THE FUTURE of UNVERSITY NUCLEAR ENGINEERING PROGRAMS

and

UNIVERSITY RESEARCH & TRAINING REACTORS

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EXECUTIVE SUMMARY

Nuclear engineering programs and departments with an initial emphasis in fission were formed in the late 1950's and 1960's from interdisciplinary efforts in many of the top research universities, providing the manpower for this technical discipline. In the same time period, for many of these programs, university nuclear reactors were constructed and began their operation, providing some of the facilities needed for research and training of students engaged in this profession. However, over the last decade, the U.S. nuclear science and engineering educational structure has not only stagnated but has reached a state of decline. The number of independent nuclear engineering programs and the number of operating university nuclear reactors have both fallen by about half since the mid-1980s. In contrast, the demand for nuclear-trained personnel is again on the rise. Workforce requirements at operating U.S. nuclear power plants are increasing and will undoubtedly remain high, given the plans for plant-life extension in the vast majority of operating light-water reactors in the U.S. Moreover, new initiatives have begun in applied radiation sciences in collaboration with industrial and medical researchers as well as new biotechnologists. Finally, nuclear science and engineering (NS&E) continues to be needed in national security as well as providing the US Navy with effective, safe nuclear propulsion. Thus, the future of nuclear science and engineering programs must be reevaluated and refocused as the new century begins.

In November 1999, DOE Office of Nuclear Energy, Science and Technology requested that NERAC establish an ad hoc panel to consider educational issues related to the future of nuclear science and engineering; i.e., address the future of nuclear engineering programs, establish a process toward support of university research and training reactors, and identify appropriate collaborations between DOE national laboratories and university programs. To this end the panel is making a series of recommendations to the NERAC and the DOE.

<u>University Nuclear Engineering Programs</u>: Our vision is have DOE assist universities as they refocus these programs to enhance advances in nuclear science and engineering as applied to security, power and medicine and to maintain the necessary human resource for continuing the discipline through the 21st century. These efforts would be to:

1. Enhance the graduate student pipeline to maintain the health of the discipline by increasing doctoral fellowships (~20) and masters scholarships (~40) with funds of $5 million/yr.
2. Assist universities in recruiting and retaining new faculty in nuclear science and engineering by establishing a Junior Faculty Research Initiation Grant program for peer-reviewed grants in basic research.
3. Expand research discoveries in nuclear science and engineering by increasing the Nuclear Engineering Educational Research program (NEER) to $20 million/yr (includes item 2).
4. Help improve the undergraduate nuclear science and engineering discipline and maintain a core competency in nuclear systems engineering and design.
5. Encourage and support a national activity of communication and outreach in nuclear science and

engineering to identify its basic benefits for the country in the next century.

University Research and Training Reactors: University reactors are an important part of the nuclear science and engineering infrastructure that must be maintained, because experimental facilities (particularly facilities involving ionizing radiation and nuclear reactions) must be part of the educational basis of the discipline for undergraduate training and graduate research. To insure that such facilities are properly supported the panel recommends the following actions.

The panel proposes that a competitive peer-reviewed program augment current DOE financial support for these university reactors. This program would have the following elements:
1. Maintain the current base program for university reactor assistance program, which provides funds for reactor refueling, operational instrumentation, and reactor sharing at $4.3million/yr.
2. Institute a competitive peer-reviewed university reactors research and training award program, which would provide for reactor improvements as part of focused effort that emphasizes research, training and/or educational outreach, with the following elements:

- Specific award criteria which qualify university reactors for participation in the competition,
- Peer-reviewed competition for innovative research, training and/or outreach proposals,
- Multi-year grants that could involve multi-university, multi-disciplinary collaborative teams,
- Awards for research, training and/or outreach purposes with the total competitive program funds at a level of $15 million annually.

University - DOE Laboratory Interactions: The panel examined several approaches that could increase collaboration between universities and laboratories. Some of these strategies have the common theme that would require exercising some level of central authority within the DOE.

- Increased Nuclear Engineering and Health Physics Fellowships: These are an excellent means of interacting with top graduate students. The panel believes that for this and other reasons the funding for NE/HP Fellowship Program should be substantially increased.

- Increase personnel exchanges between Laboratories and Universities: Laboratories could create programs such as a "Distinguished Visitor Program," under which university faculty could spend extended periods (e.g. sabbaticals) at laboratories. Laboratories could encourage its staff to give seminars and/or spend time as visiting faculty at universities.

- Designated University Awards: Universities provide largely untapped resources that could participate more fully in DOE applied and basic research programs. To take more advantage of this resource, DOE could negotiate a certain percentage of the laboratory's budget to be subcontracted to universities. Laboratory management could also require individual programs (or divisions or directorates) to subcontract a certain amount or percentage to universities each year.

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THE FUTURE of UNVERSITY NUCLEAR ENGINEERING PROGRAMS and UNIVERSITY RESEARCH & TRAINING REACTORS

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Background

Nuclear science and engineering was born from the early discoveries of noted physicists in the late 1890's; e.g., Roentgen (X-rays), Rutherford (alpha and beta radiation). These scientific findings along with the discovery of fission in the 1930's, led a group of physicists to recommend that the United States support research and development for the common good of the nation; i.e., nuclear science and engineering would provide for our nations security, would supply its power and would contribute to medical advances enhancing human health. Nuclear engineering programs and departments with an initial emphasis in fission were formed in the late 1950's and 1960's from interdisciplinary efforts in many of the top research universities, providing the manpower for this technical discipline. In the same time period, for many of these programs, university nuclear reactors were constructed and began their operation, providing some of the facilities needed for research and training of students engaged in this profession. Since the 1960's United States universities have led the world in this technology with a commitment to furnish the necessary human resources and the associated infrastructure.

