
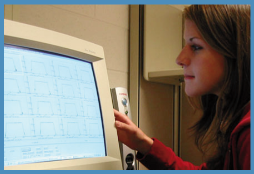


A VISION FOR NUCLEAR SCIENCE EDUCATION AND OUTREACH FOR THE NEXT LONG RANGE PLAN

January 2007

Submitted to the Nuclear Science Advisory Committee by the community for consideration in the 2007 Long Range Plan.

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Preamble

On December 1 through 3, 2006, Brookhaven National Laboratory (BNL) hosted a workshop titled "Vision for Education and Outreach in Nuclear Science" that included representatives from all subfields of nuclear science, as well as educators, outreach professionals, and representatives from the funding agencies. Appendix A contains the agenda for the workshop and Appendix B a list of participants in all parts of the process of assembling the vision (workshop, particpations, contribution, etc.).

The workshop examined successful ongoing programs and models for education and outreach both within and outside nuclear science, with the goal of developing a strategic plan to leverage Department of Energy (DOE) and National Science Foundation (NSF) investment in these areas. The meeting was organized in response to the charge from the DOE and NSF as part of the Long Range Plan process, to *"discuss the contribution of education in nuclear science to academia, medicine, security, industry and government, and strategies to strengthen and improve the education process and to build a more diverse research community."* The full charge to the Nuclear Science Advisory Committee (NSAC) is duplicated in Appendix C.

The Workshop explored a number of models, both internal and external to our nuclear science community, and discussed goals, strategies and implementation actions specifically targeted towards:

1. Recruiting the next generation of nuclear scientists.
2. K-12 education and public outreach.
3. Fostering diversity.

The discussion elucidated the need to define goals and strategies that:

1. Are actionable.
2. Are achievable.
3. Leverage existing programs and unique strengths.
4. Focus on nuclear science.

An important foundation for discussion at the workshop was the extensive data collected by the NSAC Subcommittee on Education in its 2004 report, *Education in Nuclear Science: A Status Report and Recommendations for the Beginning of the 21st Century* [1].

The present report is based on discussions held at the BNL workshop and on data available from published reference material. It documents areas in which nuclear science is playing a role in meeting societal needs and recommends ways in which the program might strengthen the education process, build a more diverse research community, and enhance its contributions in maintaining the nation's competitiveness in science and technology. Appendix D – published under separate cover – constitutes a compendium of many of the activities presently carried out by our community. This compendium will be kept as a living list with online access for the use of the nuclear science community.

Executive Summary

Education and outreach are central to the mission of both the DOE and the NSF. They are the fundamental underpinnings that support the mandate of the agencies to advance the broad interests of society (e.g., in academia, medicine, energy, national security, industry, and government) and to help ensure United States competitiveness in the physical sciences and technology.

Over the past decade, numerous studies have pointed to an increasingly urgent need to prepare more U.S. citizens for leadership roles in basic and applied physical sciences. The recent National Academy of Sciences report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future,* is the latest and most visible report that paints a dire picture of America's future if the number of Americans entering careers in science, technology, engineering and mathematics (STEM) fields does not increase significantly.

Similarly, education and outreach are key components of any vision of the future of nuclear science. The unquestionable importance of these efforts is recognized within the field, evidenced by the many and diverse activities engaged in by members of our community. These programs are having a profound impact. They establish clear evidence that an individual's efforts can make a difference. They also serve as models for strategies to enhance education and outreach in the nuclear science community.

The December 2006 BNL workshop, "Vision for Education and Outreach in Nuclear Science," examined a number of models, both within and beyond the nuclear science community, for successful education and outreach. The objective of the workshop and subsequent discussions was to define goals and strategies for a community-wide effort in nuclear science education and outreach. Important criteria for the goals considered were that they should be actionable and achievable and that they should leverage existing programs and the unique strengths of our community. Based on these discussions, two major recommendations emerged:

Recommendation #1. Nuclear science faces a potentially serious shortage of trained workers in pure and applied research, nuclear medicine, nuclear energy and national security. To cite just one example, *The Education and Training of Isotope Experts,* a 1998 report submitted to Congress by the American Association for the Advancement of Science (AAAS), notes that, "Too few isotope experts are being prepared for functions of government, medicine, industry, technology and science." Based on a comprehensive survey of the nuclear science workforce over the previous decade, the Nuclear Science Advisory Committee in 2004 recommended a significant increase in new nuclear science Ph.D.'s during the next decade.

Increasing the number of Ph.D. nuclear scientists, especially U.S. citizens, includes the need to increase participation from the full diversity of backgrounds. It also requires introducing students to nuclear science and its research before they start graduate school. Because these two points can be very effectively addressed at the undergraduate level, the first recommendation focuses on undergraduate education and research:

> ***The nuclear science community should increase its involvement and visibility in undergraduate education and research, so as to increase the number of nuclear science Ph.D.'s and the number of scientists, engineers and physics teachers exposed to nuclear science.***

Recommendation #2. An effective program of nuclear science outreach is also essential to ensure a broad, basic knowledge of nuclear science in U.S. society, enabling informed decisions by individuals and decision-making bodies on a wide range of important topics, including nuclear medicine, energy policy, homeland security, national defense and the importance and value of nuclear science research. At present, the public, and even scientists in other disciplines, are often uninformed or misinformed about nuclear science and its benefits. In public discussions, any topic involving the word "nuclear" is likely to generate unreasoned reaction to the word itself, preventing informed discussion on important technical and societal issues that should be of primary interest. Therefore, the second recommendation involves outreach to undergraduate non-physics majors, K-12 teachers and students, and the general public:

> ***The nuclear science community should develop and disseminate materials and hands-on activities that illustrate and demonstrate core nuclear science principles to a broad array of audiences, so as to***

enhance public understanding and appreciation of nuclear science and its value to society.

It is important to recognize that these recommendations are by no means the only choices that could have been made and that they constitute only a small subset of the many important activities that are currently underway. It is also crucial to recognize that the strength and future of the education enterprise in nuclear science in the United States requires funding support both for educational opportunities that will inspire the next generation of nuclear scientists and for the research and state-of-the-art facilities that drive that inspiration. One will not prosper without the other.

The workshop participants are convinced that a community-wide effort to implement these two recommendations will provide the greatest leverage in benefiting the entire spectrum of education and outreach needs in nuclear science, improving the vitality and diversity of the field, and contributing to U.S. competitiveness and societal needs.

Introduction

Nuclear science research in the United States provides profound benefits that broadly advance the interests of society and help to ensure U.S. competitiveness in technology and the physical sciences. Whether diagnosing physical ailments without invasive surgery, helping ensure adequate supplies of electrical power, developing tools to guard the nation's borders against the transport of dangerous materials, ensuring the nation's ability to defend itself, detailing the structure of matter and understanding the source of energy in our sun, or exploring the state of matter that existed at the beginning of our universe, nuclear science plays a central and unique role in securing the nation's scientific, economic and technological future.

As stakeholders in the nuclear science enterprise, every member of the field has a vested interest and even a moral obligation to contribute to nuclear science education and outreach. Whether mentoring young students and early-career scientists who will make the next big discovery, teaching at a 4-year college, university, or community college, conducting research at a university or national laboratory, or reaching out to school children or the general public, education is an important responsibility for us all.

Perhaps more so than at any time in the past, the future of the field is crucially dependent on articulating the excitement, importance, and value of nuclear science research to a broad array of audiences and on educating a diverse nuclear science workforce.

A Climate Survey

Fifty years ago, Sputnik and the space race launched an unprecedented investment by the United States in science and engineering, whose strengthening became a national priority. During that period of growth, nuclear science enjoyed a special status because of its societal importance to national defense and energy production. Particle accelerators were constructed at many universities and national laboratories, sometimes justified by little more than a letter of intent. Following this period, at the end of the Cold War, this expansion subsided, as did growth in the size of the nuclear science workforce.

The scientists who began careers as faculty or national laboratory researchers during that time have retired or are nearing that milestone. Those who were students during that exciting period are now relatively mature in their careers. As a consequence, the aging of the nuclear science workforce is a genuine concern, particularly in view of the increased demand projected for nuclear scientists and engineers in national defense, nuclear medicine, nuclear research, and the nuclear power industry. Figures 1 and 2, taken from the NSAC education report [1], give the age distributions of faculty and national laboratory researchers, respectively, for those identifying themselves as nuclear scientists.

In addition to concerns about an aging workforce, exposure of students to the basic principles of nuclear science at many universities has become marginal, as retiring faculty members are replaced with new hires from 'emerging' disciplines such as nanotechnology and biophysics. The conclusion is that if these trends are not reversed, this deteriorating

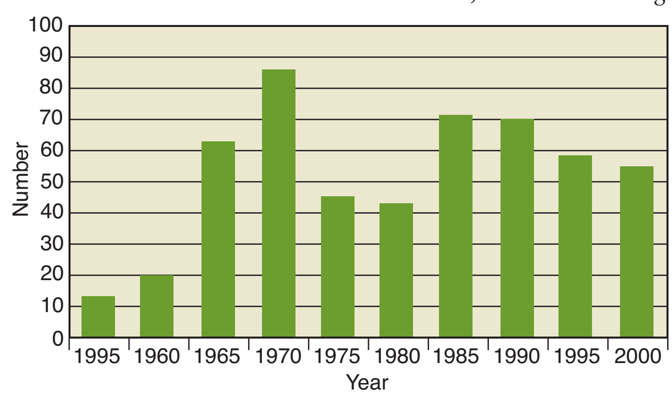


Figure 1. Year of Ph.D., consolidated in five-year increments, for those identifying themselves as nuclear scientists with rank of professor (emeritus excluded) on tenure track at four-year colleges and universities in the U.S. Data on year of hire were not available but can be estimated as year of Ph.D. plus four years.

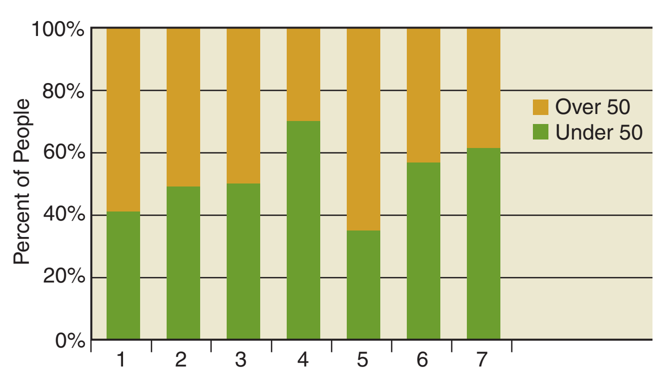


Figure 2. Age distribution of nuclear scientists at seven DOE national labs. The laboratories (ANL, BNL, JLab, LANL, LBNL, LLNL and ORNL) are identified only by numbers [1, pp. 1-11].

situation, recognized as a crisis in nuclear and radiochemistry for many years, may soon extend to the entire field. A 1998 study group reported to Congress, in *The Education and Training of Isotope Experts* [2], that unless a series of rescue actions were soon adopted to "restore the health of education for the vital isotope parts of our national and local infrastructures," the consequences would be "diminished national security, less effective medical care, less biomedical progress, impaired safety, weakened competitiveness."

Nuclear science is not unique, and this situation reflects in part the broad erosion of U.S. excellence and leadership in all STEM disciplines. The projected increase in jobs in STEM fields related to national security, thus requiring U.S. citizenship, compounds an already challenging problem. The recent National Academy of Sciences report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* [3], is the latest and most visible report that paints a dire picture of America's economic future if the number of Americans entering careers in STEM fields does not increase significantly. The three main factors leading to this concern are:

1. The aging of the U.S. scientific and engineering workforce.
2. A decline in the number of U.S. students interested and prepared to enter these fields.
3. An increased global competition for STEM talent that threatens the supply of non-U.S. scientists and engineers upon which the U.S. has relied heavily for many years.

