Directorate for Mathematical and Physical Sciences
Advisory Committee Meeting Minutes
November 7-8, 2002

Thursday, November 7, 2002
Morning Session

Welcoming Comments

The MPSAC Chair, Dr. Joseph Salah, Chair of the Mathematical and Physical Sciences Advisory Committee (MPSAC) called the meeting to order at 8:30 A.M. He introduced Dr. John Hunt, the Acting Assistant Director of MPS. The minutes of the May 2002 were approved subject to some minor edits. In response to a question concerning a search for a new Assistant Director, Hunt said that a search committee was being formed.

Update of MPS Activities

Hunt described funding within the Directorate with respect to the NSF-wide Strategic Goals of People, Tools, and Ideas, with respect to NSF initiatives such as Biocomplexity and the Environment, and with respect to MPS areas such as Mathematics, Origins of the Universe, the Quantum Realm, and Molecular Connections. He provided a summary of MPS award size and duration as well as the number of actions, awards, and success rates for each Division. He described the MPS FY 2003 budget request and noted that several congressional subcommittees and two authorization bills (one titled the "NSF Doubling Act") had recommended increases to the NSF budget. Dr. Neil Tyson and Joe Salah had questions regarding a possible negative reaction by OMB to the congressional budget recommendations, but Hunt stated that this did not seem to be the case. He then compared the current Senate and House Appropriations bills, both of which had significant increases for MPS with respect to the request level.

With respect to the Major Research Equipment (MRE) account, the Office of the Inspector General (OIG) had questions concerning cost overruns and practices within MRE projects. The National Academy will assemble a panel to look into these matters. Further discussion was postponed in order that the MPSAC meet with the Directorate for Education and Human Resources Advisory Committee (EHRAC) for a joint symposium.

Joint MPS and EHR Advisory Committee Symposium

Dr. Fiona Goodchild described the goals of the symposium: to inform both the MPSAC and the EHRAC of how one can integrate "*the science of learning*" with teaching in the classroom. All of the speakers at the symposium had used research in the science of learning to change how they taught classes.

Dr. Judith Ramaley, Assistant Director for EHR noted that EHR was trying to encourage the integration of research and education, across science and engineering and education departments, as well as between higher education and K-12 and other institutions. Faculty had to understand that teaching required the same clarity of purpose and knowledgeable understanding of the literature as was expected with respect to their own field of scientific research.

Dr. Robert Mathieu, a University of Wisconsin astronomer, served as chair of the panel. He is part of the University of Wisconsin's National Institute for Science Education.

A Physicist's View on Learning Theory: Dr. Joseph Redish, a University of Maryland physicist and a member of its Physics Education Research Group, was the first speaker. He noted that physics majors learn little in the traditional introductory physics course. He wondered how educators can squeeze new knowledge into the curriculum (e.g. technology, computing, genetics, etc.) and what had to be dropped in order to do so. He commented, "Education is harder than physics." He proposed two solutions:

I. Triangulate among:

1. Phenomenological observations of people in classrooms;
2. Idealized experiments to probe fundamental learning mechanisms; and
3. Topics from neuroscience that can be applied. For example, how does long-term memory work and under what conditions can it be ready for use? How important is context and how do irreducible principles get mapped onto context? How do expectations affect cognition?

II. The second category of solutions for Redish is management of knowledge. “Frames” affect how we manage knowledge. Examples of frames for a student in a course include:

1. Social (who will I interact with during this course – teaching assistants, professors, *etc.*);
2. Material (what materials will I use?);
3. Skills (what will I be doing here?); and
4. Affect (how will I feel about what I’m doing?).

Students’ frames may shift from class to class. One inappropriate view is “I have to memorize in order to pass this course.” Traditional instruction worsens this belief. The professor can address student expectations explicitly and focus on correcting them.

It is important for an educator to pay attention to messages, both overt and covert. An overt message stated in class (*e.g*. a professor says “It’s important for you to learn the concepts.”) can be defeated by a covert message (*e.g.* a homework assignment based on a plug-and-chug approach).

Redish described an experiment involving an algebra-based physics class, consisting of 100 students with lecture, recitation, and lab. “Meta-learning” changes were made to the class – *e.g.* in class, a problem is given where the students find themselves with a contradiction. By sticking with the correct principles, they can learn that if one is consistent in one’s reasoning, physics can help you to resolve contradictions. Cookbook labs are discarded for labs in which students are given a task and some equipment. They make measurements and have to ask if what they are doing makes sense. This gets them away from being solely focused on “getting the right answer.” Redish showed diagrams of amount of time students spend in various modes of thought – in traditional labs, they spend most of their time on “logistics” and very little in “sense-making.” In the new labs, they spend more time on “sense-making.”

Redish showed a video clip of a new student talking with an experienced student. The experienced student was saying, “Redish makes you think – that’s his goal.” The new students replied “It’s fine if I have to think, as long as I still get an A.”

Redish noted that it is becoming increasingly dangerous for teachers to continue to teach students only how to follow a protocol. We are trying to move large numbers of people into the sciences. It is time for the teaching community to drastically improve its teaching methods.

Change Makes a Difference – A Chemistry Story: Dr. John Wright of the University of Wisconsin-Madison described the benefits he had seen by introducing active learning strategies into his analytical chemistry courses. In trying to persuade colleagues to adopt a similar approach, he used their input to design a unique study to try to convince them of the value of his approach. The study, which he has published, involves students in his second-semester freshman chemistry course. They were taught with “Structured Active Learning” (SAL), and compared with a cohort taught by another instructor, who used a more traditional “Responsive Lecturing” approach. The approximately 200 students had had a common first-semester course and were placed in octiles based on prior performance. At the end of the semester, 25 UW-Madison faculty from other fields interviewed the students (groups of 8 students per faculty member) without knowing which approach they had had, and ranked them based on various criteria. By a variety of metrics, students who had experienced the SAL approach outperformed those who had been taught using the RL approach. The SAL-taught students also felt more confident about their skills and had a more positive attitude toward science (they felt better prepared, had more confidence, articulated a greater enjoyment of science, and felt better able to connect concepts to applications), both at the time of the study and in a subsequent survey. Wright characterized the essentials of motivation for faculty and students as requiring a worthwhile reason for change, a belief that they can change, and belief that change will lead to success. Active learning approaches can move students away from memorization as a path to success in college science, technology, education and mathematics (STEM) courses and into paths where they learn to solve problems by reading, visualizing, analyzing, exploring, planning, executing and checking.

Can Faculty Change? Yes! Josefina Arce of the University of Puerto Rico-Rio Pedras shared STEM faculty comments that indicated that faculty viewed poor performance by students in their courses as due to the fact that students were not very good and/or didn't try hard enough. It was common, also, to blame K-12 teachers for college student shortcomings. Arce discussed the importance of motivation and the need for faculty to provide information and an appropriate environment to facilitate student learning. She described an exercise in which she had students bring in spectra and deduce chemical structures from their spectra to illustrate the process. As strategies for engaging faculty in reform, Arce described the value of professional development activities like workshops and course coordination meetings across different lecture sections. Her analogy was that bringing researchers in contact with educational knowledge was like a reaction collision where proper orientation and sufficient activation energy are needed. Appropriate programs and individuals can serve as catalysts for the process. Arce shared pre- and post-conceptual learning results, based on measures developed by William Robinson at Purdue University that showed her sections improved markedly and received better grades with fewer course withdrawals. The active learning-based changes have led to more chemistry majors, principally recruited from transfer students and students not originally intending to major in chemistry.

The Context for Change in STEM Higher Education: Dr. Robert Mathieu of the University of Wisconsin spoke about building a capacity for change in college STEM faculty. He cited the “Shaping the Future” NSF document from 1996, which emphasized the need to integrate research and education. Mathieu identified NSF programs that promote this ideal, including the NSF graduate and postdoctoral fellowships, CAREER and DTS awards, but noted that the educational portions of, *e.g.*, the CAREER proposals are typically not as substantive or well-conceived as the research portions of the proposals. Important Notice No. 127 from NSF emphasizes the broader impact requirement in project summaries, and the STEM community needs help to move in the direction of better integration of research and education.

Mathieu described the new Center for the Integration of Research on Teaching and Learning (CIRTL) that he will lead with support from MPS and EHR. It is a partnership with Michigan State and Pennsylvania State Universities that will help graduate and postdoctoral students develop professionally. He noted the leverage that graduate training at research universities provides, as many graduate students will become faculty across the full spectrum of postsecondary institutions. Within the campus structure CIRTL will provide a mechanism for helping graduate and postdoctoral students learn to disseminate scientific knowledge to various audiences.

Questions that were asked after the presentation included how to allocate teaching assistants without creating strife among faculty; the time lag between a project like CIRTL and the current need for help in integrating research and education; and how broader impact issues are being addressed.

Following these presentations and discussion, during the lunch period the meeting broke into separate groups that discussed these presentations and the impact of the NSF review criteria on the research community. The groups reconvened following lunch and summarized their discussions to the full assembly.

The MPSAC and the EHRAC committed to working together and to set up continuing channels of communication and collaboration. There was also agreement that a joint working group should be established, and that both the MPSAC and the EHRAC would consider this and communicate further.