However, over the last decade, the U.S. nuclear science and engineering educational structure has not only stagnated but has reached a state of serious decline. The number of independent nuclear engineering programs and the number of operating university nuclear reactors have both fallen by about half since the mid-1980s. On the other hand, the demand for nuclear-trained personnel is again on the rise. Workforce requirements at operating U.S. nuclear power plants are increasing and will undoubtedly remain high, given the plans for plant-life extension in the vast majority of operating light-water reactors in the U.S. In addition, there is a continued growth of nuclear power in the Pacific Rim and continued advances in the design of a future generation of nuclear fission reactors. Moreover, new initiatives have begun in applied radiation sciences in collaboration with industrial and medical researchers as well as new biotechnologists. Finally, nuclear science and engineering (NS&E) continues to be needed in national security and includes technology related to arms reduction and verification and enforcement of international treaties as well as providing the US Navy with effective, safe nuclear propulsion. Thus, the future of nuclear science and engineering university programs must be reevaluated and refocused as the new century begins.

NERAC Charge to Panel

In November 1999, DOE Office of Nuclear Energy requested that the Nuclear Energy Research Advisory Committee (NERAC) establish an ad hoc panel to consider educational issues related to the future of nuclear science and engineering. The DOE, in consultation with NERAC, specifically asked this panel to address the following:

- The future of nuclear engineering as a discipline (including recommendations for the future evolution of university nuclear engineering programs or departments);

- The establishment of a fair process to assist DOE in the formulation of a program for university research and training reactors that are vital to the Nation's nuclear science and engineering research and educational infrastructure;

- The appropriate relationship between these university programs and the national laboratories in the conduct of nuclear science and engineering research and training.

It was requested that the panel complete its work in time to report to the full NERAC at the meeting currently planned for the end of May 2000. This summary report presents the panel findings and recommendations. Appendices are provided to document the information that was provided to the panel via responses to surveys and interviews.

Nuclear Science and Engineering in the 21st Century

As we move into the 21st century, the current public perception of the nuclear ‘industry’ in the U.S. might be characterized as one of stagnation if not decline. This perception should be a major cause for concern when considered in the face of some indisputable facts:

- Current electrical energy production relies on nuclear fission power to produce almost one-quarter of the electricity in the U.S. (statistics are similar for Europe and growing substantially for the Pacific Rim);

- Nuclear science and engineering is a cornerstone of the medical establishment for the diagnosis and treatment of disease;

- Security for the U.S. in an international framework will continue to rely on technologies related to nuclear stockpile stewardship, arms reduction, arms verification and enforcement of international treaties, and on nuclear propulsion.

The panel also believes that environmental sustainability is an important component of each of these nuclear science and engineering application areas, and will require a continuing expertise to properly manage nuclear science and engineering by-products.
Such a contradiction between perception and actual facts seems to stem from the events of the last decade in which there has been no clear vision articulated for the need and benefits of nuclear science and engineering in the upcoming century. This situation is even more distressing given the growing concern over global warming associated with the increasing use of fossil fuels in all energy sectors, the increased demand by the public for improvements in biomedical advances that improve public health, and the need for increased vigilance regarding our national security. It is not the task of this panel to address the roots of this situation, however, we feel it is important to acknowledge its presence and identify the resultant effects on the human resource and associated infrastructure of the discipline. These effects could be summarized as:

- A serious decline of nuclear science and engineering personnel, the relevant technical facilities and the needed institutional support for each of them;
- A growing imbalance between the supply of qualified personnel and the demand;
- A persistent lack of effective communication with the public, both technical and non-technical, which leads to public opinion based on incomplete information.

Nuclear science and engineering needs to be an important part of the nation's research and development landscape for this next century. A substantive and lasting investment in our human resource as well as our infrastructure is needed to enhance and provide for the public good through technology advances that support our nation's security, that supply its power and that contribute to medical advances, thereby enhancing human health. Most importantly, the DOE has a mission to support NS&E through its research and educational programs so that our manpower is allowed to thrive and so that the associated infrastructure is preserved.

Nuclear Engineering University Programs

Most of the current nuclear engineering programs and/or departments began in major research universities between 1955 and 1965. The undergraduate programs and graduate research initially focused on the fundamental and practical aspects of nuclear science and engineering as applied to nuclear power and health physics. As the number of programs grew and the demand for fission power also increased in the marketplace, the graduate research programs expanded in other promising areas of research, such as accelerators, radiation sciences, material sciences, plasma physics and fusion. Nuclear science and engineering was the first unified discipline that educated engineers in phenomena that spanned from the microscopic (atoms, nuclei) to the macroscopic scale (power plants, medical devices). Given the economic trends and the energy needs of the following thirty years, the demand for electrical power derived from fission power plants has peaked and has stagnated within the United States, with no new plant orders for almost three decades. This, coupled with the lack of clear vision in the political arena of the need for nuclear power, has left nuclear engineering programs with an image of a discipline with an uncertain future, with a diminished reputation and with significant questions as to its societal value among the general public.

A central issue that our panel has addressed is the future of nuclear engineering as a discipline. Nuclear science and engineering is undergoing an identity crisis at the undergraduate level. The survival of some departments and their nuclear engineering majors are becoming problematic. To seek a broader appeal some departments are considering that the focus in nuclear power engineering be substantially broadened, but this may cause a dilution in the undergraduate core content of fission reactor engineering systems and their associated fuel cycles. Individual choices in undergraduate curriculum content will vary for each individual nuclear engineering program. Nevertheless, the panel is unanimous in its belief that the nation must maintain nuclear engineering as an undergraduate discipline and carry on an open discussion as it evolves into the 21st century.