Much of the data from labor statistics and education has been gathered together in *Science and Engineering Indicators,* an NSF report published by the National Science Board [4]. The competition is intense; China has the fastest growing economy the world has ever seen, allowing for an exponential increase in support for basic and applied research [4]. In addition to plans to build 100 new world-class universities [5], China recently announced plans for 1000 new fellowships per year, allowing Chinese graduate students to study abroad before returning to China to receive their degrees [6]. India, Japan, China and South Korea have doubled the number of bachelor's degrees in the natural sciences since 1975 and quadrupled the number of engineering degrees. The European Commission has doubled the funding for personnel [7] in STEM disciplines.

As a consequence of such attractive programs outside the United States, the foreign-born talent pool that has traditionally supported the U.S. enterprise in the physical sciences and technology may not be there in the future. As opportunities become more available in other countries, or even in their home country, fewer students may come to the United States for graduate school and postdoctoral research; and the number that stay for permanent careers is leveling off or beginning to decline [8].

Shirley Jackson, former head of the Nuclear Regulatory Commission (NRC) and president of RPI, has summarized this 'quiet crisis' in many published speeches. One in particular, called the *Graying of NASA* [9], specifically addresses concerns about nuclear science and technology:

> "Another critical case in point is in nuclear science and technology. Like the NASA workforce, the nuclear workforce is approaching retirement age without a corresponding influx of appropriately qualified younger personnel to replace them. Fewer young people are studying nuclear science, nuclear engineering, and related fields at the university level, and many universities have given up their nuclear education programs altogether, because of a lack of interest and the perception that the nuclear power industry is fading.
>
> Yet, ironically, the nuclear power industry is recording better performance than in any time in its history, and it may be poised for expansion for the first time in decades. The safety, performance, and economic competitiveness of the nuclear industry are at an all-time high. This is occurring against a backdrop of heightened concern about nuclear safety and nuclear terrorism.
>
> We must protect ourselves against acts of nuclear and radiological terrorism by rogue nations and terrorist groups. This forces us to ask: Who will maintain and enhance our existing nuclear technology, and who will design the next generation of technologies in nuclear power and other fields? Who will look out for U.S. interests as the world polices nuclear nonproliferation and guards against nuclear terrorism?"

The Gathering Storm report is widely credited with triggering bipartisan support in Congress for the Advanced Competitiveness Initiative (ACI) [10], which calls for a doubling of the basic research budget for the DOE Office of Science, NSF, and the National Institute of Standards and Technology (NIST) over the next decade. As noted in the guidance from the Office of Science and Technology Policy concerning ACI, this initiative is particularly targeted toward *"key Federal agencies that support basic research in the physical sciences and engineering that has potentially high impact on economic competitiveness....* To achieve this doubling within ten years, overall annual increases for these three agencies [would] average roughly seven percent. *Specific allocations[would] be based on research priorities and opportunities.* In addition to the doubling effort at these three agencies, similarly high-impact basic and applied research of the Department of Defense should be a significant priority." [11]

Regardless of the details of any particular legislation, the "take-home" message is clear: For the United States to remain a world leader in science, technology, and business, significantly increased investment by the nation, in both research and education in STEM disciplines—including nuclear science—is essential. Correspondingly, for nuclear science to prosper, the value of nuclear science and its basic research to society—to economic competitiveness, energy security, and national defense—must be clear to all stakeholders as well as to the general public.

What role does nuclear science have in assuring America's competitiveness? An education in nuclear physics provides extensive technical ability, problem solving skills, and critical thinking skills that enable attractive careers in other areas and disciplines, and provide invaluable contributions to society. The specialized knowledge and training provided through a degree in nuclear science have unique applicability to areas such as nuclear medicine, energy, and national security. Several recent reports document the future need for workers trained in applied nuclear areas such as nuclear medicine, engineering, health physics and radiochemistry.

An assessment of present and future workforce needs in nuclear medicine, funded by the Society of Nuclear Medicine, is presently underway and will be completed by September 2007. The preliminary report [12] released by this group notes that available workforce data assessing the number of scientists employed in nuclear medicine is inadequate. The report notes that researchers in a variety of other fields are necessary to advance nuclear medicine, including physics, chemistry, engineering, computer science and pharmacy. The report also notes that the "effects of hardware technology on the nuclear medicine professional suggest demand for scientific experts in physics, engineering and computer science for research, development, implementation and maintenance of these highly capable devices. Commercial producers of these products would necessarily require scientists for all phases of the development process. Although nuclear medicine represents a niche market, it is a growing market and one that promises continuing appeal at least in the near future."

In the areas of homeland and national security, our nation's applied laboratories rely on scientists trained in nuclear physics, chemistry and radiochemistry to fill roles in a wide variety of activities, such as working with radioisotopes, developing new generations of imaging detectors, nuclear forensics, and maintaining the nation's stockpile of nuclear weapons. Many workers in these areas are nearing retirement age. Figure 3 illustrates the magnitude of the problem by showing the loss of workforce through retirement and attrition that is expected by 2010 at one such laboratory, Pacific Northwest National Laboratory (PNNL) [13].

Agencies such as the Department of Homeland Security (DHS) and DOE's National Nuclear Security Administration (NNSA) recognize the need for a proactive approach to replacing these workers, who are often required to be U.S. citizens. A recent trend in these agencies has been to allocate new research money to specific areas of need, with the underlying goal of training students who will become the future

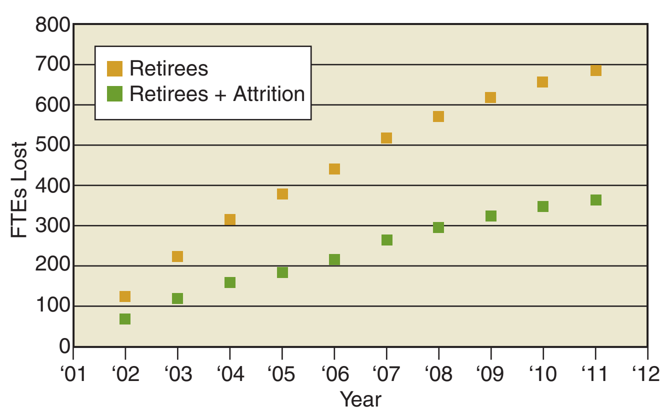


Figure 3. PNNL projections for loss of workforce.

workforce. Both organizations are funding graduate fellowships. In addition, the DOE NNSA is in the fourth year of funding for the Academic Alliance Program (SSAAP), an initiative directed towards the specific science needs of the stockpile stewardship program. For one of these needs, low energy nuclear science, the program has funded one major center at Rutgers University for research at Oak Ridge's HRIBF and individual investigator grants at several universities. The SSAAP is in its infancy, and the ultimate career paths of students and postdoctoral fellows who participate have not yet been tracked. However, the program has been enthusiastically embraced by the young scientists involved and is considered a success by the NNSA laboratories. The Department of Homeland Security is following this model in a recent call for proposals through the National Science Foundation. This new program will also be directed towards nuclear science, primarily in the area of instrumentation.

Nuclear energy, which currently generates 22% of the energy used in the United States, is another national need that has traditionally been fed by nuclear science and engineering graduates at all levels. The Nuclear Energy Institute estimates that, over the next decade, the industry will need 150 percent of the available supply of nuclear engineers just to maintain the current capability in nuclear energy [14]. Any increase in U.S. reliance on nuclear power generation to meet the nation's future energy needs will require a significant increase in the number of trained nuclear workers. Such an increase seems entirely plausible given the major expansion of nuclear power generation capability planned by other world powers such as China, India and Russia.

The Nuclear Science Workforce

As part of the NSAC Education Subcommittee activities, a survey was conducted of Ph.D.'s in nuclear science who graduated between July 1, 1992, and June 30, 1998. There were 585 reported graduates in the field during that period. 412 were located and asked to respond to a survey. Of these, 251 responded, a return rate of 61%. 195 responded to a question concerning their present career, resulting in the breakdown in Table 1. Less than 40% of respondents remained in a nuclear science career, with another 40% going into totally unrelated fields. The majority of the latter group (more than one-fourth of the total) ended up in business or industry.

Current Employer	In nuclear science		In a related field		In a different field		Total	
	N	%	N	%	N	%	N	%
Ph.D. University	27	13.9	15	7.7	10	5.1	52	26.7
Other college/ university	9	4.6	10	5.1	6	3.1	25	12.8
National lab	34	17.4	8	4.1	6	3.1	48	24.6
Business/ Industry	3	1.5	8	4.1	52	26.7	63	32.3
Government agency	1	0.5	4	2.1	2	1.0	7	3.6
Total	74	37.9	45	23.1	76	39.0	195	100

Table 1. Career path of nuclear science Ph.D.'s after 5-10 years.

A more recent survey looked at career tracks of students in the RHIC program. Data were gathered from the STAR, Phenix and Brahms collaborations. From 1998 through 2006, sixty-seven students received their Ph.D.'s from U.S. universities, about 50% of the total sample. While the majority of students tracked still have postdoctoral appointments, 25-30% have already left the field, pursuing careers as diverse as banking/stockmarket (5), software (2), power industry (1), defense (2), and unspecified industry (3). The group that has left nuclear science is strongly weighted towards U.S. citizens, possibly because there are more job opportunities for U.S. citizens. This same trend was seen in the NSAC education report surveys.

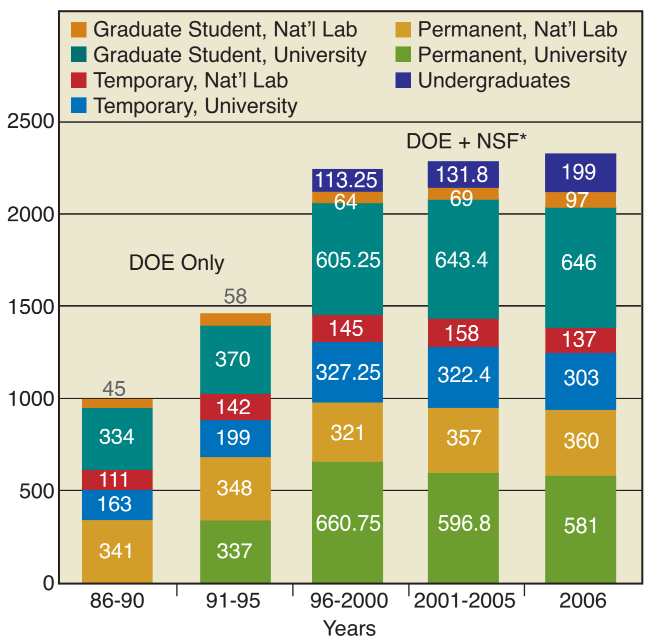
DOE has collected data on students who received Ph.D.'s in 2005 or 2006 and who had full or partial support from DOE NP. The sample of 169 new Ph.D.'s consisted of 79 U.S. citizens (46.9%) and 90 non-U.S. citizens (53.1%). 92% of the U.S. citizens and 74% of the non-citizens were staying in the U.S. for their first postdoctoral or other position. The data does not break out whether these positions are temporary or permanent. Even this early in their careers, a significant number of these students are moving on to nuclear-science-related fields such as medicine (4%) and nuclear energy (7.7%), and even more are leaving the field entirely for business and industry (almost 12%). The results of this survey are in Table 2, in a format similar to Table 1.

