA, AST- 9820546).*

- Excellent public outreach efforts were supported by the AST Division and have been tremendously successful. A major new exhibit *'Exploring the Universe'* opened in September 2001 at the Smithsonian Institution's National Air and Space Museum *(DeVorkin, AST-0083463).* An interactive exhibit called *'Astroflow'* was installed at the Strasenburgh Planetarium in Rochester, NY. It has allowed users to interactively control, visualize and explore simulations of cosmic events such as exploding stars, comets diving into the atmosphere, and jets of gas driving through interstellar clouds *(Frank, U. Rochester, AST-9702484 – a CAREER award).*

III. AST DIVISION MANAGEMENT

The COV is pleased to report that the management of the AST Division is presently in excellent hands. The COV members were impressed with the Division Director and his vision, as well as the exceptional efficiency and organizational skills of the Executive Officer. The COV recognized that the AST Division has undergone a change in management in the past year, and has had to satisfy various demands that are marked with substantial national visibility. These include the

- NRC decadal survey of 'Astronomy and Astrophysics in the New Millenium',
- OMB-mandated review of NASA and NSF astronomy management: Committee on Management of Research in Astronomy and Astrophysics (COMRAA),
- Recompetition of the management of the National Optical Astronomy Observatory and the National Solar Observatory, and
- Initiation of the Atacama Large Millimeter Array – a complex international project under the Major Research Equipment (MRE) program.

The AST Division is handling the complex issues associated with the above initiatives with foresight and sound planning.

We are also pleased to note the excellent work of the Program Directors within the AST Division, and the vitality of the overall Division. This should enhance the community's trust and confidence in the NSF stewardship of the ground-based astronomy resources in the U.S. But we found that all the Program Directors and managers are fulfilling many simultaneous tasks and carry multiple responsibilities, as already mentioned in Section 1 of this report. While the proposal handling workload is heavy and the reporting requirements are sizable and growing as at all MPS Divisions, the launch of major astronomical projects such as ALMA and the EVLA, the planning for the large projects recommended by the decadal survey, the enhanced interactions with other Federal agencies, and the initiative to strengthen community relations, are all adding major responsibilities and stresses on the Division and its staff. The AST Division is severely undermanned.

- **Our first and most urgent recommendation is to increase the staff in the AST Division**.

The urgency is driven by the critical need to dedicate close attention and oversight to the large projects that are being started. There is substantial risk if the management of these large projects is not handled properly.

The recommendation for additional staffing also appeared in the previous COV review, but unfortunately has not been achieved. Apart from the need to add new staff positions, several existing positions are presently unfilled and this is exacerbating the situation and stressing the current staff in the Division. In order to respond to the difficulty of attracting rotators to AST, the Division has developed an innovative plan through the competitive award of Senior Fellowships in Science and Public Policy. The award would allow mid-career scientists to spend two years at NSF in public service, to be followed by two years at the home institution to reestablish or broaden their research programs. The COV strongly endorses this program and commends the AST Division for this original idea. It is hoped that this action as well as others, together with the enhanced vitality within the Division that would make it more attractive for scientists to come to NSF, will help resolve the staffing problem.

A related recommendation is the provision of an adequate travel budget for the Program Directors. This will serve to enhance their contacts with the community, maintain up-to-date knowledge of new developments and scientific results, and bring more satisfaction to their challenging work.

IV. STRATEGIES AND IMPLEMENTATION PLANS

One of the major challenges currently confronting the AST Division is the development of a sound response to the initiatives for ground-based astronomy identified by the U.S. astronomical community in the NRC Survey of Astronomy and Astrophysics for this decade. The survey has set the community's priorities for various projects based on scientific merits and on the technological developments required to maintain U.S. leadership in astronomy.

The AST Division Director has recognized that the current process for determining how best to implement the recommended initiatives, namely through unsolicited, unmanaged proposals, is not adequate, and a new process needs to be identified. Various possible approaches were presented and discussed with the COV, and the benefits of each were reviewed. It was clear that no single approach would be applicable to all projects, and a mix of different approaches would provide the best response to the various initiatives on both the large and moderate scale. We commend the AST management for its recognition of the need to prepare a plan at the earliest possible time for the implementation of the decadal initiatives in order to maximize progress across the various disciplines in astronomy. We also commend the AST Division for initiating preliminary design studies in the community for several of the new projects, and for encouraging the community to take advantage of various NSF-wide initiatives such as ITR, MRI and other programs to support some of these studies.

- **The COV recommends that 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 community in the NRC Decadal Survey. The Division needs to actively engage the community on a continuing basis in the planning effort.**

There are two classes of projects within the decadal initiatives. Large telescopes with costs over $80M clearly belong to the MRE category and need to be developed sufficiently so they can compete within that budget category. Moderate projects in the $10M class are currently difficult to plan since there is no process to handle them within the constrained AST budget. A careful phasing of these projects based on their readiness needs to be prepared.

Initial funding requirements over the next decade for both the large and moderate projects have been estimated. The profile indicates a need for a steady enhancement of the AST Division budget by about $40M over the next 6 years to support the moderate initiatives. Such an increase would not be inconsistent with the desired enhancement of the overall NSF research budget.

The AST implementation plan when completed can set the budget goals clearly, and the MPS Directorate can hopefully use this plan to justify the requests for the out-year budgets. The COV inquired about the budgeting process within NSF, and although the details of the budget build-up for a particular year remained unclear, the COV encourages that the implementation plan be seriously considered in setting the future budget requests for the AST Division.

V. PROGRAMS

RESEARCH GRANTS

The COV subpanels considered each of the proposal categories in the research grants to individuals, namely Planetary Astronomy (PLA), Stellar Astronomy and Astrophysics (SAA), Galactic Astronomy (GAL), Extragalactic Astronomy and Cosmology (EXC), Advanced Technology and Instrumentation (ATI), and Education and Special Programs (ESP). Overall, 322 proposal 'jackets' in the FY1999-2001 period were reviewed, providing an adequate sample for assessment (24% of all proposal actions). We note that the AST Division has implemented a review process primarily based on expert panels in order to allow a ranked comparison amongst proposals in the different subfields. We present below some general observations and recommendations, and then summarize each of the subpanel reviews and comments for the various AST programs.

As a whole, the COV was impressed with the extensive documentation, appropriate review panel composition, and fairness of the awards. Because of the relatively small size of the AST community, arranging for panels is a challenge for the Program Directors, and we commend them for their efforts in seeking and constructing these panels. The COV found that the review process is fundamentally strong and efficient, and possesses the necessary integrity.

The COV also examined how well the AST community is responding to the 'broader impact' criterion and how well the review panels value this criterion. It was found that most proposers at least mention the broader impact of their research in general terms, although most do not identify it specifically in a special section of the proposal. Many of the NSF-supported programs in the research grants involve students, both at the graduate and undergraduate level, and are therefore helping in the general scientific education of the workforce and in the training of future generations of scientists. The COV did note an improving trend between FY2000 and FY2001 where the importance of specifically discussing the broad impact of the research work is being more widely appreciated by the community. On the other hand, it appeared as though only a minority of the panel reviewers have so far actually used the broader impact criterion in their assessments. Although it is recognized that this criterion may not apply to all researchers, the COV expects that it would be a relatively easy criterion to fulfill by the astronomy community if it were better understood. It should be recognized for example that the criterion extends to education at all levels, beyond K-12 outreach.

- **The COV recommends that the AST Division explore new ways to enhance the AST community's response to the 'broader impact 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.**

One general concern was shared by the COV. The future of astronomical research rests on the shoulders of the youngest members of the profession. However, many institutions have rules that prohibit all but permanent members from becoming Principal Investigators for grants. This has fostered a system where junior researchers often have their work submitted for funding by more senior colleagues. While the senior colleagues will generally mention the contribution of the junior researchers in the proposal, there is no official recognition of their contribution. NASA has created a title of "Science PI" to recognize this problem. The normal PI still has overall and fiduciary responsibility for the grant but the contribution of the junior researcher is officially enunciated and

tracked. This approach is very beneficial for the future careers of junior researchers and formally recognizes their important contributions, while meeting institutional rules. We realize that the NSF proposal forms need to apply to all divisions, and suggest that NSF consider incorporating a similar mechanism of Science PI for NSF grant proposals to encourage our future scientific leaders.

1. Planetary Astronomy (PLA)

The Planetary Astronomy Program provides funding for U.S. astronomers carrying out theoretical and observational studies of the detailed structure and composition of planetary surfaces, interiors, atmospheres, and satellites; the nature of small bodies (asteroids and comets); the origin and development of the solar system, and related laboratory studies.

Planetary Astronomy is unique amongst disciplines of astronomical research because, though NASA does not in general fund ground-based astronomy, ground-based planetary astronomy is funded through both NSF and NASA. However, the NASA funding is generally tied to mission-specific science. The NSF Planetary Astronomy Grants Program offers a funding source that is not tied to specific mission goals and is very complementary to the NASA funding. The NSF Planetary Astronomy Program Director appears to maintain excellent communications with his counterparts at NASA, thus avoiding program overlap.

The Planetary Astronomy program offers a special challenge for proposal review because of the breadth of the discipline. Proposals can range from observational to theoretical to laboratory projects, and from solid surfaces to atmospheres to icy bodies. Thus, in a review panel of only 4 or 5 members, it is quite likely that the breadth of the proposals will exceed the expertise of the panel members. Recognizing this, it is important to consider soliciting external (*ad hoc*) reviews when the research base of the panel experts does not adequately cover the PLA subfield for the particular proposals under review.

2. Stellar Astronomy (SAA)

The program encompasses a broad range of observational and theoretical studies of stars. In particular, these studies involve the formation of stars, the fundamental physical parameters, structure and evolution of the Sun and normal stars, the characteristics of stars in the Milky Way Galaxy as probes of stellar age and composition, the processes by which stars return material to the interstellar medium via winds, large scale mass loss and supernova explosions, and the end stages of stellar evolution such as white dwarfs, neutron stars and black holes.

The COV subpanel concluded that the proposal review process for the SAA section is working well, and was impressed with the strengths of the review panels assembled. In all cases examined, the panels had sufficient experts to evaluate the wide-ranging variety of proposals.

There was much discussion of a few cases where proposals fell on the borderline for funding. It eventually became clear why they were or were not funded; most of these were programmatic decisions made by the Program Director. Some members of the subcommittee inquired whether the panels might be able to help the Program Director in setting priorities for those borderline cases. Without attempting to infringe on the discretion of the Program Director, it was suggested that perhaps the panels might at least give some opinions or advice to the Program Director about the

weight to be ascribed to those borderline proposals in terms of scientific diversity, gender equity, geographic concentrations, new investigators, etc.

3. Galactic Astronomy (GAL)

The Galactic Astronomy program, in response to the rapidly changing scope of the Extragalactic Astronomy and Cosmology program, expanded in 2001 to include galaxies beyond the Milky Way to the Local Group galaxies, and further added in 2002 nearby galaxies at distances up to a few Mpc. This change is appropriate because the increasing resolution and sensitivity of modern observational facilities has made it possible to study nearby galaxies in similar detail to conventional studies of the Milky Way.

Care must continue to be taken to ensure that review panels cover the wide variety of fields appropriate to the expanded scope of GAL proposals. In 2001, the proposal review process carefully divided the proposals into panels with emphasis on interstellar medium, stellar populations, and fundamental astronomy and processes. The results of the proposal review appear to be fair.

