BPA News

Board on Physics and Astronomy • The National Academies • Washington, D.C. • 202-334-3520 • national-academies.org/bpa • Winter 2005-2006

Plasma 2010: An Assessment of and Outlook for Plasma Science

An assessment of plasma science in the United States is being conducted as part of the decadal assessment and outlook *Physics 2010.* Since publication of the previous decadal study of this area in 1995, the field has undergone rapid advances and significant changes—ranging from a refocused mission of the DOE fusion science program to new plasma processing technologies arriving in the commercial marketplace to significant advances in understanding how to confine plasmas. A new field called high-energy-density physics has been defined that foretells new connections between astrophysical phenomena and laboratory experiments. It is timely and important to identify the compelling science opportunities in plasma science and to frame a strategy for realizing them. Also, recommendations from the last decadal study have been implemented by the agencies and an assessment to provide feedback is now appropriate.

Previous NRC studies played an important role in defining the fields of plasma and fusion science and identified research opportunities at the frontier. On the basis of new insights and advanced understanding, scientists are poised to address key questions in the areas of plasma turbulence and self-organization, plasma dynamics with asymmetric magnetic fields, extreme and unusual plasma states, and nonlinear plasma interactions with intense electromagnetic fields. One of the areas of greatest promise is the effort to achieve sustainable fusion power; this goal cannot be realized without an integrated approach to the science and technology challenges.

With support from DOE, NSF, and NASA, the National Research Council formed a committee with broad expertise in plasma science and neighboring areas. The Plasma 2010 Committee will address the following tasks in a report that will communicate the scientific opportunities well to policy makers and scientists in other fields:

1. Assess the progress and achievements of plasma science over the past decade.
2. Identify the new opportunities and the compelling science questions for plasma science, frame the outlook for the future, and place the field in the context of physics as a whole.
3. Evaluate the opportunities and challenges for the applications of plasma science to fusion and other fields.
4. Offer guidance to the government research programs and the scientific communities aimed at addressing these challenges and realizing these opportunities.

The committee met for the first time on September 30-October 1, 2005, in

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In this issue:

Innovation and U.S. Competitiveness

Natalia J. Melcer, NRC Staff

On October 12, 2005, the National Academies released a report focused on a comprehensive, coordinated federal effort to bolster U.S. competitiveness and preeminence in science and technology. The report, titled *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, was requested by Senators Lamar Alexander (R-TN) and Jeff Bingaman (D-NM) of the Senate Energy and Natural Resources Committee, with endorsement by Representatives Sherwood Boehlert (R-NY) and Bart Gordon (D-TN) of the House Science Committee. The senators requested answers to the following: What are the top 10 action items, in priority order, that federal policy makers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?

To answer these questions, the National Academies convened a committee of 20 members consisting of CEOs, university presidents, Nobel prize winners, and former presidential appointees. In only 10 weeks, the committee collected data and information, heard from experts, and prepared a lengthy report on the topic. The recommendations from 13 issue papers related to the present study were collected in advance of the first and only meeting to review the work of others. At that meeting, the committee held five focus groups in K-12 education, higher education, research, innovation and workforce issues, and national and homeland security. The contributions of more than 60 experts at the focus group sessions were combined with the literature and committee interviews to afford more than 150 recommendations and implementation steps. However, following its own discussions, each focus group identi-

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Highlights of the Fall Meeting of the Board on Physics and Astronomy

The Board on Physics and Astronomy met for its annual autumn meeting on November 6-7, 2005, at the Beckman Center of the National Academies in Irvine, California. Calling the meeting to order, chair Burton Richter thanked everyone for making the trip; he then provided some perspectives on the meeting agenda. Organized around a set of three working groups, this Board meeting would focus on developing new strategic thrusts for the Board as well as identifying important connections to other activities within the National Research Council.

Before breaking out into the three groups, the Board discussed its current portfolio of activities.

C. Megan Urry, co-chair of the Committee on Astronomy and Astrophysics, led a preliminary discussion on the outlook for astronomy and astrophysics. She described the growing challenge of supporting large-facility operations at the National Science Foundation's Astronomy Division. Because maintaining and operating the current suite of capital investments occupies nearly 80 percent of the division's budget, it is difficult to identify resources to exploit cutting-edge opportunities. NASA is still developing a new strategic approach to astronomy and astrophysics, she said, and therefore it was difficult to predict what level of resources could be carried forward.

Jonathan Bagger presented some preliminary remarks about the physics side of the Board's portfolio. He noted that while the Board's decadal survey of physics (Physics 2010) was well under way, there were a number of important issues to consider, such as interdisciplinary research, international benchmarking, a holistic view of physics, and contemporary articulation of the role of physics in society.

Frances Hellman introduced the longer-term strategic outlook for the Board, mentioning issues such as economic competitiveness and educating the next generation of scientists, engineers, and teachers.

During the afternoon session of the meeting, the Board met in three separate groups to address these different areas.

Reconvening as a group, the Board heard a presentation from Michael S. Turner, Assistant Director for Mathematical and Physical Sciences at NSF. Dr. Turner described the broader landscape surrounding physics and astronomy and commented on the impact of the physical sciences during the 20th century. Commenting that "the 20th century is a hard act to follow," he shared his personal articualtion of bold dreams for science in the next century. His list included topics ranging from providing sustainable energy to power our planet to reconciling quantum theory and general relativity to revealing new mysteries of the quantum world and new states of matter. He then characterized some of the obstacles that science will likely face, including the need for priority-setting and global coordination in an increasingly interconnected world.

On the second day of the meeting, the three working groups reported back to the full Board, followed by an extended discussion.

Meg Urry summarized the discussions of the astronomy breakout session. In terms of the NSF's role in supporting the field, the group discussed the in-progress senior review and the process by which large research facilities are identified, prioritized, and proposed for construction in NSF's Major Research Equipment and Facilities Construction Account. In thinking about NASA, the group considered the existing advice on relative science priorities and implementation strategies. As science demands larger and more complex facilities to explore the frontiers, independent reviews of cost and schedule will be even more important. In addition, the scientific opportunities since the last decadal survey have expanded with the discovery and prominence of dark energy. As the astronomy and astrophysics community considers how best to improve the decadal survey process, the Board should explore new approaches as well.