Figure 4 shows the nuclear science workforce (head count, not FTE) that is supported by the DOE and NSF nuclear physics budgets. The graph shows numbers for per-

Current Employer	In nuclear science		In a related field		In a different field		Undec-ided		Total	
	N	%	N	%	N	%	N	%	N	%
Ph.D. University	51	30.2	11	6.5					62	36.7
Other college/ university	9	5.3	13	7.7					22	13.0
National lab	21	12.4	13	7.7	4	2.4			38	22.5
Business/ Industry					20	11.8			20	11.8
Medical School/Hospital			7	4.1					7	4.1
Other			3	1.8					3	1.8
Undecided							17	10.1	17	10.1
Total	81	47.9	47	27.8	24	14.2	17	10.1	169	100

Table 2. Career path of graduating nuclear science Ph.D.'s in 2005/2006 (DOE supported only).

manent staff, temporary staff and graduate students at universities and national laboratories. These numbers are taken from the DOE 2006 nuclear physics workforce survey [15] added together with numbers from the NSF.



*Undergraduate headcount only available from NSF

Figure 4. The nuclear science workforce. Data includes headcounts of permanent and temporary staff, graduate students, and some undergraduates, as determined by full or partial support by DOE or NSF nuclear physics offices.

The total number of graduate degrees awarded over the last 20 years is given in Figure 5. Two sets of data are plotted. One is from the DOE 2006 workplace survey [15] and the other is from the NSF Survey of Earned Doctorates (SED) [16]. The latter survey is based on self-reporting of nuclear physics and nuclear chemistry degrees by the students and should include those supported by both NSF and DOE. The SED numbers appear to be under-reported by approximately 15%. There are large fluctuations in both sets of data, so five-year averages have been plotted. The two surveys show an identical and alarming trend, a significant decrease in Ph.D.'s of about 20% from the latter half of the 1990s to the first half of the current decade.

In projecting future workforce needs in nuclear science, taking into account retirement of present faculty members, hiring trends at national laboratories, and increased need in areas like homeland security and nuclear energy, the NSAC Education Committee reached the conclusion that the field can sustain about 100 Ph.D.'s per year, an increase of about 20% over present numbers. This number may be even higher now that nuclear energy has become a viable future energy source. Contrary to these projected needs, the number of new Ph.D.'s in nuclear science is decreasing.

As part of the NSAC education report [1], surveys were also conducted of present graduate students and postdoctoral fellows. These surveys provide a snapshot of the field's

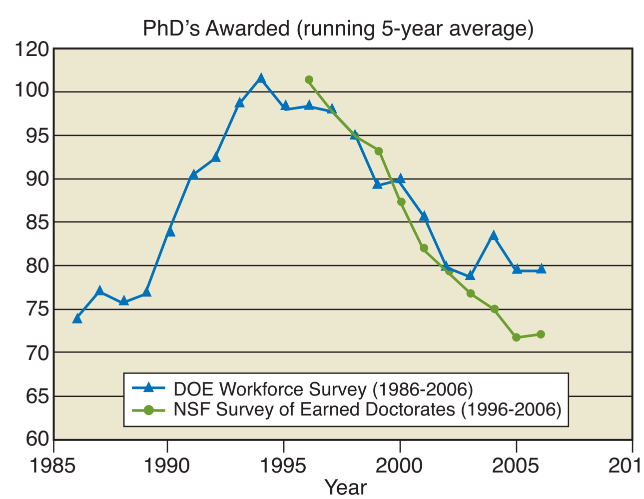


Figure 5. Ph.D.'s awarded 1986-2006. Data is from [15], for students with full or partial support from DOE Nuclear Physics, and [16], summing those self-identifying as being in nuclear physics or chemistry, including students supported by both NSF and DOE. Running 5-year averages have been shown to eliminate fluctuations.

Source		DOE 2006 Workforce Survey		NSAC Education Report, Ph.D.'s 5-10 Years Out
Gender		**U.S. Citizen**	**Non-U.S. Citizen**	**U.S. Citizens**
Male		81%	88%	88%
Female		19%	12%	12%
Race				
Caucasian		90%	69%	90%
Asian or Asian American		5%	30%	1.2%
Black or African American		1%	0%	1.2%
American Indian or Alaskan Native		0%	NA	1.2%
Hispanic		4%	1%	0.6%
Mixed race or ethnicity				6.2%

Table 3. New nuclear science Ph.D.'s.

demographics. In 2005, 40% of graduate students in all physical sciences were foreign-born [17]. This percentage was about the same among the 630 nuclear science graduate students surveyed in 2004 [1]. In 2004 there were 352 post-doctoral fellows in nuclear science in the United States, of whom 71% were foreign-born. We do not appear to be doing an adequate job of growing the next generation of U.S. nuclear scientists to fill the needs of the basic research community, as well as national needs. We are also not educating a diverse workforce. The 2006 DOE Workforce Survey [15] includes statistics on the 92 new Ph.D.'s in the field. These are listed in Table 3. The gender equity has been steadily improving, and the number of new female Ph.D.'s is now at 17%. However, the number of new Ph.D.'s coming from traditionally under-represented U.S. minorities is still woefully low.

For nuclear science to survive and prosper in the United States, every member of the field must play a role in helping to prepare a diverse next-generation of scientists and to improve public understanding and appreciation of nuclear science and its value to society. Ultimately, this is key to ensuring the future health of basic research in nuclear science.

Recommendations

The BNL workshop considered strategies for collectively addressing the DOE/NSF charge to NSAC "to discuss strategies to strengthen and improve the education process and prepare nuclear scientists for careers in academia, basic research, medicine, national security, industry, and government." The agenda and list of participants are in appendices A and B. A series of panelists from within and outside the basic nuclear science community presented models, including ones in the areas of recruiting the next generation of nuclear scientists, K-12 education and public outreach, and fostering diversity, that may have been less familiar to the participants. The subsequent discussions focused on defining goals and strategies that are actionable, achievable, valuable, and manageable, and that leveraged existing programs and unique strengths of the nuclear science community. These combined criteria led us to recommend two goals for a unified collective effort in this area over the next decade:

1. *The nuclear science community should increase its involvement and visibility in undergraduate education and research, so as to increase the number of nuclear science Ph.D.'s and the number of scientists, engineers and physics teachers exposed to nuclear science.*

2. *The nuclear science community should develop and disseminate materials and hands-on activities that illustrate and demonstrate core nuclear science principles to a broad array of audiences, so as to enhance public understanding and appreciation of nuclear science and its value to society.*

It is important to recognize that these goals are by no means the only choices that could have been made, and that they constitute only a subset of the many important ongoing activities that need to continue as part of a coordinated effort to strengthen nuclear science education and outreach. The workshop participants were convinced, however, that significant progress in these specific targeted areas will provide the greatest leverage in benefiting the entire spectrum of education and outreach needs in nuclear science, improving the vitality and diversity of our field, and contributing to U.S. competitiveness and societal needs.

BP1: CURRENT BEST PRACTICE

UNDERGRADUATE RESEARCH: CHANGING OUTCOMES IN PHYSICS AT TENNESSEE TECH

Engaging students in funded research projects when they are undergraduates has a significant impact on the students' educational accomplishments and career choices. The Tennessee Technological University (TTU) physics department, which only offers the bachelor's degree in physics, has been steering students toward graduate degrees and careers in physics since the late 1970s. Because it is a regional, predominantly undergraduate university in a state not known for generously funding higher education, one might not expect TTU to have a program that has sent a string of students on for Ph.D.'s in physics at places like Georgia Tech, the University of California at Berkeley, Yale University, Michigan State University, Rutgers University, Indiana University, Duke University, and North Carolina State University; but this is just what has happened.

This abrupt turnabout in student outcomes came when TTU physics majors were offered the opportunity to engage in research under the guidance of the TTU physics faculty on projects at accelerator facilities at Argonne National Laboratory, Florida State University, Oak Ridge National Laboratory, Institut Laue-Langevin at Grenoble, the University of Notre Dame, Duke University, and other institutions. Sustained research funding from the Department of Energy's Division of Nuclear Physics that included support for TTU undergraduates was key to making this happen.

While the number of Ph.D. degrees awarded in the nuclear sciences has been steadily declining over the past decade, eleven TTU graduates have attained Ph.D.s or are in graduate school in this subfield alone. Currently, TTU physics graduates hold faculty or staff positions at Brookhaven National Laboratory, Oak Ridge National Laboratory, the University of New Mexico, the University of Hawaii, and Vanderbilt University. Graduates from Tech's physics program have won a Presidential Early Career Award for Scientists and Engineers (PECASE), are contributing to research at Brookhaven's Relativistic Heavy Ion Collider, and hold positions such as that of Deputy Director of the Marshall Space Flight Center in Huntsville, Alabama.

Former TTU undergraduate Dan Bardayan, who today studies stellar reactions at Oak Ridge National Lab, is the recipient of a 2006 PECASE award.

From an unlikely regional public university has come an unlikely result. Like many physics departments, TTU's has a rigorous curriculum. What distinguishes TTU's undergraduate physics program from many others is the importance the physics faculty place on giving students the opportunity to engage in cutting-edge nuclear research throughout their four-year undergraduate education.

Undergraduate Education and Research

As noted in the workforce discussion, the field of nuclear science is facing a potentially serious shortage of trained workers in pure and applied research, nuclear medicine, nuclear energy, and national security. In 2004, based on a comprehensive survey of the nuclear science workforce over the last decade, the NSAC recommended an increase in the number of new nuclear science Ph.D.'s during the next decade, in order to return to an average of approximately 100 per year.

Increasing the number of Ph.D. nuclear scientists, especially U.S. citizens, includes the need to increase participation from the full diversity of backgrounds. It also requires introducing students to nuclear science and its research before they start graduate school. Because these two points are very effectively addressed at the undergraduate level, the first recommendation focuses on undergraduate education and research. Undergraduates are the wellspring of the pipeline, and we have the tools and the talent to make a difference. Such an effort best leverages the resources of our community, building on existing programs (e.g., REU, SULI, CEU, RUI) and the work of university departments, national laboratories, and individuals.

BP2: CURRENT BEST PRACTICE

ACS SUMMER SCHOOLS IN NUCLEAR AND RADIOCHEMISTRY

Students at the 2006 BNL site suit up to begin an experiment

The objective of the American Chemical Society's Summer Schools in Nuclear and Radiochemistry is to increase the number of outstanding undergraduate students introduced to the fields of nuclear chemistry and radiochemistry. Held at San Jose State University in San Jose, CA, and at Brookhaven National Laboratory in Upton, NY, the Summer Schools are intensive, six-week courses in fundamental principles of nuclear and radiochemistry. Each site hosts 12 students annually, and students can receive college credit toward their undergraduate degrees. Participating students are introduced to course materials and activities that would otherwise not be covered at their home institutions, broadening their perspective on the field of chemistry and exposing them to basic and applied nuclear science principles. Many of the graduates of past summer schools, having also completed advanced degrees in nuclear science disciplines, have found career positions in research or applied nuclear science fields, including permanent positions with the U.S. Department of Energy national laboratories.

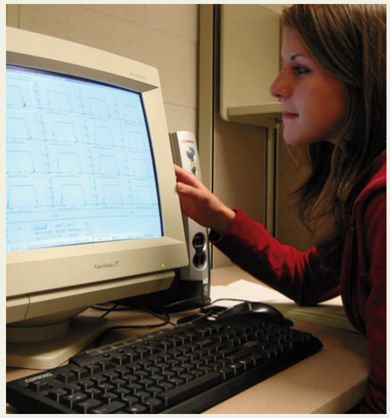
The Summer Schools program was started in 1984 at San Jose State University, and expanded to the Brookhaven National Laboratory in 1989. The Division of Nuclear Chemistry and Technology of the American Chemical Society is the intellectual oversight body of the Summer Schools. The U.S. Department of Energy's Office of Basic Energy Sciences (BES) has provided funding for the program. These funds are used to cover student stipends; travel, living, and educational expenses; salaries for the site directors; and salary and travel expenses for participating lecturers and teaching assistants. The students receive nuclear and radiochemistry training equivalent to a three-hour, upper-level undergraduate course, along with a two-hour, hands-on laboratory experience, within the six-week summer period. Each student also completes radiation safety training at the beginning of the session. A guest lecture series, several one-day symposia, and organized field trips to nuclear-related research and applied science laboratories enhance the curriculum. This enrichment affords an opportunity for students to see the broader impacts of nuclear science in today's world, and to experience some of the future challenges through formal and informal discussions with leaders in the diverse fields represented by nuclear chemistry and technology.