The number of nuclear science and engineering programs at the undergraduate and graduate level has experienced a precipitous drop, particularly in the last decade, as Figure 1 indicates. The closure of these programs and departments is linked to the enrollment of undergraduate and graduate students as well as the research support from federal and industrial sources. Another feature that compounds this problem is that the faculty in the discipline are aging. Over two-thirds of the faculty are 45 years or older and the number of new faculty hires has diminished by over 10% in the 1990's.

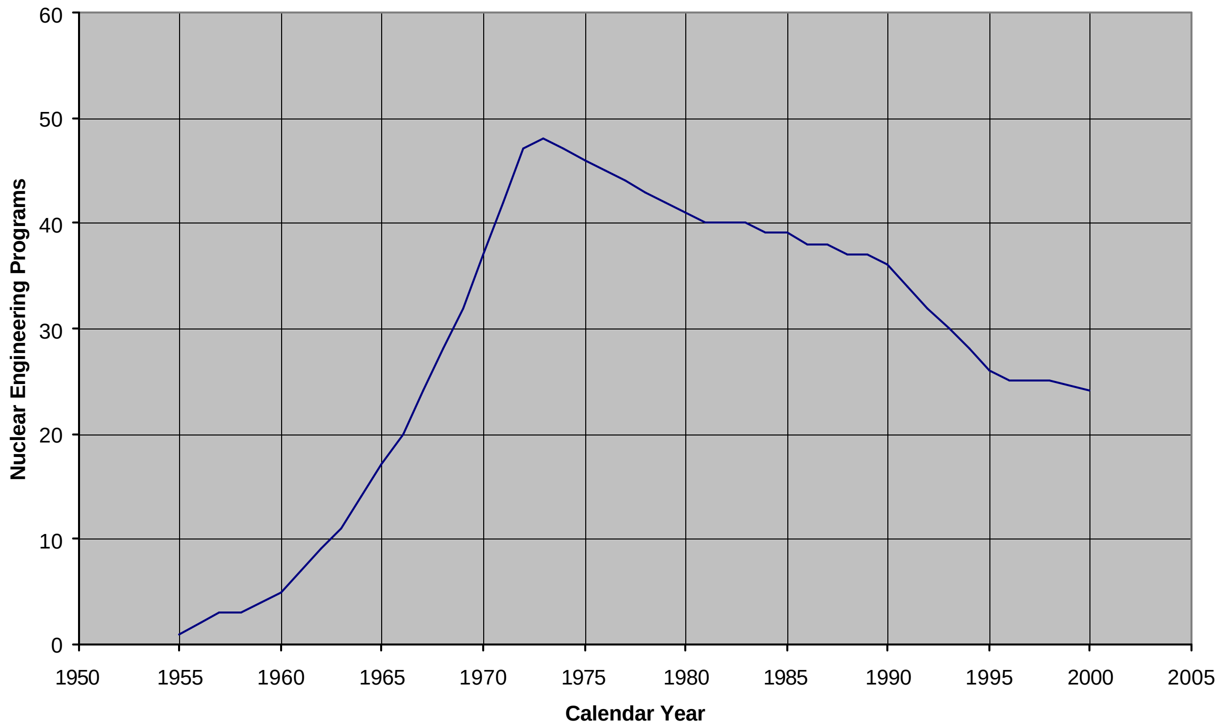

Figure 1: History of Nuclear Engineering Programs in the United States

Enrollment in nuclear engineering programs in the U.S. exhibited an alarmingly sharp downward trend in the 1990s, as shown in Figure 2. Enrollment is much lower now than ever before since the discipline became established in the early 1960s; as a result the supply of nuclear-educated personnel is at a 35-year low.

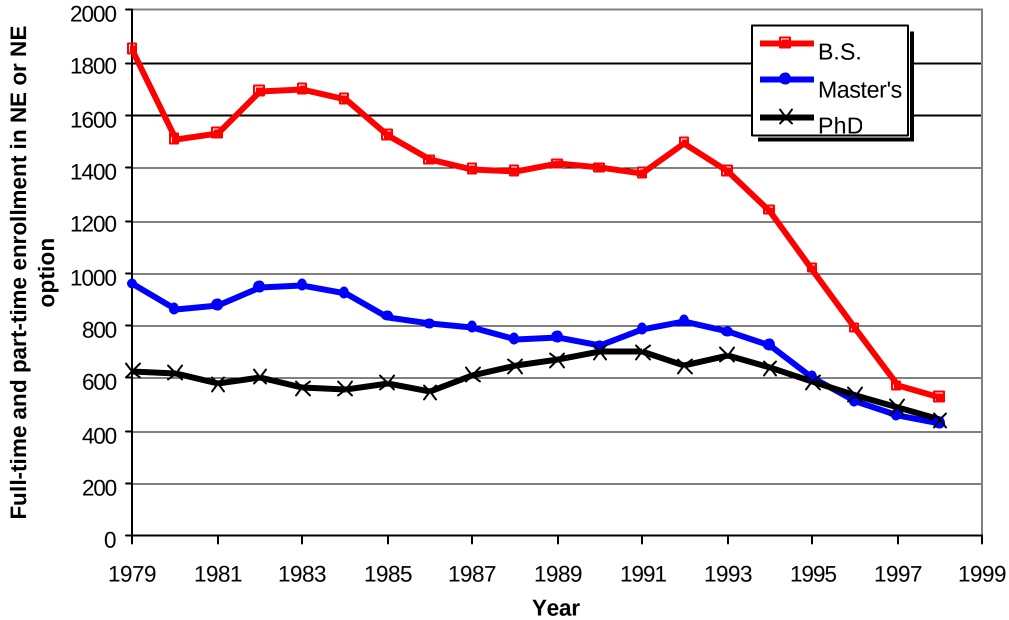

Figure 2. Nuclear Engineering Enrollments in U.S. Universities.
(Taken from DOE Manpower Assessment Brief. U.S. Department of Energy. No. 44. Prepared by Oak Ridge Institute for Science and Education. May 1999.)