Appendix I of the Minutes of this meeting contains a description of these discussions.

The joint session of the MPS and EHR Advisory Committees concluded at 1:30 P.M.

Thursday, November 7, 2002
Afternoon Session

The meeting of the MPSAC reconvened at 2:00 P.M.

Update of MPS Activities (continued)

Hunt commented on MPS interactions with NASA concerning astronomy activities. Dr. G. Wayne van Citters, Jr., Director of the Division of Astronomical Sciences(AST), described the formation and first meeting of a Joint Advisory Committee between NASA and NSF on joint astronomical activities. The meeting took place in October 2002. AST was to respond to the recommendations of this committee in November 2002.

Hunt noted that there had been a workshop on underground science, and Dr. Joseph Dehmer, Director of the Division of Physics, summarized the meeting. Approximately 300 people participated.

Hunt was asked about whether funding of Centers would reduce funds available for support of individual investigator research. Hunt responded that while Center funding has increased over the past 20 years, the success rate for individual investigator proposals has remained fairly constant. In response to a question on the issue of NSF staff overwork, he responded that things have improved in Division of Chemistry, and that, in general, MPS has been successful in hiring well-qualified staff. Salah asked about the status of dedicated staff for large facility programs. Hunt responded that MPS is sensitive to the issue, and a request for an increase of AST staff may be in order. There was a question whether a need existed for the AC to deliberate on more effective interaction with Congress. Hunt responded that NSF is doing well in communicating with Hill staff, as are segments of the research community.

MPS Response to MPSAC Recommendations on Hart-Rudman Report: Plans for a Joint MPS-Intelligence Community Workshop

Dr. Adriaan de Graaf, Executive Office of MPS, noted that the primary response to the recommendations todate has been to form a partnership with the Intelligence Community (IC) and to jointly develop and sponsor a workshop. This workshop will include 63 participants, and will take place November 19-21, 2002. Five areas of interest to the intelligence community (www.intelligence.gov) were jointly decided upon, and the workshop will seek input from the research community on identifying research needs and opportunities in these five areas. A workshop report will be available on the internet, absent any identified US areas of weakness. Dr. Neal de Grasse Tyson noted that the AC recommendations are broader than terrorism. De Graaf responded that MPS has focused on the workshop as a first step. Other items will be addressed. Dr. Lon Mathias questioned the choice of the workshop focus areas, and suggested that Protection and Neutralization appear to be missing. De Graaf noted that the five areas resulted from many joint discussions, and are of high priority to the intelligence community. He noted that a possible workshop outcome could be a joint solicitation for research. Salah raised the issue of preserving academic standards while engaging in security research. De Graaf noted that this issue had been discussed and attention will be given to melding of the MPS and intelligence community cultures. Salah suggested that the workshop chairs be asked to give a presentation of the workshop findings at the next AC meeting.

Overview of and Plans for MPS International Activities

Dr. Eileen Friel provided an overview of the scope of international activities in MPS. Five areas of involvement were highlighted:

1) International Partnerships and Large Scale Projects;
2) Individual Investigator and Group Activities;
3) Conferences and Workshops;
4) Financial Investments; and
5) Issues and Future Plans.

With respect to International Partnerships and Large Scale Projects, special mention was made of the International Gemini Observatory (US, UK, Canada, Australia, Argentina, Brazil, Chile) and, in particular, the strong central management for the coordination of activities such as providing support to local users. NSF's strong role in influencing public outreach and education was highlighted. There was some concern expressed by the MPSAC about security issues at these large facilities. It was pointed out that they are mostly in very remote locations. Mention was also made of the Atacama Large Millimeter Array (ALMA) to be located in Northern Chile. Construction was begun in 2002 with an estimated nine years for completion.

The Large Hadron Collider (LHC) project involves NSF and the Department of Energy (DOE) in a partnership with CERN. NSF's special role in this project is the support of the many investigators involved with the construction of two major detectors - ATLAS and CMS. An up-date of LIGO (Laser Interferometer Gravitational Wave Observatory) was also provided, as was a discussion of the Astronomy National Observatories where 10-20% of the users come from outside the U.S. Overviews were also provided of the Borexino Experiment (on solar neutrino detection) at Gran Sasso, Italy and the Auger Project (high energy cosmic ray experiment) in Mendoza, Argentina. NSF and DOE jointly fund both projects.

Not all international projects involve large facilities, and specific mention was made of the many international activities supported under the Materials Research Science and Education Centers (MRSEC). Others are being planned for the new International Materials Institutes that are just now being established. Another area of intense activity has been the many international conferences and workshops sponsored by MPS to enhance international cooperation. Also, ongoing projects involve Partnerships in Education with outreach to international partners through public programming, school programs, teacher training and Research Experiences for Teachers (RET). There are special programs that are broadening participation in select areas such as the U.S. - Africa High School program jointly supported by MPS and the Office of International Science and Engineering. These international activities involving MPS facilities and centers are open to international researchers and their students.

Individual investigator awards provide support (together with INT) to host foreign visitors and students, and support for collaborations involving the use of facilities abroad. Funding for single disciplinary conferences and workshops typically includes international participation. Some involve joint support with agencies in other countries designed to explore and create opportunities for international collaboration (US-Europe, US-Asian Pacific, US-Pan American, US-Africa). The total financial investment for MPS in international activities is $84.6 million.

With respect to issues and future plans, it is recognized that there are many challenges to building an international portfolio: How does MPS balance its overall portfolio against investments in individual investigator activities and Centers? How does one handle data sharing and patent issues? How much support can the U.S. afford to devote to building major facilities, and how do we encourage cost-sharing from other countries? And how does one best manage and coordinate all of these activities?

The MPSAC asked about the policy background for NSF's international activities, and additional questions about these activities and other specific projects led to a request for an overview of the entire MPS INT portfolio. Jeanne Pemberton also commented that a white-paper response to the Hart-Rudman Report vis-a-vis NSF's INT issues needs to be put on the agenda for the next MPSAC meeting.

Report on Environmental Advisory Committee

Dr. Jean Futrell provided an update on the presentation given by Dr. Marge Cavenaugh at the MPSAC May 2002 meeting on the Environmental Research and Education (ERE) Report and related activities. The report comprises a ten-year outlook for ERE. It is expected to be made available to the public in January 2003. The report will clarify NSF's role in this field; highlight cross-Foundation activities; develop a role for the ERE advisory committee; and blend into NSF strategic elements of people, ideas and tools.

A review was done during the summer of 2002 and involved comments from Federal agencies, professional societies, the rest of NSF and the general public. Implementation of the report will involve communication and an initial focus on enabling activities. A brief synopsis of the latest activities in the related Biocomplexity and the Environment strategic area was also presented.

Questions were asked concerning the main goals of the ERE committee, and Dr. Don Burland, Executive Officer of the Chemistry Division, commented that a working group made up of members from the community would be established. Futrell commented that the EREAC is looking for gaps in the current portfolio.

Long-Range Planning for MPS: Future Opportunities and Directions for Research and Education; MPS Priority Areas

In the introduction to this session, Hunt noted that with respect to future opportunities for research and education, a new budget cycle begins in the Spring of 2003 and that NSF begins to develop the FY 2005 budget in April 2003. MPS has not done as well as it could have in competing for resources. There is a need to stimulate exciting concepts and garner support for these activities. In the following discussions there are 11 topics that will be discussed. He asked the MPSAC which of these topics should be pursued. How is one to maintain the core, and what new directions are needed?

A description of the some of the discussion on these topics follows.

Broadening discovery-based learning in the MPS disciplines

Goodchild felt that community colleges should be a part discovery based learning, including minority involvement and researchers without other resources. Baker commented that one must make sure researchers at community colleges have interest and time (institutional support) to do research. Perhaps faculties at these colleges choose not to do research. Hunt noted that there is an existing program on advanced technology education that focuses on community colleges. Morrison said that it was important to include traditionally black institutions. Tyson asked about the input community college faculty needed from researchers, given that they are not involved in cutting-edge research? Blandford commented that community colleges have a pool of qualified students who could do very well. Pemberton noted that accessible instrumentation could easily involve community colleges, but this is not a panacea for getting instrumentation to undergraduate institutions. Hilborn commented that about one-half of K-12 teachers learn their science at two-year institutions and it was a reason to include community colleges. Appelquist felt that involvement of community colleges should be in partnership with research institutions.

Salah asked if the MPSAC endorsed the idea of involving community colleges. The MPSAC agreed, and moved to the topic of mid-scale instruments and infrastructure.

Mid-scale instruments and infrastructure

Baker asked whether initiatives have a "sunset clause." Sanders noted that what was being proposed by MPS was an increase in funding for items that fitted between the Major Research Instrumentation (MRI) and Major Research Equipment (MRE) categories, plus operational funding for major facilities after they have been constructed. Dehmer said that in physics, one builds, measures, shuts down, and goes on to the next thing. In astronomy, the life cycle for facilities is much longer. Morrison felt that support for operating costs should have a sunset clause, or science programs would be slowed down. Baker noted that there is a lot of mid-range instrumentation coming on line and those facilities are not being optimally used. For example, there is a large pool of people who can benefit from a $10 million to $15 million beam line that can run for 10 to 25 years. There is a need for beam time to look at small things using tools not found in a normal lab.

