INIE funding: University consortia put over $9 million to good use

BY RICK MICHAL

The DOE's Innovations in Nuclear Infrastructure and Education program has helped universities strengthen nuclear engineering education in the United States . . . but the program may be going away.

IN SPITE OF all the good it has done, and as much as it seems needed, the Department of Energy's Innovations in Nuclear Infrastructure and Education (INIE) program is likely to die an early death. After a successful run of four years, the program could be zeroed out—along with its parent, the DOE's University Programs—when Congress issues the federal government's budget for fiscal year 2007.

The program's demise would be caused by the DOE's lack of a request for funding—except for fuel—to continue the University Programs. Funding awarded in 2006 will serve INIE throughout 2007, but no new funds will be made available unless Congress, through consultation with congressional staff, finds the University Programs to be worthy of extension.

INIE, which was first funded in 2002, was created to strengthen nuclear engineering education programs through the innovative use of university research and training reactors and the formation of strategic partnerships among the universities, the DOE's national laboratories, and the U.S. nuclear industry.

The funding was expected to help universities fill the nuclear-engineering manpower pipeline with students who would go on to work in the industry. Program dollars would be used, for example, to upgrade laboratory equipment and computers, establish distance-learning programs, and modernize aged facilities that often seemed to prospective students to be leftovers from a past era.

A goal, as reported in a government review of the program issued in 2005, was to fill the university pipeline with 1500 nuclear engineering students by the year 2015. INIE's own success, however, might have caused its downfall, at least according to the review. It noted, "In fact, enrollment levels for 2005 have reached upwards of 1500 students, the program's target level for the year 2015. In addition, the number of universities offering nuclear-related programs also has increased. Government support for these programs no longer appears necessary." (The review can be found online at <www.whitehouse.gov/omb/expectmore/detail.10003403.2005.html>.)

With the nuclear industry forecasted to go through big changes—new plants expected to be built, the attrition of the current-day workforce—the pipeline may need a steadier stream than those 1500 students. Certainly that may be so, but it is not likely to be provided through INIE funding.

Since 2002, INIE has supplied a total of about $39 million to university consortia through 2006. The summaries that follow describe how those consortia used some of the $9.4 million of funding under the INIE program in 2006.

Consortium of Big-10 University Research and Training Reactors

Participating institutions
Pennsylvania State University (INIE lead)
Purdue University
University of Illinois, Urbana-Champaign
University of Wisconsin, Madison
Ohio State University (added in 2004)
University of Michigan (added in 2005)
University of Cincinnati (added in 2006)

Reactors
PSU: 1-MW Breazeale reactor
PU: 1-kW reactor
UW: 1-MW reactor
OSU: 500-kW reactor

Number of years in INIE (as of 2006): 4

INIE funding for the Consortium of Big-10 University Research and Training Reactors was $1.9 million in 2006, its fourth year in the program. While all the consortium's members collaborate on all work areas, each concentrates its activities on one or two specific tasks: Ohio State, Penn State, and Wisconsin are upgrading facilities; Illinois and Purdue are developing software and visualization tools; Michigan is establishing a teaching and research laboratory utilizing neutron generators; and the University of Cincinnati will focus on subcritical reactor modifications and distance-learning course support. The consortium also receives the support of the nuclear industry and DOE laboratory partners.

All consortium members took part in the INIE-funded mini-grant program, which seeks to broaden the participation of researchers, educators, and students in the field of nuclear science and technology by providing access to Big-10 nuclear facilities. Twenty-one projects were funded at a cost of $199 000 in 2006.

At Pennsylvania State University, the consortium's INIE lead university, work is under way to expand the Radiation Science and Engineering Center (RSEC). According to Jack Brenizer, chair of Penn State's nuclear engineering department and a professor of mechanical and nuclear engineering, the architectural design of the RSEC is complete, letters of support have been obtained, and an expression of interest letter has been sent to the DOE. Penn State has committed $1 million to the project and is seeking additional funds from external sources.


