# The Nuclear Sun Shines Bright on South Carolina

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**Abstract**
The confluence of a number of in-state and out-of-state factors has motivated the establishment of a new graduate nuclear engineering program at the University of South Carolina (USC) in the Fall of 2003. One factor weighing greatly in favor of this effort is the large and thriving commercial nuclear industry in the State of South Carolina. The growing and expected continued need for nuclear professionals makes the establishment of this program timely and positioned to participate in and contribute to new and growing national research initiatives in nuclear engineering. The program covers a broad spectrum of academic interests through the recruitment of faculty with differing research backgrounds and interests and the strategic use of adjunct faculty from the surrounding professional nuclear community. Both internal and external funding is leveraged to provide support for the hiring of tenure-track faculty, adjunct faculty, and graduate student assistants. A dynamic and innovative distance education component is built into the program enabling students to enroll in classes and obtain degrees without having to relocate. This serves well those nuclear professionals seeking post-graduate degrees to further their career goals. A remotely operated radiation detection and instrumentation laboratory course will be offered in the Spring 2005, which will give remote students access to laboratory equipment for completing laboratory assignments and gaining experience with nuclear instrumentation. The alignment of these various interests and the current direction in education and research is believed to promote the growth of this new program and promote nuclear engineering education for the next generation of nuclear professionals and on into the future.

## Introduction

In Fall 2003, the Department of Mechanical Engineering at the University of South Carolina (USC) launched a new graduate program in nuclear engineering and by end of Spring 2005 will graduate its first Masters Degree student.

Bucking what otherwise would seem to be conventional wisdom, given that a new nuclear plant has not been ordered in the US since 1978, the establishment of this program is owing to a confluence of several different factors not the least of which is that more than half of all electricity consumption in the state of South Carolina is provided by nuclear capacity. The replacement of retiring workers alone might serve as *raison d'etre* given the recent trends in relicensing and power uprates at existing plants which ensures they will remain operating for at least a few more decades. Other in-state factors include the presence of a fuel fabrication facility owned by Westinghouse Nuclear Fuel and the recently designated Savannah River National Laboratory (SRNL) with a cold war legacy but poised to take on new R&D challenges and respond to initiatives of national import. This proximity to a national laboratory provides an excellent opportunity for collaborative research. In fact, a memorandum of understanding

(MOU) has been signed between the University and SRNL and a collaborative proposal has already been submitted for review by the U. S. Department of Energy (DOE).

Indeed, a larger justification for this new program may be viewed through the lens of new R&D initiatives on a national scale that serve to increase demand for nuclear professionals. Some of these include the hydrogen economy proposed by President Bush and others and efforts at using nuclear and radiological technologies to bolster homeland security. If hydrogen as an energy carrier is to supplant the use of gasoline in automobiles, then 225 GWe of generating capacity will need to be added to supply only 25% of existing automobiles. No other primary source of power other than nuclear can meet this challenge over the coming decades without exhausting financial and natural resources and without unacceptable environmental consequences. In fact, nuclear power generation has long been competitive, but with natural gas and coal prices at all time highs, the capital costs of new generating capacity is starting to look very attractive.

Other national programs fueling the need for more nuclear professionals with post-graduate degrees include programs for strengthening homeland security and the development of new space propulsion technology for very far reaching future missions. Contributions by nuclear professionals in areas such as improved methods of radiation detection and surveillance at US ports and in personal screening devices are already making a difference and will continue unabated as terrorist grow more brazen and sophisticated.

**Faculty**

In the first year of this new program, two new faculty members have been recruited and hired to serve as full-time champions of this nascent program. At its earliest point and continuing, the program additionally relies on some five or six full-time existing faculty members for teaching and advising of graduate students with as many more adjunct faculty members to assist in bearing the teaching load.

Indeed, the close proximity of the Westinghouse Fuel Manufacturing Plant and SRNL provides a ready source of professional talent and experience, which as been used in constituting advisory committees and as a supply of adjunct faculty that are needed to cover the broad topics/classes that need to be offered from the beginning but at a time when the program is still in its infancy. Furthermore, adjunct faculty members offer unique insight to students from an industrial, commercial, or government R&D laboratory perspective. This special interaction of graduate students with outside professionals enriches their learning experience and provides them advantages when applying for jobs, internships or other programs.

Taken together, new faculty expertise covers a broad spectrum of nuclear and radiological science and application, from reactor design and nuclear fuel, to medical isotopes and radiation detection. This breadth of interest and expertise allows new incoming students and current mechanical engineering students to be mentored by a faculty member with closely aligned interests and valuable insight and experience.

