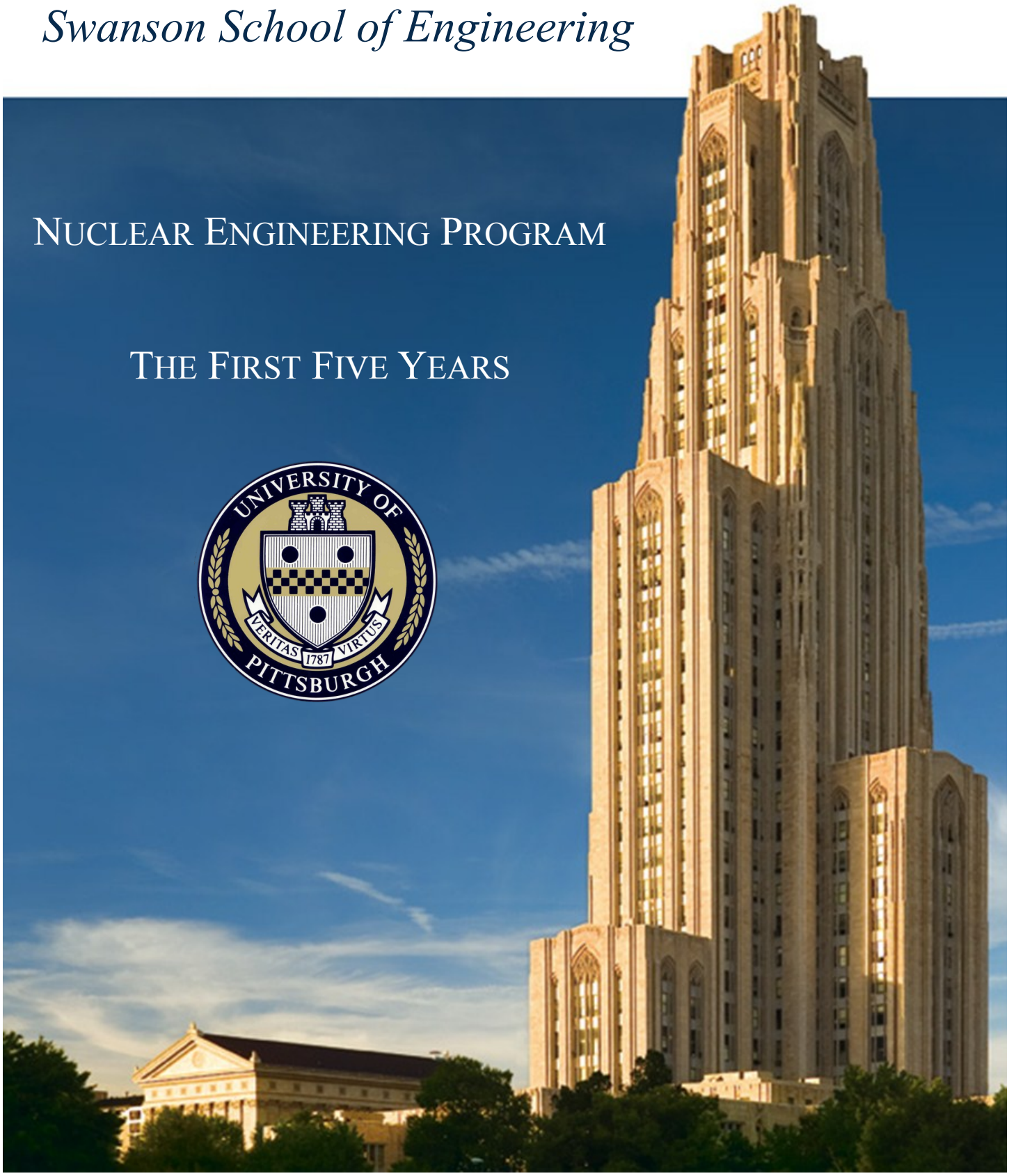
University of Pittsburgh

Swanson School of Engineering



Nuclear Engineering Program

The First Five Years

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SUMMARY

In 2006, The University of Pittsburgh and Westinghouse began a joint relationship to develop an academic certificate program in nuclear engineering. This program has enjoyed tremendous success and has become a benchmark for other developing nuclear engineering certificate programs in the nation.

In 2010, the success of the certificate program stimulated the university to hire a full-time, nuclear engineering faculty member, Dr. John Metzger, who now serves as Director of Nuclear Programs. Dr. Metzger has extensive nuclear experience at national laboratories, architect-engineering firms and the Bettis Laboratory where he was an instructor at the Bettis Reactor Engineering School. Dr. Metzger has been aggressive in continuing to improve the program with additional course offerings and a proposed MS program in nuclear engineering. Dr. Larry Foulke, the original Director, is still very much engaged in teaching and serves as Director of Nuclear Education Outreach.