4. Extragalactic Astronomy and Cosmology (EXC)

The COV subpanel for this section was uniformly impressed not only by the completeness of the reviews written by the panel, but also by the fairness and sensitivity of the overall action provided by the Program Director both in written and verbal feedback to the PI. The COV noted that individual reviews, while clearly providing a useful independent assessment of a proposal, were often reconsidered during the panel discussion where the panelists had the benefit of being able to compare the merits of one proposal against all of the others under consideration and were able to hear from other experts with different perspectives. The COV found that the overall review benefited from the 'give-and-take' during the panel discussions, and that the summary provided by the NSF program officer presented a fair and comprehensive picture of the total review process.

The EXC section continues to be the largest of the four research programs within the Astronomy Research Grants unit. The COV noted that the 'funding rate' of EXC proposals increased from 27% to 31% between FY1999 and FY2001, but was slightly below that of the other three research grants programs. Perhaps this was a reflection of a conscious effort not to fund larger numbers of proposals with smaller dollar awards. Given that the average dollar amount awarded over all AST research grants is already too small (~$75,000) to adequately fund even a single postdoctoral researcher, and that the pressure to fund many meritorious proposals is great, the COV understands that difficult choices need to be made when considering the number of proposals to accept. We agree that the mean dollar awards should not be allowed to dip much further below current levels.

In considering the future health of the program, the COV expressed a few concerns about the increasing scope of the EXC program. The COV cautioned that the proposal pressure on the EXC program may become even more severe with the continued growth of the numbers of proposals to study new and exciting phenomena associated with the very early Universe. The COV noted a continued shift in proposals submitted to the EXC program away from studies of individual, nearby galaxies and AGN to studies of large-scale structure, gamma-ray bursts, and other high-z phenomena. Members of the COV were concerned that meritorious studies of nearby galaxies might be shortchanged, either by assigning them to the Galactic Astronomy program or by not having a sufficiently large subset of panel reviewers who were expert in studies of nearby galaxies. As has

been mentioned in section 3 above, the AST Division needs to be vigilant in finding expert reviewers to ensure that all topics covered by proposals assigned to the EXC program have adequate scientific representation on the EXC review panel.

5. Advanced Technologies and Instrumentation (ATI)

The ATI program supports the development of innovative instrumentation at all wavelength bands used in astronomical research. The ATI Program Director also administers the astronomical proposals submitted to the NSF-wide MRI program, and the Advanced Electro-Optical System (AEOS) program that provides access to the Air Force's 3.8m-telescope on Maui, Hawaii, in collaboration with AFOSR. Administratively, the ATI program is part the O/IR unit within AST.

Inspection of the proposal jackets by the COV indicated that the proposal review process was handled fairly for all of the above programs. The review panel recommendations were internally reasonably consistent, and the actions taken by the Program Director were generally compatible with those recommendations. In the few cases where the panel recommendations were not followed, the rationale seemed reasonably clear and justified. For example, in one case the Program Director funded a risky but highly innovative project, led by a powerful team, that had a very large potential payoff. This particular example illustrates what we perceive to be a wise use by the Program Director of his discretion to achieve an appropriate balance between reasonably assured and risky projects.

The COV noted an explicit recognition in the ATI program to support the training of the next generation of astronomy instrument builders. An interdisciplinary post-doctoral fellowship program competed across the MPS Directorate may be one solution. Because instrument development is fundamental to astronomy's continuing success, the COV suggests that an aggressive approach be pursued to making graduate and post-doctoral fellowships in instrumentation available outside of grants. For example, students and post-doctoral researchers could receive fellowships to train on, and contribute to, otherwise fully funded projects at national centers, observatories, or universities.

Finally, it is apparent that the ATI program is extremely diverse. Although the ATI program's website appears to have all the pertinent program information, the COV suggests that the ATI Program Director provide additional clarification of the distinctions among the various technology sub-programs (e.g. ATI, MRI, AEOS, TSIP) to further assist interested investigators in obtaining information about the program efficiently.

EDUCATION AND SPECIAL PROGRAMS (ESP)

The AST Division is well positioned to help advance science education within the United States through the captivating interest that astronomy provides and the broad appeal that it possesses. AST's ESP covers education and training at all levels, as well as public outreach. Its goals include supporting innovative new projects in education and outreach, and providing incentives to researchers in order to integrate education as part of their research programs.

The ESP core programs include faculty early career development (CAREER), Research Experiences for Undergraduates (REU) and for Teachers (RET), the Astronomy and Astrophysics Post-doctoral Fellowships (AAPF), and Research at Undergraduate Institutions (RUI). ESP also represents AST's involvement in NSF and MPS cross-cutting programs such as ADVANCE which aims at increasing the participation and advancement of women in science careers, and the MPS Distinguished Research

Fellowship Program (DRF). The COV was impressed with the management of the rather diverse ESP program. Examination of the jackets showed excellent proposal processing, including thoughtful reviews, appropriate allocation of awards, and sensitive communications between program officers and proposers.

The CAREER program is the most visible implementation of the strategy to provide incentives for researchers to be engaged in education. The COV commends the ESP Program Directors for their commitment to insuring that the CAREER program of the Astronomy Division accomplishes its goal of fostering both forefront research programs and advanced education initiatives in young faculty. Over the three years reviewed by the COV, there has been a notable improvement in the quality of the education components of the CAREER proposals. This change in the community response is a direct result of the resolve of the Program Directors to support excellence in all facets of the successful CAREER proposals and to broader expertise in the review panels.

Another commendable development in ESP is the initiation in 2001 of the Astronomy and Astrophysics Post-Doctoral Fellowships program which is a three-year fellowship portable to any institution, and which must include an educational component. The strong response of 51 proposals is a clear endorsement of a felt need fulfilled by the program. Equally important is the fact that 9 of the 10 initial offers were accepted, in some cases competing with prestigious Hubble Fellowships with similar benefits but solely a research mission. This is seen as a clear statement that young Ph.D.'s are at the vanguard of a broadening perspective on the roles of forefront scientists. In addition, the COV was particularly pleased with the number of awards in astronomy (6) for the first year of the MPS DRF program.

The REU site programs in astronomy have been most effective in training students and attracting them to science, and students have enjoyed the discovery aspects of astronomy through observations at various radio and optical telescopes. There are currently 14 active REU sites in astronomy, and the number appears to be limited by community interest in supporting sites rather than by NSF funding. This was of concern to the COV, particularly as there also appears to be some turnover in REU sites. REU sites are often initiated enthusiastically by a researcher, but the program is not generally institutionalized possibly due to the lack of adequate funding support for infrastructure at some sites. In other words, when an REU site director moves on, the cost of program maintenance is too high to be attractive for replacement by new leaders.

We commend the AST Division for pursuing and encouraging outreach activities to bring the excitement of astronomy to the public. The support provided for the exhibit at the National Air and Space Museum when EHR was unable to jointly support it for administrative reasons is an excellent investment. Encouragement of the visitor centers at NAIC, NOAO, NSO, and NRAO, is laudable and will amplify the message to the public about the importance of investments in science and in the education of the next generation of scientists in the U.S.

More broadly, the COV feels that it is essential that efficiencies in ESP be gained through more active collaboration by the Program Director with other MPS divisions, and preferably with divisions in other Directorates such as EHR. The similarities of education initiatives across research divisions are far greater than the disciplinary differences; it makes little sense for each to innovate and evolve independently. The COV was pleased to hear about the Education Working Group organized by the OMA Director within MPS, and to see the Internships in Public Science Education (IPSE) program

arise from this collaboration. This Working Group is well poised to develop a strong strategy for education and public outreach across all the MPS divisions.

NATIONAL CENTERS AND OBSERVATORIES

The COV heard comprehensive presentations from the Program Directors responsible for oversight of the astronomy national centers. This included the operations of the national facilities and some of the new major projects that are being undertaken in AST. The presentations covered the radio astronomy unit and its facilities – the National Astronomy and Ionosphere Center (NAIC), the National Radio Astronomy Observatory and the ALMA project, and the University Radio Observatories (URO). A most interesting presentation on Electromagnetic Spectrum Management (ESM) was also provided. Presentations on the optical/IR unit covered the National Optical Astronomy Observatories (NOAO), the National Solar Observatory (NSO), and the Gemini telescopes. We summarize our evaluations of each of these Centers and Observatories below.

1. Radio Astronomy Facilities Unit

The Radio Astronomy Facilities Unit consists basically of three parts: (1) the National Centers of NRAO and NAIC, (2) the University Radio Observatories (UROs), and (3) the Electromagnetic Spectrum Management (ESM). These are three parts of a coherent whole with the National Centers providing unique major instruments that are beyond the scope of any single university or consortium of universities; the UROs providing unique and productive, but smaller scale, instruments which are available as training platforms for students in addition to their forefront research activities; and the ESM coordinating protection and sharing on a national and international scale primarily for the heavily oversubscribed radio frequency spectrum. These three components help to maintain and improve the strength of US radio astronomy in particular and its contribution to astrophysics in general. Oversight of these facilities by the NSF appears strong and is directed towards the need to maintain diversity, quality, and balance among these facilities. Maintaining balance between a center as large as NRAO with a budget of ~$40M/year, and a small URO such as the CMVA with a budget of ~$0.4M/year, while phasing out older facilities and establishing newer ones, is very challenging. However, the AST Division appears well aware of the difficulties and is establishing mechanisms to maintain and, to the greatest extent possible, increase the vitality and diversity of the Radio Astronomy Facilities Unit.

(a) NAIC

An extensive upgrade of the Arecibo radio telescope has been completed, and this facility – the largest in the world – remains an important tool for astronomical research. This fact is demonstrated by a number of scientific highlights that resulted from Arecibo observations, including continuation of a long history of discovery and study of Galactic pulsars, discovery and investigations of low-surface-brightness, dark-matter dominated galaxies in the local Universe, spatially resolved studies of Galactic and Local Group High-Velocity Clouds, and high-resolution radar maps of the surface of Venus and of near-Earth and main-belt asteroids. The radar observations are supported by NASA.

NAIC has for many years been one of the leaders in the area of education and public outreach. The Visitor and Education Facility has an astonishing 120,000 visitors per year. A new Science Teacher

Training Course is an example of Arecibo leading the way in this area, and this activity could provide a model in pre-college science education for other national centers.

The committee's concerns for NAIC in the longer-term involve the potentially redundant capability between Arecibo and the newly commissioned Green Bank Telescope (GBT), and the relatively lower demand for observations at Arecibo (oversubscription ratio of 1.8) compared with some of the other NSF AST facilities. The track record of excellent science based on Arecibo data strongly suggests that it is currently a vital and well-utilized facility. The demand for Arecibo capabilities in the GBT era will need to be monitored.

(b) NRAO

NRAO is a very well-managed and highly productive national center. It offers instrumentation which is unique in the world and which has kept US radio astronomy at the forefront. NRAO's facilities attract scientists from many other countries, and some 30% of the institutions making use of NRAO telescopes are foreign. NRAO annually provides about 20,000 observing hours to 950 different observers. As of 2001, it is operating only three facilities – the VLA, the VLBA, and the GBT – all world-class. In 2000, the 12-m radio telescope at Kitt Peak was closed, and its key staff are now supporting the development of ALMA.

The three facilities operated by NRAO offer an excellent balance of sensitivity and resolution. Although it is now 20 years old, the VLA continues to be highly productive. NRAO's plan to upgrade the VLA (the EVLA-1 program), leading to an increase of a factor of 10 in sensitivity, is well-considered and is a high pay-off investment for the future. The GBT is only now coming into full-time operation and will be the premier single-dish radio telescope in the world. Although the larger NAIC Arecibo telescope has higher sensitivity for some applications than the GBT, the full sky coverage of the GBT, allowing long integration times and larger source samples, gives it a significant net advantage.