Brenizer

Brenizer said that Penn State was also developing a virtual reactor for neutron activation experiments and criticality experiments. Regarding Penn State's Breazeale reactor, work continued on modeling the beam ports and benchmarking the predicted neutron spectra with existing experimental data in order to use these models to evaluate new beam port/core configurations. A modular code package has been developed for size and shape optimization of a moderator tank.

Penn State also initiated work to develop a more efficient means of data acquisition and storage, better post-processing techniques, and a more accurate quantification of water present in radioscopic images.

At the University of Illinois at Urbana-Champaign, an Internet-based lab was under development. The lab will allow those at remote sites to watch an experiment, acquire data, interact with on-site personnel, and possibly control part or all of the experiment. As a demonstration of the lab's capabilities, a boiling heat transfer experiment has been implemented in which surface and center point temperatures of a hot ball (about 400 °C) immersed in a 100 °C water bath are measured using two thermocouples and displayed using software and online tools, under the control of the remote user.

Illinois also was involved in an on-line reactor experiment conducted at the University of Massachusetts at Lowell. Students at Illinois had the same access to audio, video, and data as students at UMass–Lowell. Illinois has continued its collaboration, this time with the University of Wisconsin at Madison, on the development of a remote reactor laboratory.

Ohio State used some of its INIE funding to upgrade lab supplies. The equipment purchased included NIM (nuclear instrument module) bins, power supplies, pulse generators, oscilloscopes, spectroscopy amplifiers, NaI detectors, signal generators, multichannel analyzers, alpha spectroscopy setups, a laptop and LCD projector, mount/tether equipment, chairs for the control room and classrooms, and a white board for the control room.

Midwest Nuclear Science and Engineering Consortium

Participating institutions
University of Missouri, Columbia (INIE lead)
University of Missouri, Rolla
University of Missouri, Kansas City
Linn State Technical College
Polytechnic University of Puerto Rico
Kansas State University (added in 2005)

Reactors
UMC: 10-MW reactor
UMR: 200-kW reactor
KSU: 250-kW reactor

Number of years in INIE (as of 2006): 3

INIE funding has allowed the Midwest Nuclear Science and Engineering Consortium to hire 10 new tenure-track faculty members and one part-time instructor in the three years that the consortium has existed. Three of these new hires have replaced instructors who left the consortium's campuses, and "two of these three would not have been hired without INIE investment," said Wynn Volkert, a professor of radiology, chemistry, and biochemistry at the University of Missouri at Columbia and the interim director of the school's Nuclear Science and Engineering Institute.


Volkert

The University of Missouri at Columbia is the lead university in the Midwest consortium, which received $1.34 million in INIE funding in 2006. According to Volkert, the consortium's goals are to enhance the undergraduate and graduate nuclear engineering and radiation science programs at the member schools and to increase the use of its reactors by developing research programs with national laboratories, nuclear power plants, and other academic institutions.

Thanks to INIE funds, Volkert said, the number of undergraduate students in nuclear engineering programs has increased at Linn State's Advanced Technology Center and on the campuses of the University of Missouri at Rolla and Kansas State University. For example, enrollment of undergrad students at UM–Rolla increased from 133 in fall 2005 to 170 in fall 2006. Graduate student numbers also have increased at KSU, UM–Rolla, UM–Columbia, and UM–Kansas City.

At Linn State, six students graduated in June 2006 with Associate of Applied Science in Nuclear Technology degrees, and four of them accepted jobs at nuclear power plants. As a result of INIE's support to Linn State's program and the program's resulting success, the U.S. Department of Labor has awarded a $2.3-million grant to Linn State and UM–Columbia to work together to develop an educational program to be used on a nationwide basis for radiation protection technicians. This project will involve partnerships of technical colleges and nuclear utilities throughout the United States.

Volkert said that INIE also was used to set up a distance-learning system at UM–Columbia to link all Midwest consortium institutions. The system, called Vbrick, was first used to deliver a course taught at UM–Columbia to UM–Rolla. Vbrick's implementation with UM–KC is nearing completion, and connectivity issues with KSU and Polytechnic University of Puerto Rico (PUPR) are being evaluated. INIE funds have also been used to work with Lincoln University, a historically black university, to increase the participation of minority students in nuclear science.