The program currently consists of two certificates in nuclear engineering – one for undergraduate and one for graduate students. These certificate programs provide "constituency-driven" coursework for nuclear engineering education. Instruction is provided by 14 adjunct faculty from Westinghouse, Bettis and the Beaver Valley Nuclear Station.

The Pitt program serves the local nuclear engineering community by providing a source of engineering graduates for employment, and ease of opportunity for professionals to enhance their academic credentials by taking relevant, technically current coursework. We believe this program provides the following benefits to the nuclear industry:

- Academic relevance with attention to basic competencies needed for integrated plant knowledge.
- Academic focus on nuclear safety and operations.
- Stimulation of student interest in nuclear technology.
- Research support.
- Cost savings.
- Innovative instruction.
- Productivity and efficiency.
- Promotion of the profession.

Southwestern Pennsylvania is a nuclear engineering mecca in the U.S. It has access to adjunct faculty who can provide important instruction in nuclear systems, operations, safety, safety culture, transient and accident analysis, regulations, and lessons learned from industry experience.

ACADEMIC RELEVANCE

The certificate programs are designed to generate a "farm system" of future engineers to support nuclear workforce replenishment needs. Each certificate program is composed of 15 credit hours of coursework. The curricula of the certificate programs are designed so that earned credits may be applied toward any one of the University of Pittsburgh's traditional engineering degree programs.

The emphases of the undergraduate level certificate program are on the fundamentals of nuclear technology, the broad spectrum of technical and social issues encountered in the nuclear industry, and the opportunities afforded by the nuclear industry's renaissance. The undergraduate program is sufficiently flexible to accommodate students from a wide spectrum of engineering disciplines. Experience to date has shown that the undergraduate program is a magnet for attracting traditional engineering students to nuclear power engineering. This has been evidenced by the large enrollments (See Figure 1), the variety of engineering majors represented by the students (Figure 2), and an increased interest in nuclear careers. Since 2006, a total of 132 undergraduate certificates have been awarded.

Courses currently offered in the undergraduate level nuclear engineering program are:
(see http://www.engr2.pitt.edu/mems/undergraduate/nuclear-certificate.html)

ENGR 1700: Introduction to Nuclear Engineering

ENGR 1701: Fundamentals of Nuclear Reactors

ENGR 1702: Nuclear Plant Technology

The emphases of the graduate level certificate program are on nuclear operations and safety, operating experience, and current issues related to long-term nuclear plant improvements**.** These focus areas for the graduate certificate program not only fulfill a recognized educational need, but also take advantage of the unique industrial resources in the Pittsburgh area that can develop relevant competencies and facilitate student learning. For the graduate certificate program, enrollments continue to grow (Figure 3) with 38 students having achieved the requirements for graduate certificate. Over 1,400 credit hours have been delivered.

Courses currently offered in the graduate level nuclear engineering program are: (see http://www.engr2.pitt.edu/mems/graduate/nuclear-certificate.html)

ME / ENGR 2100: Introduction to Nuclear Engineering

ME / ENGR 2101: Nuclear Core Dynamics

ME / ENGR 2102: Nuclear Plant Dynamics and Control

ME / ENGR 2103: Integration of Nuclear Plant Systems with the Reactor Core

ME / ENGR 2104: Nuclear Operations Safety

ME / ENGR 2105: Integrated Nuclear Power Plant Operations

ME / ENGR 2110: Nuclear Materials

ME / ENGR 2115: Heat Transfer and Fluid Flow in Nuclear Plants

ME / ENGR 2120: Mathematical Modeling of the Nuclear Power Plant

ME / ENGR 2125: Case Studies in Codes and Standards

ME / ENGR 2130: Environmental Issues and Solutions for Nuclear Power

Much of the engineering and other technical workforce in the nuclear power field is preparing to retire over the next decade, just as companies are poised to experience strong growth in demand for their nuclear products and services. As a result of many years of workforce development neglect in this area, there currently are few university students or new nuclear industry employees with adequate educational and technical background who are ready to fill the impending technical talent gap. The overall costs for developing this potential talent pool will be large. This program is expected to reduce the overall costs to industry to attract, recruit and educate future talent.

Program content has been and will continue to be developed in consultation with engineers, managers, and education specialists from local constituencies, such as Westinghouse Electric Company and FirstEnergy Corporation, as well as from the global nuclear engineering infrastructure, such as the Institute for Nuclear Power Operations (INPO) and the International Atomic Energy Agency (IAEA). Course work takes advantage of nearby facilities at Westinghouse, and the Beaver Valley Power Station. "Dynamic learning activities" at these facilities provide students with a hands-on experience. The availability of these facilities and subject matter experts is a major strength of this program.

