A Proposal to the National Science Foundation
for a Small Grant for Exploratory Research (SGER)
to Develop a Undergraduate Minor Concentration in Nuclear Fission Power Engineering

Co-Principal Investigators:
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Summary

A planning grant (SGER) is sought to develop a national curriculum in nuclear fission power engineering that would serve as a certificate-based, minor concentration for undergraduate students majoring in traditional engineering degree programs. With the renewed interest in nuclear power as a key component of the nation's energy portfolio, there is growing concern about the availability of engineers trained in nuclear technology in view of the very significant erosion in university nuclear engineering programs and facilities over the past two decades. Even with a rapid infusion of new resources, the time required to rebuild the necessary faculties and facilities and stimulate student interest makes it highly unlikely that conventional nuclear engineering programs can provide a flow of graduates adequate to meet the near-term needs of industry and the federal government.

We propose to form a team of faculty members drawn from the leading nuclear engineering programs in the nation to develop a minor concentration in nuclear fission power engineering that colleges and universities could offer to students enrolled in conventional undergraduate engineering degree programs (e.g., mechanical engineering, electrical engineering, chemical engineering, industrial engineering, materials science and engineering, and computer engineering). This effort would augment nuclear engineering graduates in the near-term and supplement the growth of nuclear engineering majors in the long-term. This multiple-course nuclear power curriculum would include a summer practicum involving extensive laboratory experience (perhaps at a regional university reactor facility or national laboratory) taken between the junior and senior years of the undergraduate major. This proposed nuclear-power minor curriculum would be supported by extensive computer and network resources, including nuclear code simulation packages, web portals, and technology enhanced learning for on-campus and off-campus distance education.

We believe that such a program has the potential for rapidly expanding the production of engineers and scientists capable of contributing to our nation's nuclear energy programs since it would draw from the large cadre of engineering and science majors rather than the small enrollments of nuclear engineering degree programs. In fact, industry has long expressed interest in hiring nuclear engineers more broadly trained in general engineering majors such as mechanical engineering, electrical engineering, and computer engineering. Furthermore, this approach is particularly attractive to universities since it would allow them to respond to growing national needs in nuclear energy without the necessity of major expansion of existing nuclear engineering faculty or facilities (unlikely in the current budget climate in any event). The program would be designed to be highly transportable, and since both the content and support of the proposed program would be provided by a team of faculty members drawn from leading nuclear engineering programs across the nation, individual institutions would not have to commit additional resources to build new capabilities. In particular, this effort would intends to produce teaching tools such as course resources,

web-based lectures, and software simulations that could be used at institutions that do not have access to nuclear engineering faculty.

Moreover, this effort could serve as a useful model in engineering education for addressing the need for engineers trained in other highly specialized areas such as integrated manufacturing, nanotechnology, quantum engineering, and biotechnology. An undergraduate minor concentration would allow students to prepare for careers in these fields without sacrificing the broader educational experience (and market opportunities) provided by a more conventional degree program. Furthermore, by developing a curriculum and supporting materials for a minor concentration using a team of national leaders in the given specialty, colleges and universities could offer such specialized curricula without significant additional investments in new faculty and facilities. In fact, the model we propose may well represent the future of engineering education as technical knowledge continues to fragment into subdisciplinary specialties and universities face growing constraints on resources for faculty and facilities.

Background

There has been growing anxiety about the future of this nation's capability in nuclear fission technology even as renewed interest in nuclear power has been stimulated by concerns about the impact of fossil fuels on global climate change, the growing imbalance between energy supply and demand, both regionally (e.g., California) and in the developing world, and other nuclear technology-related issues including the proliferation of nuclear weapons technology and materials and the disposal of radioactive waste. As Vice President Cheney stated in outlining the nation's new energy strategy on April 30, "If we are serious about environmental protection, then we must seriously question the wisdom of backing away from nuclear power, which is, as a matter of record, a safe, clean, and very plentiful energy source."

Yet we face a growing crisis in the availability of scientists and engineers trained in nuclear technology. Over the past decade the number of nuclear engineering programs in the United States has declined by half (from 80 to 40), the number of university research and training reactors by two-thirds (from 76 to 28), and enrollments have dropped by almost 60% (from 3,440 to 1,520). As noted in a recent planning study by the Department of Energy's Nuclear Energy Research Advisory Committee: "Nuclear engineering programs in the United States are disappearing. Without concerted action by the federal government, most of the existing nuclear engineering programs will soon evaporate or be absorbed and diffused into other engineering disciplines."