Other infrastructure improvements supported by INIE funding include a new gamma spectrometer system, auto sample changing system, spectrophotometer, and particle spectrometer at UM–Rolla; a portable multichannel analyzer and neutron diffractometer at KSU; and radiation detection lab equipment at PUPR.

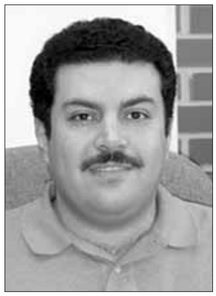
Multi-University Southeast INIE Consortium

Participating institutions
North Carolina State University (INIE lead)
University of Maryland
Georgia Institute of Technology
University of Tennessee
University of South Carolina
University of Florida (added in 2004)
South Carolina State University (added in 2004)

Reactors
NCSU: 1-MW PULSTAR
UF: 100-kW Argonaut
UM: 250-kW TRIGA

Number of years in INIE (as of 2006): 3

The Multi-University Southeast INIE Consortium received $2.65 million in INIE funding in 2006. Its lead institution, North Carolina State University, used INIE funds to establish a video conferencing and Ethernet data link system that allows the delivery of experiments from the PULSTAR reactor to other consortium members. According to Ayman Hawari, director of the nuclear reactor program and associate professor of nuclear engineering at NC State, five experiments—approach to critical, flux distribution measurement, control rod calibration by period method, rod drop, and power defect—were delivered to the Georgia Institute of Technology. Seven more—reactor startup, approach to critical, rod calibration with the rod bump method, temperature coefficient of reactivity, heat balance for determination of reactor power, inverse kinetics based on rod drive in data, and foil irradiations—were sent to the University of Tennessee. South Carolina State University is expected to take advantage of this system for its nuclear engineering curriculum in the near future.

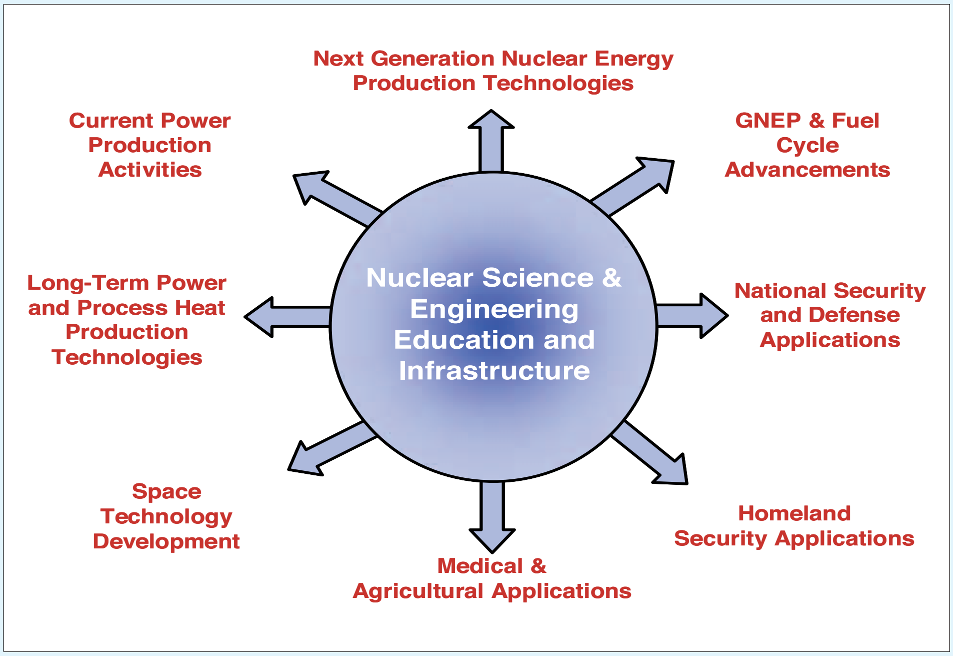

Hawari

NC State also completed the design of the cryogenic system in the Ultra-Cold Neutron Source, and components for that system have been ordered. The neutronics design has been completed and the guide system has been inserted into the PULSTAR reac-

ANS special committee's report: The need for federal funding of nuclear education

Following the U.S. Department of Energy's fiscal year 2007 budget submission, which states that "Federal assistance [for nuclear education] is no longer necessary, and the 2007 Budget proposes termination of the University Reactor Infrastructure and Education Assistance Program," the American Nuclear Society, at the request of current president Harold McFarlane, formed the Special Committee on Federal Investment in Nuclear Education.

