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Education, Training, and Workforce Development

Special Section begins on page 31

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DEPARTMENTS

Coming up . . .

February—Special Section on Instrumentation & Controls

March—21st Annual Reference Issue

April—Special Section on Supply Chain

On the cover: Graduate research assistant Robyn Collette researches the rapid growth of promising inorganic scintillator candidates at the University of Tennessee at Knoxville's Scintillation Materials Research Center. An article about the growth and transformation of UTK's nuclear engineering program is included in the Special Section on Education, Training, and Workforce Development, which begins on page 31. (Photo: University of Tennessee at Knoxville)

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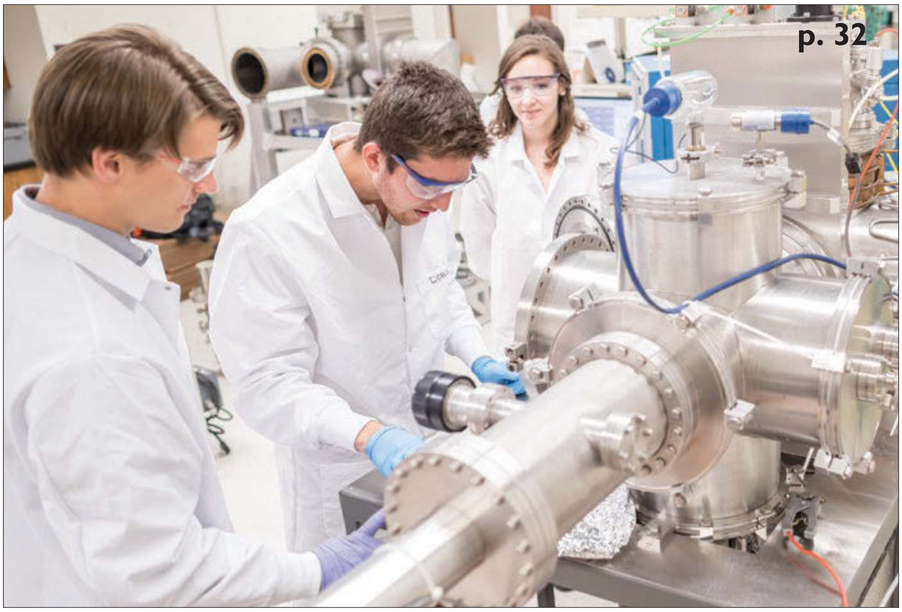
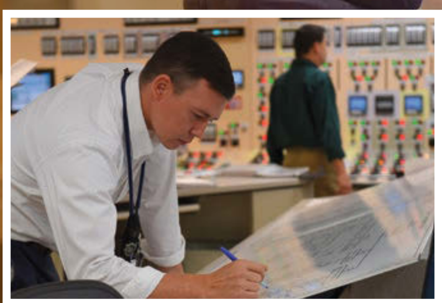