There has been concern among members of our community that the number of schools with nuclear physics faculty is declining. If this is true, it is not evident in the number of permanent staff at universities that are being supported by DOE and NSF nuclear physics. There may be a redistribution of nuclear physics faculty among subdisciplines of nuclear physics or a broadening of the definition of what a nuclear physicist does. A quantitative study of this question is beyond the scope of this document. However, it is well documented that the nuclear chemistry community has been faced with declining numbers of students and faculty for many years and that the situation in that subfield is critical. Nuclear chemistry faculty members are not being replaced when they retire. The number of new Ph.D.'s in nuclear chemistry each year is now at such a low level (<4) that the NSF Survey of Earned Doctorates is no longer counting it as a separate category.

An aggressive plan to recruit more U.S. undergraduates into nuclear science careers must of necessity require considerable outreach to women, minorities, first-generation college, and students from other traditionally under-represented backgrounds. It is a fact that if the STEM disciplines were attracting under-represented groups at the same rate at which they attract white males, not only would many more

THE MONA COLLABORATION: A MULTI-INSTITUTIONAL RESEARCH COLLABORATION WITH UNDERGRADUATE PARTICIPATION AT ITS CORE

The Modular Neutron Array (MoNA), a major experimental device located at the National Superconducting Cyclotron Laboratory (NSCL), was assembled almost exclusively by undergraduate students at ten different, primarily undergraduate, colleges and universities. Following the completion of the array—nine layers of sixteen plastic scintillator bars, each $200 \times 10 \times 10$ cm^3—the MoNA collaboration continued as an ongoing, multi-institutional research collaboration that includes undergraduate participation as a central feature.



Undergraduate student Tina Pike developing a calibration scheme for MoNA.

Since 2004, members of the collaboration—faculty, grad students, and undergraduates—have gathered for an annual collaboration meeting, where papers and experiment proposals are written, data analysis issues are addressed, responsibilities are delegated, and the collaboration itself is renewed and reinvigorated.

This multi-institutional model of undergraduate research participation offers a number of important advantages for nuclear science in particular, since most experiments are now performed at national user facilities. Students who are place-bound, either because they are non-traditional students with family commitments or because they feel cultural constraints, can participate in a meaningful way even if they cannot devote an entire summer to the research experience. The MoNA model also promotes year-round and multi-year research participation, which makes it more likely that students will see a project through to publication. Regular contact with students and faculty from other institutions helps MoNA undergraduates to see themselves as part of the nuclear physics community, and so encourages them to continue on this career path.

Undergraduate students from the MoNA collaboration institutions have participated at the NSCL in every MoNA experiment to date, and MoNA undergraduates are carrying out essential components of the data analysis for these experiments.

Members of the MoNA collaboration have worked hard and creatively to ensure the continuing participation of faculty and students from the undergraduate institutions. Weekly videoconferences, recently enhanced by new hardware, thanks to a grant from the state of Michigan, provide an opportunity for discussion of data analysis issues, ideas for future experiments, and other topics. With one of the videoconference sites in the MoNA data collection area at the NSCL, students can even carry out online data analysis during experiments without traveling to the NSCL. Email distribution lists, including one restricted to undergraduate students, provide avenues for asynchronous communication.

So far, fifty-six undergraduates and one high school student have participated in research as part of the MoNA collaboration. The next MoNA experiment, tentatively scheduled for May 2007, will provide yet another opportunity for students at the collaboration institutions to experience the thrill of participation in cutting-edge research in nuclear physics.

U.S. citizens be studying nuclear science, but we would readily achieve the goal to increase by 20% the number of nuclear science Ph.D.'s annually awarded in the U.S. In order to attract significant numbers of talented new students into nuclear science programs, it is necessary to recruit from a broad cross section of the student population and to proactively work on increasing the number of individuals from traditionally under-represented backgrounds who are exposed to nuclear science at the undergraduate level.

Introducing the basic principles of nuclear science and providing advanced courses and laboratories to physics and chemistry students as part of a basic curriculum has the collateral benefit of exposing more future teachers, engineers, and other professionals to nuclear science, its broad applicability to careers at all levels of schooling, and its value to society.

How do we effect change at the undergraduate level? We propose a three-pronged approach, all of whose elements are important:

BP4: CURRENT BEST PRACTICE

CONFERENCE EXPERIENCE FOR UNDERGRADUATES

The Conference Experience for Undergraduates (CEU), held annually since 1998, has become a valuable addition to the fall APS Division of Nuclear Physics (DNP) meetings. Since its inception, approximately 630 undergraduate students from colleges and universities across the country (and a few from abroad) have participated. The goal of the program is to provide students who have conducted undergraduate research in nuclear science a "capstone" conference experience, with the goal of strengthening retention of these talented students in the field.

The CEU draws applications from students around the country and abroad. Their application materials are considered by an independent review committee, and travel and lodging grants are awarded based on project merit. Support for the CEU is provided by the NSF, DOE, and DNP. Students who don't receive awards are often able to participate based on assistance from their advisors or home institutions. For most, participation in the DNP meeting represents their first professional conference experience and the first opportunity to present their research to a broad professional audience.

At the 2005 CEU in Maui, 16 Japanese undergraduate students were also able to participate, and there was good exchange between the American and Japanese students, bringing an international flavor to the program.

Each year the CEU includes several activities designed for the participants. In addition to the undergraduate research poster session (which is always a well-attended session), there are also two special nuclear science seminars presented at an advanced undergraduate level by prominent members of the DNP, an evening dessert social, and a graduate school information session at which representatives from several universities and laboratories meet with the students to discuss graduate school opportunities. In addition to CEU activities, students are also full participants in the meeting, and are encouraged to attend as many of the regular sessions as they can.

Survey and anecdotal data indicate several benefits of CEU participation. Students discover that scientists are genuinely interested in their research, that is, that their work is valued and highly relevant to the field as a whole. They meet peers, graduate students, and established scientists who share a common interest and bond in physics and research, and many students catch an inspiring vision of a future in nuclear science. They see first-hand how fundamental communication and sharing of ideas occurs among professional scientists. They have a unique opportunity to discuss graduate school opportunities with scientists from several top institutions and laboratories. Survey data also suggest increased student interest in graduate school in general and in nuclear science in particular. Each of these benefits serves to strengthen retention of talented students in nuclear science.

Finally, the DNP community benefits from the energy and excitement that bright young scientists bring to the meeting.

1. Engage undergraduates in **research**. It has been demonstrated that undergraduates who have been involved in research go on to pursue graduate degrees at a higher rate, are more likely to remain active in research in their professional careers [18], and often stay in the subdiscipline in which they interned. The early exposure to research also has been shown to decrease the time a student spends in graduate school [19].
2. In the **education** process, ensure that undergraduate physics majors are exposed to nuclear science as early and often as possible.
3. Make nuclear science **visible** to as many undergraduates as possible, in both STEM and non-STEM courses of study. Introducing nuclear concepts to a broad range of undergraduates will have impacts on multiple areas: future teachers, an informed public, and

FS1: A FUTURE IMPLEMENTATION STRATEGY

A NUCLEAR PHYSICS SUMMER SCHOOL: A PRELUDE TO A RESEARCH EXPERIENCE

The nuclear science community has a strong tradition of providing research experiences for undergraduates through the NSF REU or RUI grants, the DOE SULI or CCI programs, university programs and individual grants. However, many students come into these programs woefully unprepared, with little knowledge of nuclear science and minimal hands-on experience. They may spend most of a 10-week summer internship on a steep learning curve that can be extremely frustrating for student and mentor alike.

We propose a nuclear physics summer school for rising juniors, modeled after the successful nuclear chemistry summer school. This school would last 6-8 weeks and take place at an institution with a facility. It would consist of a combination of lectures and hands-on activities, and students would be instructed in the basics of nuclear physics and its tools and techniques.

Recruitment for this school would be primarily from institutions with no facility or existing nuclear science program, and would contain an aggressive diversity component. Students would be expected to pursue a research program the following summer, and the school faculty and mentors would help place them with nuclear science groups.

informed national leadership in science, technology, government, business and medicine.

During the course of the workshop, many activities that could lead to improvements in these three areas were discussed. A categorized list is included in Appendix E-1. Herein, a broad strategy is outlined which should lead to demonstrable results in each of the three areas. The sidebars either describe a current best practice or a possible future strategic implementation. These are not meant to be inclusive, but to illustrate possibilities.

STRATEGIES FOR UNDERGRADUATE RESEARCH

Undergraduate research has been demonstrated to engage students early in their education and is also an area in which nuclear science has existing programs and strengths. The graduate student survey in the NSAC education report [1] documented that 92% of the female and 88% of the male graduate students surveyed had been engaged in undergraduate research experiences. An integrated approach is called for that identifies promising students early in their education, provides them with opportunities throughout the undergraduate experience, and helps with the transition to graduate school.

- Home institutions play an important role in engaging students early in their education. As seen at Tennessee Technological University, engaging undergraduates in research in their freshman or sophomore years of college and then maintaining involvement until graduation has a significant impact on student outcomes (see Sidebar BP1, *Undergraduate Research: Changing Outcomes in Physics at Tennessee Tech*).
- For rising juniors, we propose a summer school that will provide both knowledge and hands-on experience in basic nuclear science concepts, preparing students for active engagement in nuclear science research the following summer, when they are rising seniors (see Sidebar FS1, *A Nuclear Physics Summer School: A Prelude to a Research Experience*). This summer school will be patterned after the highly successful nuclear chemistry summer school, which has been in operation since 1989 at two locations (see Sidebar BP2, *The ACS Summer Schools in Nuclear and Radiochemistry*).
- We propose to expand summer research experiences for undergraduates, leveraging existing programs at college and university departments and national laboratories.
- Where possible, research experiences should continue throughout the school year. For example, member institutions of the MoNA collaboration facilitate this through weekly video-conferences and a video hookup in the data collection area at the NSCL (see Sidebar BP3, *The MoNA Collaboration: A Multi-Institutional Research Collaboration with Undergraduate Participation at its Core*).

FS2: A FUTURE IMPLEMENTATION STRATEGY

INTEGRATED MENTORING

It has been recognized that mentoring of students at all levels is an important factor in the retention of students in the field. The most effective mentoring can be done by the Ph.D. advisor for graduate students and by the professor or scientist supervising the research projects for high school and undergraduate students. A potential problem is the transition from one phase to the next (from high school to college, and from college to graduate school). Due to the lack of mentoring and guidance, students who are still undecided about their future direction might leave the field.

For example, a survey of undergraduate students attending the Conference Experience for Undergraduates at the 2003 Fall DNP meeting was included in the 2004 NSAC report on education in nuclear science [1]. The results revealed that, following their research and CEU experience, about 20% of the students thought they would probably continue with nuclear physics in graduate school, and about 40% would consider it. Only 15% were definitely pursuing a Ph.D. in nuclear physics. While this number is still high compared to the AIP survey of incoming graduate students, in which 4% are planning to study nuclear physics [17], it still leaves a large number of undecided students among those who already have in-depth experience in nuclear physics research and were motivated to apply for the CEU.

The advisor of the students should be encouraged to continue to mentor (and not only track) students when they move on to the next stage. If it is not practical to continue this role, they should take proactive steps to ensure a seamless continuation of the students' mentoring and guidance at the next institution. To facilitate these activities we recommend exploration of options to form a national mentoring network.

- CEU provides a professional development opportunity for students, especially as they transition to graduate school (see Sidebar BP4, *Conference Experience for Undergraduates*).