ACADEMIC EMPHASIS

The certificate programs at the University of Pittsburgh differ from more traditional nuclear engineering graduate programs by placing emphasis on integrated plant operations, plant safety, and operating experience. Knowledge of integrated nuclear plant operations is cited by employers as one of the major missing competencies in new employees and even experienced engineers. The ability to analyze the cause and effect relationships between events that are separated both spatially and temporally is a prime indicator of higher order cognitive thinking and is an essential nuclear safety competency for engineers working in a complex industrial setting like a nuclear power plant.

The program's focus is not intended to diminish the importance of traditional nuclear engineering education. Nevertheless, there remains a critical need for engineers with integrated, cross-discipline knowledge to mitigate the tendency of engineering disciplines to 'silo' into their own areas of expertise without an adequate understanding of their interfaces with other disciplines. The program's unique emphasis is aimed at providing the (discipline) engineer with the ability to work with the engineers, for example, who design the instrumentation and control systems, plant operations and maintenance staff, licensing engineers, or core reload analysts.

Course work for the graduate certificate program, in particular, includes in-depth studies related to the dynamic behavior of the reactor core and the entire nuclear plant, both with and without the instrumentation and control systems. The course work then introduces the major systems in a nuclear power plant and emphasizes how operations of and

faults in those systems and components can affect reactivity and core transient behavior. Studies of nuclear systems and components are taught at the graduate level by having students grapple with complex, real life scenarios in team fashion.

Following the introduction to nuclear systems and components, the graduate course work reviews the development of reactor safety concepts, the emergence of safety strategies and culture, and scenarios of severe accidents and how their damage can be mitigated. Risk-influenced regulatory practices are introduced and quantitative use of probabilistic risk assessment is described in terms of its use as a guide to intelligent decision-making. The characteristics of accident progression in the reactor vessel and containment in the unlikely event of core melting/loss of coolant accident and relocation of fuel material are explained. Offsite consequences of such severe accidents are explored. Source terms, dispersion of radionuclides, and dose projections are developed for both conservative and realistic evolutions. Protective actions and emergency preparedness are introduced. Course work also covers regulatory aspects of nuclear operations and the roles that the NRC, INPO, WANO and the IAEA play and what impact each has on plant operations. An introduction to regulatory requirements, Safety Analysis Reports, and nuclear safety and licensing is provided. Safety culture is stressed using guest instructors who live with safety culture on a daily basis. Guest instructors include the Senior NRC Resident Inspector at Beaver Valley and the Site Vice-President at Beaver Valley.

The capstone course in operations and safety involves hands-on simulator workshops and classroom experiences to promote an understanding of how the integrated plant works under normal conditions and the challenges the operator faces under abnormal circumstances. Emphasis is placed on understanding plant characteristics and controls, rather than on developing control manipulation skills. Intended outcomes are an aptitude for predicting transient behavior of the integrated plant and a command of reactivity management and control that is important for efficient operation of a nuclear plant. The following student quote was provided after a recent Beaver Valley simulator session: “The best part of the trip was seeing the workforce (i.e., licensed operators) for an operating reactor. In class, we discuss human error as being a major factor in accidents. Prior to visiting Beaver Valley, I did not realize how many individuals work on and for nuclear reactors. With such a large number of people involved, it’s no wonder human error might occur at some level.”

In short, we believe that partnering with local constituencies provides students with the most relevant knowledge to prepare them to work in the nuclear industry.

STUDENT PROJECTS & ENGAGEMENT

Engineering 1050: Product Realization is a unique interdisciplinary course that focuses on product analysis, product design and product development. In this course students are assigned to a project and a team as they would in a professional setting. The student teams then work in conjunction with industry sponsors to develop plans for emerging and existing products. Through these projects students work to find solutions to complex problems while learning and experiencing what it means to be an engineer. Projects have included:

- Communication Through Containment Walls
- Personnel Tracking at Nuclear Plants w/RFID
- Mitigation Techniques for BWR Standpipe Acoustic Resonant Excitation
- Eddy Current Probe Design—Nuclear Power Systems
- Development of Wireless Eddy Current Probe for Nuclear Reactors
- Reactor Hold Down Spring Analysis
- Micro-boat Sampling System
- Power Supply for Nondestructive Testing of Wireless Probe
- Propulsion Method for Heat Exchanger Pipe Inspection Probe
- Wireless Incore Detector for Power Distribution Measurement in a Nuclear Reactor
- Passive Cooling of Nuclear Fuel Rods
- Evaluating Bearing Forces in an Unbalanced Motor
- Linear Motor Development

Each Fall term the University hosts Nuclear Engineering Night, at this event students are able to network with professional engineers, learn more about the industry, and engage leaders in the field. Keynote speakers have included:

Dale E. Klein (Chairman, NRC), Aris Candris (President, Westinghouse), and William D. Magwood (Commissioner, NRC) and Peter B. Lyons (Assistant Secretary for Nuclear Energy) who served as the keynote speaker for the 2011 Nuclear Engineering Night. The event draws over 250 students and faculty each year and dozens of industry participants.