Salah asked whether one should include MRE operational costs. Sanders felt that NSF needs a "doctrine" for supporting instrumentation initiatives throughout the life cycle. One might ask for a funding line that doesn't take funds out of programs or MRE. Hunt noted that under MRE rules, the requesting unit must bear the cost of operation. For the LHC, the MPS contribution to that will be about $20 million, not the $10 million originally planned (this increase was primarily due to mostly due to grid computing).

Salah asked the MPSAC whether they called for a separation between operational costs and mid-scale instrumentation costs. The MPSAC responded in the affirmative.

Blandford noted that at NASA the reaction would be: "Let us devise a creative program throughout MPS which one could compete for, so that one could say 'We have an option for doing science on this scale.'" Aizenman commented that in the NASA model operational costs are requested in the budget; in the NSF model, it is up to the proposing Directorate to provide future operational costs. Pulleybank asked if this included access to large-scale computing resources and the response was in the affirmative. Sanders noted that life cycle estimates are often unreliable due to technology changes. Morrison commented that this, like the previous item, is an NSF-wide issue. NSF is more nimble since it hasn't locked up dollars into the future. Committing to a 20-year instrument decreases opportunities for other initiatives.

Increasing core support.

Futrell noted that the Hart-Rudman Report on homeland security report suggested this was the right course to take. Salah asked if MPS should have a major thrust in national security linked to core support. Siegmund did not like the way the "investment and balance" statement is written. It seems more important to stress the role the physical sciences are playing in biomedicine. Hilborn felt that the argument must be made on intellectual and scientific merit. The life sciences are changing character, becoming more like the physical sciences. Pemberton stated that core support was very important in terms of educating the workforce. Morrison said that there is a widely held feeling in the public that the 21st century is that of the biological sciences.

Mathias wondered is one should make the case that the infrastructure in MPS (instrumentation, human resources) is contributing to the progress of the biosciences? Neuhauser commented that quite a few physicists work in biology, and, as a result, are better trained to come up with solutions to certain problems. Blandford felt that linking with National Security should be done carefully, not in a "cynical" or negative way.

Salah asked if one should separate the national security effort from core support. Pulleyblank said that the response to Hart-Rudman included reinforcing the core as a way to ensure the ability to respond to any unanticipated event. Salah then proposed that a couple of separate paragraphs on National Security be added to this section for added visibility

The discussion then turned to NSF priority areas.

NSF Priority Areas

BE: Biocomplexity and the Environment

Dr. Donald Burland, Executive Officer of the Division of Chemistry, described this initiative. The first competition for this initiative took place in 1999 and was narrowly focused (mainly microbiology, *etc*.) The program for 2001 to 2003 includes coupled biogeochemical cycles and genomes and involves many areas of mathematics, science and engineering that are related to environmental science, such as dynamical systems and materials science. The status of Biocomplexity and the Enviornment (BE) as a priority area ends in FY 2003; the FY 2003 competition is for $31.53 million.

The funds for this program, along with the other biotechnology and nano area projects, are not included in the MPS budget; rather it is an NSF-wide program. The total BE request in FY 2003 is 79.2 million dollars; MPS is requesting 4.70 million.

ITR: Information Technology Research

Dr. Barry Schneider, Program Director for Atomic, Molecular, Optical and Plasma Physics in the Division of Physics, described this initiative. NSF is the leading government agency involved in this area. The Computer and Information Science and Engineering Directorate (CISE) has the largest share of ITR funds; MPS is next with 33 million dollars.

About 70% of the funds are to be spent for the large and medium-sized grants, but 25% go to small awards. The reviewing is done differently in the different divisions; some use panels, some mail review. The large and medium proposals are handled centrally through CISE, but all directorates participate in the reviewing. There are many activities co-funded with CISE.

Examples of project funded under this area involving MPS were provided. Examples included a Center for Theoretical Biological Sciences and Physics (CTPB) at the University of California at San Diego, a Gravitational Physics Network at Florida, advanced parallel computing techniques with applications to computational cosmology, and computational tools for materials design at Pennsylvania State University.

Since the ITR initiative ends at the end of FY 2002 and the stated intent is that ITR funds remain within Directorates, the question arises as to what MPS should do with respect to renewals for funding in this area. It was felt that. ITR renewals should involve computational and multifaceted intensive science of direct interest to MPS.

Nanoscale Science and Engineering in DMR

Dr. W. Lance Haworth, Executive Officer of the Division of Materials Research, described this initiative. This is an interagency initiative. The agencies involved and their FY03 requests in millions of dollars are: NSF, $22.1M; Department of Defense, $201M; Department of Energy, $139.3M; National Institutes of Health, $43.2M; NASA, $51M; NIST, $43.8M; Environmental Protection Agency, $5M; Department of Transportation/FAA, $2M; Department of Agriculture, $2.5M; Department of Justice, $1.4M. (The Department of Justice is interested in the authenticity of results.) The total FY 2003 request is about 710.2 million dollars. This priority area ends in FY 2005.

There are seven research areas in this initiative at NSF:
1. Biosystems at the nanoscale;
2. Nanoscale structures, novel phenomena, quantum control;
3. Device and system architecture;
4. Nanoscale processes in the environment;
5. Multiscale, multiphenomena theory, modeling and simulation;
6. Manufacturing processes; and
7. Societal and educational implications.

There are several funding modes for these research areas. These include:

1. Funding through the core programs and also through NSF wide solicitations for interdisciplinary research (NIRT), with about 50 awards per year;
2. Exploratory research (NER), about 50 awards per year;
3. Centers (NSEC), with about 6 awards per year; and
4. Undergraduate education (NUE), a new area this year.

The level of participation by MPS in nanoscale science is 93.08 million (estimated) for FY02, out of a total of 198.71 million for all directorates in FY02; 103.92 million is requested by MPS for FY03, out of a total request of 221.25 million.

Examples of projects funded in this initiative include a project at Cornell University, "Tunneling spectroscopy of Electron-in-a-Box Energy Levels in Metal Particles", the "Physics web", and "In pursuit of the ultimate storage medium at the University of Wisconsin.

Mathematical Sciences Priority Area

Dr. Deborah Lockhart, Acting Executive Officer of the Division of Mathematical Sciences (DMS), described this initiative. Lockhart began with a discussion of why the Mathematical Sciences were declared a priority area.

While the U.S. is currently a world leader in the mathematical sciences, this leadership is very fragile. The number of undergraduate math majors and the number of graduate students has dropped. There has also been a decline in the amount of funding for mathematical sciences over many years. At the same time opportunities are increasing significantly for interaction with science and engineering, and mathematics has a large impact on the rest of science.

MPS will support three components in this initiative: fundamental mathematics and statistics, connections to other sciences and engineering, and mathematical sciences education (especially projects with a large impact). For the second component, interdisciplinary mathematics, the emphasis will be on three categories of problems:

1. Mathematical and statistical questions arising from large data sets;
2. Managing and modeling uncertainty; and
3. Modeling complex nonlinear systems (such as predicting behavior, analyzing brain function with wave patterns).

The budget for FY 2003 is uncertain. There was a start-up appropriation in FY 2002 of $30 million, all within MPS; the FY 2003 request is for $60.09 million NSF-wide, of which $47.4 million would be within MPS.

The implementation mechanisms for this initiative are to increase grant size and duration, to increase support for undergraduates, graduate students and new PhDs, to encourage collaborative research groups, to build new mathematical science institutes (including in the future to build interdisciplinary centers), to promote cross-disciplinary training, and to increase educational enhancement efforts.

In FY 2002 three new institutes were established: the Mathematical Biosciences Institute (MBI), at Ohio State University; the Statistics and Applied Mathematical Sciences Institute (SAMSI) at Duke University and the American Institute of Mathematics (AIM) at Palo Alto, California. The focus of SAMSI is to bring mathematicians and statisticians together to look at data-driven problems. AIM runs workshops focused on important mathematics problems. In addition three new partnerships have been formed:

1. Computer Algorithms for Geometric Objects (CARGO), a partnership between DMS, CISE, and the Defense Advanced Research Project Agency (DARPA), with 12 awards totalling about $3 million;
2. Mathematical Biology, a partnership between DMS and the National Institute of Health's National Institute of General Medical Sciences (NIH/NIGMS). This includes general medical sciences and and awards total $18 million $6 million came from NSF; and
3. Mathematical Geosciences between DMS and NSF's Directorate for Geosciences (GEO).

Goodchild asked about the lack of diversity in mathematics. Lockhart pointed to the Grants for Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE) program, which promotes diversity, and also mentioned that when new institutes and new proposals come forward, diversity is a major issue in the reviewing. Goodchild asked what mechanisms exist to promote diversity in the presently funded institutes and in institutions. Lockhart answered that some institutes, such as AIM, are hiring personnel specifically to promote diversity.

Learning for the 21st Century Workforce

Dr. Henry Blount, Head of the Office of Multidisciplinary Activities (OMA) within MPS, stated that the production of well-trained capable scientists is the most important product of MPS. It is a mantra for NSF to produce a technically trained, diverse and internationally competitive workforce. This initiative is NSF-wide and $185 million is requested for FY 2003; the MPS portion of this request is $5.97 million.