To guarantee success in this endeavor, we must take leadership roles at our home institutions and network among our community by:

- Helping to place promising students with nuclear scientist mentors.
- Mentoring and providing academic advice and career counseling to physics and chemistry students, especially those interested in nuclear science.
- Networking with colleagues at other institutions to keep a living list for the nuclear science community of students interested in continuing to graduate school in nuclear science, so as to give these students the best opportunities throughout their undergraduate experience and as they transition to graduate school (see Sidebar FS2, *Integrated Mentoring*).
- Developing a community-wide strategy for recruiting promising students from traditionally under-represented groups, including women, so that we are working together to recruit more of these students into nuclear science, rather than competing against each other for the small number of students available now.

Undergraduate research experiences should be recognized by the agencies as an important component in training the next generation of nuclear scientists. Undergraduate participation should be part of the reporting requirements for all agencies.

STRATEGIES FOR UNDERGRADUATE EDUCATION

The number of undergraduate courses offered in nuclear physics and chemistry across the nation is low, leaving students who do not have access to such courses largely ignorant of the field, even into their graduate studies. To reach future nuclear scientists, future physics teachers and other S&T professionals, nuclear concepts need to be sustained in both modern physics and general survey physics.

According to statistics gathered by the NSAC education report [1] from AIP statistics and through phone calls, six out of 23 Ph.D.-granting institutions (18%) with 20 or more physics majors offered nuclear physics courses. Of the remaining institutions, 12 departments (43%) offered a combined nuclear and particle physics course. However, two of these departments had no nuclear physicist on the faculty.

Of the seven bachelor's-only departments that averaged 15 or more physics majors per year, two offered a course in

FS3: A FUTURE IMPLEMENTATION STRATEGY

WORKSHOP ON NUCLEAR PHYSICS IN THE UNDERGRADUATE CURRICULUM

The importance of students' exposure to nuclear physics topics during their undergraduate studies has been recognized by the 2004 NSAC report, *Education in Nuclear Science* [1]. The report states: "The undergraduate years offer the prime opportunity for introducing students to the tools and methodology of physical science. The window of time during which science can grab their interest and propel them toward a career in science is rather narrow, and it is therefore especially important that the nuclear science community focus appropriate attention on these crucial years for the recruiting and retaining of interested students in the field." A survey of physics departments revealed that "a large portion of students entering graduate school have no formal instruction in nuclear physics until they encounter it (if they do at all) in graduate school."

It is therefore important that the community explore options to improve the exposure of undergraduate students to nuclear physics. We thus recommend a workshop on "Nuclear Physics in the Undergraduate Curriculum." This workshop could be held in connection with the fall meeting of the Division of Nuclear Physics.

The workshop participants would evaluate the current situation, highlight best practices, and discuss how to make the nuclear physics elective course more attractive to the students. It should address the recommendation of the NSAC report to establish "an online nuclear physics instructional materials database, for use in encouraging and enhancing the development of undergraduate nuclear physics courses." The formation of this database has been recommended in order to offer nuclear physics content to departments where the small number of physics professors limits the curriculum to only the basic core courses.

nuclear physics, and two others offered a combined nuclear/particle or nuclear/atomic course.

College and university faculty need to work within their departments to ensure that nuclear physics courses (with at least 50% nuclear physics content) are offered or continue to be offered. A means of disseminating nuclear physics and astrophysics course material to schools with no nuclear faculty should be examined (see Sidebar FS3, *Workshop on Nuclear Physics in the Undergraduate Curriculum*).

One way to reach many students is to inject nuclear-related experiments into the large upper-division laboratory courses taken by all chemistry and physics majors. The experiments must both use modern equipment and be of current interest to the society at large. This tactic has been used successfully at Washington University (see Sidebar BP5, *Advanced Laboratories in Nuclear Science*).

STRATEGIES FOR IMPROVING THE VISIBILITY OF NUCLEAR SCIENCE AMONG UNDERGRADUATES

It is important to increase campuswide visibility of nuclear science at all schools, and, more particularly, visibility within physics and chemistry departments that don't have nuclear science faculty. For those students going on to pursue graduate degrees in physics or chemistry, this will introduce nuclear science as a career choice before they start choosing a graduate school. For physics or chemistry majors who enter the job market with a bachelor's degree, one of the applications of nuclear science may become an attractive career choice. And for students with other majors, they will constitute an informed public. Increasing the visibility of nuclear science at predominantly undergraduate institutions and at institutions that contain a large population of traditionally under-represented minorities will be an essential step in improving the diversity of our field. The overall effect of increasing visibility within physics and chemistry departments would be (1) an increase in the number and diversity of Ph.D.'s educated in nuclear science, and (2) an increase in the number of S&T and health professionals and future physics teachers exposed to nuclear science.

A distinguished lecturer program, which has proved successful in plasma physics, is one approach to increasing visibility within physics or chemistry departments at schools with no nuclear science. These lecturers should be provided with travel money to visit schools in their region to talk about nuclear science in general and their research in particular (see Sidebar FS4, *Distinguished Lecturers*).

FS4: A FUTURE IMPLEMENTATION STRATEGY

DISTINGUISHED LECTURERS

To continue as a vital field, attract new students, and combat the fear of the word nuclear in the eyes of the general public, we must establish an effort focused on bringing our message to the right audiences. We propose to establish a program of "Distinguished Lecturers in Nuclear Physics," patterned after the successful program already established in the plasma physics community.

There are two ways these lecturers could interact with undergraduate students and the general public. First, it is important to personally and individually reach the large undergraduate population of physics majors from non-research institutions and from research institutions that do not offer graduate programs in nuclear physics. The latter group of students could be reached most effectively if each distinguished lecturer were to present several undergraduate seminars in their region, proactively contacting physics departments and volunteering his or her services. The ultimate goal would be to ensure that every undergraduate physics major in the country has heard at least one seminar on the exciting field of nuclear physics before he or she graduates.

In addition, using modern Webcast techniques, a small number of distinguished lecturers would be able to reach a larger community, allowing questions to come from students and/or members of the general public. Facilities to host such Webcasts already exist at most national laboratories and at many universities.

For both methods of dissemination, it will be necessary for the success of the program to provide the distinguished lecturers with graphics and other material that would make the material exciting and target it to the level of the audience. This will require a concerted community effort.

BEYOND THE UNDERGRADUATE DEGREE

One anticipated outcome of focusing on enhancing undergraduate education, research, and visibility in nuclear science is to increase the number of nuclear science Ph.D.'s who are U.S. citizens. To fully realize this outcome will require a commitment to attract a diverse cadre of U.S.-trained students to our discipline and prepare them for the wealth of career opportunities that will be available to them. In addition to basic nuclear science research and higher education, career options extend to applications of nuclear science that meet national needs: nuclear energy, nuclear medicine, homeland security, environmental remediation, nuclear safeguards, etc.

The NSAC education report [1] discusses many interventions aimed at increasing the number of nuclear science Ph.D.'s prepared to contribute to national needs. We endorse the report's recommendations with respect to graduate student and postdoctoral scholar education and training:

- The nuclear science community should assume greater responsibility for shortening the median time to the Ph.D. degree.
- As recommended by the Secretary of Energy's Advisory Board (SEAB) in 2003 [20], prestigious graduate student fellowships should be developed by the Office of Science in the areas of physical sciences, including nuclear science, that are critical to the missions of the DOE.
- Also as recommended by the SEAB 2003 report, new training grant opportunities in nuclear science should be established.
- Prestigious postdoctoral fellowships in nuclear science should be established with funding from the NSF and the DOE.

As reported in reference [1] and summarized in Table 1, fewer than 40% of Ph.D.'s in nuclear science stay in nuclear science, almost all in the academic research environment of universities or national laboratories. Among the others, the NSAC education survey found a significant degree of disappointment arising from an unrealistic expectation of careers in academic or national laboratory positions. Enhanced career advising and mentoring is very important, and community-wide resources should be developed to prepare students for careers beyond the traditional job market. Therefore, interventions should include regular professional development activities for graduate students and postdoctoral fellows. For example, workshops associated with the DNP meeting could highlight career paths outside basic research and higher education (see Sidebar FS5: *Professional Development Workshop*). Such activities would complement those available at universities or national laboratories.

BP5: CURRENT BEST PRACTICE

ADVANCED LABORATORIES IN NUCLEAR SCIENCE

Introducing nuclear topics into first year chemistry and physics survey courses will reach a wide spectrum of students and thus can begin to generate a nuclear-literate undergraduate population. However, this step should only be the beginning. The more places in the curriculum we can interject nuclear topics the better. One means of reaching students is by injecting nuclear-related experiments into the large upper-division laboratory courses taken by all chemistry and physics majors. The experiments must both use modern equipment and be of current interest to the society at large. Examples of such topics are: identification of Pb by x-ray fluorescence (of relevance for lead poisoning), Mossbauer spectroscopy (of relevance for the presence of water on Mars), and positron annihilation (of relevance to PET imaging.) This exercise is used at Washington University in both chemistry and physics advanced laboratories.

Outreach

Nuclear science is an active and exciting field. From detailing the structure of matter and understanding the source of energy in our sun to exploring the state of matter that existed at the beginning of the universe, nuclear science is alive with an array of important scientific pursuits and technological developments that profoundly impact our society. Applications of research in nuclear physics, chemistry, medicine and engineering continue to have a powerful and beneficial effect on the economy, health, technology, and security of our society and will profoundly affect our future. Important examples of the benefits made possible by nuclear science abound, for example: diagnosing physical ailments without exploratory surgery, alerting families to the threat of fire, helping ensure adequate supplies of electrical power, guarding against biological agents carried through the mail, guarding our country's borders against the transport of dangerous materials, and ensuring the nation's ability to defend itself.

Yet, the public and even some scientists in other fields are often uninformed or misinformed about nuclear science and its benefits. A book-length study documents that, in public discussions surrounding any topic involving the word "nuclear," the important technical and societal issues that should be of primary interest to informed citizens are drowned out by unreasoned reaction to the word itself [21]. For example, the medical technique now known as magnetic resonance imaging was initially called nuclear magnetic resonance. The present title, while descriptive, is notable for the absence of the word "nuclear," which was removed when it was said to have raised serious concern among potential patients. In the political realm, the discussion of radioactive waste disposal is a confused political issue and only in the last year or two has there been serious discussion of the positive aspects of nuclear power generation.

We conclude that a broad, basic knowledge of nuclear science is critical for an educated population that can deal effectively with a wide range of important scientific topics, including medicine, energy policy, homeland security and defense. It is equally critical for the future of nuclear science in the U.S.

WHO WE NEED TO REACH

How can we improve on the efforts already being made by national labs, universities and individuals? We have looked at models from other subdisciplines of physics and from nuclear energy. We propose to leverage existing efforts by implementing a unified national effort to attack this problem. We will partner with each other and with outside groups, such as the nuclear energy community, to develop and disseminate materials and hands-on activities that are specifically directed towards nuclear science.

Introducing nuclear concepts to a broad range of **undergraduates** will have impact on multiple areas: future teachers; an informed public; informed national leadership in science, technology and medicine; and the business, government and non-profit sectors. While the public sees science focused on medicine and the environment in a positive light, anything "nuclear" is often viewed with a mixture of anxiety and misunderstanding. Above all, an informed public is a necessity if the true value of fundamental and applied nuclear science is to be recognized. To achieve this goal we need creative

FS5: A FUTURE IMPLEMENTATION STRATEGY

PROFESSIONAL DEVELOPMENT WORKSHOP

After earning her Ph.D. in nuclear science, Joann Prisciandaro joined the faculty of the University of Michigan Hospital.