Not surprisingly, it appears that the demand for nuclear engineers now exceeds the supply. The gap by which demand exceeds supply is expected to grow unless the supply increases significantly.[1] If this gap does in fact grow in the near future, as predicted, it could be quite detrimental to national interests. Figure 3 illustrates this growing gap between the needs of the fission nuclear power industry and the expected supply of BS and MS nuclear engineering graduates. These estimates are based on a study conducted by the American Society of Engineering Education (G.Was and coworkers, 1999).

1 Labor Market Trends for Nuclear Engineers Through 2005: 1999 Update Report. Prepared by Oak Ridge Institute for Science and Education. October 1999.

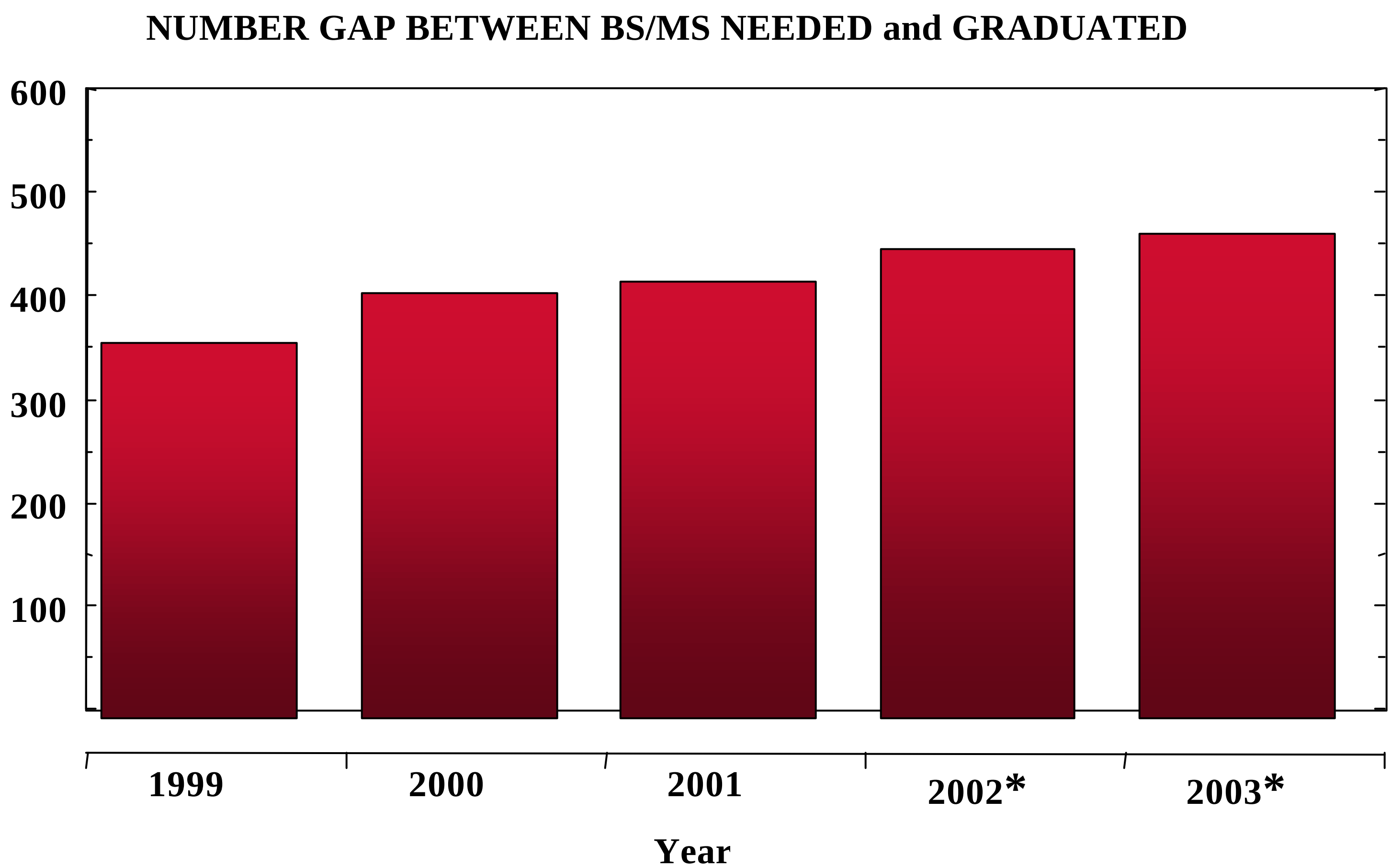

Figure 3. Gap between BS and MS Annual Employment Needs and Students Graduated: For the Fission Nuclear Power Industry (Taken from "Manpower Supply and Demand in the Nuclear Industry", ASEE Study, prepared by G. Was, T. Quinn, D. Miller, November 1999)

Perhaps more importantly, declining enrollments and the closure of nuclear engineering programs feed on one another: declines lead to closures, which lead to further declines. The panel is gravely concerned that if this continues, the U.S. will lose its nuclear-engineering education infrastructure and thus lose the ability to produce the human resources that will be vital to the nation's interests in the decades to come.