p. 32

Nuclear News Special Section

Education, Training, and Workforce Development



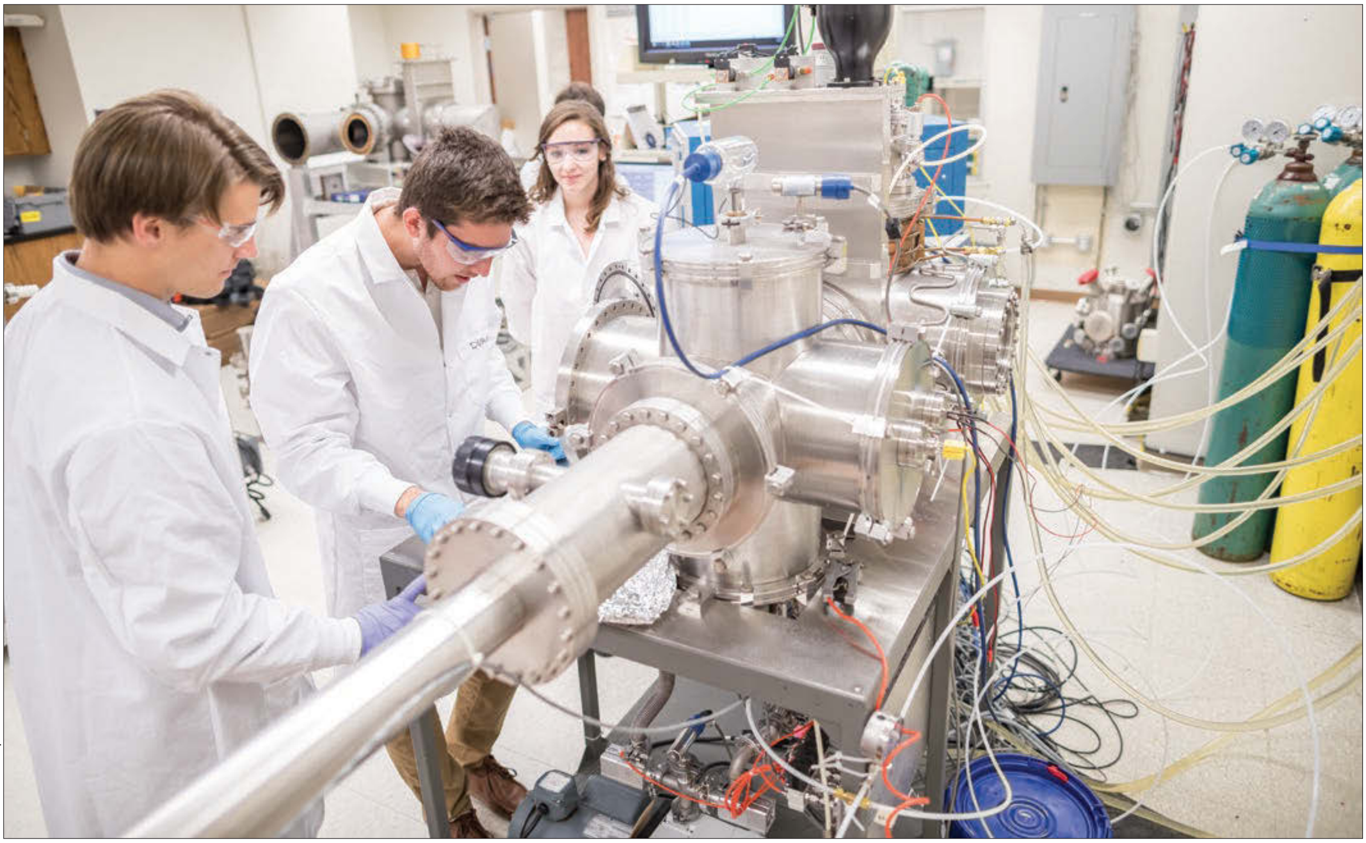


Photo: University of Tennessee at Knoxville

Several of Prof. David Donovan's students (from left), Jack Nowotarski, Jonah Duran, and Lauren Finney, perform research using the plasma materials interaction chamber at the University of Tennessee at Knoxville.

U of Tennessee nuclear engineering: A decade of transformation

Through a systematic approach and with a clear vision of success, UT has reshaped its nuclear engineering Ph.D. program into one of the best in the country.

By J. Wesley Hines

In 2018, the University of Tennessee at Knoxville's Nuclear Engineering Department (UTNE) graduated 24 doctoral students—a record number for any nuclear engineering program in the United States, ever. These graduates have gone on to work in industry, government, and national laboratories supporting the nuclear industry in energy, security, and medicine.

Success like that didn't just happen overnight. It was the result of foresight, planning, growth, and carefully considered decisions made over a period of years in an effort to create the most well-rounded and high-value program possible. The process and strategies implemented to transform the department—which graduated only two Ph.D. students in 2008—are described in the following pages.

Forming a vision

In 2008, UTNE had nine faculty members, 24 Ph.D. students, and $2 million in external research expenditures, and its graduate program was ranked 11th in the country by *U.S. News and World Report*. At that time, the department had tripled its enrollment over the previous decade and had increased its tenured/tenure-track faculty from seven to nine in the prior year. The department, however, had a much grander vision and began a major initiative to improve its program ranking to the top five. Lee Dodds, department head at the time (and now a professor emeritus in the Nuclear Engineering Department), coined the phrase "Drive to the Top Five," and the department began a process to develop a strategy for growth and quality improvement. Improving the department's ranking and reputation would lead directly to the desired outcomes: recruitment and retention of more qualified students and faculty, and better competitiveness for federally funded research grants.