STIMULATION OF THE FUTURE WORKFORCE

The undergraduate program has been sufficiently flexible to accommodate students from a wide spectrum of engineering disciplines. Experience to date has shown that the undergraduate program is a magnet for attracting traditional engineering students to nuclear power engineering. This has been evidenced by the large enrollments (See Table 1), the variety of engineering majors represented by the students (Figure 2), and the increased interest in nuclear careers. A steady-state enrollment of 200 students is projected in the undergraduate certificate program with approximately 40 BS graduates per year who earn the nuclear certificate. The enrollment for the three undergraduate nuclear engineering courses has grown substantially. In the two past academic years the total enrollment for the three courses has approached 300 students. Many of these undergraduates are obtaining entry-level engineering positions with in the local nuclear power industry. The Pitt program has become a "benchmark" standard for other startup nuclear engineering programs. Inquiries about the success of the program have been received from international universities (University of Alexandria in Egypt, Qassim University in Saudi Arabia), and U.S. universities (Auburn University). The Nuclear Engineering program has been recognized as having exceptional educational potential from ex-CEO of AREVA, Tom Christopher, NRC Commissioner William Magwood, Nuclear Energy University Program Director, John Gilligan, DOE Assistant Secretary of Energy Pete Lyons, Dennis Miotla, Deputy Assistant Secretary for Nuclear Facility Operations at DOE, and former NRC Chairman, Dale Klein. The individuals named above have been instrumental in encouraging the development of a Master's Degree program.

Indeed the Pitt program takes advantage of unique industrial resources in the Pittsburgh area (Westinghouse, Bettis, FENOC, Cheswick, BPMI) who provide the adjunct faculty of the program.

Adjunct faculty are drawn from the local nuclear energy community – providing depth and breadth of coverage of relevant, technically current coursework. There are a wealth of active professionals supplemented by recent retirees who can be called upon to both assist with the development and teaching of regular course offerings, modules and directed study. The Swanson School of Engineering already provides a wide array of complementary courses related to nuclear operations and safety in chemical, civil, mechanical, industrial, materials and electrical engineering. These direct ties to the School's six departments create program flexibility enabling it to accommodate students from all areas and allow for future program enhancements.

Pitt's graduate certificate (soon to be an MS degree in nuclear engineering) serves as an attractive draw for international students who by virtue of their exposure to Pittsburgh and Westinghouse will develop knowledge of Westinghouse nuclear technology.

RESEARCH

The University of Pittsburgh's Nuclear Engineering Program recognizes the importance of developing research capabilities in nuclear science and technology to support the needs of the state's nuclear constituency, complement its strong nuclear engineering academic program, and support the development of a Masters of Science degree in Nuclear Engineering with a thesis/research option.

The DOE-NE created Nuclear Energy University Programs (NEUP) in 2009 to consolidate its university support under one program. NEUP funds nuclear energy research and equipment upgrades at U.S. colleges and universities, and provides scholarships and fellowships to students.

In FY2011 the NEUP Program had major grant opportunities to engage university research and development of nuclear science and engineering:

Research & Development - The program supports projects that focus on needs and priorities of key Office of Nuclear Energy programs, including fuels cycle, reactor concepts, and transformative "blue sky" research.

Infrastructure - The Department of Energy recognizes that in order for universities to conduct cutting-edge research and educate the next generation of nuclear scientists and engineers, they need the best equipment and infrastructure possible.

Integrated Research Projects – This solicitation was to support University, Laboratory and industrial teams in developing a new generation of highly efficient reactors and new methods to store used fuel are two key issues for the Department of Energy's Office of Nuclear Energy.

Fellowships and Scholarships – the fellowships fund graduate students and the scholarships undergraduate students studying nuclear science and engineering and related fields.

The University of Pittsburgh's Swanson School of Engineering enthusiastically responded to these opportunities this past year. In many cases the University's submittal included teaming with local nuclear engineers and researchers.

Under the research and development program, Pitt submitted 15 separate white papers covering a variety of topics related to nuclear science and technology. Five of the Principal Investigators were invited to submit full proposals, which was slightly better than the national average. The five full proposals submitted are listed below:

Advanced I&C and Human-Machine Interface using Adaptive System Identification and Control, PI Professor D. Cole in collaboration with Westinghouse.