Moreover, the decisions in hiring both current full-time faculty members, in a significant part, revolved around new faculty research interests in areas of special emphasis by the University. These new hires span at least two of the four special focus areas including Next Energy,

examining new energy technologies for a clean and secure energy supply, and Biomedical Engineering. Emphasis on clean energy technologies such as the dual use of nuclear energy for electrical power and the production of hydrogen as an energy carrier serves to broaden the University's research portfolio and provide the possibility of larger multi-investigator, collaborative efforts in this important area of research within the University. Research into the use of radioisotopes and radiation in medical applications provides new expertise to the University's growing bioengineering initiative and this cutting edge research raises the focus and visibility of this program for making lasting contributions to public health and well being.

In addition, two new full-time nuclear engineering faculty members are currently being sought to complement the two existing full-time nuclear engineering faculty members and better enable the department to offer a full suite of nuclear engineering courses. New faculty will be sought with research interests that complement existing faculty but still provide expertise in the University's aforementioned core research initiatives. What is desired therefore would be a "critical mass" of experience and expertise moving forward to focus and strengthen the program in these vital areas of research.

**Program Focus**

This new program is focused on graduate education offering Masters and Doctoral degrees in nuclear engineering as well as a non-thesis Masters of Engineering degree, which is particularly accommodating to distance education students seeking a post-graduate degree but cannot make the time commitment for a thesis due to existing commitments or adequate research advising cannot be arranged on the job site or remotely through USC faculty.

The focus on graduate education complements nicely the undergraduate program in nuclear engineering offered at South Carolina State University (SCSU). The close proximity of these programs gives students graduating from SCSU the opportunity to continue to their graduate education within the state. Furthermore, the close proximity allows the faculty at both universities to offer select courses to the other university to diversify course offerings and allow a broader exposure for students in terms of faculty expertise and academic or research interests. The emphasis on breadth as well as depth of knowledge is recognition of the importance of a diverse and varied academic experience to the training of independent and well-rounded professionals. Exchanges such as these maximize the capabilities afforded each institution given their finite resources. This collaboration was formalized through the execution of a memorandum of understanding (MOU) between the universities in the Fall of 2003. It provided for this exchange of faculty for course offerings and encouraged the development of collaborative research proposals. However, perhaps most significant is the emphasis on recruitment and training of qualified students, particularly minority students, to increase diversity in the nuclear engineering community. Both programs recognize the importance of student recruitment in developing new programs and building a legacy and reputation for future generations of students to follow as a model.

Not neglecting its own undergraduates, the USC program also offers a minor in nuclear engineering to enrich and broaden their undergraduate education. This gives undergraduate students from other disciplines who desire a career in the nuclear industry the opportunity to gain valuable training to better equip them for the transition to an industrial/commercial environment.

The program is also strengthened by an aggressive distance education component or focus. All classes taught for the program are offered through distance education either streaming video over the Internet or on video tape. Assignments and information are exchanged electronically through an online learning portal, *Blackboard*. Two-way live video exchanges are also available to those distance education students at facilities with similar or compatible technologies. The radiation detection and instrumentation laboratory course will offer innovations in distance education that will enable distance education students to perform experiments and gain experience with equipment in the laboratory from a remote location. More on this topic is discussed below.

**Financial Support and Resources**

Program support comes from a number of resources from industry, federal funding through the DOE, internal funding, and competitively awarded grants. Success at securing funding in many cases is doubly rewarded with matching funds or grants. Industry grants provide funding for graduate student assistantships and help focus research on issues of direct relevance to the commercial sector. More than just relevant, these collaborations are focused on significant engineering problems such as fuel element design and improved effluent monitoring techniques. By bringing together industrial partners and research faculty to solve challenging, real-world problems, the learning and research experience is enhanced for graduate students, particularly those seeking careers in the nuclear utility sector upon graduation. This funding provided by utilities is leveraged against DOE matching funds that broaden the support and help bring in additional students. Similarly, internal funding of new faculty salaries and startup packages are also leveraged against DOE funding to support new faculty doing research in targeted areas of interest to DOE such as nuclear hydrogen production and medical isotope production. In fact, this direction toward matching of internal and external funds to bring new faculty on-board follows what is titled as the *Centenary Plan* by the University and seeks to hire 100 new faculty members in key research areas that broaden and strengthen the University's research focus.