There is a long tradition of Ph.D.'s in nuclear science playing leadership roles in applications of nuclear science, from nuclear energy to nuclear medicine, from homeland security to environmental remediation. The nuclear science community is committed to sustaining the training of Ph.D.'s in nuclear science to continue to address challenges facing the nation and enhancing American competitiveness. The challenge to our community is that our graduate students and postdoctoral scholars are distributed across the country. Those in residence at national laboratories have less access to the career development activities that many universities host. At the same time the many postdocs and graduate students in smaller university groups have less access to learning about the broad range of applied science opportunities that a multi-purpose national laboratory could provide.

To provide an opportunity for all of our graduate students and postdocs to learn about the challenging opportunities in applied science that require nuclear science backgrounds, we propose hosting workshops at our professional meetings, such as the annual meeting of the DNP of the APS. An example could be a workshop that focuses on presentations from Ph.D. and postdoctoral alumni who now are making significant contributions in medical physics. These alumni could talk about the paths to their present careers, how they are using their nuclear science training to address our challenges in diagnosing and treating disease, and advising our current graduate students and postdocs on how to prepare themselves for these careers. These presentations could be complemented by a tutorial on medical physics, introducing our current students and postdocs to the anticipated challenges in medical physics. To facilitate networking, a reception could be hosted, possibly by recruiters from medical facilities. This workshop would not only facilitate preparing current graduate students and postdocs for careers in medical physics, but would help more established members of our community, faculty members, and national lab staff in preparing future students and postdocs for such careers.

Of course, medical physics is only one area appropriate for highlighting the challenging career opportunities available to nuclear science Ph.D.'s. Analogous workshops could be hosted every 1-2 years, focusing on opportunities in homeland security, nuclear waste remediation, nuclear energy, nuclear safeguards, or stewardship science.

Joann Prisciandaro illustrates how training in nuclear science prepares students for service to the nation. Joann plays an important role in cancer treatment at the University of Michigan Hospital, where she is on the faculty of Radiation Oncology Physics. She received a Ph.D. degree in nuclear chemistry, studying nuclei far from stability with radioactive beams at Michigan State University and the National Superconducting Cyclotron Laboratory under the direction of Paul Mantica. She says "As a student in a nuclear physics laboratory, I was given the opportunity to work with experts and independently on various experiments. This required setting up and testing electronic equipment, interpreting the response of radiation detectors, understanding the interactions of radiation, writing subroutines and analyzing data. The experience and knowledge I gained as a nuclear scientist has prepared me well for radiation oncology physics."

approaches to education, ones that engage the non-science student intellectually in real-world topics.

Preservice and inservice high school teachers need knowledge of nuclear science concepts, access to nuclear scientists as a resource, and tools for introducing nuclear science in an inquiry-based setting into the modern classroom. Too often, the teachers themselves are not trained in physics, but have general science education degrees, so they are not comfortable with the material. In fact, in some states, e.g., North Carolina, teachers are discouraged from getting physics degrees because teachers with a more general science education are more easily hired [22].

Engaging promising **high school students** in research-related activities will point them towards the physical sci-

BP6: CURRENT BEST PRACTICE

CLARK UNIVERSITY WMD COURSE

Effective science education for non-science students is an important challenge that must be met if we are to have broad support from the public for science education and research.

Clark University designed a course, Chem. 007, Science of Weapons of Mass Destruction [WMD], for just this purpose. Here, the science behind WMD is discussed in a small seminar environment, and students perform laboratory experiments illustrating the concepts each week. Topics include low-energy explosives, nerve agents, biological agents, and nuclear devices. In each case, introductory science concepts are used to explain how the device works. Historical examples are reviewed, such as the Oklahoma City bombing, Wisconsin Army Research Lab bombing, Tokyo Sarin subway attack, World War I and Kurdish gas attacks, anthrax letters, "dirty bombs" and Hiroshima/Nagasaki. The technical and regulatory means for containing and preventing the use of these weapons are also discussed.

Approximately one-third of the course deals with nuclear science. In the laboratory, students learn to use absorbers to identify different types of radiations, and engage in a "hunt for contraband nuclear material" in which they discover and characterize hidden sources in a simulated homeland security exercise.

The course is limited to 20 students, of whom about two-thirds have little or no scientific background. In addition to normal classroom activities, each student prepares a term paper on a special topic and gives an oral presentation before his or her peers at a symposium. Guest speakers from the FBI and state emergency response teams are a regular component of the course. The course receives rave reviews from students at all levels and has a long waiting list each time it is offered.

ences and perhaps nuclear science as a potential career option.

Engaging **middle school students** will spark their curiosity and interest in science at an early stage, and aid in directing them towards science as a future career choice.

We need to fight the initial unreasoned fear the word "nuclear" creates in the **general public,** so that they can move beyond that into an appreciation and understanding of nuclear science and its value to society.

STRATEGIES FOR IMPROVING NUCLEAR SCIENCE IN UNDERGRADUATE AND K-12 EDUCATION AND REACHING OUT TO THE PUBLIC

As in the case of undergraduate education, many activities were suggested to implement this strategy. A few examples are discussed here; others are listed in Appendix E-2.

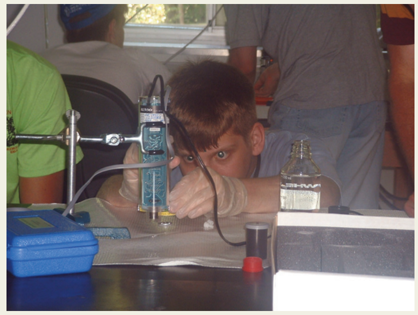
The Internet has become a significant source of information, as well as an inexpensive way of distributing it. Students and teachers frequently rely on it as their only source of knowledge. While there is much information about nuclear science already on the Web, a website with the sophistication and eye-catching appeal of ParticleAdventure.org or UniverseAdventure.org does not exist.

We propose to develop a nationally coordinated website as a resource center for students, educators and community members engaging in education and outreach (see Sidebar FS6, *National Nuclear Science Website*). This will require a network of individuals across the field, including stakeholders with appropriate resources to develop the Website and keep it current. This Website will serve all levels, from outreach to the general public (e.g., discussions of societal issues) to the undergraduate curriculum (e.g., sharing of course material).

At the **undergraduate** level, all the suggestions made in the first half of this document will increase the visibility of nuclear science on the college campus among all students. One proven strategy for introducing nuclear science concepts to non-science majors is to develop imaginative courses that satisfy general science requirements and also contain an introduction to nuclear science concepts. The Weapons of Mass Destruction (WMD) course at Clark University (see Sidebar BP6, *Clark University WMD Course*) is one example of such a course.

There are several models in physics that achieve successful

PHYSICS OF ATOMIC NUCLEI



Pre-college student researchers at NSCL's Physics of Atomic Nuclei (PAN) summer camp.

Physics of Atomic Nuclei (PAN) is a residential summer camp at the National Superconducting Cyclotron Laboratory (NSCL) on the campus of Michigan State University. The program, currently in its fourteenth year, is co-sponsored by NSCL and the Joint Institute for Nuclear Astrophysics. PAN is designed to introduce pre-college students and teachers to the fundamentals of nuclear science and nuclear astrophysics, current research in those fields, methods of nuclear experimentation, and life in the university environment.

Admission to PAN is competitive; teachers and students are required to submit applications with references. There are no restrictions on applicants, except that the teachers must conduct science courses at the middle or high school level, and the students must have completed at least one year of high school. PAN organizers accept the twelve teachers and twenty-four students who show the most initiative, interest and aptitude. The program is free for all participants, offering room and board at MSU for the duration and a small travel stipend.

The teachers who are accepted come to campus for two weeks in late July/early August. During the first week, they take on the role of student for a series of lectures by faculty researchers about rare isotope science at NSCL and other projects. The teachers gain laboratory experience by performing experiments with radioactive sources. The capstone for the teachers' first week is to construct a cosmic ray detector (CRD), with which they must be familiar for the second week's activities.

When the students arrive for the second week of the PAN program, they are also treated to faculty lectures. These lectures (and those in the first week) are followed by small-group-based question/answer sessions that offer feedback to the lecturer and encourage interaction between PAN participants and staff. However, most of the students' time is spent in hands-on experimentation with radioactive sources and the CRDs. Each team is given the opportunity to design, implement and conduct its own experiment using the CRDs. It is during this week that the teachers use what they have learned while guiding a team of students through their research. At the end of the program, students present their findings to an audience of PAN participants, staff, and parents.

It is the goal of PAN for students and teachers to gain appreciation and excitement for science, in particular nuclear astrophysics. In addition, it is expected that the educational tools and experiences offered to teachers through PAN will encourage them to incorporate nuclear science (perhaps in the context of astrophysics) into their classes. All PAN teachers are offered continuing support, whether it is NSCL tours, CRDs on loan, or small grants for classroom equipment.

outreach to **inservice and preservice teachers** by engaging them together with scientists in research-related activities and with each other in curriculum development. The Physics of Atomic Nuclei (PAN) is a summer camp that has been run at Michigan State since 1981 and was expanded to Notre Dame in 2006 (see Sidebar BP7, *Physics of Atomic Nuclei*). Other models for successful summer programs include Quarknet and Plasma Camp, in the high energy and plasma physics communities, respectively. We propose to adopt the best practices from each of these models, and start a pilot camp that could later be expanded to laboratories and university facilities across the field (see Sidebar FS7, *Summer Camp for High School Teachers and Students*). We plan to explore innovative funding scenarios for such a series of summer camps, for example, partnering with the DOE national laboratories in the newly-formed Academies Creating Teacher Scientists (ACTS) program, which was part of the 2007 DOE budget request.

FS6: A FUTURE IMPLEMENTATION STRATEGY

NATIONAL NUCLEAR SCIENCE WEBSITE

We propose to create a new nuclear science Website that offers the fundamentals of our field for those interested in its basic information and current research. This Website will enable students, teachers, parents, and the general public to access items such as:

- Nuclear science essentials at several different age-appropriate levels.
- Its history and the people, including engineers and other individuals who contributed to the discoveries.
- Virtual access to selected experiments, allowing students and teachers the unique opportunity to collaborate with researchers throughout the country.
- Current research, written at a level that the public can understand.
- Games, puzzles and worksheets that excite.
- Instructions for building hands-on experiments that can be used in the classroom.
- Collections of successful outreach, K-12, undergraduate, and graduate activities.
- Lists of potential speakers that can be sorted by geography.
- As well of as many other items that are of interest to the public.

This new website will be a central resource for the achievements and potential of nuclear science. The site will inform the public of exciting scientific efforts and results, at the same time demystifying some of the issues related to the application of nuclear techniques. Furthermore, it would encourage students to consider nuclear science as a career.

Such an effort might be organized by creating a core group at one institution, with groups all over the nation collaborating and contributing. Material would be developed by teams of scientists, teachers and students. There are many successful models, e.g., Compadre [25], that could be emulated.

It is also important to engage **high school students** as early as possible in order to capture and sustain their interest in physics as a career choice. This can also be done through science camps and research internships. One example of a successful summer program is the Summer Experience in Physics for students at the Rickover Naval Academy (see Sidebar BP8, *Argonne National Laboratory Summer School Experience in Physics*).

At present, neither DOE nor NSF supports formal programs for high school student research experiences. However, several laboratories and universities have internally funded very successful programs. These have been shown to sustain students' interest in science careers as they enter their undergraduate years [23]. Individual scientists have also given their time to mentor high school students for the Intel and other national science fairs. These efforts should be recognized and expanded where possible. Whether in a short, intense summer internship or in a year-long sojourn towards a major science fair, mentorship of a bright high school student requires a substantial commitment of time and patience, but can be very rewarding.

Conveying the excitement of nuclear science to the general public is critical for the health of the field. The activities of public affairs offices at some of our national laboratories are excellent best-practice models that the nuclear science community can use in targeting outreach to specific audiences, e.g., the science community, funding agencies, elected officials, educators and students, the science-attentive public, general public, and both science and mainstream media. For example, Brookhaven National Laboratory's Community, Education, Government and Public Affairs directorate has worked collaboratively with members of the RHIC community to communicate about RHIC, while managing controversy over the perceived possibility of creating black holes, turning a potential negative into a positive (see Sidebar BP9, *A Black Hole Ate My Planet*).