Jonathan Bagger described the key points of discussion in the physics breakout session. For instance, the group considered the emerging interfaces and cross-connects with other areas of science that the Board might consider exploring. One approach would be to organize discussions with other elements of the National Academies in areas such as materials science and engineering, energy and the environment, biological physics, solid-state chemistry, computational science, and science education.

The group also considered the ongoing decadal survey of physics, *Physics 2010*, from a broader perspective. Analyses of the major subfields of physics (atomic, molecular, and optical physics; condensed-matter and materials physics; elementary-particle physics, nuclear physics, and plasma physics) are either under way or are planned to begin over the next few years. Considering the breadth of physics, a number of other important areas of inquiry were identified (such as cosmic-ray physics, neutrino astrophysics, gravitational physics, and fluid physics); the group considered ways to include these areas in the existing planned efforts. However, a significant part of the intellectual activity within physics is taking place at interfaces with other fields and in emerging areas, such as particle astrophysics, biological physics, high-energy-density physics, accelerator science and technology, and computational physics. While the first of these is well treated in the existing *Connecting Quarks with the Cosmos* report, it will be important to include the other areas in *Physics 2010.*

In order to reflect the unity of physics, the group discussed ways to explore the impact of physics on society. For instance, the Board might consider a physics and society volume of *Physics 2010* that could assess "what physics is good for" in areas such as energy, national security, the environment, education, technology, health, culture, and economics. The Board could even consider convening a truly interdisciplinary panel to make these types of assessments in a credible way. The group also considered the value of an overarching report that could capture the broad connecting themes of both physics and astronomy. To be most effective, such a report should be prepared for a general audience.

Finally, Frances Hellman discussed the highlights of the future-outlook breakout session, echoing many of the same points as Meg Urry and Jonathan Bagger. Reflecting on the active portfolio of the Board, her group considered several cross-cutting issues: education and communication of science to the public and the need for metrics, including international benchmarking. The National Acaemies' recent report *Rising Above the Gathering Storm* highlighted both of these issues and their strong interplay with a discussion of national competitiveness. The Board might consider undertaking a study to identify in what areas of physics the nation should excel, or perhaps what it would take to achieve world leadership in certain areas.

Communicating science to the public was a second important topic of discussion. The NAS president has recently encouraged the NRC to consider methods for expanding the dialogue with the public, emphasizing that the discussion efforts for most reports are widely perceived as monologues. For instance, the group considered ways to make reports prepared under the Board's auspices more broadly accessible, both in content and in access. In particular, the group discussed the need for a more coordinated online and Web presence for BPA reports. Some reports might even communicate well to high-school or college students interested in science. Connecting these thoughts to the issue of science education, the group discussed possibilities for the Board to participate in a broadly based assessment of the effectiveness of science education.

Wrapping up the day's discussions, Vice Chair Anneila Sargent outlined the key action items from these discussions and thanked everyone for their participation and creativity. She suggested that the Board consider inviting chairs of related units of the NRC to future meetings to more fully explore interdisciplinary activities as well as to become educated about both sides of the interface. With a warm California sun high overhead, the Board retired for a pleasant luncheon and adjourned. ■

Committees of the Board on Physics and Astronomy

Committee on Astronomy and Astrophysics
C. Megan Urry, Yale University, and Roger D. Blandford, Kavli Institute for Particle Astrohysics and Cosmology, *Co-chairs*

Committee on Atomic, Molecular, and Optical Sciences
Pierre Meystre, University of Arizona, *Chair*

Plasma Science Committee
Cary B. Forest, University of Wisconsin at Madison, *Chair*

Committee on Radio Frequencies
Karen St. Germain, Naval Research Laboratory, *Chair*

Solid State Sciences Committee
Marc A. Kastner, Massachusetts Institute of Technology, *Chair,* and Peter F. Green, University of Texas at Austin, *Vice Chair*

Atomic, Molecular, and Optical Physics 2010 (AMO 2010)*
Phillip Bucksbaum, University of Michigan, and Robert Eisenstein, *Co-chairs*

Condensed-Matter and Materials Physics 2010 (CMMP 2010)*
Mildred S. Dresselhaus, Massachusetts Institute of Technology, and William J. Spencer, SEMATECH, *Co-chairs*

Elementary Particle Physics 2010 (EPP 2010)*
Harold T. Shapiro, Princeton University, *Chair,* and Sally Dawson, Brookhaven National Laboratory, *Vice Chair*

MRSEC Impact Assessment Committee
Matthew V. Tirrell, University of California at Santa Barbara, *Chair*

Plasma Science 2010*
Steven Cowley, University of California at Los Angeles, and John Peoples, Fermi National Accelerator Laboratory, *Co-chairs*

Rare Isotope Science Assessment Committee
John F. Ahearne, Sigma Xi and Duke University, and Stuart J. Freedman, University of California at Berkeley, *Co-chairs*

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*Elements of the new survey *Physics 2010*

First Report from Physics 2010: AMO2 010 Committee Issues Interim Report

Phil Bucksbaum and Robert Eisenstein, Co-chairs, and Michael H. Moloney, NRC Staff

The BPA's *Physics 2010* decadal survey is under way. Studies have commenced in elementary particle physics, plasma science, and atomic, molecular, and optical (AMO) science.