Key funding for laboratory equipment for both education and research comes through a consortium of universities aimed at promoting the enhancement of nuclear engineering education and infrastructure. This funding is currently providing the establishment of a radiation detection laboratory to be used in teaching the radiation detection and instrumentation laboratory course which will be offered remotely through advanced distance education technology (see more on this below). This same lab will serve the needs of research efforts involving radiation measurements and characterization.

USC has also pursued direct support of the program from DOE through "Plus-Up" requests to support growth and expansion of research and teaching in areas of interest to DOE such as the clean energy initiative supporting research in nuclear hydrogen production. A congressional appropriation in FY2005 will enable the University to hire two new faculty members, support fellowships for exceptionally talented graduate students, and make key investments in infrastructure. The hiring of two new faculty members will leverage the internal matching support of the University through its earlier mentioned Centenary Plan and its Faculty Excellence Initiative which provides matching funds to support the recruitment of 150 new USC faculty members. Matching resources using internal funds will also be used to renovate lab space and make key infrastructure improvements that support core USC research interests and

maximize research potential in the focus areas identified by the University. USC has demonstrated expertise, success, and potential for expanded research profile in key nuclear related areas such as advanced fuel development and radioisotope production. Existing collaborations with MUSC and SRNL hold great promise. Investment in equipment and infrastructure in each of these areas further enhances USC's ability to engage and partner with these and other institutions as well as internally to seek larger, multi-investigator, and long-term research programs.

Support won through competitive grants such as the Nuclear Engineering Education Research (NEER) program, supports innovative and cutting edge research which raises the visibility of USC among research universities and provides support to graduate students through research assistantships. This NEER grant looking at increasing the conductivity of nuclear fuel elements is timely and of direct importance to industry, which further enables commercial and industrial interests to see the value in the program and encourages their larger participation and support. Additional support for students will be available in the form of scholarships and fellowships from the American Nuclear Society (ANS), National Academy for Nuclear Training (NANT), and DOE starting in Fall 2005.

**Advisory Board**

While the program found its true champion in the form of the Department Chair, Abdel Bayoumi, the broad support and interest in this new program is evident from the list of individuals that make up the USC Nuclear Engineering Advisory Board (see Table I). Chaired by retired Admiral George Davis, the board is responsible for making recommendations on program direction and emphasis and to ensure the quality and relevance of the program. The chairman, Admiral Davis, is key in organizing the board and serving as a spokesman to media outlets in promoting the program. The industrial/commercial relevance of the program is insured by the strong contingent of industrial and utility officers. Senior Vice Presidents or Chief Nuclear Officers of the three nuclear utilities of South Carolina, Duke, SCANA, and Progress

**TABLE I.** USC Nuclear Advisory Board Members.

| Constituency | Position/Role in Constituent Organization |
|---|---|
| Nuclear Navy (Chair) | Admiral (retired) |
| SC Nuclear Advisory Board | Chairman |
| Duke Energy | Senior Vice President & Chief Nuclear Officer |
| SCANA | Senior Vice President & Chief Nuclear Officer |
| Progress Energy | Senior Vice President & Chief Nuclear Officer |
| Westinghouse Electric Company | Director of Product Design |
| Southern Nuclear Company | Vice President for Engineering |
| Savannah River National Laboratory | University Programs Coordinator |
| University of Florida | Professor and former Department Chair |
| South Carolina Universities Research and Education Foundation | Director |

Energy, serve on the board as well as the Vice President for Engineering of Southern Nuclear with plants in neighboring states and the Director of Product Design for the Westinghouse Fuel Fabrication Facility in Columbia. To adequately address the program's direction from a regulatory perspective, the Chairman of the South Carolina Nuclear Advisory Committee which reports to the Governor, also is a member of the board. Education and/or research objectives and focus is provided by representatives from SRNL, University of Florida, and the South Carolina Universities Research and Education Foundation (SCUREF). SCUREF's Director, Craig Williamson, serving as the representative to the board has been invaluable in identifying and pursuing educational and research opportunities to aid the program's growth and has championed the program before administrators and legislators alike. This level of support, direction, and oversight is essential in maintaining the focus and relevancy of the program both now in its infancy to make best use of its human and capital resources but also in the long-term as the program evolves and new challenges come to light.