There are four vital pieces to this initiative:

1. Undergraduate research;
2. Preparing future faculty;
3. Institutional alliances and interaction; and
4. Research on workforce development as a result.

MPS projects in this initiative include:

1. A new science learning center ($2 million) – the first of the NSF-wide program of Centers for Learning and Teaching;
2. GK-12, a project in which graduate students go into elementary classrooms ($1 million);
3. Interagency research initiatives ($2 million); and
4. A distinguished teaching scholars program ($0.3 million).

Adjournment

The meeting adjourned at 6:30 P.M.

Friday, November 8, 2002
Morning Session

Salah convened the meeting of the MPSAC at 8:30 am.

Hunt distributed copies of the May 30, 2002 memo from John H. Mar burger (Director, OSTP) and Mitchell Daniels (Director, OMB) to the Heads of Agencies on FY 2004 Interagency R & D Priorities and pointed out the guidance that it implies for NSF.

Follow Up to MPSAC/EHRAC Symposium

Goodchild reported that participants in the previous day's joint MPS/EHR symposium recommend that a small subcommittee of people from the MPS and EHR advisory committees for follow up activities. This group would keep information flowing, keep in touch with Henry Blount's working group, plan continuing events, advocate for more information on broader impacts and more attention to evaluation. There might also be a joint program solicitation. Pemberton, Hilborn, Goodchild, Gates, and Neuhauser volunteered to serve on the subcommittee.

NOTE: Additional Recommendations of the MPSAC sent to MPS on December 9, 2002 are included in these minutes as Appendix II.

Preparation for Meeting with NSF Director

Salah called for topics to bring up in the upcoming meeting with Dr. Colwell. Suggestions included her view of the role of MPS, the context for the AD/MPS search, her vision for large projects and priorities, and possible questions on NSF and homeland security.

Continued Discussion of MPS Future Opportunities and Directions

Salah asked that MPSAC members prepare their assigned write-ups within one to two weeks so that he can circulate them to the AC and then forward to MPS.

Advancing Mathematical and Statistical Science

Siegmund led the discussion on three topics from the MPS staff-developed papers – Computational Science, Mathematical Sciences, and Statistical Science.

The discussion included comments on the motivation for mathematics research, the importance of statistics to other areas of science, and the relation of this combination of topics to the existing Mathematical Science Priority Area.

Siegmund commented that the value attached to participation in interdisciplinary activities sets statistics/computational science apart from core mathematics. Traditionally mathematics values long-term problems. Statistics and computational math view themselves as starting from a specific application and then providing something of general value and also important for the application. Trying to make this distinction clear is the reason to have 3 documents. Pulleybank, commenting on the computational science paper, asked if the emphasis was for the study of algorithms/computation or on an increasing role in other fields of science. Siegmund felt that computational science might be restricted to the MPS environment. He noted, with respect to statistics, that roughly 20% of the support is from NIH. Morrison commented that the page for mathematical sciences reflects what is in place for the math priority areas whereas the statistics and computational science pages include extensions of existing programs. Neuhauser would like to see the three topics remain as separate units. Pulleyblank asked if the breakdown into the three areas was firm, and whether there was value in integrating the three areas. Salah said that the MPSAC was not suggesting a new initiative, but that the three areas could be combined.

Siegmund and Neuhauser were asked to prepare the MPSAC position paper on this topic.

Exploring Molecular Science and Engineering

This discussion centered on an MPS staff-developed paper on Molecular Science and Engineering, which emphasized terahertz (THz) spectroscopy. Dr. Art Ellis, Director of the Division of Chemistry (CHE), pointed out that THz spectroscopy has potential for biomolecules. CHE may have a workshop for this field. DOE and the National Institute of Standards and Technology (NIST) are interested in this topic.

During the discussion Siegmund stated that the document was inconsistent with the others: one-third of the paper was devoted to molecular science/engineering and two-thirds focused on a specific kind of spectroscopy. Ellis responded that a number of individuals within the community and MPS have remarked that terahertz spectroscopy is insufficiently explained, and important for biomolecular research. Blandford asked whether this could become part of an inter-agency initiative. Pemberton felt there was a need in this area, while Futrell stated that within the context of complex molecules this was one kind of spectroscopy – perhaps this should be stated more broadly. Blandford felt that while a workshop would be great, it hardly constituted a strategy. Ellis commented that a workshop was needed to test the waters.

Futrell and Pemberton were asked to prepare the MPSAC position paper on this topic.

Understanding the Universe

Blanford noted that the staff paper on Origins of the Universe overlapped many things already going on. This was one possible route for strategic planning in Astronomy. Other areas that should be included are high-energy astrophysics, extra-solar planets and star/planet formation. It would be worthwhile to rethink the package. Van Citters felt that this rethinking had to include an overall national strategy for astronomy, including activities at NASA and DOE working together on a national strategy in response to recent reports from the National Research Council. Blandford commented that cosmology remains a central part of astronomy, but perhaps “origins” is not the right word. Dehmer remarked that astrophysics involving neutrinos and gamma-rays are also important areas, overlapping with physics. Gates noted that the NAS report “*Quarks and the Cosmos*” described other emerging areas such as string theory.

Blanford and Tyson were assigned to prepare the MPSAC position paper on this topic.

Creating a New Initiative in the Biophysical Sciences

Baker noted that the staff paper on Quantitative Biology was very compelling. She asked if this was something new or a packaging of existing core MPS activities. There was discussion as to whether this should be renamed, with biology being removed from the title – perhaps changing it to “*Molecular and Physical Basis of Life Processes*.” Neuhauser, while understanding the objection to using the word “biology,” felt that MPS has to move into biology, since the biology community lacks sufficient quantitative capability. There was discussion of whether this should be maintained as a separate initiative or made part of the core activities. The MPSAC concluded that this topic should be kept separate from core support, but with a link to the Biocomplexity and the Environment initiative.

Baker and Bob Hilborn were asked to write the MPSAC position on this topic.

Enhancing Quantum Science and Engineering

Applequist stated this was a very important, emerging area in the atomic, molecular, and condensed matter communities.. Neuhauser noted that there was an overlap with "quantitative biology" and wondered whether the two should be kept separate. Applequist felt they should be kept separate.

Applequist agreed to prepare the MPSAC position paper on this subject.

Underground Science

Morrison noted that neutrino physics and the opportunity to build an underground lab is exciting although the costs are not well understood. He asked if there had been any discussion of an interagency approach. Dehmer replied that there is interest from the DOE and that the scientific programs for an underground lab would be about 75% physics (dark matter, possibility of proton decay) with the remaining 25% including biology, geology, and national security. *Salah decided to table discussion of an MPS AC position on Underground Science until the next meeting (April, 2003) when there should be a one-hour presentation on the topic.*

Meeting with the NSF Director, Dr. Rita Colwell

The NSF Director, Dr. Rita Colwell, outlined recent NSF budget history and noted that it had increased by about 60 percent in the last four to five years. NSF is recognized for management excellence in many areas. She stated that two important areas for the next few years are addressing needs in the physical sciences and engineering, and integrating research and education. She appreciates having AC members involved in outreach. She summarized Congressional actions on the FY 2003 budget to date and asked the AC to back the entire NSF budget, not just the MPS part of it. She noted that the search for a new Assistant Director for MPS is underway with the appointment of an external search committee. She invited comments from committee members.

In response to questions from various members of the committee, Colwell noted that:

- The search committee for the new AD/MPS should be announced soon. She is seeking a person who knows the community, works well with other disciplines, is visionary, and can pull the communities together within budget constraints;

- Her recent speech to the AAAS is on the web and outlines her plans to strengthen the MPS core research;

- NSF programs such as IGERT, GK-12, and the Graduate Fellowships are important ways to integrate research and education. It is important to integrate vertically and horizontally;

- We need to take better approaches to teaching to capitalize on different learning styles;

- NSF is expected to do well in Congress to allow us to increase grant size and duration, increase grad student stipends, link better with community colleges, and process the backlog of large projects;

- She thinks NSF needs to find an appropriate way to provide operations funding for new large projects; and

- The basic research programs of NSF, as currently structured, are relevant to national security. NSF's best contribution to national security is to continue what NSF is currently are doing. The original NSF enabling legislation of 1950 is still applicable.

General Discussion and Lunch

At the conclusion of Colwell's presentation, the MPSAC had a general discussion of members' reactions to her presentation. Members were pleased to hear concrete plans for the search for a new MPS AD and were pleased with her comments on Hart-Rudman related efforts within MPS.

Goodchild commented that there appeared to be no incentive for scientists to assist in the K-12 program. Hunt responded that NSF needs to get reports on successful projects and report them to the MPSAC, and there is a need to show incentives for involving research scientists.

Salah commented on the need for integrated strategic planning. There appears to be no integrated mechanism in NSF. Colwell had encouraged individual constituencies to get together, and said that priorities should be set within MPS. Salah noted that if the MPSAC were to become involved in strategic planning it would be a multi-meeting process.

It was noted that the MPSAC has not been involved in putting forward MPS-related MRE projects. The situation has been different for the initiatives or focus areas, where the MPSAC has been an advocate. Salah asked the Committee to think about a process for setting priorities that could become an agenda item for the next meeting.