A vision such as this requires leadership, teamwork, and buy-in from the entire faculty to make structural changes to promote and reward performance improvements. The faculty coined the tagline "Study Nuclear Engineering: Save the World," which encapsulates everything

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nuclear engineers do, including in the areas of energy, medicine, and security. Carbon-free nuclear power has the ability to reduce greenhouse gas emissions and combat global warming, to ensure that following generations have the same opportunity to grow up in a world with clean lakes and lush forests. Faculty also focus on the need to treat cancer and other diseases through the use of radiation-based diagnostics and treatment. Rounding out the message is the application of nuclear security policy and technology to make the world a safer place to live. This tagline has brought the faculty, staff, and students together to have a positive impact on our world and on that of following generations.

Planning and evaluations

For several years, Prof. Larry Townsend led a yearly benchmarking assessment to identify important performance metrics and compare UTNE's performance to the top nuclear engineering programs in the country. Metrics such as enrollment, research expenditures, and the number of graduates and tenured/tenure-track faculty were routinely collated by the American Society for Engineering Education. Departmental productivity data, such as research expenditures and number of graduates, were normalized by the number of tenure-track faculty to better understand the productivity of individual faculty members at the top programs. This benchmarking effort identified several areas for improvement, chief among them the recognition that the number of Ph.D. students was the single most highly correlated metric to national ranking. This should come as no surprise, as high-impact, novel research is driven by Ph.D. candidates in successful research programs. National research impact can be tracked by the number of high-quality journal publications, primarily authored by successful Ph.D. candidates. In addition, the number of Ph.D. students is related to research expenditures, because virtually all full-time Ph.D. students are funded by research projects. Increasing the number of Ph.D. candidates supported within UTNE would require significant growth in externally awarded research grants and would result in greater research impact on issues of national significance.

After performing the benchmarking studies, the department developed goals and updated its strategic plan at a faculty retreat. The number-one goal driven by the department's board of advisors and students' future employer expectations was to develop a strong safety culture, but other goals focused on actionable steps to improve departmental and faculty performance metrics. These strategic goals were used to develop an implementation plan that delegated specific responsibilities to the faculty and to the department head. The implementation plan outlined quantitative expectations for faculty teaching loads and evaluations, Ph.D. students supported and advised, research expenditures, salary recovery, journal paper publications, and national professional service activities. The department head was assigned responsibilities to develop and implement plans to improve graduate recruitment; undergraduate research, internships, and co-ops; faculty and student diversity and representation; faculty development and growth; and communication with internal and external stakeholders. The faculty unanimously approved the strategic plan and moved forward with its implementation.

In 2012, I became the head of the Nuclear Engineering Department, with its 12 faculty members and a *U.S. News and World Report* national ranking of 9. One of my first initiatives was to tie faculty annual performance evaluations to the expectations stated in the strategic plan. I developed an evaluation rubric with several quantitative metrics in each area of teaching, research, and service for each level of faculty: assistant, associate, full, and Governor's Chair. The underlying purpose of these quantitative annual evaluation rubrics was to challenge faculty to meet ambitious performance goals and to help faculty align their efforts with the departmental priorities articulated in the strategic plan.

The faculty unanimously approved the evaluation rubrics, which were incorporated into the departmental bylaws. Over the next several years, the faculty exceeded the majority of their performance metrics, which has led, with agreement of the faculty, to continued revision of the faculty expectations at each level. By providing explicit, quantifiable performance goals, faculty know where to focus their time to best support departmental goals and encounter no surprises at their annual performance evaluations. Faculty have welcomed the continuing update of performance expectations and have responded with continually improving performance.

Faculty growth

One area where the department was clearly deficient in 2008 was the number of tenure-track faculty. Some of the top programs had up to 20 faculty members, which allowed them to benefit from economies of scale in distributing teaching and service loads. When a department must teach the classes required for an accredited nuclear engineering program with nine faculty members, there is much less time for them to propose and perform research and mentor graduate students. Larger faculty sizes allow for smaller teaching and service loads and more time for scholarly activities, leading to greater national impact.

As all academics understand, the goal of increasing the number of faculty is limited by college resources. The state of Tennessee and Oak Ridge National Laboratory (ORNL), however, developed the Governor's Chair (GC) program to bring exceptional researchers to work jointly with the nation's largest multi-program laboratory and the state's flagship university. Each GC hire comes with a junior hire to build a small team in the thematic research area.

