Issues in Physics & Astronomy

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Decadal Survey of Astronomy and Astrophysics Begins

Michael McElwain, NRC Mirzayan Fellow & Michael H. Moloney, Astro2010 Study Director

The NRC's Astronomy and Astrophysics decadal survey—Astro2010—is moving ahead under the umbrella of the BPA and our sister board the Space Studies Board (SSB). NASA, NSF, and DOE are the sponsors of the survey that has been asked to evaluate the field of space- and ground-based astronomy and astrophysics, recommending priorities for the most important scientific and technical activities of the decade 2010-2020. The principal goals of the study will be to carry out an assessment of activities in astronomy and astrophysics, including both new and previously identified concepts, and to prepare a concise report that will be addressed to the agencies supporting the field, the Congressional committees with jurisdiction over those agencies, the scientific community, and the public.

Over the past 40 years, the Astronomy and Astrophysics decadal reviews have played a vital role in the selection of major astronomical activities and subsequent scientific discoveries. Some decadal survey prioritization highlights include the development of adaptive optics systems, the Very Long Baseline Array, the Hubble Space Telescope, the James Webb Space Telescope, and the Spitzer Space Telescope.

In early September 2008, NAS President and NRC Chair Dr. Ralph Cicerone appointed Dr. Roger Blandford to chair the survey. Dr. Blandford is the Luke C. Blossom Professor of Physics and Pehong and Adele Chen Director of the Institute for Astrophysics and Cosmology at Stanford University. He is a distinguished theorist with broad expertise in high-energy astrophysics and cosmology and he brings to the survey an extensive knowledge about both ground- and space-based astronomy. Dr. Blandford is a member of the National Academy of Sciences, a fellow of the Royal Society, a fellow of the Royal Astronomical Society, and a member of the American Academy of Arts and Sciences. He was chair of the panel on High-Energy Astrophysics from Space during the Astronomy and Astrophysics in the New Millennium survey. He is also a former co-chair of the NRC's Committee on Astronomy and Astrophysics (CAA) and has served two terms on the SSB.

Between September and November 2008, Dr. Blandford worked with the NRC

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In this issue:

Atomic, Molecular, and Optical Sciences Committee Reestablished After AMO Decadal Survey

Stephen Pratt, Chair, Committee on Atomic, Molecular, and Optical Physics

The Committee on Atomic, Molecular, and Optical Sciences (CAMOS) is a standing activity of the BPA. Committee membership represents the breadth of the atomic, molecular, and optical (AMO) sciences, forming a multidisciplinary group of experts from universities, government laboratories, and industry. After a period of dormancy during the writing of *Controlling the Quantum World: The Science of Atoms, Molecules, and Photons*, the AMO volume of the Physics 2010 Decadal Survey, CAMOS has been reestablished, and I have the pleasure of accepting appointment as its chair.

With my colleagues drawn from across the AMO community, CAMOS plans to provide active stewardship of the agenda laid out in the *Controlling the Quantum World* report. Our goals are to provide a means for dialog with federal agencies on AMO science and related fields, to examine emerging topics in AMO science, and to explore multidisciplinary connections with other fields of science and technology. We will also provide a venue for discussion among AMO scientists across this diverse field.

CAMOS will have its first meeting this Spring, and will also hold a town hall meeting at the annual meeting of the American Physical Society Division of Atomic, Molecular, and Optical Sciences, which will be held in Charlottesville, Virginia in late May. We look forward to receiving input from the AMO community on our future plans.

Our current outlook is now focused on the science opportunities identified in the report *Controlling the Quantum World:*

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

James C. Lancaster, Robert L. Riemer, & David B. Lang, BPA Staff

The Board on Physics and Astronomy held its annual Fall meeting on November 1-2, 2008 at the Beckman Center of the National Academies in Irvine, California. After warmly greeting all in attendance, vice-chair Adam Burrows, Princeton University, welcomed new members and briefly outlined the meeting's agenda; chair Marc Kastner, MIT, was unable to attend the meeting because of illness.

The Board first heard status reports on several BPA-sponsored studies that either have been completed or are nearing completion. Bill Colson discussed the results of a recent study assessing the feasibility of free-electron laser technology for naval applications. The study's purpose was to evaluate what scientific limitations exist that might prohibit developing a free-electron laser system for deployment at sea. The committee found that while there are significant technological and scientific advances that must take place before such a system can be built, there did not appear to be insurmountable scientific barriers to the development of such a system.

Ron Davidson, Princeton Plasma Physics Laboratory and BPA member, next gave a summary of the outcome of the NRC Review of the Plan for U.S. Fusion Community Participation in the ITER Project, which was completed in July 2008. The committee that conducted the review, chaired by Patrick Colestock, Los Alamos National Laboratory, concluded in its report that U.S. participation in planning for ITER had been strong relative to its level of contribution to the project of about 9%. It also found that the U.S. fusion program was threatened by the unstable commitment to the project embodied in the decision to not fund the first installment of U.S. support to ITER in FY2008. The committee's report also recommended several goals and metrics to be considered in the future development of the plan for U.S. participation in ITER.

The third status report discussed with the Board was the materials synthesis study, presented by Paul Peercy. The committee conducting that study examined the state of research in the United States whose primary focus is discovering novel materials and growing single crystals of known materials. The principal charge of the study is to develop recommendations on how the United States should respond to a significant drop-off in industry-funded basic research and to increases in international support for these areas. The report has been completed and is in review, with an expected dissemination time in spring 2009.