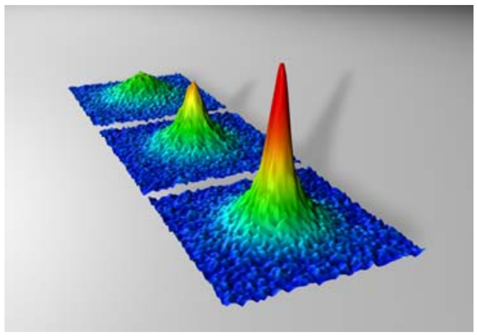
The AMO 2010 study is focused on identifying the most compelling opportunities in AMO science and technology over roughly the next decade. The charge for the study was devised by BPA's standing committee on Atomic, Molecular, and Optical Science (CAMOS) in consultation with the study's sponsors, the Department of Energy and the National Science Foundation. The committee carrying out the AMO 2010 study, which held its first meeting in April 2005, has been asked to assess the state of AMO science, emphasizing recent accomplishments and identifying new and compelling scientific questions.

The charge for this study requests an interim report to summarize the committee's opinion on the key opportunities in forefront AMO science and in closely related critical technologies. The interim report, the first of the Physics 2010 series, was released on November 15, 2005. It presents opportunities in AMO in terms of six grand challenges laid out in the form of six questions. The report also identifies how AMO science supports national R&D priorities.

The committee has solicited and continues to welcome input from the AMO community and the broader scientific and physics communities. The committee hopes that the release of the interim report will also generate further input from colleagues, and e-mail comments can be sent to <amo2010-input@nas.edu>. The committee's interim report is freely available online at <http://books.nap.edu/catalog/11482.html> but because it is a short report, its full text is reproduced below.

The committee's work on the final report is continuing with an enthusiasm inspired by tremendous excitement within the AMO science community about future R&D opportunities. It looks forward to sharing that compelling excitement with the broader R&D community and its sponsors, with the release of its final report in mid-2006.

Controlling the Quantum World of Atoms, Molecules, and Photons: An Interim Report



Time of flight images showing a fermionic condensate. Courtesy of JILA/University of Colorado.

Atomic, molecular, and optical (AMO) science illustrates powerfully the ties of fundamental physics to society. Its very name comes from three of the twentieth century's greatest advances: the establishment of the atom as the building block of matter; the development of quantum mechanics, which made it possible to understand the inner workings of atoms and molecules; and the invention of the laser. Advances made possible by the scientists in this field touch almost every sphere of societal importance in the past century. Navigation by the stars gave way to navigation by clocks, which in turn has given way to today's navigation by atomic clocks. The laser has replaced the knife for the most delicate surgery. Our nation's defense depends on rapid deployment using global positioning satellites, laser-guided weapons, and secure communication, all derived directly from fundamental advances in AMO science. Homeland security relies on a multitude of screening technologies based on AMO research to detect toxins in the air and hidden weapons in luggage or on persons, to name a few. New drugs are now designed with the aid of x-ray scattering to determine their structure at the molecular level using AMO-based precision measurement techniques. And the global economy depends critically on high-speed telecommunication by laser light sent over thin optical fibers encircling the globe.[1]

AMO scientists are proud of their central role in science and society in the twentieth century, and they have has been rewarded with numerous Nobel prizes over the past decade, including the 2005 prize in physics. But in this report we look to the future. At the beginning of the new millennium, what new answers do we seek? What knowledge must we obtain? Because of all that was learned in the last century about the mysterious and counterintuitive nature of quantum mechanics, we are now at the dawn of a new kind of quantum revolution, in which *coherence* and *control* are the watchwords.

The universe is still a mysterious place. How can we determine the properties of the fundamental forces of nature that shape the universe? What can we say about the most fundamental features of our natural world? What are the symmetries that govern the behavior of the universe from the subatomic scale to the cosmic? New AMO technology will help provide answers in the coming decades—in precision laboratory measurements on the properties of atoms, in giant gravitational observatories on Earth, or in even larger observatories based in space. Tremendous advances in precision timekeeping also place us at the threshold of answering some of these questions.

Society has other urgent needs, which AMO physics is poised to address. How will we meet our energy needs as Earth's environment changes and its natural resources become depleted? AMO involvement in molecular biophysics, solar energy collection and conversion, or laser fusion may contribute to a solution. Health threats are likely to increase on our interconnected and highly populated planet, and rapid response to new contagions requires the development of ways to detect biomolecules remotely through advanced laser techniques, as well as ways to measure their structure and chemistry, a priority effort at advanced x-ray light sources. The future security of our nation's most powerful weapons may depend on our ability to reproduce the plasma conditions of a fusion bomb in the tiny focus of a powerful laser. And, controlling that plasma is key to harnessing its power for beneficial uses.

These last thoughts underscore how much AMO science is also about tools. Instruments made possible by AMO science and related technical developments are today everywhere in experimental science—from astronomy to zoology. In many instances they have made possible revolutionary experiments or observations and resulted in correspondingly revolutionary new understandings.

In approaching its charge, the committee identified, from among the many important and relevant issues, six broad grand challenges that succinctly describe key scientific opportunities available to AMO science. Surmounting these challenges will require important advances in both experiment and theory. Each of these science opportunities is linked closely to new tools that will also help in meeting critical national needs.

The six grand challenges, summarized below, will each form a chapter of the committee's final report:

• ***What is the nature of physical law?*** What are the undiscovered laws of physics beyond our current model of the physical world? Recent advances in our understanding of the universe suggest the existence of an unexpected force that alters the fundamental symmetry of time. This tiny effect could be seen in the next decade in experiments that look for deviations in the nearly perfect symmetry found in atoms. Are the laws of physics constant over time or across the universe? A new generation of ultraprecise clocks will enable laboratory searches for time variation of fundamental constants. Answers will also come from AMO research that is helping to interpret astrophysical observations of the most exotic realms in the universe. The advanced technologies developed for fundamental physics experiments will also improve the accuracy of direct gravity-wave detection and of next-generation GPS satellites and will produce new medical diagnostics.

• ***What happens at the lowest temperatures in the universe?*** The coldest objects in the universe are the Bose-Einstein condensates developed by AMO physicists in the last decade. These remarkable new states of matter, typically a billionth of a degree above absolute zero, are much colder than the furthest reaches of outer space. Scientists have discovered that they have strange and wonderful properties, and in the next decade we can expect a rich harvest of interesting new physics ideas and applications—from technological breakthroughs such as clocks and inertial sensors of unprecedented accuracy, to insights into the physics of ordinary matter as well as matter under extreme conditions. We are entering an age when we can routinely and exquisitely control nature on the quantum level. This quantum coherent control has already produced a matter-wave laser, which could advance gravitational and environmental sensing.