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 (85%) 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 (particularly the new Generation IV reactor concepts). Moreover, new initiatives have appeared in applied radiation sciences in collaboration with industrial and medical researchers. Finally, nuclear science and engineering (NS&E) continues to be needed in national defense and includes technology related to arms reduction and verification and enforcement of international treaties. Thus, the future of nuclear science and engineering university programs must be reevaluated and refocused as the new century begins.

Yet, even if substantial re-investment in nuclear energy R&D and academic nuclear engineering programs were to occur, it is unlikely that in the near term the nation would be able to close the growing gap between the growing needs of industry and the

federal government for engineers and scientists trained in nuclear fission technology and the capacity of our university's nuclear engineering programs. (This shortage has been documented in a recent manpower survey conducted by the Nuclear Engineering Department Heads Organization.) It will take a decade or more to produce the next generation of faculty capable of handling expanded enrollments. In addition, this proposed approach would be more effective than having the nuclear power industry train the engineering professionals on-site, an approach adopted in several other countries that has proven to be costly and not as effective as an integrated university educational program. Furthermore, in spite of the strong market for nuclear engineering graduates, students are still reluctant to enter this field because of uncertainty about its future.

The Proposed Curriculum in Nuclear Fission Power Engineering

This proposal seeks funding for an alternative approach that we believe is capable of rapidly restoring the flow of engineers and scientists trained in nuclear fission power technology. A team of faculty members drawn from a number of the leading nuclear engineering programs in the nation will be assembled to develop a curriculum sequence in nuclear fission technology that could be added as an academic program concentration "minor" to any conventional undergraduate engineering degree program (e.g., mechanical engineering, electrical engineering, chemical engineering, computer engineering, industrial engineering) as well as selected science majors (e.g., physics and chemistry). This multiple-course nuclear power curriculum would include a summer practicum involving extensive laboratory experience (perhaps at a regional university reactor facility or national laboratory) taken between the junior and senior years of the undergraduate major. This on-site instruction would be tailored to the sites such as the reactor facilities available on several of the Big Ten campuses. The proposed nuclear power curriculum would be supported by extensive computer and network resources, including nuclear code simulation packages, web portals, and technology enhanced learning for on-campus and off-campus distance education. It would be our intention to seek both the participation in the development and certification of this curriculum by the nuclear power industry.

We believe that such a program has the potential for rapidly expanding the production of engineers and scientists capable of contributing to our nation's nuclear energy programs since it would draw from the large cadre of engineering and science majors rather than the small enrollments of nuclear engineering degree programs. In fact, industry has long expressed interest in hiring nuclear engineers more broadly trained in general engineering majors such as mechanical engineering, electrical engineering, and computer engineering. Furthermore, this approach is particularly attractive to universities since it would allow them to respond to growing national needs in nuclear energy without the necessity of major expansion of existing nuclear engineering faculty or facilities (unlikely in the current budget climate in any event). The program would be designed to be highly transportable, and since both the content and support of the proposed program would be provided by a team of faculty members drawn from top nuclear engineering programs across the nation, individual institutions would not have to commit additional resources to build new capabilities.

A collateral benefit of this program is that it would lead to an increase in graduate student enrollment in nuclear engineering. While admissions requirements vary among institutions, students who have successfully completed the proposed certificate program would have prerequisites and possibly the interest to continue on at the graduate level in nuclear engineering programs, with little disadvantage compared to undergraduate with baccalaureate degrees in nuclear engineering.

Finally, such a program might far more attractive to students because of its flexibility. Their traditional engineering (or science) degree would give them the full spectrum of career opportunities, while the nuclear power minor would qualify them to enter nuclear technology careers, should they so choose. Since the nuclear power curriculum would be designed to be compatible with the technical and general electives available in most engineering and science programs, students would be able to add this option to their existing major with minimal sacrifice in time-to-degree.

If we are to be successful in designing, developing, propagating, and supporting such a national curriculum, we will need support from multiple sponsors both within the federal government and industry for a number of activities:

- Design, develop, implement, and assess the nuclear power curriculum
- Develop the supporting resources include computer code simulators ,web support, and distance learning technology
- Negotiate sites (universities, national laboratories, nuclear industry, and possibly foreign sites) for summer laboratory/practicum programs
- Seek industry participation in curriculum development and certification for the program. (We already have some experience working with industry to develop both curriculum and summer experiences at industry sites in specific areas such as nuclear reactor safety.)

Project Participants

The development team would be drawn primarily from the faculties of the nuclear engineering departments of the Big Ten universities (i.e., the University of Michigan, the University of Wisconsin, the University of Illinois, Purdue University, Pennsylvania State University, Ohio State University, and Northwestern University). Note that these departments conduct highly ranked undergraduate degree programs in nuclear engineering in addition to graduate studies and produce over 40% of the BS, MS, and PhD nuclear engineering degrees awarded in the United States.