NRAO's Central Development Laboratory deserves special mention for its leadership in developing state-of-the-art high frequency receiver technology. It is not widely known, but the recent explosion in observational cosmology based on measuring structure in the Cosmic Microwave Background is largely owed to technologies produced by the CDL. NRAO detectors are, for instance, the heart of the ongoing NASA MAP mission. This, in fact, is an area where both NSF and NRAO could have done more to publicize a unique contribution to a highly conspicuous scientific frontier.

(c) ALMA

The Atacama Large Millimeter Array (ALMA) is one of the most anticipated new facilities in astronomy. It has undergone an extended planning and development period, with what appears to be unusually careful attention to cost containment. NSF and NRAO are to be congratulated for having secured initial construction funds for FY 2002. Nonetheless, ALMA is a complex project, not only because of the technology involved but also because of the challenge of construction at high altitude, and the project's international structure. NSF current staffing in support of ALMA is not thought to be sufficient, and we recommend that one additional full-time position be assigned to the project. Since ALMA is funded through the MRE program, it may be appropriate that additional management personnel be supported from MRE resources, if such funds could be used for this purpose.

(d) URO

The University Radio Observatories (UROs) play a vital role in the training of students and providing the sort of direct contact with instrumentation which is not possible at the large national centers. In addition to their training role, the UROs are expected to provide unique facilities and to be world leaders in their research areas. There are currently five UROs supported by NSF: (1) the Caltech Submillimeter Observatory (CSO), (2) the Five College Radio Astronomy Observatory (FCRAO), (3) the Owens Valley Radio Observatory Millimeter Array (OVRO), (4) the Berkeley-Illinois-Maryland Array (BIMA), and (5) the Coordinated Millimeter VLBI Array (CMVA) at the MIT Haystack Observatory. These are powerful instruments which carry out research in unique areas of radio astronomy, provide access to the broader community of U.S. and world astronomers, and have a long record of successful research and training of high quality astrophysics and instrumental students. Currently the UROs support approximately 500 users per year, have more than 80 PhD students and postdocs working at the observatories, and publish ~190 scientific papers per year. They have produced approximately 90 PhDs over the past 10 years.

As is appropriate, and in spite of such a record of success, there is continual review and transition of the UROs to insure that they remain forefront instruments while still providing the vital student training function. CSO is the youngest of the UROs and will continue to develop, upgrade, and improve its facilities on Mauna Kea, Hawaii. FCRAO is expected to transition to the joint US/Mexico Large Millimeter Telescope (LMT) over the next few years after its completion in 2005. The OVRO and BIMA arrays are planned to be combined at a new, higher elevation site in 2004-2005 to form the Combined Array for Research in Millimeter Astronomy (CARMA). The CMVA, which uses a global array of radio telescopes for its observations, will phase out in FY2003 as the Very Long Baseline Array (VLBA) is upgraded for operations at 3mm-wavelength. Such changes and transitions are proper for maintaining the UROs as forefront research and training facilities. To insure proper coordination, uniqueness, and challenging goals for the UROs, simultaneous competitive reviewing of all of the URO proposals is planned in Summer 2002 for requested FY2003 funding.

In summary, the URO program appears to be active, unique, and vital to the health of US science and technology development. If there is a concern, it is that the planned improvement and expansion of some existing facilities and closing of others may to lead to an over-consolidation of UROs and a potential decrease in their collective capability to allow student training. Consideration should be given to 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.

(e) ESM

The work in the AST Division regarding electromagnetic spectrum management and the concerns about the threats to the electromagnetic spectrum for radio astronomy was presented, and was indeed an 'eye-opener' for the COV. The 1999 CD movie by NSF on *"Radio Astronomy: Observing the Invisible Universe"* is an excellent presentation of the challenges facing ESM. There are tremendous commercial pressures threatening the small percentage of the EM spectrum available to radio astronomy. As the technology is becoming available to make exciting observations in the atmospheric windows between 70 and 300 GHz, it is imperative that the efforts of the NSF, in particular the NSF responsibilities to safeguard the ESM for astronomy be given full support. The COV is concerned that these efforts require more than the one FTE position devoted to this issue.

2. Optical/IR Unit

The Optical/Infrared Facilities Unit oversees the operations of several independent programs, including NOAO, NSO, the U.S. Gemini Project, and the recently-initiated Telescope System Instrumentation Program (TSIP), managed by NOAO. The ATI program is administered as part of the O/IR unit, but has been covered earlier. Except for a small increase in the past three years due almost entirely to the Gemini project, the budgets for the Unit were pretty flat in the nineties. The individual components of the Unit will be described in more detail below.

The major concern with such a diverse O/IR program is the challenging development of an optimum "investment" strategy not only for the near-term, but also for the next decade. One must balance the sometimes conflicting needs to provide telescope access, research support, development of next generation instruments, training of new scientists, and broader education and outreach goals. The O/IR Facilities Unit plays a different role in the community than the Radio Unit, owing to the proliferation of private optical observatories. The committee applauds initiatives, such as the Telescope System Instrumentation Program (TSIP), that are designed to provide access to the private facilities by the general community. This would help counteract to some extent the decline in access to NOAO telescopes, where facility closures and transfers to private groups are being traded for the development of future initiatives, such as the Large-aperture Synoptic Survey Telescope (LSST) and the Giant Segmented Mirror Telescope (GSMT) recommended by the NRC Decadal Survey.

(a) NOAO

The COV recognizes the important role of NOAO in the maintenance and growth of optical and infrared astronomy and astrophysics. State-of-the-art ground-based optical and infrared observatories have made significant contributions to scientific discoveries and play an essential complementary role to space-based observatories and space missions. NOAO facilities provide astronomers from all institutions access to premier telescopes, and for many astronomers, the only access to such facilities. NOAO observatories also serve the important function of providing the opportunity and facility for development of new instrumentation and the training of astronomers and instrument builders of the future. NOAO is faced with difficult choices in fulfilling its mission to provide advanced facilities and continuing maintenance and upgrade of existing observatories in view of necessary fiscal constraints and current uncertainty in the NOAO management contract. NOAO is managed by AURA, and its management contract has been recently recompeted, with results to be released soon.

The COV is pleased to see that reforms in the technical management at NOAO Tucson recommended by the previous COV have been addressed. We also recognize the decision to shut down NOAO operation of most telescopes smaller than 4-m and transfer most to private institutions. We commend the NOAO for taking proactive steps to strengthen the program and provide the resources and opportunities for growth of new facilities and technologies.

At the same time, the COV expressed concern, echoed by the 1999 Portfolio Allocation Review and the general community, about reduced public access to NSF-supported national nighttime optical facilities. NOAO has restructured its KPNO and CTIO operations and has added part-time access to the Gemini, WIYN, and SOAR telescopes. However, in 2003 the number of observing nights NOAO will be able to offer to the general US community will be a factor of 2.5 smaller than in 1990. Partly as a cost-saving measure, significant amounts of 4-m time have also been dedicated for specialized observing campaigns and surveys, further limiting access by the general user. This reduction in

access seems likely to have a negative impact on exploratory or risky programs, instrument development, student training, PhD thesis projects, and access to public telescopes by smaller college and university faculty and students.

The COV does not believe that the new large (8-m class) facilities alone can provide adequate time to address these goals. We recommend that NSF provide sufficient support to NOAO such that no further reduction in public access to first class optical/IR facilities becomes necessary. One specific concern was the potential elimination of support for instrument development at the remaining 4-m telescopes and even the possible closure of the facilities themselves. The COV believes the continued support of the 4-m class facilities and continued support for instrumentation for these facilities must be maintained. The plan to eliminate support for such instrumentation developments on 4-m telescopes needs to be reexamined.

- **The COV recommends that a vital instrumentation program be maintained for the 4-m class telescopes to which the national community has access.**

The COV further suggests that NSF/AST and NOAO need to present a clearer vision of the role of the remaining suite of NOAO telescopes and how their mission to train a new generation of optical and infrared astronomers will be accomplished. The use of the TSIP and creation of a program analogous to the highly successful radio astronomy UROs may be one approach. The NOAO should also consider a mechanism for at least partial support for facilities transferred to universities such that they can be made accessible to the entire astronomical community.

The COV also recommends the NSF/AST and NOAO examine the possibility of establishing observing travel support for observers granted time on NOAO facilities. A long-standing successful program at the NRAO can be used as an example, and will help build a stronger community of users.

(b) GEMINI

The COV is pleased with the progress in the Gemini program. Gemini is an excellent example of a successful large international project managed in the AST Division. Now that the construction phase has been completed, there is some concern regarding adequate funding for instrumentation and upgrades. AST should examine the instrument and operations budget to optimize Gemini capabilities. Unique approaches, such as currently proposed, involve trading of Gemini time for NASA time on Keck telescopes to enable access to a broader instrument complement. Additional leveraging of NASA, DOE and DOD development can also enhance Gemini capabilities. Particular use could be made of the enhanced NSF/NASA partnership, as recommended by the Committee on Management of Research in Astronomy and Astrophysics (COMRAA).

(c) NSO

The National Solar Observatory (NSO) operates solar instrumentation at two major sites---Kitt Peak and Sacramento Peak--for the benefit of the astronomical community. Formerly part of NOAO, NSO now is an administratively separate entity, although still managed by AURA under a cooperative agreement with NSF that includes NOAO. Solar Physics is an area of astronomy that has particular relevance to society and commerce, as for example the rapid growth in "space weather" activities over the past decade can attest.

NSO runs the two workhorse US solar telescopes: the 76-cm Dunn Solar Telescope at Sac Peak and the 150-cm McMath-Pierce (largest in the solar world) at Kitt Peak. NSO scientists have developed an adaptive optics system for the Dunn, making it one of the premier solar imaging instruments, despite its continental mountain site. The McMath-Pierce, with its all-reflecting unobscured design, is well suited for infrared work, particularly in the thermal IR beyond 3 microns. In addition to the major facilities, NSO operates the GONG project, to study global solar oscillations by means of a world-wide network of semi-autonomous monitors. NSO is also building SOLIS, an instrument cluster to provide high-precision synpotic solar measurements for research and space weather applications. Finally, NSO is designing the next generation solar facility – the Advanced Technology Solar Telescope (ATST), a 4-m off-axis system with adaptive optics yielding unprecedented resolution and sensitivity.

The committee commends NSO for its forward-looking program to provide new tools for the solar community. At the same time, NSO is faced with enormous technological challenges in the design of ATST, while constrained budgets have depleted the staff leaving fewer people to shoulder the burden. In addition, the crucial site selection process for ATST could become politicized, with potentially negative impacts to the current momentum of the project. Site consolidation represents an additional future complication that NSO will have to face after ATST is built. If these issues can be solved, solar physics faces a bright new future, indeed.

It also was noted that the new visitor center at Sac Peak has become a valuable education and public outreach tool not only for NSO, but also for the nearby Apache Peak Observatory where the Sloan Survey is being conducted.

VI. BALANCE OF PROGRAMS

Within the confines of a finite budget, it is imperative that the AST Division maintain an appropriate balance of its programs. The Portfolio Allocation Review (PAR) Committee, assembled as a result of the previous COV review, addressed this issue in its report of December 1999. Many of the PAR recommendations have been addressed by the AST Division. Based on the PAR report and on the presentations and documents presented at the COV meeting, the COV believes that, overall, the AST Division is currently allocating its resources in a productive way, but pressures will continue from various directions to adjust the balance as new demands and opportunities arise. The AST Division must maintain its flexibility and sustain a well-balanced program.