The current situation has placed the nuclear science and engineering profession in a state of serious uncertainty. A recent report by the Nuclear Engineering Department Heads organization investigated the current situation in nuclear engineering education; i.e., entitled "Nuclear Engineering in Transition: A

Vision for the 21st Century", December 1998. Their report presented a viewpoint that the nuclear science and engineering programs should continue to broaden their educational emphasis beyond just fission power to a wider range of nuclear science applications as applied to the national defense, nuclear power, medical applications of radiation science and industrial competitiveness. The panel recognizes the main points of this report and feels it gives a good overview of the expansion that has occurred for a wide range of research and graduate activities in current nuclear engineering departments and programs.

These causes for concern outlined above are reinforced by a recent 17-country Expert Group study on the status of nuclear engineering education under the auspices of the OECD Nuclear Energy Agency; i.e., draft entitled "A Survey and Analysis of Education in the Nuclear Field", January 7, 2000, 3rd Revision. The report finds that in most countries – and particularly in the United States – there are indicators that future nuclear expertise is at risk when declining university enrollments, changing industry profiles, dilution of university course content, and high retirement expectations are viewed together. The Expert Group concluded that a "failure to take appropriate steps now will seriously jeopardize the provision of adequate expertise tomorrow. Governments and industry must assure that crucial present requirements are met and future options are not precluded." Further, the report states that: "In most countries there are now fewer comprehensive, high-quality nuclear technology programs at universities than before. The ability of universities to attract top-quality students, meet future staffing requirements of the nuclear industry, and conduct leading-edge research is becoming seriously compromised. Unless something is done to arrest it, this downward spiral of declining student interest and academic opportunities will continue."

The panel strongly believes that the current state of disarray and uncertainty is unacceptable, not only for the discipline, but also for the public good of the nation. The panel proposes that NERAC recommend that DOE consider an approach that is strategic on a national level and tactical within the university culture. The vision for this program should be to enhance advances in nuclear science and engineering as applied to security, power and medicine and to maintain the necessary human resource for the discipline continuance through the 21st century. This vision would benefit from additional discussion and debate within the NERAC and DOE, before being advanced to the national level and enacted by the federal leadership. The panel would recommend to NERAC the following strategic plan and associated program elements for a future research program in nuclear science and engineering.

1. <u>Enhance the graduate student pipeline to maintain the health of the discipline</u>: This should be focused on providing a continuing resource of graduates with post-baccalaureate education and technical expertise that can be employed at our leading universities, the national laboratories and all parts of the industry; i.e., providing role models for educating and sustaining our future personnel needs. To accomplish this requires a coordinated effort for recruitment at each level in the university program as well as the proper resources for graduate student fellowships and scholarships. Currently, the DOE and the industry have limited programs for these fellowships; i.e., the current program of $0.8 million provides fewer than 5 new doctoral fellowships every year for the <u>whole</u>

nation in fission and health physics. This effort needs to be augmented in size and scope for our future success in the discipline. The panel recommends that the DOE consider the more historic AEC model for doctoral fellowships and masters scholarships in nuclear science and engineering at a steady-state level of $5 million per year; i.e., awarding a steady-state of 20 doctoral fellowships each year and 40 masters scholarships.

2. Recruit and retain new faculty in nuclear science and engineering: The panel recognizes that nuclear engineering departments have had difficulties in attracting new faculty members into their programs. In addition, even though a demonstrated need exists, some engineering administrations are reluctant to approve new positions in nuclear engineering because of the uncertainties associated with long-term student enrollments and graduate research support. The panel recommends that a targeted research program for junior faculty (6 years or less from the time of their first academic appointment) would be of great benefit to the young faculty. In addition, it could benefit the nuclear engineering programs by demonstrating to their administrators that a program exists to provide new faculty the opportunity to begin their research careers. This “Nuclear Engineering Junior Faculty Research Initiation Grant” program would be a competitive program in support of DOE basic research needs in nuclear science and engineering affiliated with the mission-oriented goals of the DOE.

3. Enable and enhance research discoveries in nuclear science and engineering: The panel supports a science-based program that is predicated on involvement of these university programs, and then extends to the national laboratories and the nuclear industry in peer-reviewed, pre-competitive research and development. A key step to accomplish this strategy is to maintain the Nuclear Engineering Education Research program (NEER) as well as significantly increase the base funding for the NEER. Currently, this program involves a very modest investment in university research into basic nuclear science and engineering ($5 million in FY2000). This program has allowed university researchers to be able to pursue high-risk ideas and make discoveries that can take us beyond our present understanding; i.e., provide the ‘spark’ for innovation and future technologies. Since the NSF and other basic science programs generally believe that nuclear science and engineering basic research is the responsibility of the DOE mission-oriented office, the NEER program plays a very critical role in sustaining the intellectual growth and development of the discipline in our university research communities. The panel would recommend that the NEER program funds be substantially increased to near $20 million per year. This program would include the Junior Faculty Research Initiation Grant program. The panel is aware of and supports the Nuclear Energy Research Initiative program (NERI). The panel also recognizes that this program should be synergistic but remain separate from the NEER program. NERI involves larger collaborative research and development tasks, which establishes a research partnership among universities, national laboratories and industry, and which places a larger emphasis on engineering applications and integrated technologies

that respond to the DOE mission guidance.