Many of the materials and programs developed to enhance the visibility of nuclear science at the undergraduate level can be used for public outreach as well. A subset of those engaged in the Distinguished Speakers' program proposed for the undergraduate community could be trained to speak at a public level, with access to a library of outreach material.

It will be crucial to network both internally and externally to leverage these efforts and ensure success. Organizations such as the American Nuclear Society (ANS) have developed

FS7: A FUTURE IMPLEMENTATION STRATEGY

SUMMER CAMP FOR HIGH SCHOOL TEACHERS AND STUDENTS

Strategies for introducing nuclear science into the K-12 curriculum must take into account the realities of the current education system in the United States. Teachers are required to teach to the standards and the tests, there is little or no time available to add additional material in modern physics, and very little money is available for classroom equipment. All these realities must be considered if we want nuclear science to mean more to our K-12 students than a decorative wall chart hanging in the classroom. Scientists and teachers must work together to develop nuclear science material and hands-on activities that can be used in a sustained way to illustrate concepts that are part of the standards.

One excellent model for this type of activity is the Plasma Camp run by Princeton Plasma Physics Laboratory. Plasma Camp is a 1-2 week camp that takes 12 teachers each year; teachers commit to attend for three consecutive years. During Plasma Camp, teachers work together with scientists to write plasma-centered curricula that are then tested and modified in subsequent years. Teachers are also eligible to apply for up to $2000 in mini-grants. Teachers who have attended the early years of Plasma Camp are still using the material in their classrooms several years later, one good measure of sustained success.

The model of Plasma Camp might be combined with the successful PAN model by having a third week which includes high school students, giving the teachers a chance to test their newly developed nuclear science curricula. We propose piloting a nuclear science camp of this type at one of the DOE national laboratories, in order to leverage resources of the new DOE Teacher Academy program, slated to be funded beginning in 2008. If this model is successful, it could be extended to other national laboratory sites and university facilities across the country.

much useful educational material related to nuclear science and its applications. For example, the DOE Nuclear Energy Office has developed a teacher training module called Harnessing the Atom, which has been piloted with some success (see Sidebar BP10, *Harnessing the Atom*). Some ways in which we can build upon existing efforts include:

- Evaluating and coordinating with existing programs.
- Coordinating among agencies.
- Developing and coordinating modules for first-responder training in nuclear science.
- Networking with outreach specialists in other subdisciplines of physical science.

VALUE AND RESPECT

Outreach takes time and effort away from other career activities and is often considered extra-curricular. This is often an impediment to scientists who might want to engage in outreach activities. The NSF's recognition of individuals' contributions to the broader impacts, broadly defined, serves as a model of the type of positive reinforcement that is essential.

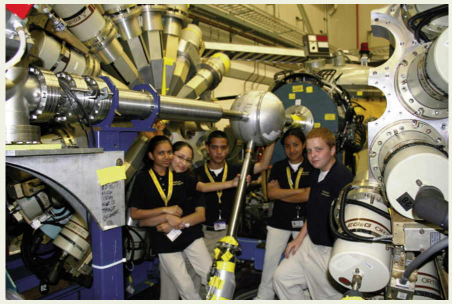
We recommend a conference with published proceedings for those committed and engaged in outreach. This could be an excellent resource, both within and outside our immediate community, and showcase the importance of these efforts and the commitment of individuals.

OUTCOMES

Successful implementation of outreach programs such as those described here should go a long way towards an enhanced understanding and appreciation of the excitement of nuclear science and its applications in all sectors of society. It will increase the number of teachers incorporating nuclear science into their courses and increase the number of students who are aware of the opportunities for a rewarding career in nuclear science and its applications. From the middle and high school classroom back to the parents, such activities will have the collateral benefit of enhancing public understanding of nuclear science and its applications and value to society.

ARGONNE NATIONAL LABORATORY SUMMER SCHOOL EXPERIENCE IN PHYSICS

The first annual "Summer School Experience in Physics" was held June 19 through 23, 2006, in the Physics Division of Argonne National Laboratory. The students had recently completed their freshman years at the Chicago Public Schools' Rickover Naval Academy. The program's goal is to give students an opportunity to interact with scientists from the lab, to learn about science at a national laboratory, and to be exposed to potential career opportunities in physics. The week-long experience allows us to include more students than would likely come to the lab in traditional summer-long research opportunities, and allows for significantly more interaction between the scientists and students than a day-long visit.



Rickover Naval Academy students pose with Argonne National Lab's Gammasphere.

Rickover Naval Academy is a new public high school in Chicago, established in 2005, and its students are required to take a year of introductory physics in their freshman year. Interested students applied for acceptance to the summer school at the end of their freshman year. Eight students were selected to participate. It is expected that in future years the number of students will vary between eight and twelve. The students traveled by bus each day from Rickover Academy to Argonne, participated in various activities from approximately 9:30 am to 3:00 pm, and then returned to their high school. Funding for the buses was provided by the ANL Physics Division (DOE), and lunches were funded through Rickover Academy.

Each day of the summer school consisted of a program which included a two-hour "practical" experience, with students working in pairs and rotating through four different experiments; an informal meeting with a scientist, graduate student or member of ATLAS operations to discuss careers and personal experiences in science; a physics talk (topics including heavy elements, origin of the elements and atom trapping); and a tour of one of the major facilities on site (ATLAS, APS and the IPNS). On the last day of the school, the students began putting together a final project, which would become two posters showing highlights of the week. A small graduation ceremony was held for the students. The ceremony was attended by many of the participating members of the Physics Division, the Rickover Academy principal and physics teacher, and the director of Argonne National Laboratory (Dr. Robert Rosner).

In the future, it is hoped that the summer school will be expanded to include a second Chicago public high school and a second parallel summer school in another division of the laboratory (e.g., the Chemistry Division). A key to the development and success of the school has been the extensive involvement of the physics teacher at Rickover, Derrick Svelnys. Derrick had an existing relationship with one of the staff members in the Physics Division (Susan Fischer), who was Derrick's master's thesis advisor. This connection was crucial in building a successful outreach program.

Concluding Remarks

There are many ways in which members of our community can, should, and do contribute to education and outreach. The recommendations in this document focused on two areas that strongly leverage existing strengths and ongoing activities: increasing the involvement and visibility of nuclear science in undergraduate education, and developing and disseminating materials and hands-on activities that demonstrate core nuclear science principles. We anticipate that progress in these two areas will result in specific and measurable positive outcomes: increasing the number of U.S. bachelor and Ph.D. degree holders prepared to meet U.S. workforce needs in basic and applied nuclear science, and enhancing public understanding and appreciation of nuclear science and its value to society. In addition, the strategies suggested in this report should provide models for future generations of nuclear scientists as they further enhance nuclear science education and outreach activities.

A BLACK HOLE ATE MY PLANET

RHIC has made international headlines since the facility's commissioning in 1999. The very idea of probing the earliest microseconds after the Big Bang has sparked people's imaginations in many directions. RHIC physics is an excellent example of how new and exciting science can capture public interest if conveyed in an open, comprehensible way.

Conveying this excitement to the public and to teachers and students at all levels is critical for the health of nuclear science. Brookhaven National Laboratory's Community, Education, Government and Public Affairs directorate has worked collaboratively with members of the RHIC community to communicate about RHIC, managing to turn controversy over the perceived possibility of creating black holes from a potential negative impact into positive public excitement.

RHIC communications focuses on clear goals:

- Communicating science accomplishments and world-class research
- Developing and nurturing relationships with targeted national and regional media
- Promoting science literacy
- Enhancing the Laboratory's image in the local community

We also identify specific audiences for major communications activity. These audiences include:

- The science community
- Funding agencies
- Elected officials
- Educators and students
- The science-attentive public
- The general public
- Media, both science and mainstream

Over the past decade, numerous studies have pointed to an increasingly urgent need to prepare more U.S. citizens for leadership roles in basic and applied physical sciences. Whether through media reports, summer tours of the collider complex, or numerous other ways of publicizing the machine, the scientists, and the science, we believe that keeping RHIC in the spotlight will encourage more students to consider nuclear science as a career choice. An education in nuclear science not only provides extensive technical ability, but also develops problem -solving and critical-thinking skills, helping graduates to attractive careers in many areas and benefiting society.

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BP10: CURRENT BEST PRACTICE

HARNESSING THE ATOM: A TEACHERS' WORKSHOP ON NUCLEAR TECHNOLOGY, ADDRESSING WORLDWIDE ENERGY DEMANDS

The Global Nuclear Energy Partnership (GNEP) combined forces with Idaho National Laboratory, the American Nuclear Society (ANS), Idaho State University, the Center for Advanced Energy Studies, Boise State University, the University of Idaho and the Idaho Department of Education to provide a physics teacher workshop on nuclear energy as part of the October 2006 Idaho State Teachers Conference.

The mission for the workshop was to increase the content familiarity and skill levels of the teachers with respect to the concepts and beneficial applications of nuclear energy, radiation, and the path forward envisioned by the GNEP. The workshop included special guest speakers and hands-on labs that covered topics such as radiation, nuclear power, new-generation nuclear power systems and alternative-energy research.

Teachers received a copy of *The Harnessed Atom*, curriculum material produced and funded by the DOE [24]. This was the first opportunity to field the curriculum, which was designed for high school students. They also received lecture notes and much additional supporting material from the ANS. Because many of the teachers harbored misconceptions about the safety of nuclear energy, a portion of the agenda was devoted to that topic.

In addition, funding was provided for equipment for the teachers to take back to their classrooms. Thirty-seven teachers took part in this workshop, many from rural areas. The overall experience provided them with up-to-date methods of teaching students about nuclear related topics, curriculum material, first-hand encounters with scientists, collaboration time with colleagues, and state-of-the-art laboratory equipment.

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Appendices

A. Workshop Charge and Agenda

B. Participant List

C. Charge from NSAC

D. Compendium of Present Activities

E-1. Possible Future Strategies—Inreach

E-2. Possible Future Strategies—Outreach

APPENDIX A:
Workshop Charge and Agenda

WORKSHOP ON EDUCATION AND PUBLIC OUTREACH IN NUCLEAR SCIENCE

December 1-2, 2006, Brookhaven National Laboratory

NSAC Charge for 2007 LRP Process:

"An important dimension of your plan should be the role of nuclear physics in advancing the broad interests of society and ensuring the Nation's competitiveness in the physical sciences and technology. Education of young scientists is central to the mission of both agencies and integral to any vision of the future of the field. We ask NSAC to discuss the contribution of education in nuclear science to academia, medicine, security, industry and government, and strategies to strengthen and improve the education process and to build a more diverse research community. Basic research plays a very important role in the economic competitiveness and security of our Nation. We ask that NSAC identify areas where nuclear physics is playing a role in meeting society's needs and how the program might enhance its contributions in maintaining the Nation's competitiveness in science and technology."