The AST Division has implemented a good organizational change for its Research Grants program. It created one research unit allowing for the funds within the four research subfields (PLA, SAA, GAL, and EXC) to adjust to the community's demands and pressures. We have noted that such adjustments have already occurred, but found that the SAA and PLA funded awards remain on average at a lower level than the other subfields thus needing some further attention in the future.

We were pleased to find that the overall level of support to individual researchers under the Research Grants Program increased steadily by about 20% over the past three years. The success rate for AST proposals has also improved and reached ~33% in FY2001. But we continue to be concerned that the funding level of AST research grants (~$75,000) remains much lower than the overall NSF level.

Our concern about the core support stems from another aspect. NSF now has many directed programs and in some of these, AST has difficulty competing (e.g. biocomplexity and nanoscale

technology). The special initiatives, while important to the overall NSF program, appear to represent an increasing fraction of the total AST budget and will reduce flexibility for budget management if they continue to grow. The COV emphasizes the importance of strengthening the core research programs in NSF/MPS, and discourages further proliferation of directed initiatives.

The COV recognizes that the AST community has had some success in a few of the directed initiatives such as the Information Technology Research (ITR) and Major Research Instrumentation (MRI) programs. For example, the National Virtual Observatory (NVO), initiated through an AST Small Grant for Exploratory Research (SGER) award *(Szalay, Johns Hopkins, AST-9876645)*, has been funded by ITR at a $10M level for the next five years. However, based on a sampling of the COV members, it appears that the characteristics of the various NSF-wide initiatives relevant to astronomy are not well understood by the AST community and not many astronomers are taking advantage of these opportunities to the extent that the COV believes is possible. As long as these special programs continue to exist, the AST Division's help is needed to clarify them for the astronomical community.

Similarly, the COV noted the surprisingly low number of grant proposals (20) to the RUI program, and suggests that the RUI, ROA, and ADVANCE programs need to be better publicized among colleges. The AST Division could take better advantage of the opportunities afforded by the MRPG, MCAA, and DRF/IPSE programs if there were greater awareness of these programs. We acknowledge that these opportunities are publicized at AAS meetings, and but more effort is needed.

- **The COV recommends that the AST Division should help clarify the 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**.

The COV discussed the balance of funding between the radio and optical observatories. The COV recognizes that the NSF's emphasis on radio facilities is a product of the different histories of radio and optical astronomy and the traditional availability of private or state support for optical observatories. Nonetheless, the success and high productivity of the URO program over the last 15 years in developing mm-wave technology that has culminated in the ALMA project is an excellent model to emulate for the optical/IR community. A university-centered optical/IR program could similarly be valuable in exploring technology for the large ground-based optical/IR telescopes planned for the next decades.

As previously noted, the COV is concerned that the national optical observatories continue to provide access to all astronomers, as stated in the charter of the NOAO. The COV recognizes that the emphasis on producing forefront science is the proper guiding principle in building larger telescopes at the expense of smaller ones. Nonetheless, there is some concern that privatizing the smaller telescopes, perhaps eventually including the 4-m, will restrict public access to observatories and therefore diminish opportunities for training graduate students in instrumentation and for observing by astronomers from institutions that cannot afford their own telescopes. The COV recommendation in this regard has been expressed under the NOAO program (section 5.2.a).

The ongoing travel funding to the Infrared Telescope Facility (IRTF) and to NRAO facilities prompted the implicit question of uniformity in travel support across all national observatories. The COV believes that the possibility of providing NSF funds to travel to observatories when observing

time has been awarded should be reconsidered by all national centers, particularly in such cases where the travel is not supported by other funding. A careful set of criteria should be developed to decide such support in an equitable manner.

The COV applauds the efforts of various programs within AST to seek national and international cooperation in planning and building new large telescopes. We commend the implementation of partnerships that have resulted in the Gemini and ALMA international projects, and endorse further efforts along these lines. Such joint cooperation is essential to produce the most scientifically productive and cost-effective telescopes of the future, to be usefully accessed by all astronomers.

The COV was pleased to learn of coordinated programs within AST with NASA, DOE, and AFOSR. In particular, COV endorses the recent COMRAA report and recommendations. Since NSF and NASA fund most of the major astronomical projects, we believe that the joint NASA/NSF advisory committee suggested in the COMRAA report is absolutely critical for program coordination and for development of an integrated strategy for astronomy and astrophysics. We were pleased to hear that interactions between NSF and NASA staff have been initiated, and that efforts are under way to charter a National Advisory Committee for Astronomy and Astrophysics. Enhanced communications between NASA and NSF will strengthen the overall U.S. astronomical research program. However, we also recognize that NASA and NSF are very different types of agencies. NSF responds to research driven by individual or group initiatives, while NASA supports mission-oriented research – both of which are needed in our overall national program. We caution, however, that the enhanced interactions with NASA will stress the AST Division staff if additional positions are not available.

VII. SUMMARY OF PRIMARY RECOMMENDATIONS

1. An increase in the staff of the AST Division is urgently needed in order to handle the new initiatives, as well as the large number of proposals and awards. The COV endorses the proposed idea of the 'Senior Fellowships in Science and Public Policy' to attract rotators to the Division, and recommends additional travel support for Division staff to interact with the community.

2. The AST Division should 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 community in the NRC Decadal Survey. The Division needs to actively engage the community on a continuing basis in the planning effort.

3. The AST Division should explore new ways to enhance the AST community's response to the 'broader impact 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 is urged to maintain a vital instrumentation program for the 4-m class telescopes to which the national community has access.

5. The AST Division should help clarify the 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.

19 April 2002

GPRA FY2002 CORE QUESTIONS AND COV REPORT TEMPLATE
COMMITTEE OF VISITORS: DIVISION OF ASTRONOMICAL SCIENCES

Date of COV:	**4/2/02 - 4/4/02**
Program/Cluster:	**None**
Division:	**AST**
Directorate:	**MPS**
Number of actions reviewed by COV: 322 out of 1341 (24%)	

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

A.1 Questions about the quality and effectiveness of the program's use of merit review procedures.

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCEDURES	YES, NO, or DATA NOT AVAILABLE
Is the review mechanism appropriate? (panels, ad hoc reviews, site visits) Comments:	**Yes**
Is the review process efficient and effective? Comments:	**Yes**
Is the time to decision appropriate? Comments: **A majority of decisions are being made within 6 months, but extenuating circumstances such as staffing and availability of funds limits such timely awards in some cases.**	**Yes**
Is the documentation for recommendations complete? Comments: **We were impressed with the extensive jacket documentation.**	**Yes**
Are reviews consistent with priorities and criteria stated in the program's solicitations, announcements, and guidelines? Comments: **An improvement has been noticed in regard to response to the broader impact criterion over the last two years.**	**Yes**

Discuss issues identified by the COV concerning the quality and effectiveness of the program's use of merit review procedures:
The COV is satisfied that the current review process for individual investigator proposals is an effective and efficient one.

A. 2 Questions concerning the implementation of the NSF Merit Review Criteria (intellectual merit and broader impacts) by reviewers and program officers.

IMPLEMENTATION OF NSF MERIT REVIEW CRITERIA	% REVIEWS
What percentage of *reviews* address the intellectual merit criterion?	**100%**
What percentage of *reviews* address the broader impacts criterion? **This varies from subfield to subfield, and is an average for the FY99-01 period. We have noticed improvement in attention to this criterion in the last two years.**	**50%**
What percentage of *review analyses* (Form 7's) comment on aspects of the intellectual merit criterion?	**100%**
What percentage of *review analyses* (Form 7's) comment on aspects of the broader impacts criterion? **The AST program directors usually address this criterion in their summaries.**	**90%**

Discuss any concerns the COV has identified with respect to NSF's merit review system.

The COV suggests that the director explore new ways to enhance the broader impacts criterion; for example, a 1-3 page appendage to the 15-page proposal devoted just to this criterion might give this criterion more visibility, elicit more thoughtful responses from applicants, and provide reviewers with a better overview of the broader impacts plan.

A.3 Questions concerning the selection of reviewers.

SELECTION OF REVIEWERS	YES , NO Or DATA NOT AVAILABLE
Did the program make use of an adequate number of reviewers for a balanced review? Comments: **The AST Division has implemented a panel approach for its reviews. The panels are generally composed of 5-8 experts and handle 20-28 proposals. The panels are generally adequate to provide a balanced review, although the program directors have to work hard to find suitable panelists.**	**Yes**
Did the program make use of reviewers having appropriate expertise and/or qualifications? Comments: **Because we are a small community, it is often difficult to find appropriate panelists for all subfields. Details are discussed in the body of the report, particularly with regard to planetary and nearby extragalactic proposals.**	**Yes**

Did the program make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups? Comments: **As best as we can determine.**	**Yes**
Did the program recognize and resolve conflicts of interest when appropriate? Comments:	**Yes**
Did the program provide adequate documentation to justify actions taken? Comments: **We were impressed by the amount of documentation provided by the program directors in the jackets.**	**Yes**

Discuss any concerns identified that are relevant to selection of reviewers in the space below.

The COV is satisfied that the recent practice of having a common submission date for the different subfields is good, in that it allows a good distribution among appropriately composed panels and allows for an overall comparison of proposal merits.

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

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
Overall quality of the research and/or education projects supported by the program. Comments:	**Appropriate**
Are awards appropriate in size and duration for the scope of the projects? Comments: **We feel that the duration is fine but the size of individual grants is still below the NSF average and below what is needed.**	**Not appropriate**
Does the program portfolio have an appropriate balance of • High Risk Proposals Comments: **Especially in the areas of ATI and SGER**	**Appropriate**
• Multidisciplinary Proposals Comments: **Particle astrophysics is dedicated to such multidisciplinary proposals**	**Appropriate**

• Innovative Proposals Comments:	**Appropriate**
Of those awards reviewed by the committee, what percentage of projects address the integration of research and education? Comments: **Especially good in Education and Special Projects (ESP), by design where 100% is aimed at integration of research and education. Most grants support students, but we would like to see the discussion of integration of research and education more fully addressed in proposals. We've noted an improvement in this area over the last three years, so we are anticipating growth in this percentage.**	25%

Discuss any concerns identified that are relevant to the quality of the projects or the balance of the portfolio in the space below.

PART B. RESULTS : OUTPUTS AND OUTCOMES OF NSF INVESTMENTS

B.1.a COV Questions for PEOPLE Goal

<u>NSF OUTCOME GOAL for PEOPLE</u>: Developing "a diverse, internationally competitive and globally engaged workforce of scientists, engineers, and well-prepared citizens."

PEOPLE GOAL INDICATORS	PROGRAM ACHIEVEMENT SIGNIFICANT, OR NOT SIGNIFICANT , OR DOES NOT APPLY, OR DATA NOT AVAILABLE (select one)
Development of well-prepared scientists, engineers or educators whose participation in NSF activities provides them with the capability to explore frontiers and challenges of the future; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Improved science and mathematics performance for U.S. K-12 students involved in NSF activities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Professional development of the SMET instructional workforce involved in NSF activities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s

Contributions to development of a diverse workforce through participation of underrepresented groups (women, underrepresented minorities, persons with disabilities) in NSF activities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Participation of NSF scientists and engineers in international studies, collaborations, or partnerships; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Enhancement of undergraduate curricular, laboratory, or instructional infrastructure; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Awardee communication with the public in order to provide information about the process and benefits of NSF supported science and engineering activities. Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s

Examples in support of the above:

Indicator 1: Development of well-prepared scientists, engineers or educators whose participation in NSF activities provides them with the capability to explore frontiers and challenges of the future.