The first nuclear engineering Governor's Chair, Prof. Howard Hall, was hired in 2009 to develop and lead a program in nuclear security, and Prof. Steven Skutnik was brought on in 2012 as his junior faculty hire. In 2010, Prof. Brian Wirth was hired as the Governor's Chair for Computational Nuclear Engineering with an emphasis in materials behavior under extreme environments, and junior faculty Prof. Maik Lang was brought on in 2013. The focus on nuclear security and materials came from an analysis of national and ORNL needs and gaps in the current departmental faculty.

In 2009, the Department of Energy's Nuclear Energy University Program was initiated, and 70 percent of early funding was in the materials area. The Nuclear Engineering Department had only one research faculty member in materials at that time, and the decision was made to invest heavily in this area. In 2013, Prof. Steve Zinkle was hired as the Governor's Chair for Nuclear Materials, with junior faculty Prof. David Donovan added in 2014. Zinkle's hiring was synergistic with the Materials Science and Engineering Department's hire of Prof. William Weber, the Governor's Chair for Radiation Effects on Materials. Adding three GCs and three junior hires in the area of nuclear materials across two engineering departments resulted in one of the strongest materials research groups in the country. The expansion of the department's expertise in nuclear security and materials concluded with the development of almost 20 new undergraduate and graduate courses that provide the foundational skills for research in those areas.

The addition of the GCs to UTNE not only expanded the department's expertise and allowed for reduced teaching loads, it also changed the culture of the entire faculty. Prior to their hiring, the UTNE faculty were predominately writing and submitting research proposals in the range of \$100,000 to \$200,000. The new GCs were submitting center-level proposals in the million to multimillion-dollar range, and the other faculty began submitting larger, more impactful grant proposals. The GCs also saw the value in hiring research facul-