4. Enhance and improve the undergraduate nuclear science and engineering discipline: The panel recognizes that the undergraduate discipline will continue to evolve in the 21st century and this evolution will be different within various university programs. Nevertheless, the panel feels that the discipline of NS&E be preserved as a "systems engineering core competency". This belief is predicated on the need for our graduates to have professional training in nuclear fission engineering within the context of systems engineering and design. This may be one of the most important responsibilities of university nuclear engineering faculty as they reestablish the groundwork for a resurgence of the discipline in the future. This is a fertile area for innovation in which research advances can play a role in the reshaping of undergraduate and graduate curriculum and their associated pedagogy. Curriculum development should be a key part of DOE resource investment in the future. The panel also recognizes that such activity requires the support of the Engineering Deans. Therefore, DOE should clearly demonstrate the importance of the discipline to its mission by direct interaction with the Engineering Deans. The panel recommends that the Director of the Office of Nuclear Energy and the Secretary of Energy initiate a discussion with the Deans at appropriate national meetings, to demonstrate their desire to maintain and revitalize the discipline as an undergraduate engineering profession.

5. Enhance the national activity in communication and outreach in NS&E to identify the broad benefits of nuclear science and engineering. It is the panel's opinion that nuclear engineering specifically (and probably the physical sciences in general) suffers from a distinct lack of understanding by the general public. One could contend that this is one of underlying reasons why the technology is viewed with uncertainty and apprehension. The panel feels that the university nuclear engineering programs may be in the best position to work with the DOE to develop an innovative approach to outreach and education. Innovations in this area could have a major impact in regard to the image of the discipline and its future human resource.

University Research and Training Reactors

Since nuclear science and engineering needs to be an important part of the research and development landscape for this next century, a substantive and lasting federal investment is needed to support the NS&E infrastructure. University reactors are an important part of this NS&E infrastructure that must be better maintained, because experimental facilities (particularly experimental facilities involving ionizing radiation and nuclear reactions) must be part of the educational basis of the discipline. Currently, there are about thirty university reactors in the U.S. (a 50% decrease in the number of reactors from 15 years ago – Figure 4) with annual direct costs of over $25 million for operations from their individual university budgets (this includes fringe benefits and indirect costs and excludes the University of Missouri-Columbia research reactor). These expenditures are specifically for the operational aspects of these nuclear reactors at each university site as well as safety and licensing activities; i.e., staff salaries as well as materials and supplies related to operation.

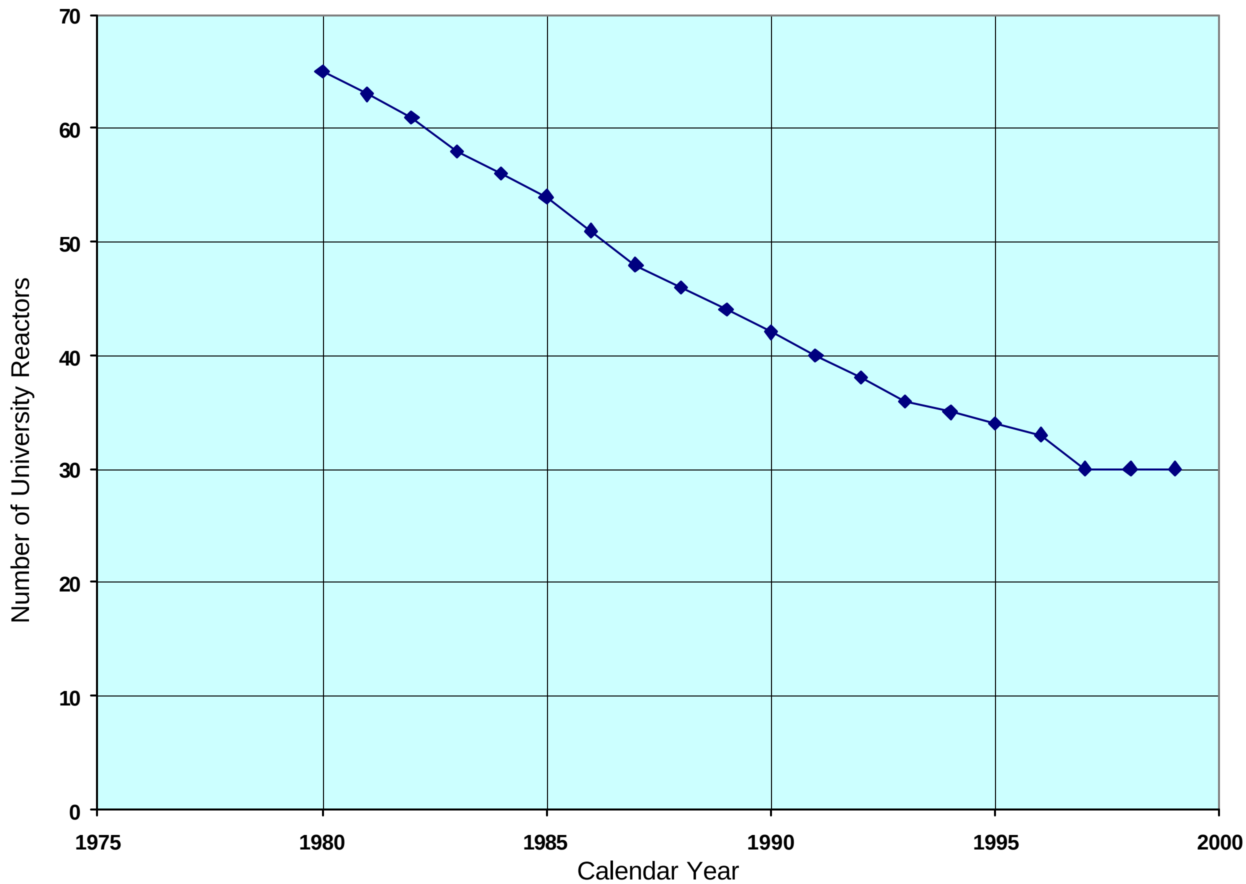

Figure 4: Population of University Research Reactors in US (Source - Office of Nuclear Energy)