FY2001 saw the first year of the NSF Astronomy and Astrophysics Postdoctoral Fellowship program. This program is designed to provide an opportunity for highly qualified young investigators within 3 years of obtaining their PhD to carry out an integrated program of independent research and education at the institution or national facility of their choice. The program is intended to recognize young investigators of significant potential, and provide them with experience in research and education that will establish them in positions of distinction and leadership in the community. Ten fellowships were awarded in FY2001 from a pool of 51 applicants. Among the first 10 fellows, 6 are women, and one is an African American woman. (Divisional report, FY2001, pg 2).

Many REU students change their educational and career plans as a result of the positive experiences they have with science and the scientific community during their REU programs. As an example, two students, Nelvin Thomas and Vincent Davis, participating in the **REU** program at **KPNO (AST-9732120 – Smith - AURA)**, were recently featured in the Arizona Daily Star, where they said that their project, hunting for asteroids, has had such a profound effect on them that they plan to enter astronomy as a result. (FY2001 divisional report, pg 5).

Brown dwarfs are cool, dim objects with masses between that of Jupiter and the Sun, so small that their cores never become hot enough to burn hydrogen into helium. Only the slow cooking of the limited amount of deuterium in the stellar interior is possible. They continue to yield surprises, the most recent coming from the observations by **REU (AST-9731795 – Giacconi – AUI)** students at **NRAO**. Using the VLA for a collaborative observing project they designed and carried out, they

discovered the first radio emission ever detected from a brown dwarf. The paper, written by the students, was published in *Nature*. Strong radio emission from brown dwarfs is unexpected because, according to conventional theories, they are not supposed to have magnetic fields strong enough to generate the radio emission. The students' surprising discovery is forcing experts to re-think their theories about how brown dwarfs work. Not only were the radio bursts from the brown dwarf much stronger than those from Jupiter, but follow-up observations showed that the object's magnetic field was surprisingly weak. These observations promise new understanding of the difference between true stars and brown dwarfs. (Divisional report, FY2001, pg 16).

Indicator 2: Improved science and mathematics performance for U.S. K-12 students involved in NSF activities.

CAREER awardee Mark **Devlin** employs a high school student to work in his laboratory, along with several undergraduate students. His work, measuring the spectrum of the cosmic microwave background anisotropy **(AST-9732960; U. Pennsylvania**), contributes to the recent result that our universe is 'flat.' (Divisional report FY2000, pg 16).

The **Caltech Submillimeter Observatory (CSO) (AST-9980846 – Phillips - Caltech)** outreach program contains an element involving working with "Upward Bound" students. The University of Hawaii, Hilo sponsors the Upward Bound Program, and its purpose is to provide an enriched environment for promising high school students from low income families. The students enter the program with an interest in math, science, and technology and have a record of performing as motivated students. The role the CSO has played is to acquaint the students with the scope of CSO's work in astronomy and engineering and introduce them to qualitative and quantitative aspects that the students can master at their own level. (Divisional report FY2000, pg 17).

The **NRAO (AST-9223814 – Giacconi – AUI)** outreach activities, partly funded the NSF Informal Science Education Division **(ESI-9726055),** included the project, "Catching the Wave." This project is creating interactive exhibits and new programs for tourists and school children in the state and surrounding region. These programs are aligned with national and state science education goals, and have the potential to enhance the science education of every K-12 student in the state and region. Programs are designed to place students in the role of being a research astronomer or engineer. (Divisional report, FY2000, pg 19).

Margaret Hanson (U. Cincinnati) has devised a near-infrared spectral classification system for massive stars to identify different stages of evolution. In the past 3 years, she has had both a **POWRE** award (**AST-9973922**: Sub-mm Studies of Massive Star-Forming Regions)) and a **CAREER** award (**AST-0094959**: Spectral Analysis of Massive Stars in the Near-Infrared) to study the infrared properties of massive stars in order to model their stellar atmospheres as they evolve. Her outreach efforts include a hands-on astronomy program on Saturday mornings for middle school and high school students in the greater Cincinnati area.

Indicator 3: Professional development of the SMET instructional workforce involved in NSF activities.

The highly successful **NOAO/NSO (AST-9613615 – Smith – AURA)** teacher enhancement program RBSE (The use of astronomy in Research Based Science Education) brings teachers to NOAO for intensive workshops and also produces Web-based educational materials. A particularly successful and widely distributed program contains the imaging data from an NOAO telescope that is used by students to discover new novae in the Andromeda Galaxy. Astronomers, high school teachers and their students have discovered 73 novae in Andromeda. Novae are stellar outbursts that lead to a rapid brightening when mass is transferred between two stars in a binary system, causing the surface layers of one star to ignite explosively from the fusion of hydrogen nuclei. The novae in Andromeda were discovered by students using images from Kitt Peak National Observatory and collectively represent the highest discovery rate for novae found in this galaxy. The long-term goal of this project is to accurately determine the novae production rate for galaxies of different sizes and shape, leading to a greater understanding of the frequency of binary stars and distribution of ages of stars in different galaxies. (FY2000 divisional report, pg 16; FY2001 divisional report, pg 6).

In FY2001, **NOAO** began a new teacher education program that expands on the activities of the "Research Based Science Education" program, with "Teacher Leaders in Research Based Science Education" (TLRBSE). This multi-year activity supported by NSF's Directorate for Education and Human Resources (EHR) is designed to train master teachers through workshops and other interactions at NOAO, who then train other teachers in their home schools and districts. The program provides encouragement and support to both experienced and novice science teachers in communities throughout the country. (FY2000 divisional report, pg 16; FY2001 divisional report, pg 6).

NAIC (AST-0041121 – Goldsmith – Cornell) continued its very successful series of Teacher Workshops at the Arecibo Observatory. A total of 40 science teachers, representing a good fraction of school districts throughout Puerto Rico, participated in the program from June 27 to July 9, 2000; these were selected from approximately 500 applicants. The workshop included two follow-up sessions and school visits by members of the NAIC staff during the school year. (Divisional report, FY2000, pg 18).

The Project RARE CATS (Radio Astronomy Research Enhancing Coordinated and Thematic Science), (**ESI-9731498**) at **NRAO** brings several K-12 teachers to Green Bank, WV for a two-week intensive course in astronomy and the scientific method. The cornerstone of the experience is a set of open-ended research projects that groups of teachers must perform on the 40-foot transit telescope. Observatory staff advises but does not assist the teams, and the teachers get concrete experience in science research. Teachers then develop research projects for their classroom students. In one form or another, the program has been in operation since 1987 and more than 750 teachers and college students in training to be science-teachers have participated as of FY2000.

This NSF-funded teacher enhancement program adds a second year "Technology Institute" which trains teachers in the use of astronomy data reduction software, specifically, the Hands-On Universe (HOU) Image Processing program. HOU, a nationally recognized program in its own right, gives teachers software tools to use in creating astronomy research projects with their students in the classroom. (Divisional report, FY2000, pg 20).

CAREER awardee Thomas **Statler (AST-9703086; Ohio University)** works on an individual basis with local teachers each year in his STARS (Science Teachers Active in Real Science) Program, to provide teachers with the tools to improve the skills of their students. In FY2000, the STARS intern worked on instrumentation for a telescope (http://www.phy.ohiou.edu/~tss/stars.html). (Divisional report, FY2000, pg 20).

Indicator 4: Contributions to development of a diverse workforce through participation of underrepresented groups (women, underrepresented minorities, persons with disabilities) in NSF activities.

The REU sites supported in AST play a crucial role in providing a science and technology workforce that reflects America's diversity. For example, of the 125 undergraduates supported in FY2001, fully 50% of them were women, and 15% were members of underrepresented minorities. These numbers are far above the percentages of participation for these groups in professional societies. (FY2001 Divisional report, pg 3).

Ten new Astronomy and Astrophysics Postdoctoral Fellowships were awarded in FY2001 from a pool of 51 applicants. Among the first 10 fellows, 6 are women, and one is an African American woman. (Divisional report, FY2001, pg 2).

One of the REU sites funded in AST (**Gregorich – AST - 9820546**), the **Cal State LA**-led Consortium for Undergraduate Research Experience (CURE), is a Los Angeles-based collaboration of Cal State L.A., Los Angeles City College (LACC), Los Angeles Southwest College, East Los Angeles College, Pasadena City College, and the Jet Propulsion Laboratory, that focuses on bringing REU opportunities to minority students in the LA area (see http://AstroMm.calstatela.edu/cure/.) In the summer of 2000, three LACC students found that a recently-discovered asteroid is in fact a new comet while working at the JPL Table Mountain Observatory tracking near-Earth asteroids, large boulders that orbit the Sun in orbits close to the orbit of Earth. (FY2001 divisional report, pg 4-5).

Indicator 5: Participation of NSF scientists and engineers in international studies, collaborations, or partnerships;

Unique among the Astronomy REU sites is that at Cerro Tololo InterAmerican Observatory (**AST-9732584 – Smith - AURA**). Annually, four US and several Chilean students spend three months during the Chilean summer at the CTIO headquarters in La Serena, Chile, where they work with mentors on the scientific and technical staff on projects that range from current astronomical research, to instrument development, to technical problems in telescope operation and optimization.

Ms. Alicia **Soderberg**, an undergraduate from **Bates College**, Maine, continued the work she began as a 1999 CTIO REU student this year with observations at the Canada-France-Hawaii telescope, as a member of the supernovae search team. Featured as one of the Science stories of the year in 1998, this research on supernovae has altered our view of the structure and geometry of the universe. (Divisional report FY2000, pg 16).

The International **Gemini Observatory** is committed to sharing both the information from and the excitement about the science and technology developed and used by the Gemini telescopes. Because of its international nature, Gemini has a unique opportunity to collaborate and facilitate work among the partner agencies. The leverage for education and public outreach is enormous, and the Gemini Public Information and Outreach Office has been very active on many fronts. One of the most visible areas has been the initiation of the Gemini StarLab portable planetarium program in both Hawaii and Chile. (Divisional report, FY2000, pg 18).

Five College Radio Astronomy Observatory (FCRAO – AST-0100793 – Schloerb) is collaborating with the Instituto Nacional de Astrofisica, Optica y Electronica in Mexico to develop and construct the Large Millimeter-wave Telescope (LMT) with funding from DARPA, the Commonwealth of Massachusetts and the government of Mexico. This collaboration has brought Mexican students to work in the FCRAO labs and to use the radio astronomy facility. Women astronomers and students have played leading and contributing roles in astronomical research efforts at FCRAO. During the last year, 1/3 of the undergraduate students involved in the ^{13}CO project described above were women. (Divisional report FY2000, pg 17).

Indicator 6: Enhancement of undergraduate curricular, laboratory, or instructional infrastructure;

MIT Haystack Observatory has been involved in a project to develop a program in undergraduate research using radio astronomy, with funding from both EHR/DUE and AST **(MIT–DUE-99952246, PI: Joseph Salah).** Using the multi-disciplinary aspects of radio astronomy, students use Haystack's 37-m radio telescope to perform research projects. As of FY2001, over 500 undergraduate students have used the telescope for class and individual projects. In addition to the 37-m program, the Haystack engineers and scientists have developed a small radio telescope (SRT), available as a low-cost kit for student construction, that can be used to learn the concepts of radio astronomy and perform experiments. After beta-testing at 20 colleges, the SRT kit has been transferred to an industrial supplier (CASSI, Inc) and is now available commercially. Over 50 units have been sold to date to small colleges across the country. Supplementing both the telescope programs is an extensive web site of teacher resources, sample projects, and telescope use instruction (Divisional report FY2000, pg 17).