Modernization and Monitoring of Nuclear Plant Systems using Adaptive System Identification and Control, PI Professor D. Cole in collaboration with Westinghouse.

Thermal Mixing and Fatigue at Core Outlet, PI Professor M. Kimber in collaboration with Westinghouse.

Automated Condition Based Monitoring of Nuclear Power Plant Systems, Structures, and Components, PI Professor J. Vipperman in collaboration with Westinghouse.

Water-Cooled Particle Bed Reactor, PI Professor J. D. Metzger

Pitt will continue to identify and respond to applicable research and development call for proposals by the DOE-NEUP Program, as well as from other agencies. Pitt will also continue to seek to engage local industry to partner in program directed research and development.

COST SAVINGS

The nuclear engineering certificate programs are the result of a cooperative effort between industry and the University of Pittsburgh. The stated goal of the program is to prepare engineers and engineering students for productive careers in the rejuvenated nuclear industry. The educational emphasis on integrated plant operations, plant safety, and hands-on learning will assure that students who successfully complete the program[s] have the knowledge and skills to meet the needs and expectations of their employer. This can translate into significant savings both in dollars and time for the nuclear industry. In addition, the location of the program in relation to major nuclear engineering employers, is projected to produce a local talent pool that will result in substantially lower recruiting and relocation costs along with higher retention rates.

Students enrolled in the undergraduate nuclear engineering certificate program also participate in co-op and internship programs. Currently, over 60% of Pitt engineering students participate in a co-op program and the Nuclear Engineering program has highlighted the opportunities available in the nuclear industry with a local employers such as Westinghouse, First Energy, and Bettis. The cost savings benefits of a co-op program include:

- Developing a pool of future employees within the particular organization's culture and philosophy
- Reducing recruiting, training, and orientation costs by hiring graduates who have experience within that organization
- Increasing retention of full time employees by hiring graduates who have already committed to the organization and the area

INNOVATION

We believe the certificate programs reflect an important and innovative initiative for nuclear workforce development. In addition to expanding nuclear knowledge to undergraduate and graduate students in the traditional engineering disciplines (e.g., electrical, mechanical, and chemical), these unique programs differ from traditional nuclear engineering education in that they are based on meetings with industry as to the educational needs of each of their organizations.

Coursework in these programs has been designed to introduce real life and relevant problems for student teams to solve. For example, topics in the Nuclear Systems and Components course cover actual operating events and problems that have occurred at the Beaver Valley Nuclear Station. In another example, the recognized need for education in Nuclear Codes and Standards led to the development of a course entitled "Case Studies in Nuclear Codes and Standards.' This course utilizes experts from Westinghouse extensively to provide a very relevant educational experience that is unique and cannot be found at any other nuclear engineering program in the U.S.

Given the close proximity of Westinghouse Electric Company, the Beaver Valley Power Station, and the Bettis Atomic Power Laboratory, there exists a robust pool of experienced adjunct faculty, education resources, learning facilities, and a fresh source of relevant industry issues. This program maximizes the existing resources of Beaver Valley and Westinghouse to promote student learning. In particular, the programs:

- Use instructional approaches that take advantage of the experience and knowledge of practicing nuclear professionals in the local service areas of western Pennsylvania. Most adjuncts have over 25 years of experience in the nuclear industry and are recognized in the industry for their expertise. For example, licensed Senior Reactor Operators (SRO) or certified SRO instructors are used as adjunct professors in the teaching of the plant systems and integrated plant operations courses.
- Utilize the full-scale simulators available at Beaver Valley and Westinghouse to reinforce the classroom learning with hands-on experience. For example, to adequately convey the lessons learned from the Three Mile Island event (considering that many students were born after 1979), the accident sequence of events is walked through with the students on the simulator. The following is a quote from a student following a recent replica simulator experience: "It allowed us to use the information that we learned throughout the semester to determine what each accident would do to the reactor. Rather than learning theory, we were allowed to apply our knowledge, and for me, that is the true test of whether or not I understand something."
- Integrate desktop simulation software into the classroom to provide "laboratory" experiences that facilitate the understanding of plant operations and promote the development of intuition regarding plant transient behavior.
- Provide for the development of teaching guides and source books as a major product of the program. The certificate programs use relevant, non-proprietary information from FirstEnergy Nuclear Operating Company and Westinghouse Electric Company in the development of teaching materials.
- Generate student interest in nuclear power engineering and increase awareness among student who would not normally have considered a career in the nuclear industry.

