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Final Technical Report to the Department of Energy

Project Identification

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Activities and Findings

Research and Education Activities

An assessment of nuclear physics in the United States was conducted as part of the decadal assessment and outlook for physics and astronomy, *Physics 2010*. The charge to the NP2010 committee is as follows:

The new 2010 NRC decadal report will prepare an assessment and outlook for nuclear physics research in the United States in the international context. The first phase of the study will focus on developing a clear and compelling articulation of the scientific rationale and objectives of nuclear physics. This phase would build on the 2007 NSAC Long-range Plan Report, placing the near-term goals of that report in a broader national context.

The second phase will put the long-term priorities for the field (in terms of major facilities, research infrastructure, and scientific manpower) into a global context and develop a strategy that can serve as a framework for progress in U.S. nuclear physics through 2020 and beyond. It will discuss opportunities to optimize the partnership between major facilities and the universities in areas such as research productivity and the recruitment of young researchers. It will address the role of international collaboration in leveraging future U.S. investments in nuclear science. The strategy will address means to balance the various objectives of the field in a sustainable manner over the long term.

To address this charge, a committee of experts was sought with prestige and experience commensurate with the task. Members include experts in the subfields of nuclear structure, quark structure, quark matter, nuclear astrophysics, and fundamental

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symmetries. Because a principal focus of the report is on the international context of U.S. research efforts, the committee included several members active in international collaborations and from foreign physics communities. Members also were selected for their broad backgrounds that will be needed to address the statement of task's charge that the committee develop a strategy for long-term and sustainable progress for this field. A list of committee members is listed in Attachment A.

The 17 members of the committee were appointed by the chair of the National Research Council. Under the leadership of Stuart Freedman (University of California at Berkeley) and Ani Aprahamian (University of Notre Dame), the committee began organizing its work shortly thereafter.

In the period covered by this report, the publicly released report underwent a complete editing by NRC staff and was issued in final form. Copies of the report and the videos produced to communicate the vitality and promise of the field of nuclear physics were disseminated to funding agencies, Congressional staff, university professors and administrators, prospective grad students, and others. An adequate number of reports will be held by NRC staff for further distribution to interested parties, in accordance with policies of the National Academies. Reports may also be made available to the public without restrictions and copies will be available for purchase by the general public from the National Academies Press, publisher of the report.

Findings and Recommendations

The findings and recommendations are divided into two sections – Following Through with the Long-Range Plan and Building the Foundation for the Future. A summary of the findings and recommendations are as follows –

Following Through with the Long-Range Plan

The nuclear physics program in the United States has been especially well managed. Among the activities engaged in by the nuclear physics community is a recurring long-range planning process conducted under the auspices of the Nuclear Science Advisory Committee (NSAC) of the Department of Energy and the National Science Foundation. This process includes a strong bottom-up emphasis and produces reports every 5 to 7 years that provide guidance to the funding agencies supporting the field. The choices made in NSAC's latest long-range plan, the Long Range Plan of 2007, have helped to move the field along and set it on its present course, and the scientific opportunities recognized as important through that process will enable significant discoveries for the coming decade.

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Exploitation of Current Opportunities

Carrying through with the investments recommended in the 2007 Long Range Plan is the consequence of careful planning and sometimes-difficult choices. The tradition of community engagement in the planning process has served the U.S. nuclear physics community well. A number of small and a few sizable resources have been developed since 2007 that are providing new opportunities to develop nuclear physics.

Finding: By capitalizing on strategic investments, including the ongoing upgrade of the continuous electron beam accelerator facility (CEBAF) at the Thomas Jefferson Accelerator Facility and the recently completed upgrade of the relativistic heavy ion collider (RHIC) at Brookhaven National Laboratory, as well as other upgrades to the research infrastructure, nuclear physicists will confront new opportunities to make fundamental discoveries and lay the groundwork for new applications.

Conclusion: Exploiting strategic investments should be an essential component of the U.S. nuclear science program in the coming decade.

The Facility for Rare Isotope Beams

After years of development and hard work involving a large segment of the U.S. nuclear physics community and the Department of Energy, a major, world leading new accelerator is being constructed in the United States.

Finding: The Facility for Rare Isotope Beams is a major new strategic investment in nuclear science. It will have unique capabilities and offers opportunities to answer fundamental questions about the inner workings of the atomic nucleus, the formation of the elements in our universe, and the evolution of the cosmos.

Recommendation: The Department of Energy's Office of Science, in conjunction with the State of Michigan and Michigan State University, should work toward the timely completion of the Facility for Rare Isotope Beams and the initiation of its physics program.

Underground Science in the United States

In recent decades the U.S. program in nuclear science has enabled important experimental discoveries such as the nature of neutrinos and the fundamental reactions fueling stars, often with the aid of carefully designed experiments conducted underground, where the backgrounds from cosmic radiation are especially low. The area of underground experimentation is a growing international enterprise in which U.S. nuclear scientists often play a key role.

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Recommendation: The Department of Energy, the National Science Foundation, and, where appropriate, other funding agencies should develop and implement a targeted program of underground science, including important experiments on whether neutrinos differ from antineutrinos, on the nature of dark matter, and on nuclear reactions of astrophysical importance. Such a program would be substantially enabled by the realization of a deep underground laboratory in the United States.