• ***What happens when we turn up the power?*** Lasers in the next decade will reach peak powers of a million billion watts concentrated in a single beam of light for a little more than one millionth of a billionth of a second. For an instant this exceeds the entire electrical power consumption of Earth. The huge electric fields in these beams approach the conditions in particle accelerator collisions and overwhelm the forces that bind electrons in atoms and molecules, leading to exotic states of matter usually found only in stars or hydrogen bombs. These lasers will help us understand the violent forces we see in the universe around us. Bright new x-ray-laser sources currently under construction will also help unravel the mysteries of how complex biomolecules work. By irradiating proteins or viruses with a brief coherent flash from an x-ray laser, crucial details about their shape can be captured, to learn what makes them so efficient as they carry out the processes of life or the spread of disease. These exotic high-powered lasers have applications to many other important technological problems as well, ranging from the prospect of controlling nuclear fusion as a source of clean, abundant energy to next-generation compact x-ray microscopes with unprecedented resolution.

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Committee on Atomic, Molecular, and Optical Physics 2010

Philip H. Bucksbaum, *Co-chair*
University of Michigan

Robert Eisenstein, *Co-chair*

Gordon A. Baym
University of Illinois at Urbana-Champaign

C. Lewis Cocke
Kansas State University

Eric A. Cornell
University of Colorado / JILA

E. Norval Fortson
University of Washington

Keith Hodgson
Stanford Linear Accelerator Center

Anthony M. Johnson
University of Maryland at Baltimore County

Steven Kahn
Stanford Linear Accelerator Center

Mark A. Kasevich
Stanford University

Wolfgang Ketterle
Massachusetts Institute of Technology

Kate Kirby
Harvard-Smithsonian Center for Astrophysics

Pierre Meystre
University of Arizona

Christopher Monroe
University of Michigan

Margaret M. Murnane
University of Colorado / JILA

William D. Phillips
National Institute of Standards and Technology

Stephen T. Pratt
Argonne National Laboratory

K. Birgitta Whaley
University of California at Berkeley

Neal Lane, *Senior Consultant*
Rice University

Neil Calder, *Consultant*
Stanford Linear Accelerator Center

BPA Staff

Donald C. Shapero, *Director*
Brian D. Dewhurst, *Senior Program Associate*
Pamela Lewis, *Program Associate*
Michael H. Moloney, *Senior Program Officer*

Innovation
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fied the top three actions it considered necessary to compete, prosper, and be secure in the 21st century.

In its final report, the committee provided four recommendations along with 20 specific implementation actions. The four recommendations focused on K-12 education, research, higher education, and economic policy. The recommendations and implementation actions are highlighted below.

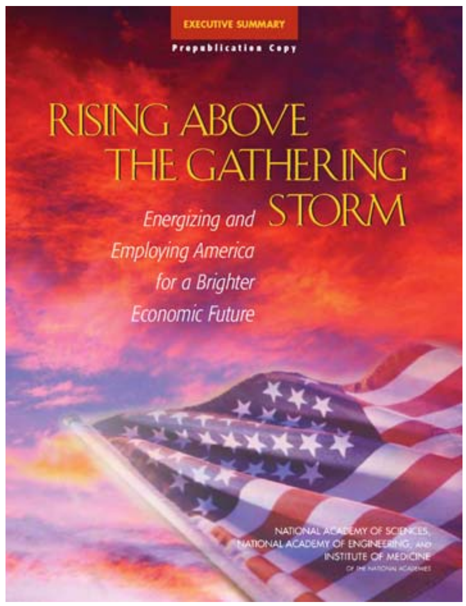
To achieve the first recommendation, to "increase America's talent pool by vastly improving K-12 science and mathematics education," the committee proposes creation of a merit-based scholarship program for undergraduates interested in pursuing degrees in the physical or life sciences, engineering, or mathematics. After graduation, the students would be required to work for at least 5 years in public schools. Another action proposed by the committee is to strengthen the skills of current K-12 teachers through training and education programs.

The second recommendation seeks to sustain and strengthen the nation's commitment to long-term basic research. Specific actions include increasing the federal investment in basic research by 10 percent each year over the next 7 years, new research grants to early-career researchers, and allocating 8 percent of federal agency research budgets to high-risk, high-payoff research. The committee also recommended the formation of a DARPA-like entity within DOE, called ARPA-E, to focus on research and development programs to meet long-term energy challenges.

To develop, recruit, and retain top students, scientists, and engineers from both the United States and abroad, the committee identified multiple implementation actions. These include awarding new undergraduate and graduate scholarships for U.S. citizens pursuing science and engineering degrees, providing a one-year automatic visa extension to international students who receive science and engineering doctoral degrees in the United States for them to seek employment, and reforming the deemed-export control system as it affects international students and scholars.

The final recommendation seeks to ensure that the United States is the premier place in the world for innovation. Specific actions include enhancing intellectual property protection, enacting a stronger research and development tax credit, providing tax incentives for U.S.-based innovation, and ensuring ubiquitous broadband Internet access.

The report has generated significant interest in the topic of America's competitiveness and was well-received by the congressional sponsors. Shortly after the report's release, congressional hearings were held. The first hearing, entitled "Innovation in Energy Technologies and Impacts on Global Competitiveness," took place in the Senate Energy and Natural Resources Committee on October 18, 2005. Mr. Norman Augustine, retired chairman and CEO of Lockheed Martin Corporation and chairman of the study committee, and



Dr. Ralph Cicerone, president of the National Academy of Sciences and chair of the National Research Council, were witnesses for the hearing.

At the Senate hearing, Mr. Augustine presented the committee's views and recommendations. He indicated that the committee had identified two key challenges linked to a strong science and engineering enterprise: creation of high-quality jobs and realizing clean, affordable, reliable energy. The recommendations address these challenges and are viewed as a "coherent set of high-priority actions; to emphasize one or neglect another would substantially weaken the package."