The Board then heard from a number of speakers on studies conducted by the National Research Council (NRC) and elsewhere that pertain to energy, and specifically to the role that science can and should play in addressing the nation's energy needs. Lawrence Papay spoke first and discussed the NRC's Energy Futures Initiative (AEFI) and the findings of the panel on which he served, the Renewable Electrical Power Panel. The concept of the AEFI arose in early 2007 in the National Academies Committee on Science, Engineering, and Public Policy (COSEPUP) and the NAE Program Committee. AEFI was also inspired by the NRC report *Rising Above the Gathering Storm* and the Energy Independence Act of 2007. The volatility of the oil market, the public acceptance of the reality of global warming, and national energy security needs provided further motivations for the AEFI and related projects. AEFI is being conducted in two phases: Foundations and Policy. The study is now in phase 1 with the goal of setting up a consistent set of assumptions and understandings upon which policy and other long-term planned can be based. Under the auspices of the AEFI, a summit on America's Energy Future was held March 13-14, 2008. The plan for the AEFI is to complete

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the foundational part of its efforts in early 2009 for use in the transition to a new administration *[Ed. note: AEFI is yet to be released as of this writing]*. In addition to the incoming Obama administration, there is interest in Congress, especially the Senate, and in industry.

Graham Fleming then discussed five grand challenges to energy sciences developed by DOE's Basic Energy Sciences Advisory Committee (BESAC), as set forth in the report, *Directing Energy and Matter: Five Challenges for Science and the Imagination*. (A summary can be found in Physics Today, July 2008.) According to Professor Graham, an integral part of these challenges is that we are going from observation to control of nature, and that manipulation of quantum states will become increasingly important in energy sciences.

Burton Richter then discussed the American Physical Society's Energy Future Report. The APS began the study in summer 2007, in order to have it ready for the next administration's transition team. The report assessed energy uses in the United States, focusing on opportunities for improving efficiency and increasing conservation. Among their conclusions is that research in the social sciences can be important in energy efficiency studies and should be included in any energy research and development portfolio. They also concluded that long-term applied research is an often neglected area in technology and science programming, and needs to be better managed and funded.

BPA member Peter Green led discussion on a proposed study developed by the BPA's Solid State Sciences Committee. The focus of this study is the long-term basic and applied research needs of the energy sector. The central challenges are seen in the areas of energy conversion processes, energy storage capability and efficiency, and a principal goal of the study is how to best develop a multidisciplinary approach to tackling these problems.

Jon Morse, NASA Astrophysics Division Director, delivered a presentation on the status of the Joint Dark Energy Mission (JDEM), a proposed joint NASA-DOE satellite. As part of NASA's Beyond Einstein Program, JDEM would investigate the nature of dark energy by studying how the expansion rate of the universe changes over time by measuring Type Ia supernovae. NASA stated that a Community Announcement of Future Solicitation would be released soon that would announce the future issue of a Announcement of Opportunity for proposals from PI-led science investigations using the JDEM observatory. NASA also indicated that the agency and DOE would soon sign a Memorandum of Understanding for the JDEM mission. Collaboration with Europe is now under discussion.

Adam Burrows began a discussion of benchmarking in physics, and explained that the Physics Survey Overview volumes have not conducted benchmarking in the past. There was some talk about possible metrics, and general agreement that portraying physics as a unified field with influence on other fields could be helpful if done properly.

Marshall Cohen, Caltech, and Co-Chair of the NRC's Spectrum Survey Committee, spoke about his committee's progress. The Spectrum Survey Committee met four times, most recently in March 2008, and put the finishing touches on its report at that time before submitting it into the NRC review process. The report will discuss the importance of protecting the radio, millimeter, and microwave spectrum for scientific studies by the radio astronomy and Earth remote sensing communities. As wireless technologies continue to proliferate, a forward-looking strategy to safeguard access by these sciences to quiet regions of the spectrum is essential.

Peter Wolynes presented a progress report on the study, "Research at the Interface of the Life and Physical Sciences." The study looks at the issues facing those working at that interface and Professor Wolynes went over, in closed session, the preliminary recommendations developed by the committee to address those issues.

To conclude the day's discussions, Roger Blandford, Stanford University, addressed the BPA as Chair of the Astronomy and Astrophysics 2010 Decadal Survey (Astro2010). He discussed the general structure that the study will take and the timelines by which it will take place. More information on Astro2010 may be found elsewhere in this issue.

On the second day of the meeting, the Board heard from BPA staff on the status of projects in progress and possible new BPA studies. Jim Lancaster began by discussing the Helium Reserve Study, a study commissioned by the Bureau of Land Management to assess whether selling down the Federal Helium Reserve in compliance with federal law is having adverse effects on critical users of helium, including U.S. science communities. The committee has been formed and contains economists and natural resource experts, as well as scientists. Three meetings have taken place and the committee hopes to have its report available for dissemination by the summer of 2009.

Jim Lancaster also briefed the committee on the status of a proposal on Undergraduate Physics Education (Physics Education 2010). The study is intended to survey the status of research on physics education and then to develop recommendations on how to more broadly disseminate best practices for teaching physics at the undergraduate level. In preliminary discussions, funding agencies have expressed general enthusiasm for the study, particularly those portions that focus on how to improve the teaching of physics. The proposal will be reworked in light of comments received.

Adam Burrows then discussed a possible Physics Overview Survey, with the goal of assessing the relative position of the United States in particular fields and then extrapolating those findings into the future. The BPA decided to continue discussion of this topic at its next meeting in Spring 2009.

Finally, Michael Wiescher led a brief discussion on the last of the subdisciplinary decadal studies to be initiated for the 2010 cycle – Nuclear Physics 2010. Dr. Wiescher highlighted some of the many, outstanding issues that will be covered by the study, including the need for international collaboration in developing future projects. The proposal was submitted to NSF and DOE in

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Astro2010 Panels Begin Work

Michael McElwain, NRC Mirzayan Fellow & Michael H. Moloney

The committee carrying out the Astro2010 decadal survey is being assisted in its task by five Science Frontiers Panels (SFPs) and four Program Prioritization Panels (PPPs). Appointed as independent NRC committees, each panel has a specific science or programmatic charge, all in the context of the overarching charge to the decadal survey.

Each SFP will prepare a report that will identify the scientific drivers of the field and the most promising opportunities for progress in research in the next decade, taking into consideration those areas where the technical means and the theoretical foundations are in place for major steps forward. The panels will clearly identify the advances in observation and theory necessary to realize the scientific opportunities they report. The Subcommittee on Science received formal community input in the form of over 320 science white papers that were targeted to one or more of the SFPs (see the article "Astro2010 Begins Receiving Community Input" on p.7 in this issue). Each panel will draw from these white papers and their own expertise to identify up to four central questions that are ripe for answering and one general area where there is unusual discovery potential. The questions and area together define the scientific forefronts of the next decade in the SFP's sub-field of astronomy and astrophysics.