We have already identified interest in participating on the part a number of faculty members at these institutions who are regarded as leaders in both nuclear engineering education and research, responsible for several of the key textbooks and curriculum development in this field. In addition, the project will involve participants from both industry and national laboratories to assist in developing the core curriculum and supporting materials.

Request for a Planning Grant

However, before developing and submitting proposals to fund the entire multiple-year curriculum development program, we first seek a small grant (SGER) from the National Science Foundation to support a preliminary planning process. Included in this preliminary phase are the following activities:

1) To first conduct a series of market surveys to better understand
   - The interests of prospective employers, including electrical utilities, nuclear equipment vendors, national laboratories and other federal agencies.
   - The attractiveness of such a minor concentration to potential students
   - The perspective of such a nationally-designed and supported curriculum on the part of colleges and universities, including HBCU institutions.

2) To form a national team of faculty (and industrial) experts and begin the preliminary design of the curriculum.

3) To perform a preliminary needs assessment for supporting resources (such as web-based, interactive textbooks, computer simulation codes, web-portals, and knowledge environments).

4) To design the summer practicum experience and identify potential sites.

5) To develop accurate financial estimates for the development, distribution, and ongoing support of the curriculum.

6) To obtain the necessary commitments for the program, e.g., of summer practicum sites, credentialling bodies, and other potential sponsors.

It is our intent to conduct this planning effort in the 2001-2002 academic year, with a target date for submitting a complete proposal to the National Science Foundation, the Department of Energy, and potential industrial sponsors by spring of 2002.

Concluding Remarks

It is increasingly clear that the nation faces a serious challenge in producing the next generation of scientists and engineers necessary to support our nuclear technology needs. Even a significant reinvestment in both university nuclear engineering programs and national research in nuclear science and technology would take a decade or more to rebuild the resources necessary to respond to both industry and government needs.

We believe that our proposed undergraduate certificate program in nuclear fission power engineering has the capability of responding rapidly and effectively to meet these needs, at least on the short term basis. Furthermore, it would provide a cadre of baccalaureate degree level engineers in traditional disciplines with the additional training necessary to work in the nuclear fission technology area. Finally, it would provide a model of how a consortium of engineering programs could work together to develop and deliver a curriculum in a particular area to a broad national audience using information technology.

Here it is important to stress that this program is not intended as a replacement for traditional nuclear engineering curricula, which will continue to be necessary to meet not only national needs in nuclear fission power but in an array of other nuclear areas such as radiological physics, nuclear fusion, and nuclear security. Furthermore our national capability in nuclear technology depends critically on viable graduate programs leading to M.S. and Ph.D. degrees in nuclear engineering. Furthermore, this initiative will depend on the active involvement of faculty in existing nuclear engineering departments to develop, implement, and maintain this certificate curriculum in the future. Furthermore, the proposed curriculum is intended to complement existing undergraduate and graduate programs by providing a unique and rapidly available source of engineering graduates to meet the growing needs of industry and government in nuclear fission technology that have expanded beyond the capacity of existing programs.

We seek the participation of the National Science Foundation as one of the early sponsors of this effort through a planning grant for the 2001-2002 academic year.

Proposed Planning Grant Budget

Salary and wages		
Faculty support		
Graduate student assistants	$30,000	
Staff support	10,000	
Total salaries and wages		$40,000
Logistics		
Travel	10,000	
Supplies	10,000	$20,000
Outsourcing survey activities		$20,000
Total Direct Costs	$ 80,000	
Modified Indirect Costs	20,000	$20,000
Total		$100,000
University cost-sharing		
J. J. Duderstadt (20% AY)	30,000	
M. L. Corradini (10% AY)	15,000	
W. R. Martin (10%AY)	15,000	
Total	$60,000	

Biographical Sketches

James J. Duderstadt
President Emeritus and University Professor of Science and Engineering
The University of Michigan

Education:

Ph.D.	1967	California Institute of Technology (Engineering Science and Physics)
B.Eng.	1964	Yale University (Electrical Engineering)

Professional Experience:

1968-1968	U. S. A. E. C. Postdoctoral Fellow, Caltech
1969-1980	Assistant, Associate, and Professor of Nuclear Engineering, University of Michigan
1981-1985	Dean of Engineering, University of Michigan
1985-1987	Provost (and Acting President), University of Michigan
1988-1996	President, University of Michigan
1997-present	President Emertius and University Professor of Science and Engineering, U. Michigan

Research Interests:
A wide range of subjects in science, engineering, and public policy, including work in areas such as nuclear fission reactors, thermonuclear fusion, high powered lasers, computer simulation, science policy, higher education, and information technology.