**Innovations in Distance Education**

A course entitled "Instrumentation for Nuclear Engineering" will be offered in the Spring 2005 semester. This course will have a classroom component as well as a laboratory component to provide students with a radiation detection and measurement laboratory experience. Since our courses are offered via distance education to accommodate students at regional nuclear utilities, the Savannah River National Laboratory and other remote locations, the challenge is to provide these students a realistic laboratory experience. We will use a combination of distance education delivery technologies to accomplish this task. The development of the laboratory and delivery mechanisms is funded in part by the Department of Energy's Innovations in Infrastructure and Education (INIE) program.

The classroom portion of the nuclear instrumentation course will be delivered using USC's standard APOGEE (A Program of Graduate Engineering Education) program in which remote delivery of classes is via internet videostreaming or videotape or DVD. In this system, lectures are presented in a classroom/studio where on-campus students can participate in the class while at the same time the class is recorded digitally (audio and video) for transmission to remote students.

Laboratory demonstrations and exercises present more of a challenge since the somewhat large and sensitive nuclear instruments are not suited for transportation to the classroom/studio environment. Further, a realistic laboratory experience for remote students must provide the "look and feel" of an actual laboratory. Using advanced distance education technologies this goal can be accomplished, providing students with a virtual laboratory experience.

Laboratory demonstrations will originate from the lab rather than the classroom studio by making use of audio/video equipment installed in the nuclear instrumentation lab. Fixed and pan-tilt-zoom cameras mounted in the lab will provide coverage of all laboratory equipment and offer simultaneous multiple views such as an instructor describing gamma ray spectroscopy at the same time as the acquisition of a gamma ray spectrum is being displayed. A wireless microphone will pick up the audio portion of the demonstration. An assistant in the lab will coordinate the cameras and other inputs (such as computer displays) to control the views presented to remote students. The distance education delivery mechanisms for these

demonstrations will be the same as for APOGEE; i.e., internet videostreaming or videotapes or DVDs of the demonstrations will be mailed to students.

An extension of this technology will allow the instructor to work one-on-one with remote students. Using headsets with microphones, the instructor and student can be in direct audio contact over the internet. Also, the video equipment installed in the laboratory can be controlled by the student to view the instructor and/or laboratory equipment as if he or she were in the lab. This arrangement enables the instructor to work directly with remote students on laboratory demonstrations and exercises.

Finally, students will be able to perform laboratory exercises independently via the internet. As shown in Figure 1, the major instruments in the laboratory include high purity germanium (HPGe), sodium iodide (NaI), low energy germanium (LEGe) and alpha particle detectors, and PCs and control software interconnected via a laboratory network. This network is connected to the USC LAN which enables access via the internet.