The SFPs were appointed in February 2009 and started to meet later that month. A major input to the panels' work has been the community's response to the call for Science White Papers. An initial internal report on the science forefronts is due in spring 2009 to the survey committee and the program prioritization panels just as the second phase of the survey is getting underway. Each SFP report will publish its own panel report volume in mid-2010. Short descriptions of the SFPs are in the box.

The second phase of the survey will focus on the prioritization process. Four Program Prioritization Panels (PPPs) will identify and recommend a prioritized program of federal investment in research activities in their respective area of astronomy and astrophysics. In formulating its conclusions, each panel will draw on several sources of information: (1) the science forefronts identified by the SFPs, (2) input from the proponents of research activities, and (3) independent cost and technical readiness assessments. The panels' recommendations will be integrated into a program for all of astronomy and astrophysics by the survey committee.

The PPPs are also receiving input in the form of a series of calls for information and white papers from the community, such as papers on technology development, theory, computation, and laboratory astrophysics.

The panels are expected to be appointed in April 2009 and meet for the first time in May 2009. They will also hold four parallel meetings on the margins of the AAS meeting in Pasadena in June 2009 where proponents of activities will be invited to present their plans to the relevant panel. The PPPs will provide the survey committee with an interim internal and confidential summary preliminary report of its recommended program and rankings by the fall of 2009 and complete its panel report thereafter. Each PPP report will be published in a panel reports volume in mid 2010. A short description of the PPP categories and focus are listed in the box.

In addition to the work of the panels, the survey committee has assembled six Infrastructure Study Groups (ISGs) to assist the Subcommittee on State of the Profession by gathering current information on infrastructure, broadly defined. The ISGs are comprised of community consultants and they have been charged to gather information and data on questions posed by the survey's Subcommittee on the State of the Profession on the issues of Computation, Simulation, and Data Handling; Demographics; Facilities, Funding and Programs; International and Private Partnership; Education and Public Outreach; and Astronomy and Public Policy. The study groups will aggregate the data and information and describe recent trends and the past quantifiable impacts on research programs in astronomy and astrophysics. ■

Science Frontier Panels

Planetary Systems and Star Formation (PSF). PSF will consider science opportunities and themes surrounding planetary systems and star formation, including solar system bodies (other than the Sun) and extrasolar planets, debris disks, exobiology, the formation of individual stars, protostellar and protoplanetary disks, molecular clouds and the cold ISM, dust, and astrochemistry.

Stars and Stellar Evolution (SSE). SSE will consider stars and stellar evolution, including the Sun as a star, stellar astrophysics, the structure and evolution of single and multiple stars, compact objects, supernovae, gamma-ray bursts, solar neutrinos, and extreme physics on stellar scales.

The Galactic Neighborhood (GAN). GAN will consider the galactic neighborhood, including the structure and properties of the Milky Way and nearby galaxies, and their stellar populations and evolution, as well as interstellar media and star clusters.

Galaxies across Cosmic Time (GCT). GCT will consider galaxies across cosmic time, including the formation, evolution, and global properties of galaxies and galaxy clusters, as well as active galactic nuclei and QSOs, mergers, star formation rate, gas accretion, and supermassive black holes.

Cosmology and Fundamental Physics (CFP). CFP will consider cosmology and fundamental physics, including the early universe, the microwave background, the reionization and galaxy formation up to virialization of protogalaxies, large scale structure, the intergalactic medium, the determination of cosmological parameters, dark matter, dark energy, tests of gravity, astronomically determined physical constants, and high energy physics using astronomical messengers.

Program Prioritization Panels

Radio, Millimeter and Submillimeter from the Ground (RMS). Observatories and telescopes that primarily observe in these wavebands.

Optical and Infrared Astronomy from the Ground (OIR). Observatories and telescopes that primarily observe in these wavebands.

Electromagnetic Observations from Space (EOS). This will include all space-based astronomical projects observing the electromagnetic spectrum.

Particle Astrophysics and Gravitation (PAG). This will include all projects exploring areas at the interface of physics and astronomy such as gravitational radiation, TeV gamma-ray astronomy, and free-flying space missions testing fundamental gravitational physics.

Astro2010 Survey Committee Meets

Michael McElwain, NRC Mirzayan Fellow & Michael H. Moloney, Astro2010 Study Director

The Committee on Astro2010, known as the survey committee, met for the first time on December 5th and 6th in Washington D.C at the National Academies Keck Center. In addition to deciding on the overarching structure and timeline for the study, the committee also met with the sponsoring agencies for the study: National Aeronautics and Space Administration, National Science Foundation, and Department of Energy (DOE). This is DOE's first time as a sponsor of the survey.

The agencies outlined each of their programs in astronomy and astrophysics and discussed their expectations for the Astro2010 survey. It was clear from the presentations that there remained a considerable uncertainty in what the budget trends for the coming decade might look like. The agencies also stressed the importance of the survey in their decision making process and of the independent cost and risk analysis the survey has been asked to conduct. The committee and agency representatives discussed the scientific and programmatic scope of the survey—discussions which informed the later decisions of the survey on the structure and focus of the panels established to assist the committee in conducting the survey.

The Astro2010 survey committee held its second meeting on January 9th and 10th at the National Academies Beckman Center in Irvine, CA. The committee invited representatives from the sponsoring agencies' advisory committees to an open session panel discussion. The participating advisory committees were the Congressionally mandated Astronomy and Astrophysics Advisory Committee (AAAC), NASA Advisory Council (NAC) Science Committee, NAC's Astrophysics Subcommittee, DOE and NSF's High Energy Physics Advisory Panel (HEPAP), and NSF's Mathematics and Physical Sciences Advisory Committee. These committees were represented by Dr. Rocky Kolb, Dr. Jack Burns, Dr. Craig Hogan, Dr. Patricia Burchat, and Dr. Joel Tohline, respectively.