With regard to long-range planning, Dr. Salah asked if there were more long-range items than the one pagers discussed earlier in the meeting. None were suggested.

Division of Physics: Overview and Issues

Dr. Joseph Dehnmer, Director of the Division of Physics (PHY), began his presentation by announcing that the Physics Committee of Visitors (COV) meeting would be held in February. A Chair of the COV had been selected but that appointing members to the COV was still taking place.

The Physics Division had an irreducible set of 4 strategic goals:

- Intellectual Frontiers
- Broader Impacts (Economy, defense, other fields of science)
- Education
- Stewardship (Maintaining the strength of physics into the future)

He presented a list of current frontiers of physics, including Bose-Einstein condensates and atom lasers for which three NSF-funded physicists received the Noble Prize recently.

Investment goals of the Division included fostering dramatic scientific advances that alter the course of physics and other fields; seeding major advances in the nation's health, wealth, and defense; international leadership/cooperation; recruitment of exceptional talent into science; and strengthening diversity in science.

Strategies used by the Division included hiring high quality program directors; making use of broad community-based advice; a proactive approach to education & diversity; the timely phase-out of mature facilities; and cooperation with other funding sources within NSF, the US, and internationally.

Priorities for the Division included individual and small group support, increasing diversity, and exploitation of new tools for discovery

Dehmer noted that the Laser Interferometer Gravitational-Wave Observatory (LIGO) will measure a displacement equivalent to 1/10,000 of the diameter of proton. It is a collaboration of 430 scientists in many countries. LIGO is now operational and doing coincidence experiments with interferometers in Japan and Europe.

He commented on the Physics Frontier Center at the Center for Cosmological Physics at the University of Chicago. On of their scientists has recently detected polarization of the cosmic microwave background for the first time.

He also described activities of individual investigators and instrumentation developed by grantees. An example he noted was the Joint Strike Fighter. The construction of this aircraft makes uses laser technology developed by LIGO, and has saved the government over $100 million.

He noted that the physics community now takes diversity seriously and that PHY is supporting a number of projects associated with education and outreach. Examples include QuarkNet, PhysTEC, and an exhibit at the National Air and Space Museum entitled "*Explore the Universe*" (a collaboration between the NSF Division of Astronomical Sciences (AST) and the Physics Division).

New opportunities for the Division include support for the Rare Symmetry Violating Processes (RSVP) project, the detection of high energy neutrinos (Icecube), activities in astrophysics, and an advanced version of LIGO. Several as yet unfunded projects were also described.

Applequist asked how PHY would handle the budget cuts required under the President's budget request. Dehmer replied that principal investigators would not be cut again (they were cut 10% last year). Something of strategic importance would suffer unless Congress increases the budget.

Divisional Meetings – Divisional Implications of MPSAC Recommendations Concerning New Opportunities for MPS

The MPSAC then broke up into groups that met with individual Divisions.

Action Items and Future Activities

Aizenman announced that future meetings of the MPSAC would meet on the first Thursday and Friday in April, and in November with the proviso that both days need to be in the same month. Thus the next MPSAC meeting will be April 3 and 4, 2003, followed by November 6-7, 2003.

Salah discussed MPS action items. (An asterisk indicates the chair of a subcommittee.)

- The EHR connection subcommittee (Fiona Goodchild*, Bob Hilborn, Claudia Neuhauser, Jeanne Pemberton) will come up with suggestions for future interactions between MPS and EHR. This subcommittee's liaison in MPS will be Art Ellis.

- Members of the AC will summarize comments on the MPS long-range plan. These were to be sent to Salah via e-mail no later than 11/21/02. They will be given to the NSF by December 8, 2002.

    Broadening Discovery-based Learning – Fiona Goodchild*, Lon Mathias
    Facility and Infrastructure Stewardship – Gary Sanders*, Shenda Baker
    Increasing core support in MPS – Roger Blandford, Bob Hilborn
    Computational Science, Mathematical. Sciences, Statistical Sciences – David Siegmund*, Bill Pulleyblank, Claudia Neuhauser, David Morrison
    Molecular Science and Engineering – Jean Futrell*, Jeanne Pemberton
    Origins of the Universe - Roger Blandford*, Neil Tyson
    Quantitative Biology – Shenda Baker*, Bob HilbornQuantum Science and Engineering – Tom Appelquist*

NOTE: COMMENTS SENT TO MPS BY THE MPSAC ON DECEMBER 10, 2002 ARE FOUND IN APPENDIX III OF THESE MINUTES

- MPS will develop a chart describing MPS investments in education by division, similar to the chart shown by Friel on MPS investments in international activities.

- MPS will prepare a brief report on educational projects already underway in MPS. This report will be distributed to the MPSAC when ready, but prior to the next meeting.

- A subcommittee (Bill Pulleyblank*, Tom Appelquist, Jean Futrell, Peter Green, Joe Salah) will study the process of how MPS should set priorities, and prepare a report. They will seek some expert input and possibly invite someone to speak at the next meeting. The subcommittee's liaison in MPS will be Adriaan de Graaf.

- *Telling the MPS Story*. Members of the MPSAC agreed that this is important, and that sometimes more depth is necessary than provided by nuggets. Hunt pointed out that OLPA is very resource-limited. Gates suggested that Tyson might be a good person to lead the discussion. Salah thought that perhaps a quarterly newsletter would be appropriate. There was insufficient time to discuss the matter further, but the MPSAC agreed to think about the subject.

Items of discussion for the AC meeting of April 3-4, 2003

1. A report on the MPS - intelligence community workshop (Moniz, Baldeschwieler, Pemberton, de Graaf).

2. Review status of other recommendations contained in white paper on Hart-Rudmann report (de Graaf).

3. A presentation on Underground Science and Laboratories (Dehmer).

4. The report of the Physics COV.

5. Discussion on the process of setting priorities within MPS.

6. Discussion on how best to tell the MPS story.

Adjournment

The meeting was adjourned at about 3:00 p.m.

Appendices

APPENDIX I

EHR/MPS Symposium held at NSF on November 7, 2002
"Integrating the Science of Learning with the Learning of Science"

Introduction to reports from group discussions – submitted, January 2003
Compiled by Fiona Goodchild, Fiona@mrl.ucsb.edu and Susan Millar

The following short reports were submitted as records of the small group discussions held after four presentations by invited scientists at the November 7, 2002 symposium on "Integrating the science of learning with the learning of science." As a predicate to these group discussions, the individual speakers at the symposium, Joe Reddish, John Wright, Josefina Arce and Bob Mathieu, presented a range of models for integrating science and education with respect to the quality of undergraduate education at their home institutions.

All of the summary reports from the groups indicated that participants were committed to the goal of achieving broader impact as well as intellectual merit in scientific research. Many of them emphasized the wide range of possibilities, including outreach to the general public and to policy makers and politicians. Most of them made specific suggestions about mechanisms that would make it possible to operationalize this idea more effectively. A summary of these recommendations is listed in three areas below:

1. Education and Public information:

- Publish and disseminate examples of successful broader impact projects, especially in journals and publications
- Compile a database of exemplar projects that researchers can search to identify what is already being done.
- Hold workshops for scientists and educators that address both research on teaching/learning and evaluation of projects that integrate research and education.

While it is not necessary for scientists to engage in the educational research community, it is important that they understand current approaches and the relevance of findings in the area of the science of learning. The newly funded Higher Education Centers for Learning and Teaching could play an important role in this education process.

2. *Examination of the effect of the Broader Impact criterion*

- NSF should collect evidence about the difference that NSF's Special Notice 127 is making to the way that scientists frame their research proposals.
- NSF should explore what sustained impacts have resulted from Broader impact activities associated with all grants, both at individual institutions and at a systemic level.

Though many of the participants see these issues as NSF responsibilities, others suggested that NSF offer incentives to researchers who can address these questions.

3. *Internal cohesion at NSF*

- NSF should sponsor more joint events, such as the one held on November 7, to promote interaction between scientists and the community of education researchers to highlight successful examples of Broader Impact activities.
- More transparency is desirable, both at the directorate and the program officer level, about possible approaches to making a broader impact. For example, the Chemistry division has prepared relevant information for its community of researchers.
- NSF directorates, especially EHR, should strive for more integration of both scientists and educators in the composition of their own review panels and the outcomes of the proposal review process.

<u>Postscript</u>

It became clear, as we listened to the group reports on November 7, that the discussion groups had moved from the symposium speakers' topic of undergraduate education to the more general issue of how to meet the broader impact requirement. We surmise that participants were responding to the recent Special Notice 127, since many of them expressed concern about this as a way of enforcing NSF's requirement that scientists consider the wider impact of their research.

Given that this symposium included scientists who are seriously committed to the integration of research and education, we believe that it is important for NSF to support scientists in their efforts to respond to NSF's Broader Impacts policy. In particular, the scientists appear to be asking for

1. Help in undertaking broader impact activities that make good use of their time and are consistent with the interests of educators, students and the public.
2. Explicit evidence of the benefits and value NSF's broader impacts policy.

We believe that without such communication and more effort to encourage interaction between directorates, there is a risk of jeopardizing the support of some of the key representatives of the scientific community, including some of those who attended this mini-symposium.