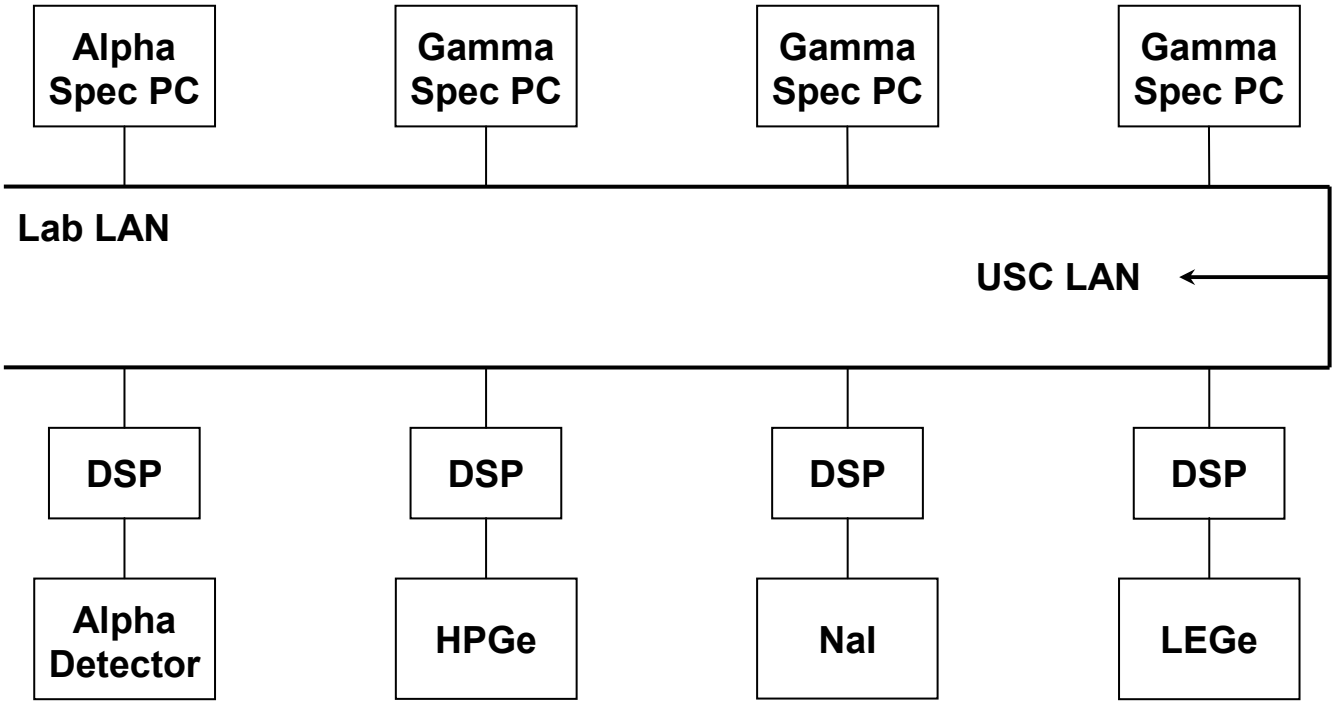


**Figure 1 Nuclear Instrumentation System**

All PCs in the system have the Windows XP operating system which provides the capability for remote desktop control; i.e., remote users can be given the authority to take control of one of the laboratory PCs and operate the spectroscopy systems just as if they were present in the lab. The only exception to this is the actual insertion and removal of samples in the detector enclosures. Two options will be used to address sample exchange. One option will be to place samples in the detector being used for the current laboratory and allow students to sign up for time periods

to run analyses while the samples are in place. A second option is to eliminate the need for a sample by making use of the gamma ray spectroscopy software's simulator module. The simulator module recreates the acquisition of any stored gamma ray spectrum such that the user would not necessarily know whether a real sample was being analyzed or a previously acquired spectrum was being recreated. These two methods will provide much flexibility in designing a wide variety of radiation and radioactivity laboratories.

Through the innovative use of multiple distance education delivery technologies, USC hopes to provide our remote customers with a virtual laboratory experience that approaches the value of actual time in a laboratory setting.

**Conclusions**

The establishment of this new graduate program in nuclear engineering serves to broaden the research focus of the University of South Carolina and raise its profile by addressing research issues of great national import such as clean energy and the use of radioisotopes in medical treatments. It also serves as a well-spring for new nuclear professional talent in a state that has made a significant investment in nuclear power and stands poised to lead the nation in the coming post-hydrocarbon economies where nuclear power will play a dominant role. While far from nucleating in isolation, the program has sought ties to industry and other academic and research institutions to ensure it relevancy and standards in a dynamic field. In addition to program relevancy and content, USC has pioneered new methods of delivery for educational instruction and virtual hands-on training through its innovative use of distance education technology. Because of the breadth and diversity of its program, its commitment to quality in education, and a willingness to experiment and innovate with new methods in education, the future indeed appears bright for the success of this program and its contribution to nuclear engineering education in the 21st century.

## Biographical Information

TRAVIS W. KNIGHT, Assistant Professor, joined the nuclear engineering program at USC in the Fall of 2004. Prior to that he served as Adjunct Assistant Professor in the Department of Nuclear and Radiological Engineering at the University of Florida where he received his Ph.D. in 2000. His research and teaching interests include advanced nuclear fuels and materials, reactor design, nuclear hydrogen production, and space nuclear power and propulsion.

MARC GARLAND, Assistant Professor, joined the USC nuclear engineering program in the Spring of 2004. His PhD, earned at the University of Maryland in 2004, was based on his research in reactor production of radioisotopes conducted at the Oak Ridge National Laboratory under the direction of Dr. Saed Mirzadeh. His research interests are in the production and use of radioisotopes in medicine, for both diagnostic and therapeutic applications.

ABDEL BAYOUMI, Ph.D., is a Professor and Department Chair of Mechanical Engineering at USC with over 25 years of teaching and research experience. Before joining USC, he was a Prof. of Mechanical and Aerospace Eng. at North Carolina State Univ., a project manager at Hewlett-Packard, and a Prof. of Mechanical and Materials Eng. at Washington State Univ. His research activities have been focused in mechanical behavior of materials, diagnosis and prognosis of mechanical systems, mechanical design, design for manufacturability, concurrent engineering, mechatronics, non-destructive testing of materials, product qualifications, and integrity.