The panel session started with each representative reporting on the role of their advisory committee and their recent activity where relevant to the survey. Each advisory committee emphasized the eminent importance of previous decadal surveys to their operations over the course of a decade. The panelists presented contemporary issues to be considered by the Astro2010 survey committee, such as the creation of new programs, the impact of short- and long-term budget variability, unexpected cost growth in programs, technology development strategies, international partnerships, and underrepresented groups in astronomy. The panelists also called special attention to relevant studies and reports that were conducted under their auspices. A question and answer session ensued afterwards, which clarified points and the road ahead. The beneficial nature of future interactions between the advisory and the Astro2010 survey committee were clear, and the advisory committee representatives were encouraged to maintain contact throughout the decadal survey process.

Since these early meetings the survey committee has been meeting by telephone on a biweekly schedule, with the subcommittees meeting more frequently by telephone in the interim. The science frontiers panels have also begun to meet to begin the process of identifying the scientific forefronts of astronomy and astrophysics in the next decade. In May the survey committee will meet, along with the program prioritization panels (PPP), to hear an interim reporting of those forefronts. The PPPs will then start the prioritization phase of the survey in earnest. The remaining schedule for 2009 is given below. ■

Future Meetings of Astro2010

- May 4/5, 2009. Astro2010 town meeting and invited sessions at APS Meeting (Denver, CO)
- May 11, 2009. Closed summit meeting of Survey Committee, SFP chairs, ISG chairs, and all PPP members (Irvine, CA)
- May 12/13, 2009. First meeting of the 4 PPPs (Irvine, CA)
- May/Jun/Jul, 2009. Final SFP meetings
- June 8-11, 2009. Second PPP meetings (Pasadena, CA)
- Jul/Aug/Sep, 2009 [TBC]. Final PPP meetings
- Sept-Dec, 2009 [TBC]. Fourth and Fifth Survey Committee meetings

Astro2010 Survey Committee Membership

Roger Blandford, *Chair*
Stanford University
Lynne Hillenbrand, *Executive Officer*
California Institute of Technology

Subcommittee on Science
Martha P. Haynes, *Vice Chair*
Cornell University
Lars Bildsten
University of California, Santa Barbara
John E. Carlstrom
The University of Chicago
Fiona A. Harrison
California Institute of Technology
Timothy M. Heckman
Johns Hopkins University
Jonathan I. Lunine
University of Arizona
Juri Toomre
University of Colorado at Boulder
Scott D. Tremaine
Institute for Advanced Study

Subcommittee on State of the Profession
John P. Huchra, *Vice Chair*
Harvard-University
Debra M. Elmegreen
Vassar College
Joshua Frieman
Fermi National Accelerator Laboratory
Robert C. Kennicutt, Jr.
University of Cambridge
Dan McCammon
University of Wisconsin-Madison
Neil de Grasse Tyson
American Museum of Natural History

Subcommittee on Programs
Marcia J. Rieke, *Vice Chair*
University of Arizona
Steven J. Battel
Battel Engineering
Claire E. Max
University of California, Santa Cruz
Steven M. Ritz
NASA Goddard Space Flight Center
Michael S. Turner
The University of Chicago
Paul Adrian Vanden Bout
National Radio Astronomy Observatory
A. Thomas Young
Lockheed Martin Corporation [Retired]

Committee on Radio Frequencies Meets

David B. Lang, BPA Staff

The Committee on Radio Frequencies held its Fall 2008 meeting at the Beckman Center of the National Academies on November 19, 2008. The meeting was opened with a welcome to the members and guests present by CORF Chair, Jeff Piepmeier, NASA-Goddard Space Flight Center.

Werner Wiesbeck from Universität Karlsruhe delivered a presentation on the application of ultrawide-band technology to automotive anticollision radars. Dr. Weisbeck commented that radar signals only include information on time, frequency, and phase. To use radar for communication between numerous vehicle-mounted devices in traffic, the signals need to be enhanced with coding. Dr. Wiesbeck noted that the concept has been proven and showed a simulation of multiple vehicle-mounted devices successfully communicating their positions and velocities to one another with adequate precision and resolution. He concluded by stating that the devices can use the available spectrum simultaneously for both radar and communication, so additional spectrum would not be needed.

Behzad Razavi from UCLA next discussed directions in communications research at high frequencies. His laboratory's focus has been to target highly-integrated transceivers with a minimal number of external components and to attain higher frequency, wider bandwidth, and lower power consumption. Interest in millimeter waves has grown in the communications community: 57-64 GHz offers the possibility of high data rate communications, 60-77 GHz could be useful for vehicular radars, of frequencies greater than 100 GHz enable advanced imaging for security purposes. Dr. Razavi also discussed "cognitive radio," a technology in development used to detect and then use unoccupied bands. For a device to be able to sense unused spectrum, a signal-to-noise ratio of about -20dB must be achieved. Since the passive radio sciences use low-noise spectrum, there is concern among these communities that future cognitive radios would transmit in their bands. Many issues still need to be resolved for these technologies to become widespread, and the committee found it important to make sure its concerns are known and understood to the cognitive radio research community.

Alan Rogers, a CORF member and senior research scientist at MIT's Haystack Observatory, delivered a presentation on instruments for studying the Epoch of Reionization (EOR), the period of time in the early universe during which matter was slowly reionized. Most instruments being built are looking for spatial structure of the redshifted 21 cm emission/absorption hydrogen line at z~8.5. Dr. Rogers noted that the powerful Orbcomm satellite downlink signal at 137-138 MHz is near the redshifted 21cm H-line. He then spoke about four current EOR experiments: the Murchison Widefield Array, the Precision Array to Probe Epoch of Reionization, the Cosmological Re-Ionization Experiment, and the Experiment to Detect Global EOR Step. The committee considered hearing more about these experiments and the science of the EOR at its next meeting in Spring 2009.