Senator Pete Domenici (R-NM) asked about the future of high-energy physics in the United States. Mr. Augustine replied that with the Large Hadron Collider coming online in 2007 at CERN in Switzerland, researchers are looking to Europe as the "place to be" and that the United States would likely lose its lead for the first time in high-energy physics.

The Senate Committee on Commerce, Science and Transportation held a hearing entitled "The Future of Science" on November 18, 2005. The committee heard from science leaders Peter Agre, vice chancellor for science and technology at Duke University; Eric Cornell, senior scientist at NIST; James Heath, professor of chemistry at California Institute of Technology; and Samuel Ting, professor of physics at Massachusetts Institute of Technology. While the hearing was focused on changes in the U.S. research community, the central themes of the NRC report were reiterated by both the senators and the witnesses.

The report release was also promoted through the American Chemical Society's Science and the Congress Project. On October 27, 2005, the ACS in conjunction with the National Academies and the U.S. Senate High-Tech Task Force presented a briefing on the report for over 120 congressional staff. After an introduction by Senator Alexander, presentations were made by report committee members on the recommendations and implementation actions.

In related activities in Washington, the House Democratic Caucus on November 15 unveiled its Innovation Agenda, and on December 6, the U.S. Department of Commerce hosted the National Summit on Competitiveness. Both events focused on recommendations similar to those of the Gathering Storm report on trying to improve America's competitiveness. On January 25, 2006, Senators Domenici, Bingaman, Alexander, Mikulski, and Hutchison announced the introduction of the Protecting America's Competitive Edge (PACE) Act. The PACE Act is a package of three bills that seeks to implement all 20 recommendations of the Academies' Gathering Storm report. In less than a week since being introduced, it has gathered over 50 cosponsors in the Senate and has garnered bipartisan support. The total cost of the bills is estimated at $9.5 billion in the first year, increasing slightly over a 7-year period. On January 31, 2006, President Bush demonstrated his support by announcing the American Competitiveness Initiative during his State of the Union address. The key elements of this initiative parallel the recommendations of the Academies' report. ■

Listening for Good Science Above the Noise

David B. Lang, NRC Staff

While we go about our daily lives using mobile phones, wireless Internet networks, and global positioning system (GPS) devices, trillions of cycles of man-made radio waves travel through our bodies every second. It's a fact of modern life, but what consequences does this have for the scientific endeavors that have historically been the drivers for radio technologies?

The radio-astronomy and Earth remote-sensing disciplines require researchers to listen for extraordinarily faint signals emitted from sources across the wide universe, including the Earth itself. The information contained in these signals gives invaluable clues to help deduce the behavior of Earth's natural systems and that of the cosmos. While researchers take every possible step to increase the sensitivity of their instruments, they cannot sample sources from a site free of radio frequency interference (RFI), leaving data susceptible to pollution. Radio astronomy has a very distinguished tradition: from revealing the remnants of the big bang to showing the afterglows of superenergetic gamma-ray bursts, radio observers have provided science with insights unobtainable with other types of telescopes. Of the 10 astronomers who have won the Nobel Prize, 6 of them used radio telescopes for the work that won them the prize. However, the radio signals arriving on Earth from astronomical objects are extremely weak: millions (or billions) of times weaker than the signals used by communication systems.

So how do you separate the weak natural signals from persistent but variable artificial ones? Sometimes you can't.

The positioning of the natural signal to be observed necessarily means that different sources of interference will be present. Earth remote sensing scientists need to worry about radar relays, communication networks, and just about every consumer product that uses electricity. In certain urban areas, particularly in the United States, the Middle East and Japan, important frequencies are so polluted by strong RFI that measurements across those areas are nearly useless. This creates gaps in information about soil moisture, vegetative respiration, ice cover, and water vapor, among others.

A radio astronomer can avoid these problems somewhat by geographical placement and topologically shielding an observatory, but research can still be impaired by space- and airborne communications. Even though astronomers keep track of a multitude of manmade satellites orbiting Earth, aircraft communications are still problematic, and there are few places in the United States where the sky is free of aircraft. This problem threatens to worsen; the Federal Communications Commission (FCC) and Federal Aviation Administration are considering allowing mobile phones and other radio communications devices to be used by passengers on aircraft. This individual convenience could affect quite a few people not on the airplane!

Scientists have adapted numerous technical techniques to work around manmade RFI as well, a process also known as RFI mitigation, and depending on whether they are looking up (radio astronomy) or down (remote sensing), their approaches can be somewhat different. Through a variety of complex algorithms and methods, including advanced filtering and statistical analysis, researchers are able to remove a substantial amount of RFI from their data.

The receive-only radio astronomy and earth-science services (also called "passive services") are not fully encroached by artificial RFI. They do enjoy some protection from the FCC and the National Telecommunications and Information Administration (NTIA) which regulate usage of the electromagnetic spectrum with guidance and input from NSF, NASA, and the wider research communities. At the frequencies where radio science is protected, other users must not interfere with their observations or must coordinate their use with the science community, depending on the level of protection mandated by the FCC.

In practice, however, this regulatory protection does not entirely protect science instruments from RFI.

For example, at the 22.235-GHz water vapor line, improperly filtered transmitters can produce out-of-band emissions in this protected band through harmonics or otherwise, which become quite problematic for sensitive Earth science measurements. RFI can be especially detrimental when it does not entirely obscure the natural signals that researchers are studying. Small variations can become indistinguishable from the natural signal itself, corrupting the scientists' data in unknown ways. The corrupted data could then be fed into weather and climate models, producing inaccuracies in weather forecasts and other data products. Somewhat ironically, the emergence of commercial services that rely on remote-sensing data to help advise the agricultural industry has started to apply competing market pressures on out-of-band emissions.