Building the Foundation for the Future

Nuclear physics in the United States is a diverse enterprise requiring the cooperation of many institutions. The subject of nuclear physics has evolved significantly since its beginnings in the early twentieth century. To continue to be healthy the enterprise will require that attention be paid to elements essential to the vitality of the field.

Nuclear Physics at Universities

America's world-renowned universities are the discovery engines of the American scientific enterprise and are where the bright young minds of the next generation are recruited and trained. As with other sciences, it is imperative that the critical, "value-added" role of universities and university research facilities in nuclear physics be sustained. Unfortunately, there has been a dramatic decrease in the number of university facilities dedicated to nuclear science research in the past decade, including fewer small accelerator facilities at universities as well as a reduction in technical infrastructure support for university-based research more generally. These developments could endanger U.S. nuclear science leadership in the medium and long term.

Finding: The dual role of universities—education and research—is important in all aspects of nuclear physics, including the operation of small, medium, and large facilities, as well as the design and execution of large experiments at the national research laboratories. The vitality and sustainability of the U.S. nuclear physics program depend in an essential way on the intellectual environment and the workforce provided symbiotically by universities and the national laboratories. The fraction of the nuclear science budget reserved for facilities operations cannot continue to grow at the expense of the resources available to support research without serious damage to the overall nuclear science program.

Conclusion: In order to ensure the long-term health of the field, it is critical to establish and maintain a balance between funding of operations at major facilities and the needs of university-based programs.

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A number of specific recommendations for programs to enhance the universities are discussed in the report. Many of these suggestions are not costly but could have significant impact. An example of a modest program that would enhance the recruitment of early career nuclear scientists and could be provided at relatively low cost is articulated in the following recommendation:

Recommendation: The Department of Energy and the National Science Foundation should create and fund two national competitions: one a fellowship program for graduate students that will help recruit the best among the next generation into nuclear science and the other a fellowship program for postdoctoral researchers to provide the best young nuclear scientists with support, independence, and visibility.

Nuclear Physics and Exascale Computing

Enormous advances in computing power are taking place, and computers at the exascale are expected in the near future. This new capability is a game-changing event that will clearly impact many areas of science and engineering and will enable breakthroughs in key areas of nuclear physics. These include providing new understandings of, and predictive capabilities for, nuclear forces, nuclear structure and reaction dynamics, hadronic structure, phase transitions, matter under extreme conditions, stellar evolution and explosions, and accelerator science. It is essential for the future health of nuclear physics that there be a clear strategy for advancing computing capabilities in nuclear physics.

Recommendation: A plan should be developed within the theoretical community and enabled by the appropriate sponsors that permits forefront-computing resources to be deployed by nuclear science researchers and establishes the infrastructure and collaborations needed to take advantage of exascale capabilities as they become available.

Striving to Be Competitive and Innovative

Progress in science has always benefited from cooperation and from competition. For U.S. nuclear physics to flourish it must be competitive on the international scene, winning its share of the races to new discoveries and innovations. Providing a culture of innovation along with an understanding and acceptance of the appropriate associated risk must be the goal of the scientific research enterprise. The committee sees one particular aspect of science management in the United States where increased flexibility would have large and immediate benefits.

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Finding: The range of projects in nuclear physics is broad, and sophisticated new tools and protocols have been developed for successful management of the largest of them. At the smaller end of the scale, nimbleness is essential if the United States is to remain competitive and innovative in a rapidly expanding international nuclear physics area.

Recommendation: The sponsoring agencies should develop streamlined and flexible procedures that are tailored for initiating and managing smaller-scale nuclear science projects.

Prospects for an Electron-Ion Collider

Accelerators remain one of the key tools of nuclear physics, other fields of basic and applied research, and societal applications such as medicine. Modifying existing accelerators to incorporate new capabilities can be an effective way to advance the frontiers of the science. Of course it is the importance of the physics and of the potential discoveries enabled by the new capability that must justify the new investment. There is an initiative developing aimed at a new accelerator capability in the United States. Fortunately, the U.S. nuclear physics community has the mechanisms in place to properly evaluate this initiative. Currently there are suggestions that upgrades to either RHIC or CEBAF would enable the new capability.

Finding: An upgrade to an existing accelerator facility that enables the colliding of nuclei and electrons at forefront energies would be unique for studying new aspects of quantum chromodynamics. In particular, such an upgrade would yield new information on the role of gluons in protons and nuclei. An electron-ion collider is currently under scrutiny as a possible future facility.

Recommendation: Investment in accelerator and detector research and development for an electron-ion collider should continue. The science opportunities and the requirements for such a facility should be carefully evaluated in the next Nuclear Science Long-Range Plan.

Book(s) or other one-time publications

The committee's final report had been published by the National Academies Press in an attractive and elegant fashion. A pdf version of the report can be downloaded for free at http://www.nap.edu/catalog.php?record_id=13438.

Other Specific Products

Internet Dissemination

As part of the efforts to make the report available to a broader audience, two videos were prepared to illustrate several of the main ideas expressed in it. Those videos are available for viewing at http://sites.nationalacademies.org/BPA/BPA_069589.

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Attachment A

COMMITTEE ON ASSESSMENT AND OUTLOOK FOR NUCLEAR PHYSICS

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