CORF also discussed the potential impact of future dynamic spectrum usage, and how the passive science service should prepare to respond. The committee also reviewed slides developed by CORF chair Jeffrey Piepmeier to be used during an upcoming presentation at the Federal Communications Commission. Finally, the committee discussed numerous possibilities for future outreach activities. ■

Highlights of the Fall Meeting of the Solid State Sciences Committee

James C. Lancaster, BPA Staff

The Solid State Sciences Committee held its Fall meeting at the Beckman Center of the National Academies in Irvine, California on October 23-24, 2008. The committee heard from several speakers on current topics of interest to communities within the solid state sciences. Paul Canfield, Senior Physicist at Ames Laboratory and Professor at Iowa State University, spoke of recent developments involving iron-arsenic-based superconductors. These are newly-discovered materials that expand superconductivity beyond oxides and offer opportunities for significant advancements in understanding the fundamental nature of superconductivity. Mark Stevens, from Sandia National Laboratories, discussed the current state of molecular dynamics simulation, and some of the needs of that community in further developing simulation models.

The committee also heard from two of its own members, Chair Barbara Jones, of IBM Almaden Research Center, and Art Ramirez, from LGS, a subsidiary of Alcatel-Lucent. They provided industry-perspectives on what advances are needed in basic scientific understanding to meet next-generational challenges in the computational world. Ian Robertson from the University of Illinois followed that discussion by reporting the results from a recent National Science Foundation-sponsored conference on public outreach efforts and future education needs in materials science and materials engineering. Finally, Paul Peercy, chair of the SSSC-initiated study on New Materials Synthesis and Crystal Growth, reported in closed session about the preliminary findings, conclusions and recommendations that will appear in their soon-to-be released report.

On the meeting's second day, the committee spent time discussing future plans, including developing ideas for possible studies. These include evaluating what new materials and phenomena will be needed to extend information technology to the next levels, and what are the computational and modeling needs of solid state science communities. ■

Astro2010 Begins Receiving Community Input

Michael McElwain, NRC Mirzayan Fellow & Michael H. Moloney, Astro2010 Study Director

As explained in "Decadal Survey of Astronomy & Astrophysics Begins" in this issue, the Committee on Astro2010 has been tasked to "survey the field of space- and ground-based astronomy and astrophysics, recommending priorities for the most important scientific and technical activities of the decade 2010-2020." These activities are extremely broad in scope, from gravitational wave detectors to ground- and space-based instrumentation that will observe astrophysical processes covering the entire electromagnetic spectrum and non-photonic astrophysics. As part of the process of completing their tasks, the survey committee, panels, and infrastructure study groups have solicited various inputs from the broad astronomy and astrophysics research community.

In order to gauge the scope of the prioritization task and, thereby, assist the survey committee in its planning, the Astro2010 survey committee solicited preliminary Notices of Interest (NOIs) from the proponents of any activity that might be presented to the Astro2010 survey. Activities include both projects such as NASA missions and ground-based telescopes, but also initiatives such as development of a major astrophysics laboratory. Leaders of teams that are planning on advocating for an activity in the decadal survey's prioritization process were asked to submit a notice of interest on or before January 14th, 2009. Over 170 NOIs were submitted. These were sorted by Program Prioritization Panel (PPP) and included 21 to the panel on Radio, Millimeter and Submillimeter from the Ground (RMS), 23 to the panel on Optical and Infrared Astronomy from the Ground (OIR), 97 to the panel Electromagnetic Observations from Space (EOS), and 20 to the panel on Particle Astrophysics and Gravitation (PAG). The full NOI information can be viewed on the Astro2010 at http://www7.nationalacademies.org/bpa/Astro2010_NOI_Input.html.

The NOI call was followed up in February by the Subcommittee on Programs issuing a Request for Information (RFI) on Activities, with response due by April 1, 2009. Activities (missions, telescopes, laboratories, specific technology development programs, etc.) were asked to submit the following information to the committee for its consideration: key science goals, a technical overview, technology drivers, activity organization, partnerships, current status, activity schedule, and cost estimates. The responses to this RFI will be used by the PPPs to make a preliminary evaluation of the maturity and scale of each proposed activity, which will help guide the selection of activities invited to present to the PPP at their meetings in June 2009. Activity teams selected to participate in the committee's independent cost estimation process will be asked to submit a response to a second, more technically detailed RFI later in the process (Summer 2009). Activity teams not selected to participate in the June meeting or the cost estimation process will continue to be considered throughout the entire survey process on the basis of this first submission. A major feature of these second round submissions will be the assessment of the costs of construction and full operations, including the support of the science, and the identification of risk. The panels and committee will be assisted by independent contractors and consultants in this assessment process.

Input was also requested on the science track of the survey. The Astro2010 Science Frontier Panels (SFPs) invited interested parties from the broad community to submit white papers focusing on how our understanding of the scientific frontiers in astronomy may be advanced in the future. White papers were submitted to one or more of the five thematic SFPs and the call suggested the papers should specifically and succinctly address the panels' charges to identify new science opportunities and compelling science themes, to place those in the broader scientific context, and to describe the key advances in observation, experiment and theory necessary to realize those scientific opportunities within the decade 2010-2020. Over 320 papers were received across all the science areas of the survey's purview. The science frontiers panels are now using these papers as part of their consideration of where the science forefronts will lie in the next decade. The papers are available online at http://www8.nationalacademies.org/astro2010/publicview.aspx.

In addition, the survey committee has invited the broad community to submit white papers in the areas of technology development, theory, laboratory astrophysics, and computation. The technology development white papers should describe how developing a specific technology in the upcoming decade will enable advances in astronomy in the future. If the idea involves proposing a large, focused initiative or center, then this is the sort of proposed activity the survey committee expects to respond to the Program Subcommittee's current Request for Information (see below). These white papers will help the survey committee and the survey's panels understand and communicate the appropriate balance between focused initiatives and general technology development. White papers will be of most use to the survey if they identify specific critical observations and opportunities to be addressed by the suggested technology development. A discussion of current state of the art and how new technology will improve the field will be helpful as well as an indication of the level of effort required and the time scale for the realization of the new technology. An indication of intermediate outputs or milestones along the way to achieving the final technology goals should be included if relevant.