Indicator 7: Awardee communication with the public in order to provide information about the process and benefits of NSF supported science and engineering activities.

Adam **Frank**, a CAREER awardee at the **University of Rochester (AST-9702484)** and his research group make the results of their research directly available to the public through a variety of venues including programs at local grade, middle and high schools. One of their efforts is a program called Astroflow, a suite of software tools that allows users to interactively control, visualize and explore realistic simulations of cosmic events: exploding stars; comets diving into planetary atmospheres; jets of hypersonic gas driving through interstellar clouds and more. Astroflow is a unique software tool in which sophisticated research-grade simulation tools are accessed via an intuitive and visually attractive interface. Currently Astroflow is installed in a specially designed kiosk at the Strasenburgh Planetarium in Rochester NY. The technology behind Astroflow has been successfully commercialized via a company Frank and colleagues have formed called Truth-N-Beauty LLC. The company has already created a position in the Rochester area and is expanding into other areas of science outreach. (FY2001 divisional report, pg 6).

The **National Astronomy and Ionosphere Center (NAIC – AST-0041121 – Goldsmith - Cornell)** has set a high standard for public outreach with its Arecibo Observatory Visitor and Education Facility (AOVEF). Built overlooking the 305m radio telescope, and funded entirely with non-Federal monies, this new Center (opened in March 1997) contains a series of exhibits describing the science done at the Observatory. These heavily "hands-on" bilingual displays were funded by NSF's Division of Informal Science Education, and provide a unique resource for Puerto Rico's 650,000 K-12 students – with the exception of the Visitor Center there are no other science museums of any sort on the Island of Puerto Rico. The Arecibo AOVEF receives 120,000 visitors and 40,000 K-12 students each year, approximately triple the number that visited before the AOVEF was built. (FY2000 divisional report, pg 18, and NAIC presentation at COV).

CAREER awardee Robert **Nemiroff (AST-9701716 - Michigan Technological University)** organized a debate on "The Nature of the Universe, Cosmology Solved". The debate was held in the Smithsonian's National Museum of Natural History in the Baird auditorium. The Baird auditorium was the site of the "Great Debate" of the astronomers Shapley and Curtis in 1920. Professor James E. Peebles presented the astrophysical cosmologist's viewpoint from Princeton and Professor Michael S. Turner presented the particle cosmologist's viewpoint from the University of Chicago. The moderator was Margaret Geller from the Smithsonian Astrophysical Observatory. The debate was quite lively and the auditorium was full. The consensus at the end of the debate was that the answer is yet to come. (ESP Annual report, FY1999).

B.1.b COV Questions related to PEOPLE Areas of Emphasis

PEOPLE AREAS OF EMPHASIS	Demonstrates likelihood of strong performance in future? (Yes, No, Does Not Apply or Data Not Available)
K-12 Education - President's Math and Science Partnership Comments:	**Does Not Apply** If Yes, provide award #s
Learning for the 21st Century: • Centers for Learning and Teaching (CLT) • NSF Graduate Teaching Fellows in K-12 Education (GK-12) Comments:	**Does Not Apply** If Yes, provide award #s
Broadening Participation • Minority-Serving Institutions (MSI) programs **Graduate Student Stipends** • Increasing stipends for GRF, IGERT, and GK-12 Comments:	**Does Not Apply** If Yes, provide award #s

Comment on steps that the program should take to improve performance in areas of the PEOPLE goal.
We understand that there are weekly meetings between the AST ESP program director and other divisional ESP program directors. Greater interaction between them and EHR might help foster new ideas in these areas.

B.2.a COV Questions for IDEAS Goal

NSF OUTCOME GOAL for IDEAS: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society."

IDEAS INDICATORS	PROGRAM ACHIEVEMENT Select one: SIGNIFICANT, NOT SIGNIFICANT, DOES NOT APPLY or DATA NOT AVAILABLE
Discoveries that expand the frontiers of science, engineering, or technology; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Discoveries that contribute to the fundamental knowledge base; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Leadership in fostering newly developing or emerging areas; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Connections between discoveries and their use in service to society; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Connections between discovery and learning or innovation; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Partnerships that enable the flow of ideas among the academic, public or private sectors. Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s

Examples in support of the above:

Indicator 1: Discoveries that expand the frontiers of science, engineering, or technology;

The spectacular burst of new information about the Early Universe (Cosmic Microwave Background or CMB) is transforming the field of cosmology. A new approach to the study of cosmology, which involves both direct observations and intensive computer modeling of the Early Universe, has come to dominate the field, much of it accomplished with AST support. The experiments **DASI (AST-0096913, OPP-9940455 - Carlstrom- U Chicago), BOOMERanG, (AST-9813920 - Ruhl-UCSB and AST-0098737, AST-9729121 and OPP-9729121 - Lange-Caltech), Maxima-1 (AST-9872979 - Jaffe, UC, Berkeley),** and the Cosmic Background Imager (**CBI**) **(AST-982989 and AST–0098734 – Readhead - Caltech)** all have contributed new or more precise measurements of the CMB emission that are analyzed to create images of the Early Universe. These images are combined with complex theoretical calculations to test different cosmological models and measure fundamental cosmological parameters such as the overall density of the universe

The above projects are good examples of experiments that push the engineering limits on increased detector sensitivity, and that can arouse keen popular interest in astronomy and thus help provide a base for enhanced public science education. (Divisional reports, FY2000 pg 4-5, FY2001 pg 8-9).

"Cosmic shear" is defined as slight distortions in the images of distant galaxies caused by large intervening structures of primarily dark matter. At the NSF-funded National Optical Astronomy Observatories (NOAO), a group of astronomers (**Tyson-Lucent Technologies**, **G. Bernstein-University of Michigan**, and **Dell'Antonio-NOAO**) detected a statistical signal of cosmic shear for the first time using wide field images with the NSF Cerro-Tololo Inter-American Observatory 4m telescope. This initial detection was based upon measurements of the images of about 50,000 galaxies and demonstrates the principles to be used in a much larger cosmic shear survey underway. These measurements will provide a powerful tool to determine fundamental cosmological parameters related to the distribution of mass in the universe, and test the foundations of cosmology. (Divisional report, FY2000 pg 6).

Several groups supported by AST have been extremely active and productive in the search for extrasolar planetary systems. Using high-precision radial velocity measurements of candidate stars, investigators monitor the presence of planets by the minute but regular changes in velocity, as the star and planet revolve around a common center of gravity. **Butler, Marcy, Vogt** and collaborators monitor about 900 stars in the northern sky using Lick Observatory in California and the Keck Observatories in Hawaii, plus another 200 in the southern sky with the Anglo-Australian Telescope (**Butler - Carnegie Institute of Washington, AST-9619418, AST-9988087; Vogt - University of California, Santa Cruz, AST-9988358; Marcy - University of California, Berkeley, AST-9520443**). They have found a majority of the known extrasolar planets.

In complementary work under the Life in Extreme Environments (LExEn) initiative administered in AST, **Cochran** & **Hatzes** (**University of Texas at Austin, AST-9808980**) are conducting a similar exoplanet search. In August 2000 they announced the discovery of a new extrasolar planet orbiting the star Epsilon Eridani. The planet is roughly the same mass of Jupiter and its distance from Epsilon Eridani is about the distance of our Sun's asteroid belt. At a distance of only 3.2 parsecs, Epsilon Eridani is the closest star to the Sun currently known to have a planet. (Divisional report, FY2000, pg 8-9).

Combining theory developed over ten years with NSF support and new observations collected with the SOHO spacecraft, **Braun & Lindsey (Solar Physics Research Corp. & Northwest Research Assoc., AST-9528249, AST-9987286**) obtained the first images of an active region on the far side of the Sun using seismic holography techniques (Lindsey & Braun, 2000, Science 287, 1799). Active regions on the solar surface cause slight indentations, producing a reduction in the propagation time of acoustic vibrations reflecting off them. This allows them to be imaged by techniques analogous to ultrasound in the medical profession. Active regions are the centers of energetic phenomena such as solar flares and coronal mass ejections whose occasional bursts of radiation interfere with telecommunications and power transmissions on Earth and can pose significant hazards to astronauts and spacecraft. Synoptic seismic imaging of far-side solar activity will allow large active regions to be anticipated more than a week ahead of their emergence at the eastern Solar limb using real time access to observations from the Global Oscillations Network Group (GONG). (Divisional report, FY2000, pg 11).

Indicator 2: Discoveries that contribute to the fundamental knowledge base;

James Jackson, Dan Clemens, Mark Heyer, and **Thomas Bania** (**Boston University, AST-9800334**) are conducting a Galactic Ring Survey (GRS), a project to map the ^{13}CO emission from a large portion of the plane of the inner Milky Way. The group takes advantage of the new millimeter wave array receiver SEQUOIA that is deployed on the Five College Radio Astronomy Observatory (FCRAO) telescope near Amherst, Massachusetts. Observing progress has been excellent. In the second season of the survey more than 7 square degrees along the Galactic plane have been completed. The resulting images represent a substantial improvement in both spectral and spatial resolution over any previous survey. The GRS is the first survey to use the full angular resolution capability of the telescope. For the first time, accurate distances, sizes, masses and luminosities for the molecular gas can be deduced. This project involves many undergraduate students, who play an essential role in the collection, archiving, and processing of the data. The program provides them with hands-on experience in operating a major telescope facility, radio astronomy fundamentals, and examples of the critical thinking process associated with astronomical research. (Divisional report FY2000, pg 7-8).

The discovery of the disrupting Sagittarius dwarf galaxy in 1994 gave dramatic confirmation to the standard cosmological model for galaxy formation -- assembly of large galaxies from smaller subunits. A collaborative project by **Edward Olszewski (University of Arizona, AST-9619524), Mario Mateo (University of Michigan, AST-9528367, AST-9619632),** and **Heather Morrison (Case Western Reserve University, AST-9619490**) is determining how much of the Milky Way's stellar halo could be made up from the accretion of smaller galaxies. They are concluding a major survey to map the galactic halo and look for kinematic evidence of substructure that is transforming our knowledge of the galactic halo, its origins and the mass of the Milky Way. Their extensive simulations and their successful identification of an extremely long stream extending from the core of the Sgr dwarf, confirm that such long stellar structures can be identified in the Milky Way halo. (Galactic Astronomy report, FY1999, pg 3-4).

Bruce Carney (University of North Carolina, Chapel Hill, AST-9619381), in a collaborative project with **John Laird (Bowling Green State University, AST-9619628)** has been exploring the chemistry, kinematics and the ages of stellar populations in the Galactic disk and halo. The thesis of

PhD student Serge Naoumov, using the NOAO optical facilities, explores the question of whether the thick disk is the ancestor of the younger thin disk, or whether it arose independently, as through a merger. He has isolated populations of stars near the galactic plane that show clear kinematic signatures of the thick disk. There is no sign of an evolution of the thick disk into the thin disk as a function of metallicity, and the thick disk significantly overlaps the thin disk in metallicity, yet retains its own kinematic signature. These results can be understood easily in terms of an independent, probably a merger, origin. (Galactic Astronomy FY1999 report, pg 6).