In addition to the innovative concepts discussed above, the educational design philosophy of the courses in the certificate programs delivers graduate courses via a blended mix of distance and web-based learning techniques. The University of Pittsburgh uses the Blackboard Academic Suite™ to enhance the effectiveness of their programs. The expertise of these organizations with the Blackboard Academic Suite™ is being applied to the courses. Current courses are being delivered in a face-to-face format, and a synchronous distance learning capability. This allows courses to reach a geographically dispersed student population, significantly increasing the worth of the certificate programs to the nuclear industry as a whole.

PRODUCTIVITY AND EFFICIENCY

Pitt's distance delivery capability permits students to attend live graduate classes while on travel. Current courses are being delivered in both a face-to-face format, and a synchronous distance-learning format. This allows courses to reach a geographically dispersed student population, significantly increasing the worth of the certificate programs to students. We have even had a student tune in over the internet from his work assignment that took him to China for a short period.

The productivity impact of this program has to be measured in terms of the expectations of workforce development and knowledge transfer from experienced nuclear practitioners to the next generation of nuclear professionals. The transfer of knowledge from the existing professional staff to new employees is expedited because the certificate programs are tailored to meet the needs of the industry. A variety of plant types are discussed in the certificate program courses experienced nuclear engineers are utilized in the teaching. Program content developed in cooperation with industry is referred to as "constituency-driven" coursework. This is not course work that has been taught by the tenured professor at a major nuclear engineering program that may have taught the same material for 20 years.

New employees who have completed the undergraduate program can begin work with greater understanding of job requirements, making them more efficient and productive new employees. Organizational effectiveness is immediately improved because these employees have a better understanding of plant operations.

This program also provides a supply of interns and co-op students to for industry. This represents a cost savings from development of a pool of future employees, reduction of recruiting / training costs, retention of full-time employees from graduate education opportunities.

As a result of this constituency driven program, local industry can expect to see measurable increases in Human Resources staff productivity. The provision of a "farm system" of future engineers with a background in nuclear operations, will simplify the recruiting process, thus freeing the staff to work on other important projects.

PROMOTION OF THE PROFESSION

The success of the program has resulted in NRC grants that provided student scholarships for undergraduate students and fellowships for graduate students. Partnering with local industry has provided stimuli to students to become interested in nuclear technology.

Pitt faculty (Metzger and Foulke) are quite active in giving presentations to civic and school groups. They provide an effective promotion of nuclear science and technology to the public that is of benefit to all in the nuclear industry.

FUTURE PLANS

Pitt continues to consider developing additional course work that provides the educational opportunities that industry is perceived to seek. Consideration is being given to:

- development of a summer Institute for Nuclear Power Engineering that would bring students from new nuclear nations to Pittsburgh for intensive 12-week summer certificate program.
- potential development of a Graduate Certificate Program in Nuclear Plant Operations" to encourage / educate students to become SRO level certified employees who are prepared to take SRO certification training.

Future courses that are anticipated to support the Master of Science in Nuclear Engineering, and are expected to be developed, include:

ME / ENGR 2106: Advanced Nuclear Power Plant Systems – this course will provide an in-depth study of nuclear power plant systems, the function and operation.

ME / ENGR 2107: Advanced Nuclear Power Plant Normal, Transient and Accident Operations – this course will be offered by Westinghouse personnel utilizing the simulator at the Waltz Mill facility.

ME / ENGR 2116: Health Physics and ALARA – this course will address the interaction of radiation with matter, the health and environmental effects of radiation, the concept of ALARA, as low as (is) reasonably achievable, through time, distance and shielding.

ME / ENGR 2117: Nuclear Reactor Theory – this course will cover the development of the neutron transport equation, multi-group theory and the neutron diffusion approximation, along with appropriate applications.

ME / ENGR 2126: Nuclear Power Plant Management and Leadership – this course will provide an in-depth look at the issues necessary to build and operate a nuclear power plant with emphasis on the nuclear power industry's culture of safety and leadership.

ME / ENGR 2127: Nuclear Power Plant Outage Management – this course will address the management of a planned refueling and maintenance outage of a nuclear power plant.

CONCLUSION

Southwestern Pennsylvania is a nuclear engineering Mecca in the U.S. It has access to adjunct faculty who can provide important instruction in nuclear systems, operations, safety, safety culture, transient and accident analysis, regulations, and lessons learned from industry experience. A continuing partnership between local constituencies and the Swanson School of Engineering at the University of Pittsburgh has continuing benefits for the industry as a whole.

The Swanson School of Engineering is ideally located to provide world-class education for engineers interested in a major or minor in nuclear engineering.