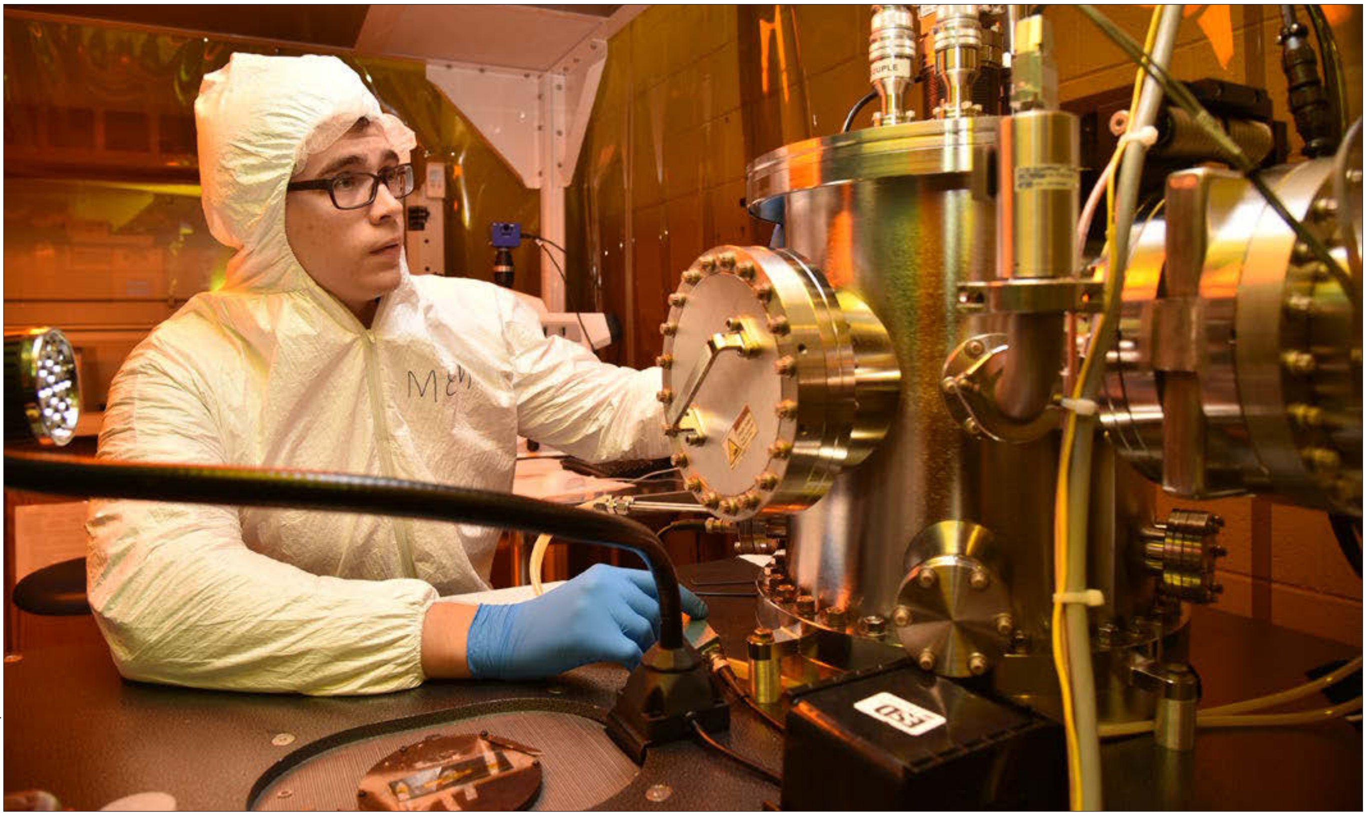

Photo: University of Tennessee at Knoxville

Ph.D. candidate Michael Moore conducts research on how to sputter and diffuse an activator material into a scintillator in the Micro-Processing Research Facility, located in the university's Joint Institute for Advanced Materials.

ty, postdoctoral researchers, and research scientists to grow large research groups, while prior faculty focused primarily on investing research dollars in master's and doctoral students. Faculty members are limited as to the number of Ph.D. students they can effectively mentor, and the incorporation of dedicated research staff allowed that number to grow. Also, the department was limited to a certain number of tenured/tenure-track faculty lines, but to break from that restriction, the department grew its full-time research faculty to increase external research and scholarly impact. In addition to their 16 tenured/tenure-track faculty, it currently has three full-time research faculty, 11 research scientists, six postdoctoral researchers, 13 part-time research faculty, and close to 30 adjunct faculty who assist with teaching, research, strategic initiatives, and student mentoring.

The department also developed transparent processes to stimulate teamwork with the goal of supporting all faculty to be successful. One such process was the sharing of individual performance metrics. Monthly reports comparing current-year individual faculty research expenditures and salary recovery with prior-year numbers are sent to all faculty. This allows them to identify year-to-year changes and offer assistance when warranted. This was one of many processes that affected the growth of UTNE research expenditures from $2 million to $12 million over a decade.

Incentive systems

It is one thing to have top faculty and known performance expectations, but how does one incentivize a faculty member to far exceed those expectations? The department's research-oriented faculty incentive system has two components. The first is based on research incentive funds (RIF). When external research budgets include overhead, an amount equal to 30 percent of that overhead flows back to the department as RIF. Most engineering college departments split RIF between the department operating budget and the faculty member, but nuclear engineering returns 100 percent of the RIF to the faculty member to use for scholarly activities, such as supporting undergraduate research, traveling to conferences to present research results, and purchasing research equipment. Faculty can most efficiently invest these resources to improve their productivity year over year. The RIF returned to the faculty is on the order of $400,000 each year. By allowing faculty to proportionally benefit from performing external research, they are incentivized.

The second method of incentivizing faculty to exceed expectations is through the Research Incentive Plan (RIP), the stated purpose of which is to enhance the quantity and quality of externally funded research by incentivizing faculty. The mechanism for doing so is to provide a salary supplement in the form of a yearly bonus for faculty who are effective in securing extramural funds while maintaining their other scholarly responsibilities. UTNE's departmental bylaws explicitly state the expectations in a rubric form, and the faculty must meet or exceed expectations in each overall area of teaching, research, and service to be eligible for the RIP program. If eligibility requirements have been met and the department head determines that resources are available within the unit, an incentive payment—based on the amount of RIF returned and the faculty salary recovered—is given at the end of the fall semester. The Nuclear Engineering Department is highly engaged in research, and faculty are expected to recover 20 percent of their salary (on average, they recover 32 percent each year). The bonus is up to 15 percent of the faculty member's nine-month salary, and approximately two-thirds of the faculty have become eligible for a bonus each year.

A third incentive program is focused on graduate students. To celebrate student scholarship, the department established the First Step Award. When a graduate student publishes his or her first paper as first author, a financial award is given and the paper is posted on the First Step Award board, which is prominently displayed outside the departmental administrative office. Having their first peer-reviewed journal article displayed has become graduate students' badge of honor.