The first major product of the Wisconsin H-Alpha Mapper (WHAM) project is an H-Alpha northern sky survey (**Ronald Reynolds, University of Wisconsin, AST –9619424)**. These new data allow exploration of the spatial and kinematic structure of the warm, ionized component of the interstellar medium (ISM) in our Galaxy. Recent results can be found at http://www.astro.wisc.edu/wham/ . WHAM's velocity-resolved maps complement the narrow-band filter imaging projects that are in progress such as the Virginia Tech Spectral Line Sky Survey (**John Simonetti and Brian Dennison, Virginia Polytechnic Institute, AST-9800476,** results are shown at http://www.phys.vt.edu/~astrophy/halpha.html) and a southern H-Alpha Sky Survey spearheaded by John Gaustad of Swarthmore. WHAM surveys ionized hydrogen through the H-Alpha line in a manner analogous to previous surveys of neutral hydrogen made through the 21-cm radio line. By combining WHAM results with 21-cm maps of neutral hydrogen, Reynolds can explore the relationship between the diffuse ionized and neutral media. Downloadable data from the H-Alpha survey are available to the public via the web. (Galactic Astronomy FY2000 report, pg 3-4).

Christopher McKee's (UC Berkeley, AST-9530480) theoretical studies have shown that the ionization of the Warm Interstellar Medium (WIM) gas well above the galactic plane in the halo, which has long been a mystery, can be accounted for by radiation from old supernovae remnants. They have found that this hypothesis can successfully account for a variety of observations, including results from surveys of the ISM (e.g. **Reynolds'** WHAM survey, **AST-9619424**). (Galactic Astronomy FY2000 report, pg 4).

Indicator 3: Leadership in fostering newly developing or emerging areas;

FY2001 saw also the beginning of coordinated efforts to realize the 'National Virtual Observatory'. The first concept of the virtual observatory was developed with the help of an Small Grant for Exploratory Research award **(Szalay – Johns Hopkins Univ. – AST-9876645)** that enabled fuller discussions in the community and the creation of a white paper on the idea. This year's ITR competition saw the culmination of this effort with the support of a large collaborative project to build the framework for the NVO (**Szalay – Johns Hopkins Univ. – AST-0122449)**. This project, which received a strong recommendation from the recent Decadal Survey, will federate astronomical data sets and establish them as a common resource for both researchers and the public. The project will focus not only on the archives, but establishing the protocols, standards and tools that will permit the large astronomical datasets of the future to be fully utilized. Coordinated efforts are also underway at collaborating institutions to develop archives, visualization tools, and related resources. (Divisional report, FY2001, pg 17).

Dr. Andrea Ghez, at the **University of California at Los Angeles**, is carrying out a diffraction-limited study of the Galaxy's central stellar cluster **(AST-9988397**). This program addresses three classes of questions regarding the properties and environs of the Galaxy's central supermassive black

hole. The primary goal of this program is a dynamical study of stars located in the inner regions of the Galaxy. Recent measurements of the velocities of stars near the center of the Milky Way have provided the strongest evidence for the presence of a supermassive black hole in a galaxy, but the observational uncertainties poorly constrain many of the properties of the black hole. Determining the accelerations of stars in their orbits around the center provides much more precise information about the position and mass of the black hole. Analysis of 1995-1997 data clearly demonstrated the existence of a 2.6×10^6 Msun black hole at the center of our Galaxy. With continued monitoring, the proper motion accuracies now surpass all other measurements. Consequently, Dr. Ghez' is the first group to detect accelerations for three stars in the central stellar cluster. (Galactic Astronomy FY2001 report, pg 3-4).

The Advanced Technology and Instruments (ATI) program started support to adaptive optics over 15 years ago. Today, adaptive optics is maturing into a very powerful tool for high spatial resolution imaging. Adaptive optics will probably enable long-exposure diffraction-limited performance across a wide field of view, from telescopes as large a 30 to 100 meter clear aperture. A few years ago, astronomical adaptive optics were limited to correcting for atmospheric turbulence over a small area of about 6 arc-seconds and required that a bright star be in the field. Today astronomers have learned how to create an artificial star in the sky using lasers, and have learned enough about the dynamics of the turbulent atmosphere to measure and forecast correction over arc-minutes field of view for telescopes in the 10 to 20 meter size category**. (AST 9731169 Ed Kibblewhite - University of Chicago)** (ATI report FY2000, pg 4).

Indicator 4: Connections between discoveries and their use in service to society;

Laboratory studies of molecules and processes of interest in planetary, cometary and interplanetary chemistry, has broad use in the science and engineering community. An example is that of **George Atkinson**, of **Innovative Lasers Corporation (AST-9618704)**, who is using intracavity laser spectroscopy (ILS) in the laboratory to detect and characterize weak absorption features in the 1-3 micron wavelength range from molecules associated with planetary atmospheres, such as carbon monoxide, nitrogen, and methane. This new technique provides the opportunity to measure absorption properties under experimental conditions not readily available with conventional experimental methods. The success of the ILS methods for the detection and characterization of weak absorption features could be utilized for the detection of other gaseous species in industrial applications in semiconductor manufacturing, chemical processing or environmental monitoring. (Divisional report, FY2000, pg 13).

Synoptic data routinely obtained through telescopes built by **NSO** (AST-9613615 – Smith – AURA) or operated by NSO are a vital part of international solar monitoring efforts, used by NOAA and the USAF to produce "space weather" predictions. The infrastructure of NSO also enables other efforts. For example, the upgraded telescopes for the USAF's ISOON (Improved Solar Optical Observing Network) are being constructed at NSO under a USAF contract. (Divisional report, FY2000, pg 14).

A new area of technological development in the field of radio astronomy pursues the real-time adaptive cancellation of unwanted radio interference using adaptive digital filters and special signal processing algorithms. This new area of research, funded for the first time this year (at **NRAO** and through **AST-9987339; Jeffs – Brigham Young University)** will enable radio telescopes to operate more effectively in the presence of unwanted radio signals. This technology of real-time cancellation

of unwanted radio interference now being developed for astronomy has direct application to increase the effective bandwidth of radio communication channels for commercial purposes. (Divisional report, FY2000, pg 15).

The **Five College Radio Astronomy Observatory (FCRAO – AST-0100793 – Schloerb)** instrumentation effort is concentrated in the areas of low noise receiver development in the 1-3 mm bands at low cost, and local oscillator source development for mm to submm bands. Both of these areas may eventually result in spin-offs to the general population. Near mm-wave transmitters and receivers are now coming into wide use for broadband wireless distribution of services presently on fiber or cable. The main advantage is a much lower installation cost. This work is a direct beneficiary of research over the past several years, and one of the principle companies in the field is Telaxis Communications, a spin off of the UMass radio astronomy observatory. New luxury automobiles are now being equipped with collision avoidance radars at 77 GHz (at one time a development of Millitech, now Telaxis). As this technology cost decreases, these radars will be found in nearly all cars in a few more years. (Divisional report, FY2000, pg 15).

Indicator 5: Connections between discovery and learning or innovation;

The "Grand Challenge Cosmology Consortium (GC3)" **AST-9803137 (Norman – U. Illinois, U-C)**, is "devoted to harnessing the power of parallel computers to explore the origin of large scale structure in the universe and how galaxies form." They produced a sequence of filament-condensation-galaxy formation in the early universe which was incorporated in a popular IMAX movie, *Cosmic Voyage,* viewed at science museums and centers throughout the country. To illustrate some of their results, the consortium also produced an animated video for the Boomerang publicity (above) by NASA and NSF that received extensive coverage by the media. (Divisional report, FY2000, pg 5, 14-15).

CAREER awardee **Robert Nemiroff (AST-9701716; Michigan Technological University),** in addition to his research efforts, supports one of the most successful astronomical outreach web sites, Astronomy Picture of the Day (APOD). The APOD web site is accessed by thousands of people. The site is used extensively by teachers and students, at all levels, as well as by the general public. This activity is a joint venture with a colleague of Nemiroff's at NASA's Goddard Space Flight Center, and is jointly sponsored by NSF and NASA. (Divisional report, FY2000, pg 15).

Indicator 6: Partnerships that enable the flow of ideas among the academic, public or private sectors.

The Astronomy Division, in collaboration with the Physics Division and the Office of Multi-disciplinary Activities, is supporting the creation and installation of a major new permanent exhibit, *Explore the Universe*, in the **Smithsonian Institution's National Air and Space Museum, (AST-0083463 - PI: David DeVorkin)**. This exhibit, which opened in September 2001, will provide the 9 million annual visitors to the Air and Space Museum with a perspective on how our understanding of the Universe has changed over time as the tools we use to study it have evolved. The exhibit makes use of a selection of artifacts, working models, images, interactive videos and computer programs, hands-on exhibits, and live demonstrations to explore scientists' view of the Universe as well as how they use ground- and space-based technology to study it. (FY2001 divisional report, pg 7).

B.2.b COV Questions related to IDEAS Areas of Emphasis

IDEAS AREAS OF EMPHASIS	Demonstrates likelihood of strong performance in future? Select one: Yes, No, Does Not Apply or Data Not Available
Biocomplexity in the Environment Comments:	**Does Not Apply** If Yes, provide award #s
Information Technology Research Comments: **See example and award number below.**	**YES** If Yes, provide award #s
Nanoscale Science and Engineering Comments:	**Does Not Apply** If Yes, provide award #s
Interdisciplinary mathematics Comments:	**Does Not Apply** If Yes, provide award #s

Example in support of the above:

Information Technology Research

FY2001 saw also the beginning of coordinated efforts to realize the 'National Virtual Observatory'. The first concept of the virtual observatory was developed with the help of an Small Grant for Exploratory Research award **(Szalay – Johns Hopkins Univ. – AST-9876645)** that enabled fuller discussions in the community and the creation of a white paper on the idea. This year's ITR competition saw the culmination of this effort with the support of a large collaborative project to build the framework for the NVO (**Szalay – Johns Hopkins Univ. – AST-0122449)**. This project, which received a strong recommendation from the recent Decadal Survey, will federate astronomical data sets and establish them as a common resource for both researchers and the public. The project will focus not only on the archives, but establishing the protocols, standards and tools that will permit the large astronomical datasets of the future to be fully utilized. Coordinated efforts are also underway at collaborating institutions to develop archives, visualization tools, and related resources. (Divisional report, FY2001, pg 17).

Comment on steps that the program should take to improve performance in areas of the IDEAS goal.

B.3.a COV Questions for TOOLS Goal

<u>OUTCOME GOAL for TOOLS:</u> Providing "broadly accessible, state-of-the-art and shared research and education tools."

TOOLS INDICATORS	PROGRAM ACHIEVEMENT Select one: SIGNIFICANT, NOT SIGNIFICANT, DOES NOT APPLY or DATA NOT AVAILABLE
Provision of facilities, databases or other infrastructure that enable discoveries or enhance productivity by NSF research or education communities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Provision of broadly accessible facilities, databases or other infrastructure that are widely shared by NSF research or education communities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Partnerships, e.g., with other federal agencies, national laboratories, or other nations to support and enable development of large facilities and infrastructure projects; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Use of the Internet to make SMET information available to the NSF research or education communities; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s
Development, management, or utilization of very large data sets and information-bases; Comments: **See examples and award numbers below**	**SIGNIFICANT** If Significant, provide award #s

Development of information and policy analyses that contribute to the effective use of science and engineering resources. Comments:	**Does Not Apply** If Significant, provide award #s

Examples in support of the above:

Indicator 1: Provision of facilities, databases or other infrastructure that enable discoveries or enhance productivity by NSF research or education communities;

Over 900 papers were published last year citing the use of **NOAO** and **NRAO** facilities. Scientific results from the national facilities have a significant impact – typically 6 to 10 papers published by NRAO users each year are invited to be cover articles for the journals Nature, Science, and Scientific American. (Division report, FY 2001, pg 17).