The committee's charge was to develop a conceptual framework for future federal investments in nuclear science and engineering education. To do this, the committee was tasked with reviewing current DOE programs aimed at educating the next-generation workforce, making recommendations on the optimal programmatic structure of these programs, and proposing a set of appropriate metrics by which the programs could be evaluated for effectiveness. The committee, chaired by Warren "Pete" Miller, of Texas A&M University, consisted of the following members: Denis Beller, University of Nevada, Las Vegas; Michael Corradini,



Nuclear science and engineering workforce drivers (Graphic: NEI)

University of Wisconsin; James Duderstadt, University of Michigan; Audeen Fentiman, Purdue University; Marvin Fertel, Nuclear Energy Institute; Andrew Klein, Idaho National Laboratory; and Craig Piercy, American Nuclear Society,

tor pool. Work is under way to finalize the design of the cryostat, and shielding studies are being done. INIE is providing funds for the support of a research scientist and a graduate student. The National Science Foundation is providing the bulk of the funding ($900 000) for equipment through a separate grant.

For its Intense Positron Source, NC State completed the design of the beam line to be inserted in a PULSTAR beam port. The beam line has been constructed and tested successfully using an Na-24 source. The tests showed that the projected positron rates are ~ 5×10^8 e+/s. This project is currently funded by NSF ($1 million) and represents a direct example of how research seeded by INIE funds can be leveraged to generate additional funding for research reactors.

For its neutron diffractometer, installation was completed and testing is under way to verify system characteristics such as resolution and rocking curve. The neutron imaging facility at the PULSTAR is also completed and testing of its real-time neutron radiography and tomography system is being carried out.

At the University of South Carolina, purchases were made to complete a Web-based radiation measurement lab. Classes are being offered over the Web, including basic courses that demonstrate the principles of radiation detection instrumentation and concepts.

Georgia Tech and the University of Maryland are working together on an advanced lithium fluoride (LiF) dosimetry system. The objective of this project, which was part of the original INIE proposal in 2002, is to develop a system for a mixed neutron and gamma field. The concept is to optimize concentrations of Li-6 (which responds to $n+\gamma$) and Li-7 (which responds to γ only) in LiF such that the gamma and neutron doses can be accurately measured.

Cell irradiation infrastructure improvements are being made in support of research to evaluate the boron (or gadolinium) enhanced cell-killing effect on human prostate cancer cells.

Georgia Tech and Maryland also collaborated on a biodosimetry project that had the objective of establishing the appropriate radiation environment to perform this experimental work. Locations in Maryland's reactor were optimized using Monte Carlo simulations of potential irradiation positions.

Maryland used INIE funding to upgrade its irradiation facilities. A shielding plug was designed and fabricated to yield a neutron:gamma ratio suitable for cell irradiation studies. The ratio of fast n:gamma, which was initially 3:7, was reduced to 1:1.5, which is acceptable for the research. Also, an access plug was designed that will have an incubator in which cells can be exposed to neutrons while undergoing growth. The university allocated space for a cell culture lab, the design of which has been completed. The university would not have allocated funds for this laboratory ($115 000) if not for INIE.

In addition, the University of Florida and Georgia Tech are currently collaborating to devise novel techniques of neutron (and radiation) transport to best simulate research reactors. This work started last year and is currently under way, with INIE providing graduate student funding at both institutions.

New England Consortium

Participating institutions
Massachusetts Institute of Technology (INIE lead)
Rhode Island Nuclear Science Center
University of Massachusetts, Lowell

Reactors
MIT: 5-MW reactor
RINSC: 2-MW
UML: 1-MW

Number of years in INIE (as of 2006): 4

staff liaison.