Rising consumer and governmental demand for wider spectrum use threatens these sciences, despite the regulatory framework. If the United States wishes to reap continued benefits from the sizeable investment and leadership role it currently holds in radio astronomy and Earth remote sensing, it is vital that the basic requirements of these sciences are recognized and protected. The National Academies' Committee on Radio Frequencies plays a role in this process by providing commentary and feedback from the perspective of the scientific community in proposed changes in the regulations. ■

AMO Science (continued from page 5)

· *Can we control the inner workings of a molecule?* In the next decade we will begin to observe the processes of nature as they play out over times shorter than a millionth of a billionth of a second (less than 1 femtosecond—that is, in the attosecond regime). This remarkable new capability is enabled by advances in ultrafast laser- and accelerator-based x-ray strobes, which can detect the motion of electrons in atoms and molecules. Scientists anticipate the possibility of capturing images of motion inside a molecule or of using the laser to manipulate matter on the atomic scale. These previously unavailable tools of quantum control and feedback could help them to tailor new molecules for applications in health care, energy, and security.

· ***How will we control and exploit the nanoworld?*** The nanoworld lies in the transition region between our familiar classical world of relatively well-behaved macroscopic objects and the quantum world of atoms and molecules. These nanostructures have counterintuitive but useful optical properties that come from their subwavelength dimensions. Scientists see unique opportunities to tailor material properties for efficient optical switches, light sources, or photoelectric power generators. Negative index nanomaterials could dramatically improve optical microscopes or reduce the feature size in chip fabrication. Other applications include photonic crystals, single-photon sources and detectors, environmental monitoring, and biomedical optics, with applications such as killing cancerous cells via localized optical absorption and heating.

· ***What lies beyond Moore's law?*** Today's computers are doubling in performance every year or two. This will end when the ever-shrinking size of electronic components approaches the level of individual molecules and atoms. Quantum mechanics offers a radically different approach to information processing, whereby single atoms and photons could be the new hardware. This could lead to computers capable of solving problems that are intractable on any imaginable extension of today's computers but that are important in areas from basic science to national security. Quantum communication might provide some security against interception beyond anything possible in today's cyber infrastructure. These applications are based on the strangest and least intuitive concepts of quantum physics, such as Einstein's action-at-a-distance, which allows teleportation and the remote transfer of information without physical contact. Quantum computing is forcing us to explore both theoretical and experimental quantum mechanics at their deepest levels. Should quantum computers be realized, they would be as different from today's high-speed digital computers as those machines are from the ancient abacus.

These key future opportunities are based on rapid and astounding developments in the field of AMO science, a result of investments made by the federal government's R&D agencies in the work of AMO researchers. The committee will discuss these compelling research challenges in more detail in the final report and will highlight the broad impact of AMO science and its strong connections to other branches of science and technology. The strong coupling to national priorities in health care, economic development, the environment, national defense, and homeland security will also be discussed.

The linkages to national R&D goals are clear. The White House set forth the country's R&D priorities in the July 8, 2005, memorandum of the science advisor to the President and the director of the Office of Management and Budget. AMO scientists contribute to these national priorities in several key areas:

· Advancing fundamental scientific discovery to improve the quality of life.
· Providing critical knowledge and tools to address national security and homeland defense issues and to achieve and maintain energy independence.
· Enabling technological innovations that spur economic competitiveness and job growth.
· Contributing to the development of therapies and diagnostic systems that enhance the health of the nation's people.
· Educating in science, mathematics, and engineering to ensure a scientifically literate population and qualified technical personnel who can meet national needs,
· Enhancing our ability to understand and respond to global environmental issues.
· Participating in international partnerships that foster the advancement of scientific frontiers and accelerate the progress of science across borders.
· Contributing to the mission goals of federal agencies.

An essential part of maintaining the country's leadership in AMO science, and one of the White House's R&D priorities, is to train and to equip the next generation of American scientists. The committee is compiling data on funding, demographics, and program emphasis from the federal agencies to help it assess the current state of AMO science in the United States. The committee's conclusions will address priorities for investments in this area, as well as how the U.S. research enterprise might realize the full potential of AMO science.

The final AMO 2010 decadal report is scheduled for release in mid-2006. In the meantime, community input links and other public information about AMO 2010 can be found at the National Academies Web site.[2] Each of the grand challenges identified by the committee in this interim report will be explored in depth in the final report. In the committee's view, there can be no doubt that realizing these key opportunities in AMO science is a vital national priority. ■

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[1]For further detail on the connections between AMO science and society's needs, see National Research Council, *Atoms, Molecules, Light*: *AMO Science Enabling the Future*, Washington, D.C.: The National Academies Press (2002), available at <http://www.nap.edu/catalog/10516.html>.

[2]<http://www7.nationalacademies.org/bpa/AMO2010_Home.html>.

Assessing the Impact of NSF's Materials Research Center Program

T.I. Meyer, NRC Staff

The Materials Research Science and Engineering Center (MRSEC) program was established by the National Science Foundation (NSF) in its Department of Materials Research in 1994. The goal of this initiative was to provide focused support for complex interdisciplinary materials research and education initiatives at the university level. Awards granted under the program provide support for a 6-year period, the last 2 years of which face an external review under recompetition requirements in the program's language. Historically, the MRSEC program is a descendant of the Interdisciplinary Laboratories (IDLs) begun by the Advanced Research Project Agency under the Department of Defense in 1960. The IDL program was intended to support interdisciplinary research in materials science, mainly for military uses. Though obvious changes and transitions have been made in U.S. materials science programs since then, the MRSEC program's current ambitions reflect its origins.

The primary purpose of the MRSEC program is to undertake materials research of a scope and complexity that would not be feasible under traditional funding of individual research projects. NSF support is intended to reinforce the base of individual investigator and small group research by providing the flexibility to address topics requiring an approach of broad scope and duration. To the extent consistent with the size of the center, MRSECs incorporate the following activities: (1) programs to stimulate interdisciplinary education and the development of human resources (including support for underrepresented groups) through cooperation and collaboration; (2) active cooperation with industry and other academic institutions to stimulate and facilitate knowledge transfer among the participants and strengthen the links between university-based research and its applications; and (3) support for shared experimental facilities, properly staffed, equipped and maintained, and broadly accessible to users.