Focus: Research, Ph.D.s

In 2008, the department's graduate student body was 70 percent master's degree students and 30 percent doctoral students. To support the department's strategy of focusing on growing scholarship, the emphasis was shifted toward Ph.D. students, who would be in the program long enough to generate significant research contributions and provide national impact. By 2018, the student body had transformed to 15 percent master's students and 85 percent doctoral students. For the last three years, UTNE has had the largest Ph.D. enrollment of all U.S. nuclear engineering programs, with up to 132 Ph.D.-seeking students. About 30 of these students are funded through national competitively granted fellowships, and another nine are supported by the military. The remainder of the students are largely funded through external research awards. Figure 1 shows the strong growth of graduate school enrollment and research expenditures over the last decade.

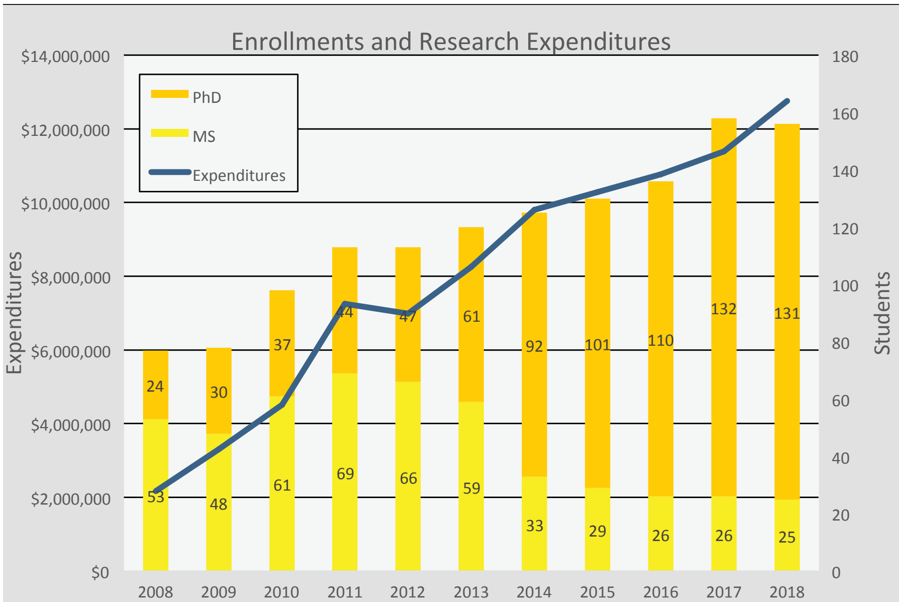

Fig. 1. UTNE graduate enrollment and research expenditures over the last decade

In fall 2001, the department started the first distance-education M.S. program in nuclear engineering in the United States. This program provided increased M.S. enrollment for over a decade, but with the entry of several other universities into the distance-education market, UTNE no longer had a competitive advantage, and enrollments were declining. With the newer focus on Ph.D. students and larger, more impactful, research projects, M.S. program growth was no longer a strategic objective, and freeing up faculty time for research activities was made a priority. In 2014, the department announced the phaseout of its distance-education M.S. degree program.

With the focus on Ph.D. students and research, the department had a need to recruit top students from across the country. In 2011, the department instituted a focused graduate recruiting process in which top students from across the country were flown in for a recruiting visit. The visit was made more impressive by incorporating a tour of unique research facilities at ORNL and a departing lunch attended by nuclear executives from the area. More than 100 nuclear-related companies are located within 50 miles of the University of Tennessee. The largest companies partner with the UTNE program to attract the best and brightest to the East Tennessee area.

In addition to recruiting top students from across the country and internationally, the department also invested in developing its own students for potential postgraduate degrees. On average, 46 percent of UTNE undergraduates participate in undergraduate research, and 66 percent participate in the co-op program or internships prior to graduation. Undergraduate research experiences and national laboratory internships give students an opportunity to decide if they enjoy research and want to pursue postgraduate education. About half of the department's undergraduates go on to graduate school after completing their bachelor's degree, with about half of those staying at UTNE.