In the areas of theory, computation, and laboratory astrophysics, white papers will identify areas or research problems in these areas that would benefit from targeted investments, including investments on scales larger than normally possible through existing grants programs. White papers will identify what resources are likely to be required and why the scientific

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staff to assemble a slate of nominees for the Committee on Astro2010 which will oversee the operation of the survey and author the survey's report, which is due for release in the summer of 2010. Most of the nominees considered came from a community-wide process that started long before the chair's appointment and that involved the astronomy and physics sections of the NAS, the members of the BPA and SSB, a number of town meetings at professional societies, and a general call to the members of the astronomy and astrophysics research community to email the Academies with suggested names. In addition, Dr. Blandford and the NRC staff, in consultation with the BPA and SSB membership, developed a set of criteria to be applied to those being considered to nomination for the committee and its panels.

The survey committee was appointed by NRC Chair Ralph Cicerone in late November 2008, and on December 5-6 the committee met for the first time and organized itself into an executive committee and three subcommittees on science, programs, and the state of the profession. At its first meeting the survey committee heard from the sponsors of the study (see Committee on Astro2010 Meets in this issue).

The executive committee includes the survey chair and the survey vice chairs on science, the state of the profession, and programs. The executive committee is responsible for the management and coordination of the subcommittees, survey panels, and study groups. Each survey vice chair coordinates the work of a subcommittee as shown in the box.

At its December 2008 meeting, the committee decided that it would be assisted in its task by creating five science frontiers panels and four program prioritization panels. In addition, the committee decided that its Subcommittee on the State of the Profession would organize the work of six infrastructure study groups comprised of consultants to the survey committee who are charged to gather data and information on the U.S. infrastructure, broadly defined, for astronomy and astrophysics. Each of the nine panels and six study groups will communicate directly with the survey committee to share the results of their studies and deliberations. All the panels and study groups are now formed and their respective memberships can be viewed on the Astro2010 website located at www.nationalacademies.org/astro2010. More information on the work of the panels can be found in "Astro2010 Panels Begin Work" on p.4 in this issue.

The survey will take place over eighteen months and occur in two overlapping phases. In the first phase the science frontiers panels and the infrastructure study groups will identify the science forefronts of the field and carry out fact-finding on the state of the profession. Outputs from these bodies will feed into the second phase that will concentrate on program prioritization. This phase will be carried out in part by the program prioritization panels and then by the survey committee itself. The Survey committee will ultimately create a prioritized, balanced, and executable program of research activities that will define the forefront of astronomy and astrophysics for the decade 2010-2020.

The strength and success of the decadal surveys is due to the widespread participation and buy-in throughout the entire astronomical community. The organization of Astro2010 was designed to encourage community input for each of the panels and study groups. Calls for notices of interest for activities and for science white papers have already been issued and concluded (see "Astro2010 Receives Community Input" on p.7 in this issue). Current and future formal invitations for community input include a call for technology development white papers, a call for state of the profession position papers, a request for information from activities (to inform the work of the program prioritization panels), and a call for white papers on theory, laboratory astrophysics, and computation. In addition, the survey committee has encouraged astronomers and astrophysicists around the country to organize town hall discussions in order to receive informal community input.

The Astro2010 committee and its panels will continue to rely on the participation and enthusiasm of the astronomy and astrophysics community as a whole, and recognizes the amount of work the community has already contributed to this critical process. ■

BPA Meeting (continued from page 3)

August 2008 but final approval has not been received.

Following lunch, the meeting continued with a roundtable discussion on what research universities will look like in a decade. Several members saw the increasingly interdisciplinary nature of research and budgetary constraints pushing universities to weaken, if not totally eliminate the current, separate-departmental structure used by most universities. Others noted that some research areas are more vulnerable to unstable support than others and significant scaling back in the amount of faculty and resources devoted them might occur. The committee also discussed an intriguing approach being considered by some universities, in which different functional components of the university, such as development, marketing and traditional research, work together in more long-term, cohesive units.

Tom Cech made the final presentation to the Board, discussing a recently-completed American Academy of Arts and Science study he chaired. The study, Advancing Research in Science and Engineering (ARISE), evaluated current mechanisms used by federal agencies to fund science and engineering research and put forward specific recommendations on how those mechanisms can be improved. The committee focused on two areas that it felt have not received sufficient attention–supporting early-career faculty and encouraging high-risk but potentially transformative research. The report sets out several specific recommendations for addressing issues in these areas and Professor Cech reported that the study has been very well received by support agencies and Congressional staff members.

This discussion brought the meeting to a close. After thanking everyone for attending, vice-chair Adam Burrows adjourned the meeting. ■

Astro2010 Input (continued from page 7)

areas identified are ripe for development. White papers that argue for broad support for theory, computation, or laboratory astrophysics were submitted through the call for State of the Profession Position Papers. If the idea involves proposing a large, focused initiative or center with a well developed plan including costs, then the author should instead respond to the Program Subcommittee's current Request for Information on activities.

Finally, the State of the Profession Subcommittee of the Astro2010 Committee has been charged with assessing the health, infrastructure, and impact of Astronomy and Astrophysics broadly defined. To this end, the subcommittee has set up six Infrastructure Study Groups that have been charged with providing information and assessments on different aspects of the state of Astronomy and Astrophysics. To assist the work of these groups, position papers were solicited from the broad community focusing on the state of the field of astronomy and astrophysics. The call encouraged submissions on broad general themes related to the state of the profession. Examples of such themes might include data and information on the need for broad support for theory, for laboratory astrophysics, for generic technology development (with advice or input concerning specific technologies more appropriately addressed to the separate Astro2010 call for Technology Development White Papers), for training of observers and instrument builders, the relevance of public outreach and astronomy education to the national well-being, diversity, the need to support both general and specific areas in astronomy and astrophysics, national facilities, and any other topic covered in the six broad areas above, including those not specifically mentioned. The papers were asked to provide the data and information on assessments made by the authors.