The panel believes that university reactors:

- Are vital for advancement in knowledge in the nuclear science and engineering education at the graduate level and provide powerful tools for the advancement of many other disciplines;

- Provide undergraduate and graduate students with an otherwise unobtainable ‘hands-on’ educational experience, allowing for discovery of nuclear fission reactor processes, understanding of critical nuclear systems and interaction of radiation with matter, which enriches their general and technical education (as well as providing for professional nuclear reactor operators with advanced certification);

- Give the general public an opportunity through outreach activities to better understand and become familiar with nuclear processes and ionizing radiation as well as nuclear fission power.

This panel recognizes that the DOE Office of Nuclear Energy currently has established the 'University Reactor Fuel Assistance and Support' program for university research and training reactors. As part of this program funds are provided for reactor refueling, reactor instrumentation and reactor sharing for users of these facilities. These current programs serve as the minimum external resource base that helps maintain this educational infrastructure for the operation of these university research and training reactors. Specifically, the DOE budget lines for reactor replacement fuel, reactor instrumentation upgrade and reactor user sharing total $4.3 million for FY2000. Note that the bulk of these funds is for reactor fuel replacement (~ $2.8 million).

However, the panel stresses the importance of improving these university reactor facilities during this critical time period. Most university research and training reactors were constructed in the late 1950's and early 1960's with 30 to 40 year operating licenses. Thus, these reactors have undergone or will undergo NRC relicensing. Concurrently, nuclear engineering programs are increasing their emphasis on radiation science to remain viable within their college and university programs. Thus, their research reactors are becoming an increasingly vital facility in their strategic planning. These reactor facilities can provide an anchor to their experimental research activities in nuclear science and engineering, being complementary to accelerator-based radiation sources; i.e., in activation studies, imaging science and basic neutron science.

To expand their capabilities and the associated research and training opportunities for these reactors, instrumentation improvements are needed that go beyond the minimum needed for reactor operation. These improvements could be in the form of research-related nuclear instrumentation linked with separate externally funded research initiatives. These improvements could also involve upgrade of facilities or development of materials for reactor operator training. In addition, such improvements could be related to educational outreach programs to the general public. Such activities would augment the importance of the university nuclear reactor to their respective academic programs and their traditional mission of undergraduate and graduate instruction within the university.

The panel proposes that current DOE financial support for these university reactors be augmented by a competitive peer-reviewed program. This program would focus on activities beyond operation and would support instrumentation upgrades for research efforts as well as facility upgrades and personnel costs that involve innovative training and educational outreach activities. The panel recommends the following elements for this expanded DOE program for university reactor support:

1. Maintain the current university reactor assistance program which provides funds for reactor refueling, the reactor instrumentation base program, and the reactor sharing base program (expanding it to allow

for on-campus user participation) at the current funding levels, subject to satisfying university reactor qualification criteria that can be developed by the panel in consultation with TRTR. The committee recognizes that this current funding level may not be sufficient for all the existing university research and training reactors continued operation.

2. Institute a competitive peer-reviewed university reactors research and training award program. This program would provide additional multi-year grants for reactor improvements that are part of a focused proposal by a group of collaborators that can emphasize research, training and/or educational outreach. This competitive award program would have the following elements:

- Specific award criteria which qualify university reactors for participation in the competition,
- Peer-reviewed competition for innovative research, training and/or outreach proposals,
- Multi-year grants that could involve multi-university, multi-disciplinary collaborative teams,
- Awards for research, training and/or outreach purposes with the total competitive program funds rising to a level of $15 million annually.

The panel believes that such a program can provide the needed financial support for qualified university research and training reactors through instrumentation upgrades associated with related externally-funded research efforts, as well as for facility upgrades and personnel costs that relate to innovative operator training and educational outreach initiatives. These resources are for activities that go beyond what is needed only for operation and provide a competitive arena where innovative ideas can be nurtured.

The panel is ready and willing to work with the DOE Office of Nuclear Energy and NERAC to establish the specific criteria and detailed program plan for this competitive peer-reviewed award program. It should be noted that such a competitive university reactor support is not intended to diminish the NEER or the NERI programs, but rather provide a specific outlet for infrastructure resources that will further enable execution of innovative ideas that come from these programs.

University – DOE Laboratory Interactions

The first of the current DOE National Laboratories were created, staffed and managed by university personnel following World War II. Thus, these laboratories began with intimate ties to universities, and substantial interactions have continued between the laboratory and university communities. The panel has surveyed several key DOE Laboratories; the surveys (see Appendix) show unanimous agreement that university interactions are beneficial and should be expanded.

There are a host of ways the laboratories and universities can continue to build upon their interactions, including collaboration on papers, student internships at labs, research subcontracts from labs to universities, large collaborative research projects (for example funded by NERI program), and many others. All of these are important and beneficial; however, the panel believes the most important interaction mechanism is to increase the engagement of faculty members (and thus their graduate students) in funded research that is of programmatic interest to the laboratories. Research funding is by far the best way to attract faculty interest; programmatic relevance ensures short-term benefit to the lab and produces graduates that are interested and expert in laboratory problems (which is a long-term benefit).