The results of the committee's work have been published in a report, *Nuclear's Human Element: Defining the Federal Government's Role in Sustaining a Vibrant U.S. University-Based Nuclear Science and Engineering Education System for the 21st Century*. In the executive summary of the report, the committee points out that "nuclear technology will continue to be a critical focal point of U.S. national security, foreign, energy, and environmental policies" well into the future, and that the United States will have to continue to educate and train new nuclear scientists and engineers in order to meet the needs of a growing industry. The report notes that from the beginnings of the development of nuclear science and engineering in the United States—as far back as the Atomic Energy Act of 1946, and then in subsequent legislation—Congress recognized that stewardship of the system "is a unique federal responsibility." In the 1980s and 1990s, however, a combination of declining enrollments, federal funding, and industry support contributed to a dramatic decline in the United States' ability and capacity to supply nuclear science and engineering (NSE) graduates to the workforce.

According to the report, the anticipated growth in the nuclear industry is putting new demands on universities to supply more appropriately trained personnel. "While reliable data are scarce," notes the report, "there is significant anecdotal evidence that the DOE, the national laboratories, other federal agencies, nuclear technology companies, and university nuclear engineering departments are currently experiencing or anticipate significant shortages of qualified U.S. NSE graduates." Therefore, the committee concludes, "a clear national interest exists for the federal government, primarily through the DOE, to continue to expand its stewardship of the U.S. nuclear education enterprise. . . . America's university-based NSE programs cannot continue to be leaders in the field without an active DOE university program."

In the report, the committee provides goals and a set of metrics for measuring the achievement of those goals, and makes six specific recommendations, based on its findings, to the DOE and Congress, as follows:

1. The DOE should undertake a detailed NSE workforce study to determine the aggregate demand for nuclear-educated graduates in the next 5–10 years.
2. The DOE should revise the current university program along the lines of what has been envisioned in the "Chicago Framework" (the results of an October 2006 DOE workshop to discuss new directions for university nuclear programs), making it more mission-driven and giving it a stronger research orientation and peer-review component.
3. Congress should retain a separate funding line for NSE university programs in the Energy and Water Appropriations Bill for FY 2007 and future years.
4. Congress should increase funding for university programs commensurate with the levels authorized under the Energy Policy Act of 2005.
5. Congress should enact and fully fund the DOE Office of Science–administered Nuclear Science Education program included in S. 2197 (the PACE [Protecting America's Competitive Edge]-Energy Act) and S. 3936 (the National Innovation Competitiveness Act).
6. The DOE should establish an interagency working group on NSE that would provide high-level guidance on the overall structure of NSE university programs.

ANS has distributed the report to members of Congress and specific personnel at a number of government agencies and nongovernmental organizations. It is available on the ANS Web site at <www.ans.org/pi/fine>. For more information, contact the Outreach Department at <outreach@ans.org>.—*Betsy Tompkins*

The New England Consortium received $1 million in INIE funds in 2006, the main share ($850 000) going to the Massachusetts Institute of Technology as the consortium's lead university. According to John Bernard, principal research engineer at MIT's reactor, INIE has allowed the consortium to expand as well as extend its research capabilities and provide services to many scientists, researchers, private industry, national laboratories, and nuclear engineering students.

The INIE-funded High Temperature Irradiation Facility (HTIF) represents a major achievement for the MIT Nuclear Reactor Laboratory, Bernard said. The HTIF was designed to provide an environment appropriate for test irradiations of high-temperature gas-cooled reactor materials. After its installation in November 2005, an initial four-month in-core irradiation was performed, with temperatures up to 1600 °C. A variety of materials relevant to high-temperature gas-cooled reactor design—including SiC, advanced gas-cooled reactor matrix graphite, and non-fueled coated particles—were irradiated.

The development and in-pile testing of high-temperature–resistant materials are essential for the Generation IV reactor program, said Bernard, who noted that the HTIF provides a unique capability among university research reactors. It also contributes to the national research mission in nuclear energy and is an important teaching facility for undergraduate and graduate students, he said.