In a recent Astro 2010 Chair's bulletin to the community, Dr. Roger Blandford noted that the purpose of this call and others is to provide input to the survey process from the research community. He said that while the calls for white papers are targeted, the intent is not to exclude input from any part of our community on any topic relevant to the committee's charge. He noted that if researchers have an idea or proposal that does not fall obviously into one of the white paper calls, then email the survey at astro2010@nas.edu describing the kind of white paper she/he would like to submit and the survey will reply with a suggestion about where such a paper should be sent. He stressed that all submissions will be reviewed by relevant committee or panel members. ■

CAMOS (continued from page 1)

The Science of Atoms, Molecules, and Photons [available at http://www.nap.edu/catalog.php?record_id=11705]. This report concludes that research in AMO science and technology is thriving. It identifies, from among the many important and relevant issues in AMO science, six broad grand challenges that succinctly describe key scientific opportunities in AMO science:

- Revolutionary new methods to measure the nature of space and time with extremely high precision have emerged within the last decade from a convergence of technologies in the control of the coherence of ultrafast lasers and ultracold atoms. This new capability creates unprecedented new research opportunities.
- Ultracold AMO physics was the most spectacularly successful new AMO research area of the past decade and led to the development of coherent quantum gases. This new field is poised to make major contributions to resolving important fundamental problems in condensed-matter science and in plasma physics, bringing with it new interdisciplinary opportunities.
- High-intensity and short-wavelength sources such as new x-ray free-electron lasers promise significant advances in AMO science, condensed-matter physics and materials research, chemistry, medicine, and defense-related science.
- Ultrafast quantum control will unveil the internal motion of atoms within molecules, and of electrons within atoms, to a degree thought impossible only a decade ago. This is sparking a revolution in the imaging and coherent control of quantum processes and will be among the most fruitful new areas of AMO science in the next 10 years.
- Quantum engineering on the nanoscale of tens to hundreds of atomic diameters has led to new opportunities for atom-by-atom control of quantum structures using the techniques of AMO science. There are compelling opportunities in both molecular science and photon science that are expected to have far-reaching societal applications.
- Quantum information is a rapidly growing research area in AMO science and one that faces special challenges owing to its potential application in data security and encryption. Multiple approaches to quantum computing and communication are likely to be fruitful in the coming decade, and open international exchange of people.

AMO Science provides a clear illustration of the powerful impact of fundamental physics on modern society. Its very name reflects three of 20th century physics' greatest advances: the establishment of the atom as a 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. The overarching emerging theme in AMO science is control of the quantum world. The six grand challenges outlined above each represent variations on this theme, and will provide exciting scientific opportunities in the coming decade. CAMOS will explore this discovery space to determine how the National Academies can best work to ensure the realization of these opportunities at the forefront of this fast-moving discipline. ■

Scientific Assessment of High-power Free-electron Laser Technology

Cy Butner, LAB Staff & Caryn Knutsen, BPA Staff

Ed. Note: This article is largely inspired by the Executive Summary of the report.

The National Research Council was asked by the U.S. Navy's Office of Naval Research (ONR) to assess the current capabilities of free-electron lasers (FELs) to deliver large amounts of energy; assess the prospects for developing such devices with megawatt-level average power capabilities; identify the key technical problems that must be solved to achieve such performance; and evaluate the feasibility of achieving power, energy, and other technical parameters specified by the Office of Naval Research. The request did not include a charge to make a determination of the requirements for effective directed-energy weapons.

The Board on Physics and Astronomy formed a committee chaired by Thomas Katsouleas (University of Southern California) to undertake Phase 1 of the study which consisted of a technology assessment of the state of the art across the free-electron laser community in order to evaluate the feasibility of achieving power and other technical parameters specified by the Office of Naval Research and to identify the technical gaps that must be overcome to achieve such performance.

Directed-energy weapons have been pursued by the U.S. military for decades; these weapons use very-high-power beams to disable or destroy targets. They typically use a single optical system both to track a target and focus the beam on the target. The Air Force has sponsored research using chemically powered lasers, the Army has researched the use of solid-state laser technologies, and the Navy has developed free-electron lasers through programs at the Office of Naval Research. A free-electron laser is an accelerator-based device that causes stimulated emission of radiation to occur from an electron beam. It generates tunable, coherent, highly collimated, high-power radiation, currently ranging in wavelength from microwaves to x-rays. While a free-electron-laser beam shares to some degree the same optical properties as optically or chemically pumped lasers (such as coherence), the operation of a free-electron laser is quite different. Unlike gas or diode lasers, which rely on transitions between bound atomic or molecular states, free-electron lasers use a relativistic electron beam as the lasing medium, hence the term "free electron."

Today, a free-electron laser requires the use of an electron accelerator with its associated ionizing-radiation shielding and other support systems. The electron beam must be maintained in a vacuum, which requires the use of numerous pumps along the beam path. Free electron lasers can achieve extremely high peak powers without damage to the laser medium. The Navy has chosen to pursue the free-electron-laser route to a directed-energy weapon, in part because free-electron lasers offer the advantage of being design-wavelength-selectable, allowing them to be designed to operate at wavelengths that are optimal for maritime environments. The free-electron laser's relatively efficient conversion of "wall-plug power" to "beam power" would make it attractive for use on a mobile platform such as a ship. However, there are still problems that need to be resolved.

The committee's report, released on December 23, presents a scientific assessment of free-electron-laser technology for naval applications. The charge from the Office of Naval Research was to assess whether the desired performance capabilities are achievable or whether fundamental limitations will prevent them from being realized. The statement of task for Phase 1 was as follows:

- Review the current state of the art and anticipated advances for high-average-power free-electron lasers (FELs).
- Using performance characteristics defined by the Navy for directed-energy applications, analyze the capabilities, constraints, and trade-offs for FELs.

The Navy provided the following performance characteristics and considerations for the study:

- Output power. Approximately 1 megawatt class at the aperture (also address the 100 kilowatt step);
- Wavelength. Three atmospheric windows (reduced absorption) at 1.04, 1.62, and 2 micrometers (1-2 micrometers); and
- Power to the free-electron laser. Approximately 20 megawatts.