The key question appears to be how to expand the collaboration between universities and laboratories. As the appended surveys show, each laboratory as a whole has compelling reasons to expand such collaborations. However, an individual program manager at a laboratory may not have sufficient incentive to interact with universities, especially given the disincentives of extra paperwork, extra overhead (in some cases) on funds, reduced direct control over the work, and local inertia. That is, while everyone agrees philosophically that involving universities is worthwhile, in practice some aspects of the current system may actually discourage such interactions.

The panel has discussed several possible approaches that could lead to increased collaboration between universities and laboratories. The laboratories in their survey responses identified some actions, while the panel identified others. These strategies are outlined below. Some of these strategies have the common theme that overcoming current disincentives could require exercising some level of central authority within the DOE.

1. Increased Nuclear Engineering and Health Physics Fellowships. Many laboratories indicated that the Fellowship programs, with their requirements for a summer practicum at laboratories, are excellent means of interacting with top graduate students. The panel believes that for this and other reasons (see section on nuclear engineering programs) the funding for NE/HP Fellowship Program should be substantially increased.

2. Increase personnel exchanges between Laboratories and Universities: Laboratories could create programs such as a "Distinguished Visitor Program," under which university faculty could spend extended periods (e.g. sabbaticals) at laboratories. Laboratories could encourage staff members to give seminars at universities, or possibly to spend time as visiting faculty at universities.

3. Designated University Awards: Universities provide largely untapped resources that could participate more fully in DOE applied and basic research programs. To take more advantage of this resource, DOE could negotiate a certain percentage of the laboratory's budget to be subcontracted to universities. Laboratory management could also require individual programs (or divisions or directorates) to subcontract a certain amount or percentage to universities each year.

Finally, it should be noted that in the course of their interactions, laboratories and universities must deal with several issues. An obvious issue is classified and sensitive unclassified subject matter. The panel notes with considerable concern that DOE policies regarding sensitive unclassified information are making it especially difficult for laboratories and universities to continue and build upon these successful collaborations. Sensitive unclassified material appears to cover an extremely broad range, or at least the range is unclear enough that laboratory staffs feel compelled to interpret its range as being extremely broad. Policies related to sensitive unclassified material appear to strongly discourage interaction with researchers outside the laboratories, especially at universities with international faculty and graduate students. A second issue is competition between the laboratories and universities for the same research dollars. Competition can be good, but in this situation it is important that each community collaborate to the extent that each enable a "win". The laboratories benefit from a strong university community, and vice versa.

Panel Summary Findings

In November 1999, DOE Office of Nuclear Energy, Science and Technology requested that NERAC establish an ad hoc panel to consider educational issues related to the future of nuclear science and engineering; i.e., address the future of nuclear engineering programs, establish a process toward support of university research and training reactors, and identify appropriate collaborations between DOE national laboratories and university programs. To this end the panel is making a series of recommendations to the NERAC and the DOE.

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3. Expand research discoveries in nuclear science and engineering by increasing the Nuclear Engineering Educational Research program (NEER) to $20 million/yr (includes item 2).
4. Help improve the undergraduate nuclear science and engineering discipline and maintain a core competency in nuclear systems engineering and design.
5. Encourage and support a national activity of communication and outreach in nuclear science and engineering to identify its basic benefits for the country in the next century.

University Research and Training Reactors: University reactors are an important part of the nuclear science and engineering infrastructure that must be maintained, because experimental facilities (particularly facilities involving ionizing radiation and nuclear reactions) must be part of the educational basis of the discipline for undergraduate training and graduate research. To insure that such facilities are properly supported the panel recommends the following actions.

The panel proposes that a competitive peer-reviewed program augment current DOE financial support for these university reactors. This program would have the following elements:
1. Maintain the current base program for university reactor assistance program, which provides funds for reactor refueling, operational instrumentation, and reactor sharing at $4.3million/yr.
2. Institute a competitive peer-reviewed university reactors research and training award program, which would provide for reactor improvements as part of focused effort that emphasizes research, training and/or educational outreach, with the following elements:

- Specific award criteria which qualify university reactors for participation in the competition,
- Peer-reviewed competition for innovative research, training and/or outreach proposals,
- Multi-year grants that could involve multi-university, multi-disciplinary collaborative teams,
- Awards for research, training and/or outreach purposes with the total competitive program funds at a level of $15 million annually.

University - DOE Laboratory Interactions: The panel examined several approaches that could increase collaboration between universities and laboratories. Some of these strategies have the common theme that would require exercising some level of central authority within the DOE.

- Increased Nuclear Engineering and Health Physics Fellowships: These are an excellent means of interacting with top graduate students. The panel believes that for this and other reasons the funding for NE/HP Fellowship Program should be substantially increased.

- Increase personnel exchanges between Laboratories and Universities: Laboratories could create programs such as a “Distinguished Visitor Program,” under which university faculty could spend extended periods (e.g. sabbaticals) at laboratories. Laboratories could encourage its staff to give seminars and/or spend time as visiting faculty at universities.

- Designated University Awards: Universities provide largely untapped resources that could participate more fully in DOE applied and basic research programs. To take more advantage of this resource, DOE could negotiate a certain percentage of the laboratory’s budget to be subcontracted to universities. Laboratory management could also require individual programs (or divisions or directorates) to subcontract a certain amount or percentage to universities each year.