During the past three years, two international groups - the High-Z Supernova Search Team (Mt. Stromlo and Siding Spring Observatory) and the Supernova Cosmology Project (Lawrence Berkeley National Laboratory) - have independently made extensive use of the **CTIO** (**AST-9613615 – Smith – AURA**) Blanco 4-m telescope to carry out searches for high-redshift type Ia supernovae in order to determine or constrain the cosmological constant and the mass density of the universe. The supernovae are discovered by observing dozens of high galactic latitude fields with the Blanco 4-m telescope just after a new moon. The field of the Bell Telephone Laboratories CCD camera (Tyson and Bernstein) contains hundreds of galaxies at redshifts between 0.3 and 0.1. Just before the next new moon, the same fields are re-observed and the images are compared, thus checking tens of thousands of high redshift galaxies. Rapid data analysis makes it possible to identify the supernovae within hours of the observation so that the follow-up photometery can begin immediately. Several hundred supernovae have been discovered by the two groups using the Blanco telescope. Based on the comparison of light curve measurements with redshift for these supernovae, by both groups, it appears that the expansion of the universe is actually accelerating, in defiance of common sense! (NOAO Annual report, FY1999, pg 2).

"Cosmic shear" is defined as slight distortions in the images of distant galaxies caused by large intervening structures of primarily dark matter. At the NSF-funded National Optical Astronomy Observatories (NOAO), a group of astronomers **J. A. Tyson** from Lucent Technologies, **G. Bernstein** of the University of Michigan, and **Dell'Antonio** of NOAO detected a statistical signal of cosmic shear for the first time using wide field images with the NSF Cerro Tololo InterAmerican Observatory 4m telescope; see http://www.noao.edu/outreach/current/dlshilite.html. This initial detection was based upon measurements of the images of about 50,000 galaxies and demonstrates the principles to be used in a much larger cosmic shear survey underway. These measurements will provide a powerful tool to determine fundamental cosmological parameters related to the distribution of mass in the universe, and test the foundations of cosmology. (Division report, FY2000, pg 6).

The newest of the large facilities available to the US astronomical community, the **Gemini** Observatories, passed from commissioning and construction into early science operations in FY2001. With both telescopes obtaining data, astronomers have full sky coverage with identical 8-meter class telescopes for the first time ever. Results from Gemini North are already appearing in the press. The

first demonstration data of the galactic center have been released to the public. Using an adaptive optics system that was funded by NSF and built by the University of Hawaii, these images represent the sharpest images ever obtained over such a large area of our Galaxy's center. (Division report, FY2001, pg 18).

Hernnstein et al. used the VLBA (**NRAO – AST-9223814 Giacconi – AUI**) to make measurements of water emission from the central regions of the galaxy NGC 4258. The measurements yielded a direct measurement of the distance to this object, about 23.5 million light-years. This result differs significantly from the inferred distance of about 28 million light years, obtained by astronomers using the Hubble Space Telescope and implies that there may be previously-unrecognized systematic errors in the Hubble distance scale for the Universe. (NRAO Annual report, FY1999).

Indicator 2: Provision of broadly accessible facilities, databases or other infrastructure that are widely shared by NSF research or education communities;

The National Radio Astronomy Observatory, the National Optical Astronomy Observatory, the National Solar Observatory, the National Astronomy and Ionospheric Center, and the Gemini Observatories provide access on the basis of scientific merit to a broad scientific user community. Over 2400 scientists and students use these facilities annually; each provides unique capability that enables research and training. More than half the PhD degrees granted in astronomy each year utilize the facilities and the data they produce. (Division report, FY 2001, pg 17).

The centers also generate substantial databases and archives of observational data, often through coordinated surveys which enable research beyond the scope of a single researcher. A recent example was the **NOAO** Deep Wide-Field Survey, an extensive, multi-year multicolor survey using the 4-meter telescopes. The first results, covering an area of 1.15 square degrees, and with it over 300,000 faint galaxies and stars, were released in January 2001. The full area will be 15 times this size, and will be completed in spring 2002. With it, astronomers will be able to study large-scale structure in the Universe, the formation and evolution of galaxies and quasars, rare stellar populations, and the structure of the Milky Way. (Division report, FY 2001, pg 17).

The VLA FIRST survey **(AST-9802791 – Becker, UC Davis and AST-9802732 – Helfand, Columbia University)** is imaging the radio sky at 1400 MHz with unprecedented sensitivity and resolution. To date a total of 2750 hours of observations covering 8000 square degrees of the sky have been reduced, analyzed, and made available through the FIRST web site (http://sundog.stcsi.edu). This project serves as an excellent example of a survey that has created a data archive which is easily accessible and very useful. (Division report, FY 2000, pg 12-13).

Indicator 3: Partnerships, e.g., with other federal agencies, national laboratories, or other nations to support and enable development of large facilities and infrastructure projects;

During FY2000 successful negotiations were completed to establish a joint program between the NSF and AFOSR to make available to the US astronomical community observing time at the Advanced Electro-Optical System (AEOS) telescope, on Maui, Hawaii. The objective of this program is to provide funds in FY 2000 and FY 2001 to the astronomical community to support astronomers to use the large (3.76-meter) advanced technology telescope for scientific research. The program is funded at the level of $2.3 million, with AFOSR contributing a total of $1.8 million, and NSF/AST

contributing $250K in each of FY2000 and FY2001. A total of 23 proposals was received in response to the FY2000 solicitation, and 5 awards were made. This solicitation will be reissued in FY 2001. (Division report, FY 2000, pg 2-3).

Indicator 4: Use of the Internet to make SMET information available to the NSF research or education communities;

The astronomical sciences rely heavily on the networking and connectivity of the internet both for the purposes of research and to make the images and results of astronomical research available to students, teachers, and the public. Our national facilities, distributed throughout the US and in Chile, offer the best examples of this use. Remote monitoring and operation of the Gemini telescopes, for example, enable astronomers in Wisconsin to 'eavesdrop' on their observations being taken at Cerro Pachon, in Chile, or at Mauna Kea, Hawaii. These facilities also rely heavily on the web to disseminate the results of their research as well as educational resources to the public. (See, for example, the NOAO outreach activity at http://www.noao.edu/outreach/). Internal communications at the Arecibo Observatory have been upgraded by the installation of a 100 Mbyte/s ethernet system, an order of magnitude improvement over that previously available, which expedites the transfer of large volumes of data. The installation of a link to the Internet2 is being funded, and will provide a low latency, high-bandwidth connection within and outside Puerto Rico. (Division report, FY2001, pg 20)

Indicator 5: Development, management, or utilization of very large data sets and information-bases;

FY2001 saw also the beginning of coordinated efforts to realize the 'National Virtual Observatory'. The first concept of the virtual observatory was developed with the help of an Small Grant for Exploratory Research award (**Szalay – Johns Hopkins Univ. – AST-9876645**) that enabled fuller discussions in the community and the creation of a white paper on the idea. This year's ITR competition saw the culmination of this effort with the support of a large collaborative project to build the framework for the NVO (**Szalay – Johns Hopkins Univ. – AST-0122449**). This project, which received a strong recommendation from the recent Decadal Survey, will federate astronomical data sets and establish them as a common resource for both researchers and the public. The project also establishes the protocols, standards and tools that will permit the large astronomical datasets of the future to be fully utilized. Coordinated efforts are also underway at collaborating institutions to develop archives, visualization tools, and related resources. (Divisional report, FY2001, pg 17).

Much of the research supported by the Division contributes substantially to the creation of scientific databases and tools to use them. Observational projects routinely create extensive databases that are made available over the web to the astronomical community, and, in many cases, to the public. In addition to those projects discussed above, are the Optical Gravitational Lensing Experiment (OGLE) project **(Paczynski – Princeton Univ. – AST-9820314),** which is known for its massive database and 'early alert' system, the Galactic Ring Survey (GRS) **(Jackson – Boston Univ. – AST-9800334 and AST-0098562),** a project to map the ^{13}CO emission from a large portion of the plane of the inner Milky Way, and the Virginia Tech Spectral-line Survey **(Simonetti – Virginia Tech – AST-9800476 and AST-0098487**), a wide field image survey of the Galaxy's warm ionized interstellar medium. (Divisional report, FY2001, pg 20).

Comment on steps that the program should take to improve performance in areas of the TOOLS goal.

B.3.b COV Questions related to TOOLS Areas of Emphasis

TOOLS AREAS OF INVESTMENTS	Demonstrates likelihood of strong performance in future? Select one: Yes, No, Does Not Apply or Data Not Available
Major Research Equipment (MRE) Comments: **See examples and award numbers below**	**YES** If Yes, provide award #s
Major Research Instrumentation (MRI) Program Comments: **See examples and award numbers below**	**YES** If Yes, provide award #s
Science & Engineering information, reports, and databases Comments:	**Does Not Apply** If Yes, provide award #s
Scientific databases and tools for using them Comments: **See examples and award numbers below**	**YES** If Yes, provide award #s
National SMETE Digital Library Comments:	**NO** If Yes, provide award #s

Examples in support of the above:

Major Research Equipment (MRE)

The Atacama Large Millimeter Array (ALMA) remains AST's investment in the Major Research Equipment account. NSF has provided funds for design and development of the facility for 4 years; the project is preparing to move into the last year of design and development before project construction, which will take approximately nine years. Construction of ALMA is envisioned as an equal U.S.-European partnership, with the likelihood of Japan as a third equal partner. The scope proposed for the U.S.-European project – an array of 64 12m antennas, with 4 receiver bands extending into the submillimeter – represents a careful balance between an optimized, cutting-edge radio telescope and responsibility to build within cost. The cost for ALMA–and in particular the North American contribution to it–has remained contained since the detailed cost audit was carried out in July 1999. As currently envisioned, ALMA will bring to millimeter and submillimeter astronomy the aperture synthesis techniques of radio astronomy, enabling precision imaging to be made on sub-arcsecond angular scales. (Division report, FY2001, pg 20).

Major Research Instrumentation (MRI).

The Magellan Instant Camera, (**AST-9977535 - Elliot - MIT**) The Magellan Project is constructing two 6.5-m telescopes on Cerro Las Campanas, Chile. MIT personnel from the departments of Earth, Atmospheric, and Planetary Sciences and Physics as well as from the Center for Space Research are building MAGIC (Magellan Instant Camera). In addition, this project is providing direct training in astronomical instrumentation from the undergraduate through the post-doctoral level. This combination of optimized scheduling and a highly efficient, instantly accessible camera will allow the Magellan telescopes to pursue science programs not possible or practical elsewhere. Such programs include (but are certainly not limited to): optical follow-up of gamma ray burst sources, the monitoring of the light from gravitationally lensed quasars, occultations of stars by solar system bodies, high precision photometry of microlensing events in the Magellanic Clouds, physical studies of recently discovered near-earth asteroids (NEOs), optical follow-up of supernovae in distant galaxies, and exploration of the Kuiper Belt. (ATI annual report, FY2000, pg 16).

Scientific Databases and tools for using them

NVO-ITR award (**Szalay – Johns Hopkins Univ. – AST-0122449**). – See above under B.2.b (pg. GPRA-17).

B.4 Please comment on any program areas in need of improvement.
Better advertisement of the special initiatives such as MRI is needed for the AST community.

B.5 Provide comments as appropriate on the program's performance in meeting program-specific goals and objectives, which are not covered by the above questions.

B.6 NSF would appreciate your comments for improvement of the COV review process, format and report template.

The COV was presented with a wealth of information through outstanding presentations and access to jackets as well as extensive documentation. The material supplied in advance of the meeting (annual reports, etc.) was useful, since there was so much to digest in a short time at the meeting.

The GPRA template forms are a useful mechanism for focusing on the results, although some of the examples we supplied fit many questions, and some of the questions are not relevant to AST.