An assessment of the feasibility of water-based nanofluids for nuclear reactors is another INIE-supported research project at MIT that Bernard said is attracting a lot of attention among nuclear engineering students and the nuclear engineering community. The potential reactor applications include advanced coolants, as well as reactor cavity flooding for in-vessel retention during severe accidents.

Another critical project being conducted at MIT is neutron phase contrast imaging, which will provide the MIT reactor with a state-of-the-art neutron imaging system. The project's aim is twofold: The imaging facility can be used for industrial and research purposes, notably in the study of materials, and the system will be of great educational value, providing insight into the experimental functioning of neutron phase contrast and providing a facility to test new ideas.

INIE funds were also used to develop the neutron capture therapy (NCT) user facility at MIT, which is now available to serve the 13 groups conducting NCT research in the United States. In addition, MIT used INIE funds to purchase a neutron diffractometer for research on novel optics such as quantum image processing, characterization of new materials, and development of new instrumentation concepts.

Another consortium member, the Rhode Island Nuclear Science Center (RINSC), used INIE funds to buy a liquid scintillation counter, tissue-equivalent ion chambers for NCT, and a neutron activation analysis sample changer for analyzing heavy metals in air filters. RINSC also refurbished two diffractometers for neutron scattering research.

In the research arena, INIE funds helped RINSC continue its gadolinium NCT research program, which is focused on determining whether Gd can reduce the mobility of cancer cells in the brain.

At the University of Massachusetts at Lowell, a collimator was refurbished, and Monte Carlo modeling is being conducted to optimize the beam line. The university also bought a high-resolution scanner, completing its remote radiography system. INIE funds have also enabled UMass–Lowell to develop an outreach program that allows students at other campuses to learn about the operation of the Lowell reactor.

Section continued

Southwest Consortium of Research Reactors

Participating institutions
Texas A&M University (INIE lead)
University of Texas
University of New Mexico
Prairie View A&M University

Reactors
TAMU: 1-MW TRIGA
UT: 1-MW TRIGA
UNM: 5-W AGN

Number of years in INIE (as of 2006): 4

INIE funding for the Southwest Consortium of Research Reactors was more than $1.27 million in 2006, the fourth year of the group's existence. Texas A&M University (the consortium's leader) and the University of Texas (UT) received the bulk of that funding.

At Texas A&M, a high-purity germanium detector was installed in the gamma spectroscopic analysis laboratory. The detector features 35 percent relative efficiency and 1.8-keV resolution. Also, a new beta/gamma ion chamber was installed in the pneumatics laboratory, replacing an existing area radiation monitor and a portable gamma ion chamber that were insufficient for determining beta dose levels while handling compact high energy beta sources from activation analysis. The new chamber has its own preset visual and audible alarms.

Texas A&M also upgraded the reactor building's air monitoring system by replacing the old ratemeters with a computer monitor to improve readability, allow better calibration of the channels, and improve manipulation of the data.

As in previous years, a significant portion of the INIE budget was devoted to the support of graduate students in order to expand the research program at Texas A&M. In 2006, support was provided for five Ph.D. students and two master's degree students.

In addition, students worked at the Texas A&M reactor and received training in reactor-related areas, specifically as reactor operators (three undergraduate students), senior reactor operators (two undergraduate students and one graduate student), duty health physicists (three graduate students), duty health physicist trainees (two graduate students), a radioactive shipper (one graduate student), and radioactive shipper trainees (three graduate students and one undergraduate student). INIE's funding of this training is considered to be research seed money in the sense that the students are building research infrastructure or performing proof of principle studies, thereby laying the base for long-term, self-supporting research programs.


O'Kelly

At UT, research work is expanding, requiring more lab space. In 2006, 600 square feet of new office space was acquired with INIE funding to free up the needed lab space. Sean O'Kelly, associate director of the Nuclear Engineering Teaching Laboratory at the university, said that the lab space will be used as a student instrument workplace equipped with distance-learning tools.