Breakout Group Instructions for Joint ACMPS/ACEHR Mini-Symposium

The members of the six groups are listed on the attached page. ACEHR and ACMPS members are distributed evenly across the groups. A chair/facilitator and a reporter is identified for each group.

Each group should address **either** question 1 or 2 **and** question 3 *(below) during the 45-minutes breakout group period. While developing your responses, please make every effort to build on your own knowledge and experiences as well as points made by the mini-symposium speakers.*

Your chair and recorder will summarize your group's suggestions and ideas in an informal report to Judith Ramaley and John Hunt, provided no later than November 14. This report also will be posted on the ACEHR and ACMPS web page. Your group's chair will present one key point from your discussion during the report-out over lunch.

Thank you for your contributions!

Questions for Discussion by Breakout Groups for Joint Mini-Symposium

1. Most STEM researchers do not have the training or skills to respond effectively to NSF's Review Criterion 2 on their research proposals, and to develop effective proposals that focus on education and outreach. How can EHR and MPS work together to address these challenges?

2. The joint AC mini-symposium committee believes that a great proportion of the education and outreach activities operated from NSF-funded research projects function under the constraints implicit in being an "add-on." This situation is only going to be intensified as researchers respond to Important Notice 127. Forced to operate under "add-on" constraints, E&O programs often:

- are unfocused and uncoordinated in their goals and program strategies;
- cannot offer the sustained programming that fosters faculty and teacher investment;
- operate with little if any of the benefits provided by evaluation and benchmarking;
- are unable to address key workforce issues; and
- generally are not able to optimize the use of scientists' and teachers' time and effort.

Do you concur with this assessment of the situation for E&O programs? If so, how might MPS and EHR help the members of the STEM research community and their institutions avoid these pitfalls of "add-on" E&O programs?

3. In order to resolve 1 and 2, MPS and EHR need to work together. Understanding how to, and finding the time to, “cross the boundaries” between disciplines is a key to achieving NSF’s goal of integrating research and education. For example, incorporating evaluation into NSF projects is proving useful as a “boundary crossing” strategy. What strategies do you suggest MPS and EHR might use to more effectively cross their own boundaries at NSF, and to further help STEM and education researchers to cross boundaries at their institutions?

EHR/MPS Mini- symposium at NSF on November 7, 2002
Notes of the breakout session from Groups 1 and 2

EHR/MPS Mini- symposium at NSF on November 7, 2002

To: Judith Ramaley and John Hunt
From: Susan C. Bourque
Date: November 10, 2002
Re: Report on Breakout discussion: Groups 1 and 2

Attending: Judith Ramaley, Arturo Pacheco, Nora Ramirez, Robert Mathieu, Susan Bourque, Ron Williams, Pat Forgione, Lon Mathias and David Siegmund.

- With respect to discussion of question 1, several suggestions were made to help develop effective proposals that focus on education and outreach. Among the suggestions were the following:
    1. Make it clearer to researchers why it is desirable for their projects to have a broader impact. Make the reasoning behind “broader impact requirements” compelling.
    2. Emphasize the national need for quantitative and scientific literacy and the research community’s responsibility to contribute to that national goal.
    3. Disseminate broadly the new research on learning to enhance faculty members’ understanding of the significance of educational research for improved teaching and learning. Help faculty members appreciate how significantly student learning can be enhanced by the use of new approaches to teaching.
    4. Address the scientific research community’s concern that Criterion 2 will require surpassing enormous hurdles.
    5. Create incentives for broader impact through budgets. Project budgets should reflect the principal investigator’s financial commitment to meeting the goals of Criterion 2.
    6. Reflect NSF’s commitment to Criterion 2 and Notice 127 in the <u>outcomes of the proposal review processes</u>. Explore the need for a joint committee from EHR and MPS to review the consistency of the message between what NSF says is important and what NSF funds.

- With respect to question 3, enhancing the ability of MPS and EHR to work together, a number of suggestions were made:
    1. Bridge the divide between education research and disciplinary communities. Find the language to translate between distinct communities.
    2. Use mini-seminar like models, where specialists within disciplines can use appropriate and meaningful examples to deliver new research findings on learning to their constituencies.
    3. Use research journals and publications to disseminate new findings on learning and teaching within disciplines.
    4. Use the new Teaching and Learning Centers to identify new “bridging possibilities” across disciplinary divides, emphasize links between MPS disciplines and research on learning and teaching. Use workshops to disseminate findings.
    5. Continue G-K12 links with graduate students, but avoid research faculty using this mechanism to obviate serious consideration of Criterion 2.
    6. Create new Ph.D.’s who include research on learning within their discipline as part of their scholarly research profile.

7. Insure that there is a mechanism to carry forward and disseminate results of studies, projects and experiments carried out under Criterion 2. Make sure we track the results of experiments to broaden impact. Recognize the need for good data and record keeping on what has been effective and what are the best practices.
8. Build on what is known and avoid the need to re-invent the wheel.
9. Make publications and information on "best practices" and successful models widely available for researchers. This will reduce the burden on researchers and perhaps enhance the possibilities of broader impact.
10. Make sure that materials are intelligible and credible from one discipline to the next. That is, make sure they "bridge" and translate effectively across fields and disciplines.

EHR/MPS Mini- symposium at NSF on November 7, 2002

Notes of the breakout session from Group 3

Submitted by Gretchen Kalonji

The majority of the discussion focused on question 1, concerning NSF's Review Criterion 2. The group strongly encouraged the NSF to undertake a rigorous evaluation of the impact of the "broader impact statement" on the portfolio of projects supported by the foundation. For example:

- What do we know about whether the statements that people are including in response to this requirement actually are making a difference in the proposal funding decisions?

- Is this requirement actually effective in encouraging people to tailor their research such that it does have a broader social impact?

The group also stressed that it is vitally important that the NSF itself take a very broad view of the concept of "broader impact". It appears, at least anecdotally, that the community is interpreting "broader impact" to refer exclusively to education and/or outreach add-on's to their research plans. Group 3 felt that we need to encourage diverse interpretations of the "broader impact" criterion, and that it would be dangerous for US science if making fundamental contributions to basic science was not considered in itself to be a valid response to the criterion. Along these lines the group encouraged the NSF to disseminate broadly a diverse set of examples of ways PI's have creatively responded to this criterion.

With respect to Questions 2 and 3, the group concurred that education and outreach activities often suffer from the "add-on effects" mentioned in the hand-out. One relatively straightforward contribution the NSF could make would be to make it easier for researchers to build on the work of others, and to make connections to work currently underway. If statements describing educational plans of funded projects could be assembled in a searchable web-based database, that could go a long way towards building more of a sustained community of scholars looking to integrate educational projects into their research plans. The NSF should also make it clear to the community that building on the work of others, and/or collaborating in a larger-scale endeavor initiated elsewhere, are also valid ways to structure their educational programs. At the very least, if it were easier for PI's to access information about projects funded through EHR and relevant educational plans for projects funded under the other directorates, we could expect to see a higher overall quality in the educational work supported by the foundation. The group concurred that it would be highly desirable for EHR and MPS to work together more closely, and that collaborating on designing mechanisms to make information on funded research more easily accessible to the broader community would be a productive direction to pursue.

EHR/MPS Mini- symposium at NSF on November 7, 2002
Notes from Group 4

Submitted by Thomas Taylor

Our group only looked at Question 3 relating to MPS and EHR working more collaboratively. Group 4 offers the following discussion points as a focus for additional dialogue within the Foundation.

1. There was strong sentiment that there are barriers between the directorates at NSF that hamper efforts to bring EHR strengths and MPS activities together. Two suggestions to remedy this problem:
   - have EHR members participate on MPS panel;
   - have EHR examine jackets so as to provide ad hoc advice to panels in other directorates
2. MPS potential grantees need more information about EHR activities - some grants have EHR activities listed that are not possible to carryout, e.g., teach molecular biology to 3rd graders (matter of scale, and no prior contact with grade school teacher).
3. Many grants simply don't have an education plan - although some intentions are well placed, there has been no assessment of what can and can not be accomplished by the researcher
4. To help remedy Nos. 2 and 3 above we suggest: some type of joint MPS and EHR workshop to explain to researchers the diverse opportunities that might be possible; what will work and what will not; how contact should and should not be made; who needs to be involved in the planning etc.
5. MPS might add some successful collaborative activities in the EHR realm to its web site, provide a booklet of ideas that appear to have been well received and that work - in reality offer assistance to its grantees about expectations.
6. Grantees need to discuss within specific disciplines at professional meetings - NSF might assist in providing staff e.g., American Chemical Society where a specific workshop might focus on EHR collaborations. Our Group felt that many researchers don't fully understand what is being requested by NSF - we also felt that there were many excellent researchers who if provided some guidance, could certainly make a meaningful impact with novel, exciting, and stimulating EHR activities. We feel strongly that the best collaborations and changes in attitude will come through an awareness within the scientific disciplines and thus the culture change needs to be reinforced at that level.
7. Once activities are instituted who will sustain? In the case of K-14, will it be the individual school?, individual classroom? NSF? or will these activities cease once a particular grant has been terminated etc.
8. In order to increase greater participation that is meaningful, and not simply an "add on" to a grant, and to maximize time and instill EHR activities in the next generation of scientists - some form of reward e.g. support for a graduate student or postdoctoral fellow. Such an individual will be involved as a portion of his/her activities in the EHR component. We suggest that this represents a meaningful strategy with long term benefits for this next generation of STEM researchers.