Honors and Awards

1991	National Medal of Technology
1991	National Engineer of the Year, National Society of Professional Engineers
1986	E. O. Lawrence Award, U. S. Department of Energy
1985	Arthur Holly Compton Prize, American Nuclear Society
Other	Various honorary degrees, honorific societies, and invited lectureshps

Advisory Boards:

1998-present	Nuclear Energy Research Advisory Committee (chair), U. S. Department of Energy
1997-present	Committee on Science, Engineering, and Public Policy (COSEPUP), NAS
1994-2000	Executive Council, National Academy of Engineering
1985-1996	National Science Board (chair 191-1994)
Other	Numerous study and advisory groups for NRC, higher education, technology

Grants (current):
State of Michigan: Core funding for Millennium Project ($1.6 million for five years)

Recent Publications

J. J. Duderstadt and L. J. Hamilton, *Nuclear Reactor Analysis* (John Wiley, New York, 1976)
J. J. Duderstadt and W. R. Martin, *Transport Theory* (Wiley-Interscience, New York, 1979
J. J. Duderstadt, G. F. Knoll, and G. S. Springer, *Principles of Engineering* (Wiley, New York, 1982)
J J. Duderstadt, *A University for the 21st Century* (University of Michigan Press, Ann Arbor, 2000)
J J. Duderstadt, "New Roles for the 21st Century University", *Issues in Science and Technology*, Vol. XVI, No. 2 (2000) pp. 37-44

Michael L. Corradini
Department of Engineering Physics
University of Wisconsin - Madison

(a) Professional Preparation

1975 - BS-Mechanical Engineering,Marquette University, Milwaukee WI
1976 - MS-Nuclear Engineering Massachusetts Institute of Technology, Cambridge MA
1978 - PhD-Nuclear Engineering Massachusetts Institute of Technology, Cambridge MA

(b) Appointments

1981-2001	Professor and Associate Dean	University of Wisconsin-Madison
1980-1981	Adjunct Professor	University of New Mexico
1978-1981	Member of Technical Staff	Sandia National Laboratories

(c-part i) Five Recent Publications

- J.Murphy, D.Schmidt, S.P.Wang, "Multi-Dimensional Modelling of Multiphase Flow Physics: High-Speed Nozzle and Jet Flows – A Case Study," Proc of NURETH-9, San Francisco CA (October 1999).
- R.M.Bilbao, M.L.Corradini, "Solid Particle Effects on Heat Transfer in a Molten Pool with Gas Injection," Proc of NURETH-9, San Francisco, CA (July 1999).
- L.S.Nelson, P.Brooks, R.Bonazza, M.L.Corradini, "Triggering Steam Explosions of Single Drops of a Molten Ferrosilicon Alloy with a Simple Encapsulated Mechanical Impactor," Metallurigical and Materials Trans B (Nov 1999).
- S.Baik, K.H.Goney, S.Kang, J.Murphy, J.Blanchard, M.L.Corradini, "Development of Micro-Diesel Injector Nozzles via MEMS Technology and Initial Results for Diesel Sprays," SAE Fuels & Lubricant Mtg, SAE99-01-3645, Toronto CA (November 1999).
- P.K.Senecal, D.P.Schmidt, I.Nouar, C.J.Rutland, R.D.Reitz, M.L.Corradini, "Modelling High Speed Viscous Liquid Sheet Atomization," published in Int'l Jnl of Multiphase Flow (December 1999).

d. Synergistic Activities

Corradini was the co-founder of the College of Engineering Teaching Improvement Program, PI of a FIPSE Grant for the Department of Education on Teaching Improvement, PI for the NSF TRP Manufacturing Engineering Education and the NSF Engr Scholars Program and a member of the Univ. of Wisconsin Teaching Academy. In addition, he is one of the original participants of the Introduction to Engineering Course begun as part of the College, and the administrative liaison for the NSF Foundation Coalition. Currently, he also serves on the Management Board for the NSF National Institute for Science Education, which is at UW.

e. Collaborators and Other Affiliations

Corradini collaborations are through the Foundation Coalition and the Big Ten Assoc. Dean Council

Total graduate students: currently 6 grad students, graduated 35 PhD and 60 MS thesis students
Total undergraduate students: currently 28 undergrad students in the nuclear engr program

William R. Martin
Professor of Nuclear Engineering
University of Michigan

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