Work is continuing in two parallel phases on UT's intense positron source, according to O'Kelly. The first phase consists of beam line characterization and optics with Na-22, the design of the positron spectroscopy system, and the design of the sample chamber. A new electromagnetic beam transport system (for 3-eV positrons) was developed to replace the original electrostatic system. An in-house system was fabricated and found to work, although positron yields were low. To increase the yields, the in-house system was to be replaced by electromagnets obtained from the Idaho Accelerator Laboratory. Also, new tungsten wire mesh etching and annealing techniques were being developed, and various beam line source modifications have been made. The second phase involving UT's intense positron source is concerned with the copper source. The focus of current work is on electroplating a thin layer of copper on a carbon substrate.

Western Nuclear Science Alliance

Participating institutions
Oregon State University (INIE lead)
University of California, Davis
Washington State University
University of California, Berkeley
Idaho State University
Reed College
University of California, Irvine
University of Nevada, Las Vegas
University of Utah

Reactors
OSU: 1.1-MW TRIGA
UCD: 2-MW TRIGA
WSU: 1-MW TRIGA
ISU: 5-W AGN
UCI: 250-kW TRIGA
UU: 100-kW TRIGA

Number of years in INIE (as of 2006): 4

The Western Nuclear Science Alliance received $1.25 million in INIE funding in 2006, the consortium's fourth year of existence. The consortium's leader, Oregon State University, received just over half of the funds.

OSU used some of the funds to enhance its distance education program, according to Steve Binney, the consortium's director and a professor emeritus of OSU's Department of Nuclear Engineering and Radiation Health Physics. Nine radiation health physics courses were taught by the distance-learning method in the past year: radiation protection (three students); radioecology (four students); radiophysics (seven students); radiation biology (nine students); nuclear rules and regulations (seven students); radiochemistry (six students); nuclear radiation shielding (two students); advanced radiation detection and measurements (five students); and applied radiation safety (eight students).


Binney

OSU also used INIE funds to support a professor, Alena Paulenova, for its radiochemistry education program. Paulenova teaches a graduate-level radiochemistry course and has developed an active research group that consists of four graduate students, two undergraduate students, and a post-doctoral researcher. The research is being conducted in the following areas: speciation and distribution of plutonium and other actinides in the UREX separation process, structural studies of actinide complexes with organic ligands, kinetics of radiochemical reactions, surface reactivity and imaging of irradiated surfaces, and radiolabeled nanoparticles for imaging.

In addition, six scholarships were provided to undergraduate minority and/or female students at OSU for study in nuclear engineering and radiation health physics. Three graduate students are fully funded under INIE, while leveraged INIE funds (with money from other sources) support 13 other students.

At the University of California at Irvine, the 250-kW TRIGA reactor is used primarily for neutron activation analysis. According to Binney, the goals of the INIE program at UC Irvine are to create a student pipeline and to expand faculty and research use of the reactor. A major activity is a junior/senior–level course in radioisotope techniques, which had an enrollment of 30 in spring 2005 and 38 in spring 2006. In addition, INIE funds were combined with dollars from other sources to purchase equipment and supplies for public outreach activities. These purchases included an LCD projector, a camera for close-up demonstrations, a laptop computer, handheld Geiger counters, Fiestaware samples, thorium mantles, uranium glass marbles, and large survey meters.

Regarding infrastructure improvements, OSU's Neutron Radiography Facility was completed in 2006. An imaging instrumentation suite that will include a capability for real-time measurements is under development, and during the past year a digital imaging plate system was ordered. Graduate students are being supported by INIE funds to assist in the development of the facility and are basing their theses on the work. Similar neutron radiography and tomography upgrades have been made under INIE at the University of California at Davis.

At Idaho State University, work continued on the replacement of the reactor console for the AGN reactor. Undergraduate and graduate students supported by INIE funds performed most of the work, according to Binney. A master's degree student whose thesis will document the console replacement is doing the overall system integration, testing, and implementation.

The University of Utah is developing a vertical beam port. The design was nearing completion at the end of 2006, and the safety analysis was proceeding. Also at Utah, a neutron-induced autoradiography system is being developed for analyzing tissue samples.

Under INIE funding, Washington State University has been conducting four-week radiochemistry education programs for regional college chemistry professors and one-week programs for high school science teachers. These faculty members in turn have incorporated this material into their curricula. NN