On the occasion of its 10-year anniversary, there is a need to assess the MRSEC program's performance and to determine a vision for its future in the modern era. Recognizing this need, NSF made an informal request to the National Research Council. In response, the NRC convened a panel of experts to conduct this impact assessment under the auspices of the Board on Physics and Astronomy (BPA); for the project, the BPA is informally collaborating with the Board on Science Education and the National Materials Advisory Baord. The task before the MRSEC Impact Assessment Committee is to

1. Assess the performance and impact of the National Science Foundation's Material Research Science and Engineering Center (MRSEC) program;
2. On the basis of current trends and needs in materials and condensed matter research, recommend future directions and roles for the program.

The assessment will evaluate the program's performance and impact and frame an outlook for its future. Factors to be considered will include the role of the MRSECs in enabling multidisciplinary research, supporting instrumentation development, providing research and education infrastructure, and facilitating collaboration and cooperation between researchers and industry. The committee will complete its work over the course of about 18 months.

In addressing its task, the committee will consider the past and future impact and performance for the MRSEC program in some of the following areas of emphasis: collaborative research, innovation and creativity, synergy, technology transfer and collaboration with industry, education and outreach, institutional relationships, leveraged investments, diversity, national strategies,

See "MRSEC" on page 11

Committee to Assess the Impact of NSF's Materials Research Center Program

Matthew V. Tirrell, *Chair*
University of California at Santa Barbara

Kristi S. Anseth
University of Colorado at Boulder

Meigan Aronson
University of Michigan

David M. Ceperley
University of Illinois at Urbana-Champaign

Paul M. Chaikin
New York University

Ronald C. Davidson
Princeton Plasma Physics Laboratory

Duane B. Dimos, *SSSC Liaison*
Sandia National Laboratories

Edith M. Flanigen
UOP, LLC (retired)

Thomas F. Kuech
University of Wisconsin at Madison

Diandra Leslie-Pelecky
University of Nebraska at Lincoln

Bruce H. Margon
Space Telescope Science Institute

Andrew Millis
Columbia University

Venkatesh Narayanmurti
Harvard University

Ralph G. Nuzzo
University of Illinois at Urbana-Champaign

Douglas D. Osheroff
Stanford University

Stuart S.P. Parkin
IBM Almaden Research Center

Julia M. Phillips, *BPA Liaison*
Sandia National Laboratories

Lyle H. Schwartz
Air Force Office of Scientific Research (retired)

James C. Williams
Ohio State University

Eli Yablonovitch
University of California at Los Angeles

BPA Staff

Donald C. Shapero, *Director*
David B. Lang, *Research Assistant*
Pamela Lewis, *Program Associate*
Timothy I. Meyer, *Senior Program Officer*

Plasma 2010
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Washington, D.C., at the Keck Center of the National Academies. The committee heard testimony from representatives of the key federal research agencies supporting plasma science and received guidance from OMB staff about how to prepare a useful and compelling report. Other invited speakers made presentations about different subfields of plasma science, including space and astrophysical plasmas, low-temperature and industrial plasmas, magnetically confined fusion, high-energy-density plasmas, and basic plasma science. The committee then spent some time formulating its work plan. As co-chair Steve Cowley remarked, "The 1995 survey focused on identifying what defines and connects all of plasma physics; a key task of this committee will be to identify what plasma physics all physicists should know." In order to achieve the strongest possible report, the committee chose to first examine each subfield of plasma science to capture its key advances and grand challenges by breaking into small groups and preparing preliminary reports. Recognizing the enormous breadth of plasma science (and engineering), the committee also prepared plans to engage the broader community. A program of site visits, focus group discussions, and town meetings was discussed and a general Dear Colleague letter was drafted for circulation to the community. Since the meeting, written comments from more than 100 different individuals have been received in response to e-mail solicitations, and nearly a dozen different site visits have been conducted. The analysis and synthesis of the gathered information will continue at the committee's next meeting, scheduled for February 4-5, 2006, in Irvine, California, at the Beckman Center of the National Academies. The committee will identify scientific themes that thread through the different areas of plasma science; these themes will be used to organize the committee's final report, expected to be ready for release before the end of 2006. ■

Plasma 2010 Committee: An Assessment of and Outlook for Plasma Science

Steven C. Cowley, ***Co-chair***
University of California at Los Angeles

John Peoples, Jr., ***Co-chair***
Fermi National Accelerator Laboratory

James Callen
University of Wisconsin at Madison

Franklin R. Chang-Diaz
Ad Astra Technologies, Inc.

Todd Ditmire
University of Texas at Austin

William Dorland
University of Maryland at College Park

Walter Gekelman
University of California at Los Angeles

Steven L. Girshick
University of Minnesota

David Hammer
Cornell University

Erich P. Ippen, *BPA Liaison*
Massachusetts Institute of Technology

Mark J. Kushner
Iowa State University

Kristina A. Lynch
Dartmouth College

Jonathan E. Menard
Princeton University

Lia Merminga
Thomas Jefferson National Accelerator Facility

Eliot Quataert
University of California at Berkeley

Timothy J. Sommerer
General Electric Research

Clifford M. Surko
University of California at San Diego

Max Tabak
Lawrence Livermore National Laboratory

BPA Staff

Donald C. Shapero, *Director*
Ms. Pamela Lewis, *Program Associate*
Timothy I. Meyer, *Senior Program Officer*
Michael H. Moloney, *Senior Program Officer*

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coordination among centers, international activities, and any important and emerging themes within the materials research enterprise itself.