EHR/MPS Mini- symposium at NSF on November 7, 2002
ACMPS/ACEHR GROUP 5 DISCUSSION NOTES

Submitted by William B. DeLauder

1. *With respect to the issue of EHR and MPS working together to address the NSF's Review Criterion 2, the Group noted that research and teaching/learning are of common interest to both units. This, therefore, provides common ground for working together on this issue.*

2. The group raised the question as to whether the focus of meeting NSF's Criterion 2 was solely on education and research as opposed to finding other ways to demonstrate a broader impact. It was pointed out that the later purpose could serve to better demonstrate to the public, including politicians, the benefit of funded research.

3. The group agreed that it was a challenge for applicants to address Criterion 2 adequately; applicants will need far more assistance.

4. One of the ways suggested to address Criterion 2 was for applicants to request funding to support graduate students to engage in teaching/learning as a part of their responsibilities.

5. It was suggested that MPS and EHR co-sponsor a symposium on teaching/learning to be attended by provosts, deans, departmental chairs, and scientists. Nobel Prize recipients and other noted scientists, who are committed to linking teaching/learning and research, should be invited to serve as presenters/motivators for the symposium.

6. The Group noted that there is a need to better disseminate information on teaching/learning to a broader audience.

APPENDIX II

MPS-EHR Collaboration on Education and Broader Impacts

Mission:

To foster collaboration and exchange of ideas between the MPS and EHR Directorates and their Advisory Committees so as to further strengthen the integration of research and education in programs supported by NSF.

Objectives:

- Initiate dialogue that will communicate the goals, needs and detailed activities of each Directorate to the other.
- Explore areas of collaboration and cooperation involving workshops, symposia and outreach to constituents in areas of mutual interest, including needs, emerging areas of discovery and concern, infrastructure issues and evaluation of program impacts.
- Develop white papers and working documents to explore how educational and research opportunities can be combined for the benefit of students at all levels.
- Explore focus areas and programs that would be co-reviewed and co-funded in the areas of STEM education and in satisfaction of the 'broader impacts' criterion.
- Explore development of an inventory of disciplinary expertise in science education.
- Promote communication mechanisms to NSF personnel and NSF constituents describing activities, available resources, upcoming workshops, online assistance and NSF funding opportunities.

Possible mechanisms:

1. Establish a short-term joint subcommittee comprised of members of both Advisory Committees (AC). Results of their work would be shared with both the EHR and MPS Advisory Committees.
   For example this subcommittee might:
   - Keep the two AC's informed about matters of mutual interest.
   - Host occasional joint sessions, such as the one held on November 7, 2002.
   - Write joint white papers to provide guidance to the two AC's.

2. Recommend ways of exchanging NSF personnel and external reviewers on panels for proposals that integrate scientific and educational research.

MPS Advisory Committee
December 9, 2002

APPENDIX III

RECOMMENDATIONS OF THE MPS ADVISORY COMMITTEE
FOR THE LONG-RANGE PLAN OF THE MPS DIRECTORATE
10 December 2002

At its meeting on November 7-8, 2002, the NSF Advisory Committee for Mathematical and Physical Sciences (MPSAC) discussed the long-range strategic planning for the MPS Directorate. The process was initiated at the meeting by reviewing various topics suggested by the MPS Divisions, and was followed by a discussion of selected topics by subgroups of the MPSAC after the meeting. The resulting recommendations of the MPSAC are provided below as an input to the MPS long-range strategic planning activity.

1. Increasing core support in the Mathematical and Physical Sciences.

From the X-ray luggage scanner at an airport to the Magnetic Resonance Imager in the local medical facility, from modern synthetic techniques for manufacturing cheap pharmaceuticals to the neutron scattering facilities used to develop new materials and unravel the molecular basis for disease, and from the data encryption algorithms that safeguard electronic funds transfers to the wondrous discoveries that we have made about the world inside the atom and within the universe at large, we are surrounded by the fruits of research into mathematical and physical science in our everyday, economic and cultural lives. As well as providing the foundation of our technological society and the basis of our national defense, this research in mathematics and the physical sciences has proven for decades to be an engine for economic growth including, especially recently, growth in the biomedical and information sectors.

The pace of discovery in basic mathematical and physical sciences is even higher in the 21st century than it was in the 20th. While it is important to support broad efforts in areas that build on the previous discoveries, the need to invest in mathematical and physical science research – to replace the seed corn – has never been greater than it is today and yet, by most indicators, this investment has lagged and we are now seeing the consequences. Our premier research laboratories are not as well equipped as needed. Our brightest young people, who might once have devoted their lives to the discipline of a research career, are being lured away by easier and more lucrative alternatives. Perhaps most damaging of all, the appreciation of mathematics and physical science and the confident understanding of its most basic principles have been seriously eroded in the population at large, from those who rely on technology to carry out their work to politicians charged with making difficult economic choices.

The field of mathematical and physical science encompasses a vast collection of strongly linked, active subfields. Although some areas of rapid growth, such as nano-technology, can be identified, the majority of the most significant discoveries – the next lasers, transistors and imaging devices – will continue to arise in an unscripted manner from the core program. This is the very nature of research. The National Science Foundation has an enviable record of success in identifying and fostering promising investigations out of the core research program in addition to supporting its more concentrated and programmatic research. There is now an historic opportunity to re-energize the mathematical and physical sciences and usher a new age of achievement in their service to society: the **MPSAC recommends a re-investment in the nation's future by increasing the financial support of the MPS core research program.**

2. Broadening Discovery-based Learning in the MPS Disciplines

The MPSAC strongly supports the increased focus on undergraduate education that integrates research into the undergraduate experience and into science courses, including those taken by first and second year undergraduates, students from community colleges and pre-service teacher candidates. The **MPSAC endorses the idea of creating Undergraduate Research Centers** (URC) that would expand opportunities for faculty to develop courses that include open-ended research projects. Such courses could infuse new vitality into the curriculum, develop a broader understanding of scientific concepts and improve problem-solving skills.

URCs have the potential to establish collaborations within disciplines and among research and community colleges to provide research opportunities to students who do not have direct access to research laboratories. The centers could provide resources for mentoring and career guidance for undergraduate students who participate in research internships, both during the academic year and summer sessions.

Two-year community colleges have a great potential to play a much stronger role in developing the S&T workforce for the 21st century. Moreover, their student population includes a high percentage of students from under-represented minority groups. While the faculty members in these colleges are often accomplished teachers, they often have limited resources available for introducing students to relevant instrumentation and technology. Mechanisms for community colleges to have access to modern instrumentation will provide necessary training for a broad group of students.

Partnerships between research universities could explore how to introduce new tools into investigative laboratory experiences as well as how to integrate current research into both introductory and upper level courses. The partnerships could provide additional opportunities for students to have access to high quality research instrumentation and real research experiences in active research laboratories. In addition, **MPSAC recommends a concerted effort to develop affordable instrumentation for training students** in scientific research at the undergraduate and community college levels, and at high school levels, to enable discovery-based research.

3. Developing and Supporting our Research Tools

- Initiative for the development of mid-scale facilities or projects

The MPSAC is aware of many opportunities for scientific tools that lie between the scales of he Major Research Instrumentation (MRI) program and the Major Research Equipment, Facility and Construction (MREFC) category. Increasingly, however, this level of opportunity has become important for researchers across the MPS disciplines. There is an emerging need for leveraging science such as can be enabled by the development of beam lines at neutron and light sources, high magnetic field laboratories, advanced computing facilities, and moderate-scale astronomical observing facilities and instrumentation. In addition, support for upgrades (such as new detectors or data collection techniques) can dramatically improve the efficiency and sensitivity of existing instrumentation at a much-reduced cost. These opportunities compete for support with the individual investigator grants.

MPSAC endorses initiatives to support mid-scale instrumentation, in order to assure support for individual investigators and to enhance the ability of MPS and NSF to realize the promise of the mid-scale scientific tools. We further urge that MPS develop a process for selecting these mid-size projects, determining optimal programmatic timeframe for construction, and a methodology and standard for oversight and management of projects of this scale.

- Support for the full life cycle of large facilities

As the NSF portfolio of large facilities grows, the exploitation and stewardship of these facilities creates pressures on the single investigator support programs. These facilities generate scientific interest that leads to growth in the interested communities and increased proposal pressure. Proper and adequate support of the operations, users, and upgrade/evolution of these facilities requires resources that also compete with the needs of the single investigator programs.

MPSAC urges MPS, and NSF in general, to consider establishing guidelines that call for the planning for facility operation and exploitation that carries these large tools from completion of construction under the MREFC account, through the remaining life cycle of the facility, while preserving the funding base for the single investigators who will conduct the enabled science.

4. Advancing Mathematical and Statistical Science

Today's discoveries in science, engineering, and technology are inextricably intertwined with research advances across the mathematical sciences, from modeling climate change to providing decision-making tools for internet-based business information systems. The mathematical sciences are essential not only for the progress of research across disciplines but are also critical for training a mathematically literate workforce for the future. From FY 2003-FY 2007, the *NSF Mathematical Sciences Priority Area* will emphasize research and education, and the **MPSAC endorses NSF's goals to advance frontiers in three interlinked areas: (1) fundamental mathematical and statistical sciences, (2) multidisciplinary research, and (3) education in the mathematical sciences.** The VIGRE program, which integrates mathematical/statistical research, the training of future mathematicians through post-doctoral and pre-doctoral fellowships, and innovative educational experiences for undergraduates, and in some cases K-12 students, is a very successful and increasingly popular innovation made possible by recent budget increases.

Three broad, multidisciplinary research themes have been identified for initial emphasis in the Mathematical Science Priority Area: (a) mathematical and statistical challenges posed by large data sets, (b) modeling and managing uncertainty, (c) modeling complex nonlinear systems. Facilitating these multidisciplinary goals are particular concerns of *Computational Science and Statistical Science.*

In recent years computation has become an indispensable part of the scientific tool kit: (i) to explore the consequences of scientific theories and (ii) to organize and process experimental data. The methodology of *Computational Science* begins with a discipline specific application, then through a process of abstraction develops general algorithms that can be applied to a variety of similar problems, and finally applies these algorithms to the discipline specific problems.

Statistical Science is especially concerned with the study of variability and uncertainty, and with decision making in the face of uncertainty. A characteristic of the field is the value placed on the individual statistician's participation in both the development of general statistical methodology and in multidisciplinary activities in (for example) biology, medicine, the social sciences, engineering, or government policy. These dual allegiances play an important role in stimulating the influx of new scientific problems and the dissemination of new ideas of wide applicability. The rapid growth in the availability of experimental/observational data, facilitated by technological advances in methods for collecting and processing data from oceanic, atmospheric, seismic, and satellite observational networks, to DNA sequencing and magnetic resonance imaging machines creates increasing numbers of opportunities for participation by statisticians in multidisciplinary research. These in turn create a challenge to educate the next generation with the appropriate balance of mathematical background, statistical methodology, computational skills, and subject matter knowledge, without letting the increasingly specialized demands of subject matter knowledge and the time commitment of software development hinder the communication that facilitates the dissemination of new ideas. This challenge is also an opportunity to prepare statisticians better to play an important role in the multidisciplinary, multi-investigator research of the future.

5. Understanding the Universe.

Over the past forty years, we have all been privileged to witness a revolution in our picture of the universe and mankind's place in it. There has been an unbroken stream of fundamental discoveries that have transformed our view of the size, age and shape of the universe from a matter of speculation to one of accurate measurement. We have found black holes and neutron stars in abundance and have observed matter exposed to conditions of pressure and temperature far more extreme than can be reproduced in the laboratory that result in enormous explosions seen across the universe. The formation of stars, for long obscured behind dusty veils of gas, can now be witnessed directly and we now know that extra solar, giant planets are very common but on quite different orbits from those of Jupiter and Saturn.

This golden age of astronomical exploration has been enabled by new technology that has opened up the entire, seventy-octave span of the electromagnetic spectrum. Technology has also made possible non-electromagnetic astronomy using cosmic rays, neutrinos and gravitational radiation. As these technological advances are still being exploited, the pace of discovery will remain high for the foreseeable future.

However, the emphasis is changing from exploration to understanding. Some parts of astronomy, such as the study of the very early universe, gravitational physics and ultra high energy astronomy, are becoming quite closely aligned with physics; others, like the search for extrasolar terrestrial planets, are presenting serious chemical and even biological problems. Attention is being focused increasingly on understanding just how and when galaxies (including their nuclear black holes) and stars formed and on how matter and energy are cycled between them and the inter-galactic and -stellar gas. Increasingly, these big questions require that results from several telescopes be compared with numerical simulations for their solution. This, in turn, means that the distinction between space- and ground-based astronomy and theory has become blurred.

Through its support of major observatories, and, especially, through its stewardship of grants to individual investigators - Tools, People and Ideas - the NSF has contributed considerably to progress in astronomy. **The way forward for the next decade has been clearly mapped out in two NRC publications which the MPSAC endorses as the appropriate path for further progress in understanding our Universe**: the *Astronomy and Astrophysics Decadal Survey Report* and the *Quarks to the Cosmos Report*. In addition, the NSF will obtain advice on how best to coordinate the implementation of these plans between the three agencies involved, NSF, NASA and DOE, from the recently-formed *National Astronomy and Astrophysics Advisory Committee (NAAAC)*. The MPSAC looks forward to hearing the recommendations of the NAAAC as they evolve.

6. Enhancing Quantum Science and Engineering

The field of Quantum Science and Engineering (QSE) is emerging from discoveries at the interface between classical and quantum phenomena in physics, chemistry, materials research, engineering and computation. QSE comprises the science and engineering underlying the creation and manipulation of material in quantum states. Such states have unique properties and we must turn to the laws of quantum mechanics to characterize their behavior. QSE has the potential for profound impact on the convergence of information technology and nanoscale science and engineering, and on the future of computing, communications, and technologies critical to homeland security. It is thus expected that QSE will emerge as a key to 21^{st} century technology, and the **MPSAC recommends an enhanced focus to promote QSE in the MPS program.**

In the last five to ten years, there has been significant progress in QSE. This includes the manipulation of single atoms by scanning-probe microscopies, atom cooling and trapping in controlled electromagnetic fields, single-atom control of chemical reactions, quantum optics and electronics in nanoscale systems of one, two, and three dimensions, and atom lasers. 'Artificial atoms' or 'quantum dots' can be produced singly and in ordered arrays. Coherent sources of atoms may make the atom laser a tool with as much impact for physicists, chemists, materials scientists and biologists as the photon laser. Complementing the many advances based on laser cooling and manipulation of atoms is the use of quantum states in condensed matter. Quantum computation involves various methods of manipulating quantum systems as a method for achieving the logic-gate operations that form the basis of quantum computation. This could provide unparalleled power for solving problems in seconds that would take many months using conventional computers.

An area impinging on QSE is that of ultra fast spectroscopy. In the optical range, femtosecond techniques allow the study of molecules or solids on the time scale of a molecular vibration. This trend is being further developed with ultra fast techniques at synchrotron light sources. These developments are pushing the time scale of experiments to the "coherence time" of quantum states such as a phonon in a solid. These ultra short time scales are in the true "quantum realm". The hope, eventually, is to go from observation of quantum states at ultra short time periods to control of these quantum states. This could in principle lead to new routes to chemical synthesis by control of electronic states in adjacent molecules and to new types of molecular electronics.

7. Exploring Molecular Science and Engineering

As we enter the 21st century, the molecular sciences are the central science underpinning both the application of science and technology to societal concerns and US leadership in key technical areas – medicine, information technology, and national security, to name just a few. At the level of nanoscience and technology the physical and life sciences converge on the process of self-assembly of functional structures guided by chemical forces of attraction operating at the level of single molecules and molecular assemblies. Achieving understanding and mastery of these processes is the grand challenge of the molecular sciences.

Such a goal was unthinkable as recently as a decade ago but can now be articulated with reasonable confidence it can be achieved within a decade. With unprecedented precision we can now image and manipulate individual atoms and molecules, characterize their behavior on surfaces and measure intramolecular and ensemble-scale properties with unprecedented accuracy. The two pillars of measurement science, especially spectroscopic methods, and computational science and modeling present the prospect of understanding complex and collective behavior noted in nature and materials. The capability of design and control of physical and chemical properties follows understanding of how things work at the level of intermolecular forces.

The widening horizons of the molecular sciences call for appropriate investments to extend the capabilities of spectroscopic methods, including magnetic resonance and mass spectrometry, to biopolymers and other complex materials. Interfacial and surface science are challenges of singular importance in miniaturization (e.g., lab on a chip) when the ratios of surface to volume increase exponentially. Combined spectroscopies, including imaging, are another area deserving special attention. A singularly unexplored region of the electromagnetic spectrum is the terahertz or THz region. This is a window to enable characterization of low frequency collective motion characteristic of polymers and biopolymers. **The THz area is explicitly recommended by the MPSAC for exploration** in concert with other Federal agencies having responsibilities in applications relating to this area, including NIST and DOE.

8. Creating a New Initiative in the Bio-Physical Sciences

The traditionally more molecular and mathematical approaches in the mathematical and physical sciences ideally position MPS to provide human resources to develop quantitative tools in and approaches to biology while simultaneously enriching the breadth of MPS research. With the rapid growth of physical and mathematical applications in the life sciences, it is timely to have MPS launch an initiative that strengthens the connections between the biological sciences and these fundamental sciences. These contributions will complement and enhance the more traditional approaches to biology, while bringing the strengths and perspectives of quantitative fields to biological problems. This initiative should include collaborative efforts between MPS, the Directorate for Biological Sciences and other federal agencies such as NIH as well as private foundations such as the Howard Hughes Medical Institute. MPS is particularly well positioned to provide opportunities for people with training in mathematics and the physical sciences to contribute to the biological sciences. **The MPS AC strongly recommends that MPS develop such an initiative in the biophysical sciences.**