- There are several active and retired engineers in the Pittsburgh area that have worked extensively in the nuclear industry at Westinghouse, Curtiss-Wright, Bettis, and the Beaver Valley nuclear plant. A large number of are interested in employment as adjunct faculty.
- The nuclear related facilities in and around Pittsburgh provide a valuable information and learning base for nuclear and mechanical engineering. The Curtiss-Wright facility in Cheswick makes nuclear control rod drive mechanisms, reactor coolant pumps and critical valves. The Westinghouse facility in Cranberry and Waltz Mills provides nuclear equipment mockups and a number of plant equipment learning tools. The Beaver Valley nuclear plants are two modern three-loop plants that are representative of over 50 plants of this type around the world.
- No other U.S. university has this combination of assets.

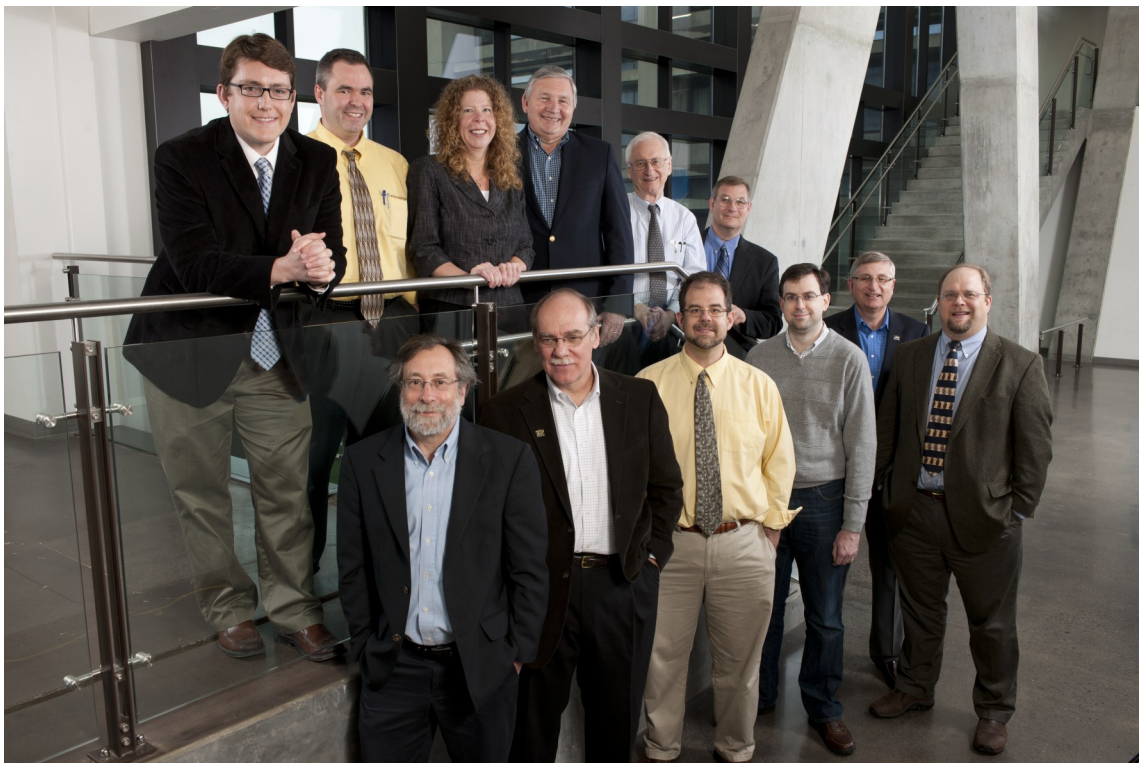

Figure 1: Undergraduate Nuclear Certificate Courses

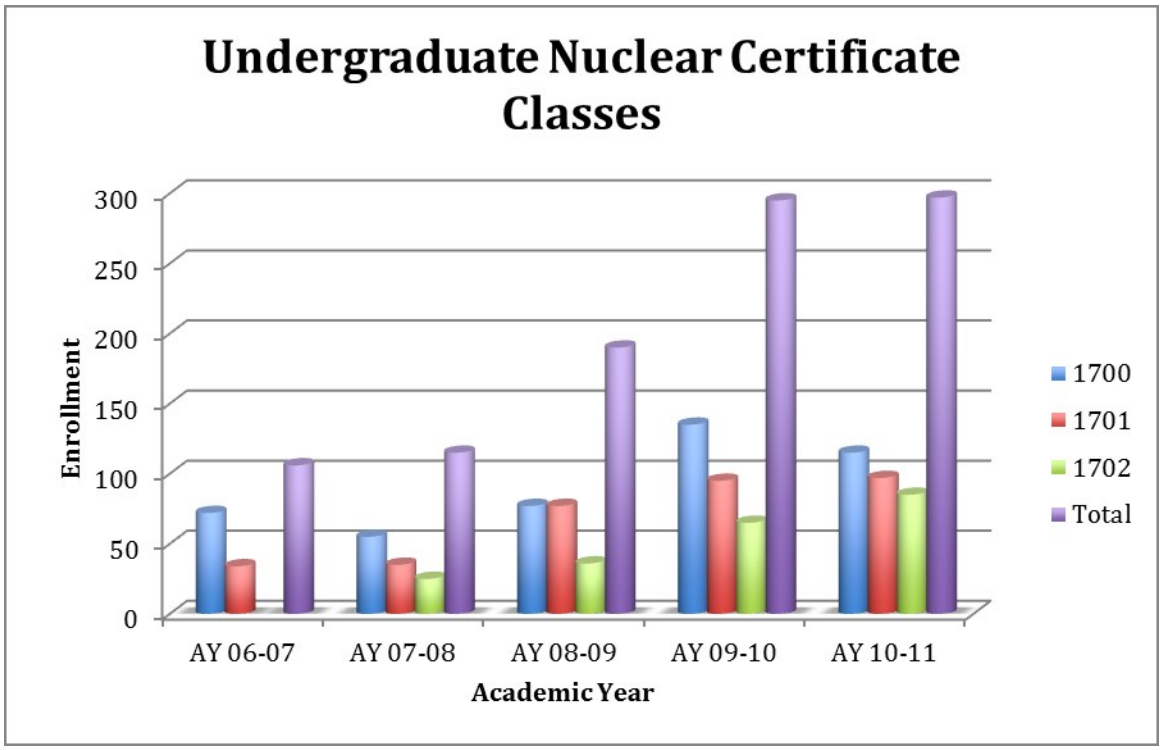

Figure 2: Typical Course Breakdown by Discipline

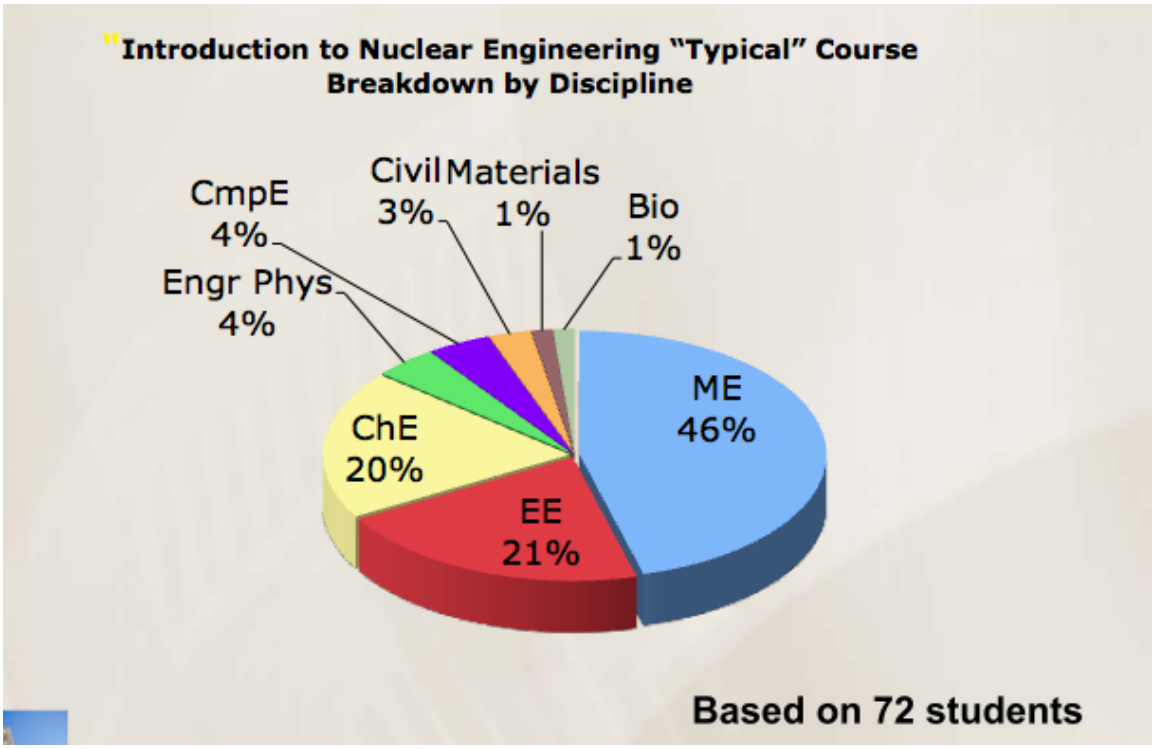

Figure 3: Graduate Class Enrollments