In 2010, the University of Tennessee and ORNL founded the Bredesen Center for Interdisciplinary Research and Graduate Education to promote advanced research and to provide innovative solutions to global challenges in energy, engineering, and computation. The Bredesen Center initially offered a Ph.D. degree in Energy Science and Engineering (ESE) and more recently added a Ph.D. in Data Science and Engineering (DSE). UTNE has several faculty with appointments as Bredesen Center faculty and who are the major advisors of Bredesen Center students. Currently, 15 of the department's 131 doctoral students are pursuing a Ph.D. in ESE, and one is pursuing a Ph.D. in DSE.

Ph.D. student enrollment is a leading indicator of Ph.D. graduates, and, as expected, increases in Ph.D. graduates followed the enrollment increases. UTNE's 2018 class of 24 Ph.D. graduates surpassed the Massachusetts Institute of Technology's 2014 class of 22. Figure 2 shows the exceptional growth in degrees granted over the last decade.

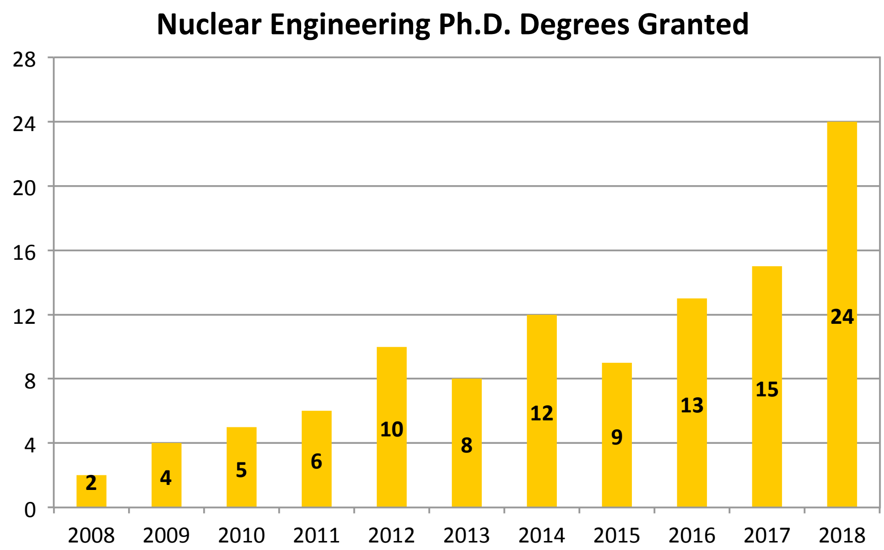

Fig. 2. Ph.D. graduation growth over the last decade

Facilities

UTNE, which has been housed in the Pasqua Nuclear Engineering Building for the past 40 years, moved to temporary quarters at the end of 2017. Pasqua was demolished in summer 2018 to make way for a new $129-million engineering complex that will house UTNE and the Tickle College of Engineering's freshman program. The department will triple its 2008 facility footprint, with 32 faculty offices, 20 postdoctoral researcher offices, staff offices, classrooms, conference rooms, collaboration areas, break areas, and 23 new laboratories, including a heavily shielded area housing a Varian linear accelerator and the proposed Fast Neutron Source[1]. These research facilities will support new research directions for UTNE and attract more top students and faculty. New instructional facilities include teaching laboratories and a full-scope reactor simulator lab. This state-of-the-art engineering complex will bring the nuclear engineering program under one roof and is on track to open in the summer of 2021.

Image: University of Tennessee at Knoxville

A computer-generated rendering of the new engineering complex that will house the University of Tennessee's Nuclear Engineering Department.

The transformation

Through a process that has included benchmarking, strategic planning, evaluating, incentivizing, hiring, and recruiting, the University of Tennessee has transformed its nuclear engineering Ph.D. program into the largest in the country. This transformation resulted from the teamwork of top students, staff, faculty, and partners, and will culminate with its relocation into new facilities.

The class of doctoral students who set the record for the largest nuclear Ph.D. engineering class in U.S. history didn't come to UT with that goal in mind. They didn't come because of a $129-million building that is finally under construction. They didn't come on a whim. They came because the department was, and continues to be, energized by a stellar faculty with big ideas who are conducting meaningful research in one of the country's top places to study nuclear engineering. It started with a plan that was laid out before they finished their undergraduate work, was followed through in detail, and has now come to fruition.

Reference

1. Hines, J. W., J. Pevey, and V. Sobes, "Preliminary Design of a Fast Flux User Facility at the University of Tennessee." *Transactions* of the 2018 American Nuclear Society Winter Meeting. NN