Handouts (to be e-mailed out in advance):

- NSAC Subcommittee on Education, Executive Summary (have several copies of full report at the disposal of the breakout groups)
- Aspen report on High Energy Physics Outreach
- Gathering Storm Report
- APS Education Department statement on future initiatives

Friday, December 1

1:00 – 1:30 pm	Welcoming remarks & discussion of process
	NSF Representative
	DOE Representative
	Organizing committee
1:30 – 3:00 pm	PANEL DISCUSSION I – Recruitment and retention of the next generation of nuclear scientists (Tim Hallman, Chair)
	Undergraduate research participation (John Mateja, Murray State)
	Nuclear Chemistry Summer School (Richard Ferreiri, BNL)
	Education partnerships at Idaho National Lab (Roger Mayes, INL)
	High School Student Research Participation (Peggy McMahan, LBNL)
3:00 – 3:15 pm	Successful public outreach (Mona Rowe, BNL)
3:15 – 3:30 pm	BREAK
3:30 – 5:00 pm	PANEL DISCUSSION II – K-12 Education (Howard Matis, Chair)
	Middle School outreach (Jan Tyler, JLAB)
	PAN for teachers and students (Michael Thoennesen, MSU)
	Plasma Camp (Andrew Post Zwicker, PPPL)
	Quarknet (Helio Takei, BNL) and Richard Gearns (teacher)
5:00 – 6:30 pm	PANEL DISCUSSION III – Fostering Diversity (Daeg Brenner, Chair)
	Women in Science (Vanita Ghosh, BNL)
	RISE (Jolie Cizewski, Rutgers U)
	Science Education Programs in Oak Ridge, TN (Wayne Stevenson, ORAU)
7:30 pm	DINNER (Sea Basin, Rocky Point)

Saturday, December 2

8:30 – 10:00 am	Breakout session 1 (Objectives and desired outcomes)

Small groups will consider a set of questions. Groups will be preassigned to ensure diverse representation.

> Where should our community's education and outreach resources be spent over the next ten years? Why? What impact will it have on our nuclear science community? Other stakeholders (e.g.,educators, students)? National needs?
>
> For the 2-3 top priority goals for our education and outreach investment, what are the desired outcomes? How will we measure success?

At this time specific programs or strategies to achieve them WILL NOT be discussed.

10:00 – 10:20	BREAK
10:20 – 11:00	Breakout groups report back
11:00 – 12:00	Large group discussion.
12:00 – 1:00	LUNCH
1:00 – 2:00	Continue large group discussion; formulate recommendations for top 2-3 goals (bullet in long range plan)
2:00 – 3:30	Breakout session 2 (Strategies and action plans)
	Small groups will consider strategies and actions to achieve the objectives decided by the large group discussion. Groups will be reformulated around the top recommendations.
3:30 – 3:45	BREAK
3:45 – 4:20	Breakout groups report back
4:20 – 6:00	General discussion, summarize recommendations, draft priorities, Charge to writing group

APPENDIX B:
Participant List

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APPENDIX C:
Charge from NSAC

U.S. Department of Energy
and the
National Science Foundation

July 17, 2006

Professor Robert E. Tribble
Chair, DOE/NSF Nuclear Science Advisory Committee
Cyclotron Institute
Texas A&M University
College Station, TX 77843

Dear Professor Tribble:

This letter requests that the Department of Energy (DOE)/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) conduct a new study of the opportunities and priorities for United States nuclear physics research and recommend a long range plan that will provide a framework for coordinated advancement of the Nation's nuclear science research programs over the next decade.

The new NSAC Long Range Plan (LRP) should articulate the scope and the scientific challenges of nuclear physics today, what progress has been made since the last LRP and the impacts of these accomplishments both within and outside of the field. It should identify and prioritize the most compelling scientific opportunities for the U.S. program to pursue over the next decade and articulate their scientific impact. A national coordinated strategy for the use of existing and planned capabilities, both domestic and international, and the rationale for new investments should be articulated. To be most helpful, the plan should indicate what resources and funding levels would be required (including construction of new facilities) to maintain a world-leadership position in nuclear physics research, and what the impacts are and priorities should be, if the funding available provides constant level of effort (FY 2007 President's Budget Request) into the out-years (FY 2008-2017).

The recommendations and guidance in the NSAC 2002 LRP and subsequent reports have been utilized by the agencies as important input to their planning and programmatic decisions. Resources have been made available to the programs' major facilities and experiments that have allowed the U.S. program to be successful in delivering significant discoveries and advancements in nuclear physics over the last five years. This has occurred in the context of constrained funding that has resulted in a reduction in the number of DOE National User Facilities and limited the ability to pursue identified scientific opportunities. However, projected funding levels in the out-years would allow the agencies to begin to address the major project recommendations in the NSAC 2002 LRP. The projected funding for DOE is compatible with implementing the 12 GeV Upgrade of the Continuous Electron Beam Accelerator Facility, and starting construction of a rare isotope beam facility that is less costly than the proposed Rare

Isotope Accelerator (RIA) facility early in the next decade. At NSF the process has been put in place for developing a deep underground laboratory project and bringing this project forward for a funding decision.

Since the submission of the NSAC 2002 LRP, increased emphasis has been placed within the federal government on international and interagency coordination of efforts in the fundamental sciences. The extent, benefits, impacts and opportunities of international coordination and collaborations afforded by current and planned major facilities and experiments in the U.S. and other countries, and of interagency coordination and collaboration in cross-cutting scientific opportunities identified in studies involving different scientific disciplines should be specifically addressed and articulated in the report. The scientific impacts of synergies with neighboring research disciplines and further opportunities for mutually beneficial interactions with outside disciplines, such as astrophysics, should be discussed.

An important dimension of your plan should be the role of nuclear physics in advancing the broad interests of society and ensuring the Nation's competitiveness in the physical sciences and technology. Education of young scientists is central to the mission of both agencies and integral to any vision of the future of the field. We ask NSAC to discuss the contribution of education in nuclear science to academia, medicine, security, industry, and government, and strategies to strengthen and improve the education process and to build a more diverse research community. Basic research plays a very important role in the economic competitiveness and security of our Nation. We ask that NSAC identify areas where nuclear physics is playing a role in meeting society's needs and how the program might enhance its contributions in maintaining the Nation's competitiveness in science and technology.

Activities across the federal government are being evaluated against established performance goals. In FY 2003, utilizing input from NSAC, the long-term goals for the DOE SC Nuclear Physics program and the metrics for evaluations of the program activities were established. It is timely during this long range planning exercise to gauge the progress towards these goals, and to recommend revised long-term goals and metrics for the DOE SC Nuclear Physics program, in the context of the new LRP, if appropriate. The findings and recommendations of this evaluation should be a separate report.

In the development of previous LRP's, the Division of Nuclear Physics of the American Physical Society (DNP/APS) was instrumental in obtaining broad community input by organizing town meetings of different nuclear physics sub-disciplines. The Division of Nuclear Chemistry and Technology of the American Chemical Society (DNC&T/ACS) was also involved. We encourage NSAC to exploit this method of obtaining widespread input again, and to further engage both the DNP/APS and DNC&T/ACS in laying out the broader issues of contributions of nuclear science research to society.

Please submit an interim report containing the essential components of NSAC's recommendations to the DOE and the NSF by October 2007, and the final report by the end of calendar year 2007. The agencies very much appreciate NSAC's willingness to undertake this task. NSAC's previous long range plans have played a critical role in shaping the Nation's nuclear science research effort. Based on NSAC's laudable efforts in the past, we look forward to a new plan that can be used to chart a vital and forefront scientific program into the next decade.

Sincerely,

Dennis Kovar
Associate Director of the Office of Science
for Nuclear Physics
Department of Energy

Judith S. Sunley
Acting Assistant Director
Mathematical and Physical Sciences
National Science Foundation

APPENDIX D:
Compendium of Present Activities

PUBLISHED UNDER SEPARATE COVER

APPENDIX E-1: Possible Future Strategies — Inreach

ACTION ITEM: INCREASE INVOLVEMENT AND VISIBILITY IN UNDERGRADUATE EDUCATION AND RESEARCH.

Implementation strategies (brainstorming session)—sidebar callouts are highlighted:

RESEARCH

- ◦ Not just summer research.
- ◦ Multiple year opportunities.
- ◦ Undergrad research.
    - – Standards/best practices for successful experience (see BP1).
- ◦ Variety of providers: on campus, individual investigator, REU, national lab, corporate lab.
- Develop physics version of NCSS/pre-REU (see FS1).
    - ◦ For rising juniors.
    - ◦ Would make under-reps more competitive for REUs.
- Enhance and sustain connections to MSI: undergrads and faculty.
    - ◦ Coordinated (rather than competing) efforts.

EDUCATION

- Add 3rd NCSS – opened to physics community.
- Funding for NCSS grads get summer research opportunity.
- DNP workshop on nuclear science in undergrad curriculum (see FS3).
    - ◦ Core curriculum discussions w/ APS/AAPT.
- Increase number of undergrad institutions that teach nuclear science.
    - ◦ Challenge: Demonstrate on-campus undergrad engagement in research.
    - ◦ Encourage collaborations with universities and national labs.

VISIBILITY OF NUCLEAR SCIENCE

- Distinguished lecturers (see FS4).
    - ◦ Undergrad institutions.
- Course on WMD.
    - ◦ Reaches non-science majors.

BEYOND THE UNDERGRADUATE DEGREE

- Reducing time to doctorate for Ph.D. students.
    - ◦ APS/AAPT grad education conference:
        - – Early engagement in research.
        - – Hardware training.
- Mentors/advisors as role models of passion for our work.
- Major new facilities to attract and retain best and brightest early-career nuclear scientists.
- Improving mentoring network: sustaining connections of early-career nuclear scientists as they transition through nuclear science.
    - ◦ Coordinated (rather than competing).
- Train next generation of detector designers and builders.
- Enhanced mentoring training.
    - ◦ AAAS book, ORAU book.
- Demonstrate realistic, exciting career options.
- Enhancing training of Ph.D. and postdocs for realistic, exciting careers meeting national needs.
    - ◦ Education.
        - – Preparing for small college teaching.
    - ◦ Other national needs (beyond basic research).
    - ◦ Workshop at DNP meeting on professional development (see FS5).
- Enhancing support and training of Ph.D. students to meet national needs.
    - ◦ Fellowships.
        - – Helps with retention undergrad to grad students in nuclear science.
    - ◦ Training grants.
    - ◦ Dissertation fellowships.
    - ◦ Opportunities at national labs (e.g., internships).

NETWORKING

- Coordinate with other agencies (e.g., JSA).
- Disseminate courses (via Web).

APPENDIX E-2:
Possible Future Strategies — Outreach

ACTION ITEM: DEVELOP AND DISSEMINATE MATERIALS AND HANDS-ON ACTIVITIES THAT ILLUSTRATE AND DEMONSTRATE CORE NUCLEAR SCIENCE PRINCIPLES TO A BROAD ARRAY OF AUDIENCES.

Implementation strategies (brainstorming session)—sidebar callouts are highlighted:

WEB BASED MATERIAL

- Interactive Web based (e.g., games).
- Ask/invite a nuke.
- Disseminate outreach talks (via Web).
- Develop, document and publish/disseminate on Web more hands-on activities (see FS6).
- Populate Wolfgang's database.

TRAINING, CURRICULUM AND HANDS-ON ACTIVITIES FOR TEACHERS AND/OR STUDENTS

- Summer camps for teachers and students (see FS7).
    - Amalgamation of PAN and Plasma Camp.
    - Pilot at national lab – expand into national lab system.
    - PAN: hands-on activities for high school teachers Quarknet-like activity.
    - Engagement in current experiments, not separated by labs.
    - Research experience for teachers.
- Annual teleconference by leading nuclear scientist to high schools.
    - Students can submit questions to scientist.
- Changing national standards of curriculum.
    - Pre-service/early career teachers engaged in curriculum development.

PUBLIC OUTREACH

- Course on WMD.
- Distinguished lecturers (see FS4).
- Lectures to first-responders.
- National public speakers bureau with speakers trained to speak at a public level with access to a library of outreach material.

OUTREACH AS A VALUED PART OF A NUCLEAR SCIENTIST'S CAREER

- More scientists to be involved (reward system, incentives).
- Conference for those committed and engaged in outreach, with published proceedings.

NETWORKING

- Evaluate and coordinate with existing programs (ANS, DOE/NE), e.g., harnessing the atom (see BP10).
- Coordinate w/ other agencies (e.g., JSA).