To properly understand and interpret the meaning and applicability of the results of this study, it is critical to identify the factors that it did not address. The present study did not address whether a megawatt-class free-electron laser will be an effective weapon in a naval context, nor did it address operational lethality factors, such as duration of the beam pulse on target or the repetition rate. More specifically, the study did not address the effectiveness of the device to perform Navy missions of interest or the physics associated with atmospheric propagation of the laser beam (thermal blooming, aerosols, weather effects, etc.). In addition, the study did not address the realistic constraints of shipboard operation and installation, such as sizing the beam generation system or engineering it to operate in a shipboard environment. These specific issues are not insignificant and may be addressed in a follow-on Phase 2 study.

The present study identifies the highest-priority scientific and technical issues that must be resolved along the development path to achieve a megawatt-class free-electron laser. In this regard, the report identifies the development of a scalable 100 kilowatt device as an important interim step. In accordance with the charge, the committee considered (and briefly describes) trade-offs between free-electron lasers and other types of lasers and weapon systems to show the advantages free-electron lasers offer over other types of systems for naval applications as well as their drawbacks. The characteristics of different types of free-electron lasers are discussed and compared in detail throughout the report.

Following a description of the state of the art of free-electron laser technology (Chapter 2), particularly as it relates to Navy interests and applications, this report presents a detailed assessment of the scientific and technological challenges that must be addressed before the current state of the art (14 kilowatt output power) can advance to the 100 kilowatt and 1 megawatt-class output power levels (Chapter 3).

The principal findings of the present study are:

See "FEL Study" on page 11

FEL Study (continued from page 10)

• There have been significant engineering and technological advances in the 30 years since free-electron lasers were first considered for directed-energy applications.
• The combination of classification and subsequent funding reductions has also led to the loss of high-average-power free-electron-laser development capabilities in certain critical areas.
• The primary advantages of free-electron lasers are associated with their energy delivery at the speed of light, selectable wavelength, and all-electric nature, while the trade-offs for free electron lasers are their size, complexity, and relative robustness.
• Despite the significant technical progress made in the development of high-average-power free-electron lasers, difficult technical challenges remain to be addressed in order to advance from present capability to megawatt-class power levels. In particular, in the committee's opinion, the two "tall poles" in the free-electron-laser development "tent" are these: An ampere-class cathode-injector combination and radiation damage to optical components of the device.
• Drive-laser-switched photocathodes are the likely electron source for megawatt-class free-electron lasers. Photocathodes have been used in accelerator applications for over two decades; however, they have not reached the level of performance in terms of quantum efficiency and robustness that will likely be required for a reliable megawatt-class free-electron laser.
• High-performance optical resonators and coatings that operate successfully with megawatt-class lasers have existed for 2 decades. However, free-electron lasers uniquely generate harmonic radiation in the ultraviolet region, which has been shown to fatally damage many of the existing high-performance coatings.
• There are a number of components for which the extrapolation to megawatt-class power levels represents an experience/predictive gap rather than a physics or technology gap.
• There are other potential, difficult technical challenges ("tall poles") not addressed in the present phase of the free-electron-laser study that may be important to future realization of naval applications. ■

BPA Update: News & Emerging Projects

• Dr. Michael McElwain joined the BPA as a Christine Mirzayan Policy Fellow in January. Dr. McElwain is a Henry Norris Russell postdoctoral fellow in the department of Astrophysical Sciences at Princeton University, and earned his Ph.D. in astronomy and astrophysics from the University of California at Los Angeles in 2007, after completing an undergraduate degree in physics at the University of Pennsylvania in 2001. He played a key role in the development of a facility-class infrared integral field spectrograph that operates behind the adaptive optics system at the W. M. Keck Observatory. Dr. McElwain is actively researching science and technology issues related to extrasolar planets, and he is simulating the effects of an anti-satellite weapons conflict on the near earth space debris environment. During his Mirzayan Fellowship, Michael is eager to learn about the decision making process used to make a wide variety of astrophysics policy recommendations, ranging from ground-based telescopes to NASA proposal cost estimates. He has been working on the Astro2010 decadal survey, and he hopes his fellowship experience will initiate a long-term career as conscientious scientist who contributes to the challenging policy decisions facing our country. In his spare time, Michael enjoys playing soccer, building stuff, eating French food, listening to National Public Radio, and experiencing new cultures.

• *Physics Education 2010*. Future success in physics research depends on the ability of the physics community to continue to recruit, retain, and prepare talented physics students. The BPA is currently working on a proposal for a decadal study on undergraduate physics education. This study would help the physics and science education communities understand both the challenges and opportunities the nation faces at this time and would help ensure that intellectual and financial resources are deployed so as to optimize their impact. The study would also identify the grand challenges facing undergraduate physics education research and examine issues underpinning the field. ■

Upcoming Meetings in 2009

March 2009

3/27-28	Plasma Science Committee, Washington, D.C.
3/28-29	Astro2010 Panel on the Galactic Neighborhood, Washington, D.C.
3/30-31	Astro2010 Panel on the Cosmology & Fundamental Physics, Washington, D.C.

April 2009

4/1-2	Solid State Sciences Committee, Irvine, CA
4/2-3	Astro2010 Panel on Galaxies Across Cosmic Time, Washington, D.C.
4/9-10	Astro2010 Panel on Planetary Systems and Star Formation, Irvine, CA
4/17-18	Astro2010 Panel on Stars and Stellar Evolution, Irvine, CA
4/24-25	Board on Physics & Astronomy, Washington, D.C.

May 2009

5/15-16	Committee on Atomic, Molecular, and Optical Sciences, Washington, D.C.
5/27-28	Committee on Radio Frequencies, 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:

Scientific Assessment of High-power Free-electron Laser Technology

Inspired by Biology: From Molecules to Materials to Machines

A Review of the DOE Plan for U.S. Fusion Community Participation in the ITER Program

Coming Soon:

Final Report of the New Materials Synthesis and Crystal Growth Committee

Final Report of the Research at the Intersection of the Physical and Life Sciences Committee

Final Report of the Spectrum Study Committee

Board on Physics and Astronomy
The National Academies
Keck Center WS923
500 Fifth Street, N.W.
Washington, DC 20001

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