The committee met for the first time in person on November 18-29, 2005, in Washington, D.C., at the Keck Center of the National Academies. At the meeting, the committee discussed possible means for quantitatively evaluating the MRSEC program and clarified the scope of the study. Issues related to innovation and individual research versus group research, industrial partnerships, program management, and educational goals and outcomes were discussed. The committee examined MRSEC educational and public outreach efforts in conversations with staff from the NRC Board on Science Education. Representatives from the NSF Division of Materials Research (DMR) gave presentations on the history and management of the MRSEC program and expressed their willingness to assist the committee with any answers or data they are able to provide. The committee divided the key tasks into four areas and formed subgroups to better address these aspects in greater detail. The research subgroup is examining the characteristics and impact of MRSEC research; the industrial outreach and innovation is exploring the impact of important technologies and the nature of MRSEC connections with industry. The education and outreach group is considering the organization, impact and appropriate goals and guidance for these efforts. The fourth group is examining the impact of management practices and shared experimental facilities along with international considerstions. Site visits, questionnaires, and telephone interviews will be used to gather data. The committee is hard at collecting and reviewing a wide spectrum of information and is preparing for its next meeting, scheduled for March 8-9, 2006, in Santa Barbara, California. It is hoped that the final report will be available near the end of 2006. ■

BPA Mission

The Board on Physics and Astronomy (BPA) was created in 1983 as the successor to the National Academy of Sciences Office of Physical Sciences. Several standing committees were assigned at that time to the BPA, including the Committee on Atomic, Molecular, and Optical Sciences, the Solid State Sciences Committee, and the Committee on Radio Frequencies. Later, the Committee on Astronomy and Astrophysics and the Plasma Science Committee were created in response to requests from the scientific community. Since its inception, the BPA has published more than 40 reports, workshops, and collaborative activities, including two surveys of physics and two surveys of astronomy.

The important questions in physics and astronomy change as we learn more about nature, and that rate of change has been increasing. The BPA seeks to inform the government and the public regarding important scientific opportunities and issues as well as the changing nature of science. It builds bridges between the evolving subdisciplines of physics and astronomy and with other areas of science. The BPA is successful if it helps the science community and society understand what is needed to advance physics and astronomy and why doing so is important.

Every activity of the BPA is aimed at accomplishing one or more of the following goals:

- Monitor the health of physics and astronomy.
- Identify trends in research and new developments at the scientific forefronts.
- Foster interactions with other fields and cooperation among academic disciplines.
- Strengthen connections to technology.
- Facilitate effective service to the nation.
- Improve public understanding of science.
- Encourage cooperation among federal agencies, government laboratories, and universities involved in research in physics and astronomy.

Approaches for achieving these objectives include the following:

- Periodic assessments of major fields. By setting priorities, these surveys provide programmatic guidance to agencies.
- Response to particular needs and requests from federal agencies, both those that have programs of research and those that play an administrative role.
- Continuing surveillance of scientific progress and identification of issues and problems in various fields. Several standing committees are focused on this task.
- Cross-disciplinary studies of special areas that lie at the intersection of several disciplines.
- Many scientific assessments address the benefits that accrue to society through technology development that follows from the pursuit of science.

BPA Update: Emerging Projects

• *Survey of the Scientific Uses of the Electromagnetic Spectrum.* The committee will prepare a report exploring the scientific uses of the radio spectrum. The report will (1) portray the science that is currently being conducted using the radio spectrum; (2) identify the emerging and compelling scientific opportunities in the relevant fields; and (3) make recommendations on realizing these opportunities. The committee will comment on spectrum usage by the relevant scientific communities but will not make specific recommendations on frequency allocation.

• *Handbook on Frequency Allocations and Spectrum Management.* A committee will prepare a report on frequency allocations and spectrum protection for scientific uses. The report will describe the radio frequency bands used by the scientific services, mainly the receive-only (so-called passive) radio astronomy and Earth remote-sensing services. It will set out principles adopted by the Committee on Radio Frequencies for the allocation of frequency bands and their protection from interference. It will serve as a reference or handbook, guiding spectrum managers and spectrum regulatory bodies on science issues, serving as a resource to scientists on spectrum regulation for research, and providing information to other spectrum users on the concerns of the scientific spectrum users.

• *NASA Astronomy Science Centers: Best Practices and Guiding Principles for the Future.* The BPA's sister unit, the Space Studies Board, has convened a committee to review lessons learned from experience with NASA's ensemble of space astronomy science centers. The committee will recommend a set of guiding principles and best practices for consideration in making decisions about approaches to meeting the needs of the astronomy community with future science centers. The committee met in August and November 2005. A final report is expected in late 2006.

New Staff Member. In response to an increased amount of work flowing through the BPA office, a new staff position of Senior Program Assistant was created in late 2005. Phillip D. Long joined the BPA staff in late January 2006 in this capacity. With a background in chemistry and history from the University of Oregon, Phillip will enhance the capabilies of the office. We look forward to working with him.

BPA Update: Meetings in Early 2006

January 2006	
1/23	EPP 2010 meeting, Washington, D.C.
1/26-27	AMO 2010 meeting, Washington, D.C.
February 2006	
2/11-12	RISAC meeting, Irvine, California
2/12-13	CMMP 2010 meeting, Irvine, California
March 2006	
3/8-9	MRSEC committee meeting, Santa Barbara, California
3/12-13	RISAC meeting, Washington, D.C.
3/31-4/1	PLSC meeting, Washington, D.C. (tentative)
April 2006	
4/6-7	SSSC meeting, Washington, D.C.
4/10-11	CORF meeting, Washington, D.C.
4/21-22	BPA meeting, Washington, D.C.
May 2006	
5/19-20	CAA meeting, Washington, D.C.

THE BPA Web site at **www.national-academies.org/bpa** provides news on recently released reports and other developments as well as a link to this newsletter in PDF format. Reports may be ordered at **www.nap.edu.**

Recent Reports:

Midsize Facilities: The Infrastructure of Materials Research

The Atacama Large Millimeter Array: Implications of a Potential Descope

Coming Soon:

Final Report of the AMO 2010 Commitee

Final Report of the EPP 2010 Commitee

Board on Physics and Astronomy
The National Academies
Keck Center, 922
500 Fifth Street, N.W.
Washington, DC 20001

BPA Newsletter for: