Department of Nuclear Science and Engineering

The Department of Nuclear Science and Engineering (NSE) had an extremely active and successful year. With strong support from the dean of the School of Engineering, the department continued to expand its faculty ranks through hiring and promotion of junior professors. The Low-Carbon Energy Center at the Center for Advanced Nuclear Energy Systems saw important growth in private-sector sponsorship for advanced fission energy research. The study titled the Future of Nuclear Energy in a Carbon-Constrained World, which has broad sponsorship from the private sector, including the Sloan Foundation, was successfully launched and has already begun to provide important insights. The Alcator C-Mod fusion experiment concluded its operations by achieving a new world record for magnetically confined fusion plasma pressure. Continuing developments in the use of high-temperature superconducting electromagnets indicate an exciting future. The department's nuclear security efforts continued to grow with the addition of Stanton Fellows and new hardware capabilities.

The department also had a successful year of fundraising. One example is a $1.6 million gift that established the David T. Leighton Fund. David Leighton was among the first to earn an MIT master's degree in nuclear engineering. He graduated from the US Naval Academy in 1945 and went on to earn a bachelor's in electrical engineering from MIT in 1948. As a naval officer, in 1953, Leighton earned an MIT master's degree in nuclear engineering before NSE was formed. For 26 years, Leighton served with Admiral Hyman Rickover in the Naval Nuclear Propulsion Program, where he helped to design and construct nuclear-powered naval warships. Leighton's legacy at NSE continues. As part of his estate plan, Leighton established an MIT charitable gift annuity as a way to increase his support of graduate students. The remainder of the gift came to MIT upon his passing. The Department of Nuclear Science and Engineering received the gift for graduate student fellowships.

Another generous gift was received from an MIT alumnus, John Hardwick, and was used to establish a new career development chair in NSE: the John Clark Hardwick (1986) Career Development Professorship. This professorship will be used to support NSE's growing cadre of outstanding junior faculty in the department: "I wanted the money I give to go to one of the big problems that the country and the world have today, and I see sustainable energy as one of them," said Hardwick. What he liked about NSE—which contributes not just to energy generation but to security, advanced materials, and quantum engineering—is that it's a young department; more than 50% of the 16 faculty members are 40 or younger. "NSE seems poised to do great things," said Hardwick. "I felt like my gift would have a big impact there."

These are only two examples of the strong devotion NSE receives from MIT alumni.

Faculty and Administration

Professors Matteo Bucci and Zachary Hartwig joined the NSE faculty this year as assistant professors.

Professor Jacopo Buongiorno, TEPCO Professor of Nuclear Science and Engineering, has been elected to the rank of fellow within the American Nuclear Society (ANS).

Battelle Energy Alliance Professor Ju Li was named a 2017 Materials Research Society Fellow. Li was recognized for groundbreaking work on the fundamental properties of ultra-strong materials and elastic strain engineering.

Professor Nuno Loureiro was promoted to associate professor with tenure.

Professor R. Scott Kemp was promoted to associate professor without tenure, was appointed as a member of JASON, and was made a Sloan Fellow.

Professor Michael Short was named Norman C. Rasmussen Career Development Professor.

Thomas J. McKrell, a research scientist in the Department of Nuclear Science and Engineering (NSE), passed away on June 9, 2017, at the age of 47.

Professor Emeritus Otto Harling passed away at 85. He was a longtime Nuclear Research Lab director who made advances in nuclear and condensed-matter physics, nuclear materials, reactor technology, and nuclear medicine.

Brian Henderson was named the Laboratory for Nuclear Security and Policy's first Stanton Fellow. The Stanton Fellowship in Nuclear Science and Security was created to honor the legacy of Frank Stanton, an American broadcasting executive who served as the president of CBS from 1946 to 1971 and then as vice chairman until 1973. He also served as the chairman of the RAND Corporation from 1961 to 1967, where he became familiar with the dangers of the nuclear arms race. His foundation has made the mitigation of the danger from nuclear weapons one of its primary missions.

Research Highlights

Professors Jacopo Buongiorno, Neil Todreas, and Michael Golay have continued to make technical progress in the development of the Offshore Floating Nuclear Plant (OFNP) concept. In the past 12 months the effort has focused on assessing major security threats to the platform from adversaries' high-speed small-boat attacks. The assessment has been accomplished with an industry-provided Monte Carlo simulation code that allowed ONFP platform security-related design weaknesses to be identified and subsequently corrected and reassessed. Various platform designs were analyzed to determine their dynamic response to severe sea conditions; in turn, that information was used to evaluate the performance of the reactor safety systems under oscillatory motion of the platform. The analysis suggests that adequate core and containment cooling can be maintained during massive storms. The OFNP concept continues to receive media and industrial attention.

Professors Neil Todreas (Emeritus) and Emilio Baglietto completed the development of a methodology to assess uncertainties in the measurement of key operating nuclear plant parameters that are critical to maintaining reactor safety and meeting environmental regulations. The methodology development drew on insights developed in the conduct of a series of five case studies of uncertainty sources and their magnitude for a series of relevant individual measurements. This research was sponsored by Électricité de France S.A. in collaboration with the Electric Power Research Institute.

Professor Anne White currently leads the new Plasma Science and Fusion Center's magnetic fusion experimental subdivision, coordinating on-campus aspects of collaborations with tokamak and stellerator experiments in the US and abroad. Professor White's research group focuses on the study of turbulent transport in fusion plasmas, with the goal of controlling the transport and improving performance of tokamaks. The group's research includes diagnostic development that will enable new heat, particle and momentum transport experiments, as well as investigations of "non-diffusive" transport, in fusion plasmas. Integrated modeling using reduced transport models plays a key role in developing novel validation tools, some employing machine learning, for the design of future fusion devices, such as the International Thermonuclear Experimental Reactor and ARC (affordable, robust, compact). White's group is engaged in experimental research at four major tokamaks [Alcator C-Mod, SDEX Upgrade, DIII-D, and the National Spherical Torus Experiment (NSTX) and NSTX upgrade (NSTX-U)] where the experimental team leads experiments, develops diagnostics, and leads validation projects using advanced turbulence simulation codes. Professor White's graduate student Juan Ruiz Ruiz (NSE) is using turbulence data sets (from NSTX) from a high-k scattering diagnostic that measures the electron scale density fluctuations directly to compare them with theory and simulation. At the DIII-D tokamak, Professor White's graduate student Pablo Rodriguez Fernandez is collaborating with General Atomics scientist Dr. Craig Petty and Princeton Plasma Physics Laboratory scientist Dr. Brian Grierson on understanding the propagation of "heat pulses" that are stimulated using electron cyclotron heating. Pablo recently published a paper in the journal Nuclear Fusion on experiments in the Alcator C-Mod that demonstrated the separation of momentum transport and heat transport. She is also involved in collaborations at the new stellarator, the Wendelstein 7-X , located in Germany.

In addition, Professor White supervises Undergraduate Research Opportunities Program (UROP) projects involving the development of small, table-top plasma devices such as "fusors"—electrostatic inertial confinement devices—to aid in classroom teaching at MIT.

Professor Nuno Loureiro obtained a National Science Foundation (NSF) CAREER award to support research into the origin and evolution of cosmic magnetic fields. He has continued his research in magnetic reconnection (partially funded through a basic plasma science and engineering grant from the NSF and the US Department of Energy [DOE], and a Charles E. Reed Faculty Initiatives Fund grant). A novel research direction that he has initiated, in collaboration with University of Wisconsin–Madison Professor S. Boldyrev, is the effect of reconnection in magnetized plasma turbulence. This has so far led to three publications, including one in *Physical Review Letters*. The key result is that disruption of turbulent eddies by reconnection is unavoidable, and leads to a fundamentally different route to energy dissipation than that predicted by the Kolmogorov-like phenomenology.

Professor Ian Hutchinson's group investigates the basic nonlinear physics of flowing plasma, using their particle in cell codes and analytic theory. The disruption of plasma wakes in simulations by nonlinear growth of electron holes and their observation in magnetic reconnection has led to renewed interest in these free-standing self-sustaining phenomena. Professor Hutchinson presented a plenary tutorial on the topic at this year's APS Division of Plasma Physics meeting. His group has developed a theoretical understanding of the kinematics of electron holes that enables one to apply momentum conservation to predict how their velocity changes. This theory shows that interactions with moving ions are crucially important in determining hole velocity and that electron holes cannot normally overtake ion streams. This fact explains how holes can be trapped between multiple ion streams in a wake. The kinematic theory also explains why electron holes cannot move more slowly than a minimum threshold speed with respect to an ion stream. A region of oscillating velocity nonlinear instability separates electron holes from the even slower ion acoustic solitons. And this unstable region explains the long-standing question of how electron holes differ from fluid solitons.

Professor Hartwig coordinates the Vault Laboratory effort, which primarily focuses on the application of particle accelerators to the measurement and modification of materials for use in fusion energy systems. Other synergistic activities, such as accelerator-based approaches for cargo container security and the development of digital data acquisition systems for accelerator-based science, are also being pursued. Several key activities were conducted during the 2016–2017 academic year. The principal achievement of the laboratory was the installation and commissioning of a new 12.5 megaelectronvolt ultra-compact superconducting proton cyclotron manufactured by Ionetix, a world leader in the development and deployment of these new machines (figure below). The device represents an order of magnitude increase in achievable beam energies at university scale, opening up new research opportunities in nuclear security (e.g., innovative methods in cargo container interrogation for smuggled nuclear material) and material science (e.g., innovative approaches for understanding radiation damage in materials that are proposed for fusion energy reactors). Work is already under way to build up complementary capabilities around this new machine to accelerate the research programs that will use it, led by graduate students Steve Jepeal and Hin Yeung Lee. The machine and the research is being sponsored through a research agreement with a private entity (Andiscern Inc.) that is interested in advancing nuclear security technologies. A second major accomplishment was the completion of graduate student Brandon Sorbom's doctoral research, which investigates radiation damage in high-temperature superconducting materials proposed for use in superconducting magnets. The work demonstrated the utility of using ion beams to induce radiation damage and opened up significant understanding of the important role of irradiation temperature in the superconductors. Several undergraduate research assistants (Monica Pham, Daniel Korsun, and Anis Ehsani) contributed to these research projects and received a great education in the trials and tribulations of experimental science.

The Ionetix ION-12^{SC} superconducting proton cyclotron installed in the Building NW13 Vault Laboratory.

The use of conduction-cooled high-field magnets provides a high performance ion accelerator in a very compact, cost-effective, turnkey system that will open new research applications at university scale.

Dr. Charles Forsberg leads the fluoride salt-cooled high-temperature reactor research efforts. The goal of this project is to develop a reactor to provide zero-carbon electricity to meet variable electricity demand while the reactor itself operates at full capacity to minimize costs. Dr. Forsberg has examined, with multiple sponsors including the US Department of Energy and the Chinese Academy of Science, an advanced nuclear air Brayton combined cycle with two different heat storage systems (one for the high-temperature turbine and one for the lower-temperature steam cycle) that is being developed to enable a power station to buy or sell electricity depending on electricity market prices. This enables the reactor to provide dispatchable electricity to the grid, replacing the historical role of fossil fuels, and to balance electricity production with demand in grids with high wind or solar output when high wind or solar conditions create excess electricity. Other project work included materials irradiations in the MIT reactor in molten salt, experiments to understand tritium behavior, and work to understand radiative heat transport in liquid salts—all at 700°C or higher temperatures.

Professor Michael Short's group confirmed two major experimental findings related to the areas of fouling resistance and rapidly measuring radiation damage. The first finding was the initial confirmation of the hypothesis that optical properties of fuel cladding coatings determine the propensity for fouling resistance in nuclear reactors, as tested by in-water atomic force microscope measurements and integrated flowing loop testing of these materials in pressurized water reactor (PWR) conditions. This work will continue as a $4.5 million project funded by Exelon, which aims to put lead test rods in a commercial PWR by 2019 (a 15-year reduction in typical deployment time). The second finding was confirmation that noncontact, nondestructive monitoring of the thermoelastic material properties of materials can determine when they undergo sudden void swelling. This issue continues to be the scourge of the light water reactor and fast reactor industries, which is additionally complicated by the time required to perform irradiation experiments (years, sometimes decades). Using their newly improved technique of dual-heterodyne transient grating spectroscopy, they successfully correlated ex situ changes in elastic properties to thermoelastic material–measured void swelling in single-crystal copper. An in situ experiment is being constructed as this is written at Sandia National Laboratory, for a proof-of-principle experiment this fall.

Professor Emilio Baglietto's group has made considerable advancement in delivering a pioneering capability of predicting critical heat flux (CHF) with a first-principle-based, three-dimensional approach. The Third International Conference on Numerical Methods in Multiphase Flows was the perfect stage this year to demonstrate the novel approach and its physical soundness, and engage the community in this effort. The work is driving interest and contributions from a larger international community, and has solicited the attention of the industry worldwide. The work is largely sponsored by the Consortium for Advanced Simulation of Light Water Reactors and spreads over a broad and multifaceted effort that involves six PhD students, one MS student, and one postdoctoral associate.

Professor Baglietto's team has delivered innovative hybrid turbulence models capable of locally controlling the level of resolution based on the turbulence characteristics. This new family of models is the enabling technology to extend the use of computational fluid dynamics (CFD) to complete reactor systems and safety analysis transients.

Industrial benchmarks of the model are being performed worldwide, and the model promises to support different key industrial challenges. Those challenges include, in particular, drag reduction for commercial vehicles, and nuclear plant operation and maintenance, where accurate and cost-effective transient flow simulations could allow considerable reduction in failure rates and maintenance costs. Professor Baglietto is the co-principal investigator on a Nuclear Energy University Programs award-winning project in collaboration with the University of Wisconsin–Madison, Virginia Commonwealth University, and Argonne National Laboratory. He is in charge of developing high-fidelity computational fluid dynamic methods for liquid sodium coolants stratification and striping phenomena.

The Computational Reactor Physics Group, led by Professors Forget and Smith, have pursued the development of high-fidelity open source software using both deterministic (OpenMOC) and stochastic (OpenMC) methods. Recent highlights in OpenMOC include the continued pursuit of high-fidelity full-core LWR simulations using the method of characteristic (MOC) by developing the implementation of on-node parallelization and domain decomposition with testing on petascale architectures. Recent developments also include integration of an MOC solver in an unstructured mesh framework to facilitate multi-physics coupling. Recent highlights in OpenMC include the development of a regularized vector-fitting algorithm to represent nuclear data in a formalism that can easily be Doppler broadened to account for varying material temperatures in multi-physics simulations. Additional developments include a novel spatially continuous depletion method that eliminates the need for spatial discretization when tracking material evolution in reactor analysis, the introduction of OpenDeplete, an open source depletion module that couples with OpenMC, and a coupling methodology using continuous temperature representation and tracking that facilitates integration with multi-physics unstructured mesh codes. The Computational Reactor Physics Group was also recently awarded a grant as part of the Exascale Computing Project, named ExaSMR, in conjunction with Oak Ridge National Laboratory and Argonne National Laboratory for the further development of Monte Carlo algorithms that can improve performance on next-generation Exascale leadership computing platforms.

Professors Bucci and Buongiorno are completing a first-of-kind experimental investigation of subcooled flow boiling and critical heat flux using advanced infrared and high-speed video diagnostics. Data were generated at ambient pressure, but also under pressurized conditions, revealing new details of heat flux partitioning on the boiling surface. This work is relevant to the design and the safety analysis of both boiling water reactors and PWRs, and is sponsored by the Consortium for Advanced Simulations of Light Water Reactors, a DOE hub. Significant progress has also been made on the project on experimental investigation of CHF in transient conditions. The aim of this project is to investigate boiling heat transfer during exponential power escalations. This work is relevant to the safety of experimental nuclear reactors used for material testing and for the production of radioisotopes used in medical diagnostics, and is sponsored by the French Commissariat a l’Energie Atomique. Finally, Professor Bucci and Professor Wang (Department of Mechanical Engineering) started a new project sponsored by Exelon on the development of CHF-enhancing coating for nuclear reactor claddings. These coatings are aimed at making nuclear reactor safer and more cost-competitive with respect to fossil fuel.

Principal Scientist Koroush Shirvan (assistant professor as of July 1, 2017) has continued to lead a team of NSE faculty and research scientists, as well as participants from four other universities, in a DOE-sponsored research program on accident-tolerant fuel for LWRs. The project is analyzing and testing experimentally the performance of several engineered coatings for the fuel cladding that will result in a drastic reduction of hydrogen generation during severe accidents, thus mitigating the consequences of Fukushima-like scenarios. So far, the project findings show that chromium and iron-chromium-aluminum material, when coated on Zircaloy, undergo significantly less corrosion in high-temperate environments. Dr. Shirvan also continued his study on a novel reduced-moderation boiling water reactor concept, supported by Hitachi, by demonstrating its fuel performance feasibility using multiscale, multi-physics simulations. Dr. Shirvan is continuing his work with the Free Form Fibers company as part of a Small Business Innovation Research grant to utilize fiber-additive manufacturing technology to fabricate a first-of-kind ceramic fuel form with higher economic potential than the tristructural isotropic fuels that are commonly used in high-temperature gas reactors. He is also continuing his work on developing the safety case for a natural-circulation lead fast reactor design as part of a Korean government multiuniversity research grant.

Professors Michael Driscoll (Emeritus) and Emilio Baglietto, together with the late Dr. Thomas McKrell and several students, completed an evaluation of using deep boreholes for disposal of high-decay-power spent fuel, such as that from Terra Power's innovative fast reactor. Calculations and laboratory simulations showed that a commercial zinc alloy could be employed to significantly reduce internal temperatures by filling voids inside fuel assemblies (or other solid waste forms) and their disposal canisters. Professor Driscoll has also begun work with a student to evaluate use of a supercritical carbon dioxide power conversion cycle for the fluoride salt-cooled high-temperature reactor under study by Dr. Charles Forsberg and others in NSE. This has great promise for a significant reduction in plant capital cost per megawatt because of the combined effects of a significant increase in thermal efficiency and a decrease in power cycle component cost.

Professor Paola Cappellaro's Quantum Engineering Group has devised several strategies to improve quantum sensors using spin defects in diamond. Efforts have included improving the sensor coherent lifetime to achieve longer measurement times and higher sensitivity, as well as using a larger number of entangled sensors. The first direction focused on improving the coherence time of the nuclear spin associated with the spin defect, using two strategies: on one side, novel control techniques are used to protect the nuclear spin from noise; on the other side, a nearby electronic spin defect is used to sense external noise variations and feedback control is applied on the nuclear spin to stabilize it. To improve sensitivity by using more than one spin sensor, the group has developed control techniques to address a small network of spin defects, entangle them, and use them for sensing. This approach promises to achieve sensitivities beyond what is possible for classical sensors. Professor Cappellaro's group also achieved the first measurement of many-body localization in a natural nuclear spin system. Although it is known that a quantum system will localize in the presence of disorder, whether this localization survives in the presence of interactions (many-body localization) is still an open question. By combining Hamiltonian engineering techniques, analytical models, and detection of spin-spin correlations via nuclear magnetic resonance techniques, the group was able to experimentally measure the characteristic logarithmic growth of correlation linked to many-body localization.

Professor Jacopo Buongiorno has been leading the MIT study on the Future of Nuclear Energy in a Carbon-Constrained World. The study involves seven faculty members from across the Institute, as well as two Harvard faculty members, six external consultants, and six students. The objective is to evaluate the prospects for innovative nuclear technologies, policy and business models, and regulatory governance mechanisms to accelerate the transition to a lower-carbon global energy system in the United States and around the world. In the past year, the study has generated interesting findings, particularly in the areas of the economic competiveness of nuclear energy in various energy markets, lessons learned from ongoing and recent nuclear construction projects, opportunities for cost reduction in the construction of new nuclear power plants, readiness and cost of advanced reactor technologies, and regulatory paths to the licensing of new nuclear systems. Input from a broad community of nuclear and non-nuclear stakeholders has been gathered through dedicated workshops and interviews. The team is progressing toward delivery of the final report in the first half of 2018. The study is supported by the Sloan Foundation, which provided core funding, as well as Electricite' de France and Shell, which became sponsors of the study in 2017.

Professor Ju Li's group is developing nanocomposite materials with metallic matrix (aluminum, zirconium, magnesium, copper), one-dimensional nanowires and nanotubes, and two-dimensional graphene dispersions that have shown superior thermomechanical properties and radiation resistance. The Li group also led the development and applications of IM3D, a parallel Monte Carlo software for efficient simulations of primary radiation damage with the ability to describing arbitrary three-dimensional geometries and microstructures, with applications in nuclear materials and ion-beam assisted nanofabrication. His group has also developed lab-on-a-chip devices to investigate buried solid-liquid and solid-liquid-gas interfaces under electrochemical potential bias, to study corrosion, fouling, and electrodeposition.

Professor Ballinger's group continues the partnership with Professor Alex Slocum (Mechanical Engineering) in the development of models for corrosion fatigue of naval submarine propulsion shafting. The results of the model suggest that the probability of unacceptable degradation for naval submarine shafting will not allow extension of the inspection interval from 6 to 12 years as has been specified for the next-generation ballistic missile class submarine propulsion shaft. An extensive follow-on program has been implemented, in collaboration with the Naval Research Laboratory, to further advance the model and reduce uncertainty in degradation estimates and to provide a path forward for increased reliability. His group continues in the use of mechanical testing in pure heavy water at LWR conditions, as a means to detect the migration and location of hydrogen, using deuterium as a surrogate, in materials. Last, the group has completed a program to measure residual stresses in nuclear fuel dry storage canisters using neutron diffraction and contour methods. A comparison has been made between the two techniques. The results will be combined with modeling to estimate the time to failure of these canisters.

The past year saw significant new activity in the group of Professor Areg Danagoulian, focusing on problems of detection and verification of special nuclear materials. One of the major thrust areas is the development of experimental techniques for the verification of nuclear warheads in the context of nuclear arms reduction treaties. The concept uses nuclear resonance phenomena to isotopically fingerprint and authenticate the fissile components of a weapon. The research team lead by Professors Areg Danagoulian and Scott Kemp worked on a methodology that uses nuclear resonance fluorescence to achieve this goal. The details were described in a paper published in the *Proceedings of the National Academy of Sciences*. The continuing research in this area focuses on developing an experimental proof of concept demonstration.

Professor Danagoulian's group is also working on developing advanced techniques in cargo security. The group used gammas from nuclear reactions, triggered by beams of accelerated ions, to radiograph and interrogate targets in a technique known as multiple monoenergetic gamma radiography. In addition to this work, Professor Danagoulian is collaborating with Professor Zachary Hartwig to extend the technique by using proton beams from medical cyclotrons.

Professor Michael Golay's research includes the formulation of a probabilistic risk assessment structure for multiunit nuclear power risks; the work is sponsored by Tokyo Electric Power Company. This project flows from the Fukushima Daiichi nuclear accident of 2011 that involved destruction of three power reactors at the same site. Until now, nuclear power plant probabilistic risk assessments have been performed only for single units. In the future, site-wide risk assessments can be expected to become the standard treatment. This work has been focused on expanding single-unit probabilistic risk assessments to consider mutual dependencies of risks between units. The causes of such risks include severe external events (i.e., earthquakes), failure dependencies among entities, and activities shared between multiple units—such as shared human errors, faulty equipment, mistaken management policies, damage propagated from one unit to another (as with debris), damage to shared facilities (roads), explosive chemicals and radioactive materials, and interactions between interconnected components and systems in different units (i.e., electrical disturbances propagating from one unit to another).

Professor Golay has also been preparing for the 2018 conference on formulation of the nuclear power role in response to climate change. This conference will be held at MIT during spring vacation week in 2018. The purpose is to examine the rationale to guide the use of nuclear energy in response to climate change, and is expected to involve about 80 international participants. It is being organized under the auspices of the NSE Center for Advanced Nuclear Energy Systems. Professor Golay is the conference chairman.

Professor Chen's group continued its collaboration with his colleagues at the University of Florence in studying toward the realization of environmentally friendlier "green" cement. Supported by DOE, they have developed a new global model for QENS data analyses of the "green" cement, using the neutron-scattering technique from experiments at the National Institute of Standards and Technology Center for Neutron Research.

Education

A total of 110 students pursued graduate degrees in NSE. Fifty-seven percent of these students worked in the fission energy field, 22% in fusion and plasma physics, and 31% in other nuclear science and technology applications, including materials, nuclear technology management and policy, nuclear security, and quantum engineering. The department awarded nine SM degrees and 14 PhD degrees in September 2016. Twenty-four students entered the graduate program in fall 2016.

A total of 39 students were enrolled in the undergraduate program during the past year, including 10 sophomores, 12 juniors, 16 seniors, and one fifth-year student. Seventeen students completed the requirements for the bachelor's degree in nuclear science and engineering from September 2016 through June 2017.

This year, the department continued to provide communication support to its students through the NSE Communication Lab, a peer coaching program launched in 2014 to help students and postdoctoral associates with their writing, speaking, and visual design needs. Staffed by a team of six graduate students serving as communication fellows, the NSE Communication Lab held 204 one-on-one coaching sessions with 86 unique visitors, or 51% of the NSE population. The lab also offered field-specific communication workshops, launched an online communication resource known as the NSE CommKit, and collaborated with instructors from eight undergraduate and graduate courses to help strengthen the communication aspect of the curriculum. One course in particular, 22.911 Seminar in Nuclear Science and Engineering, was redesigned to incorporate reforms led by NSE Communication Lab manager Marina Dang. In a class survey, 67% of students reported that they felt more confident in their presentation skills as a result of taking this class. By January, enough external institutions had expressed interest in adapting the Communication Lab model for their communities that a Communication Lab Summer Institute was scheduled to run in July 2017. At the time of this report, seven institutions have registered to participate, including Boston University, Brandeis University, and the California Institute of Technology.

Professor Baglietto has dedicated particular effort to advance the undergraduate course 22.06 Engineering of Nuclear Systems, which has seen a great increase in the number of registrants. This subject represents the first approach for students to reactor engineering and therefore has a great impact on their future path selection.

This June marked the 51th session of the MIT Nuclear Plant Safety Course, which is the longest-running professional summer session course offered by MIT. It was co-directed by Professors Neil E. Todreas and Benoit Forget. This year, the 23 attendees were drawn principally from the United States, joined by others from Canada, South Korea, and Saudi Arabia. From its inception in 1966, the course has played an important role in the professional development of hundreds of attendees from throughout the world by serving as an up-to-date exposition of ongoing developments in nuclear power plant safety. The lecturers are among the most knowledgeable worldwide experts in nuclear technology from industry, government, and academia. They are closely associated with current reactor or fuel facility safety issues, or both, as well as strategies for future plant operations and designs.

In addition, Professor Michael Golay provided directorship of two executive courses offered jointly by MIT and the Institute for Nuclear Power Operations: the Reactor Technology Course for Utility Executives, offered for the 25th time in 2017, and the Nuclear Operational Risk Management course.

Faculty Awards, Honors, and Activities

Professor Emilio Baglietto serves the role of thermal hydraulics focus area lead for the DOE-sponsored Consortium for Advanced Simulation of Light Water Reactors. Professor Jacopo Buongiorno presented two invited talks in June 2017: "Can Nuclear Energy Thrive in a Carbon-Constrained World?—Findings from a new MIT Study," presented at Imperial College, London, June 20, 2017; "Uncovering the Secrets of Boiling Heat Transfer with Advanced Diagnostics and Nano-engineered Surfaces," Ljubljana University, Slovenia, June 29, 2017.

Professor Ju Li, Batelle Energy Alliance Professor, was elected a Fellow of the Materials Research Society in 2017. He was also part of the 2016 R&D 100 Award, Category Mechanical/Materials, "Stress-Induced Fabrication of Functionally Designed Nanomaterials."

Professor Nuno Loureiro received the PAI Outstanding Faculty Award, presented by the student chapter of the American Nuclear Society.

Professor Michael Short won an NSF CAREER award in the Mathematical and Physical Sciences Directorate, in the Directorate for Materials Research in Metals and Metallic Nanostructures. His project is entitled "Quantifying Radiation Damage in Metals with Wigner Energy Spectral Fingerprints."

Professor Anne White served as a member of the Executive Committees for the American Physical Society Division of Plasma Physics and the US-EU Transport Task Force, and as a panel leader on the Transformative Enabling Capabilities Committee, which was charged by the Federal Economic Statistics Advisory Committee to assess new technologies that can accelerate the path to fusion energy development. She served as the chair of the local organizing committee for the International Sherwood Fusion Theory Conference (MIT is hosted the conference in spring 2017).

Professor Emeritus Sidney Yip was a member of the Visiting Committee of the Department of Nuclear Engineering and Radiological Sciences at the University of Michigan. He is the co–editor-in-chief of the Handbook of Materials Modeling, to be published by Springer in 2018.

Professor Emeritus Sow-Hsin Chen was awarded an honorary degree of Doctor of Science, honoris causa, from his alma mater, McMaster University, at the November Convocation on November 18, 2016. University Chancellor Susan Labarge and University President Patrick Deane made the award, as approved by the McMaster University Senate, for his groundbreaking work, including specifically his investigations into the properties of disordered materials and supercooled and interfacial water, using neutron scattering and other related scattering techniques.

A special issue of *Il Nuovo Cimento C*, edited by Professors P. Baglioni, A. Cupane, and F. Mallamace, and dedicated to Professor Sow-Hsin Chen, titled *The Structure and Dynamics of Supercooled Water and Other Glassy Materials*, was published as Vol. 39 C in September 2016. That special issue also includes a lead article by Professor Chen and others.

Student Awards and Activities

Ensign Sean Lowder, U.S. Navy: A 2017 graduate of the Department of Nuclear Science and Engineering, Lowder will be a naval reactors engineer reporting to the Navy Yard in Washington.

Qiyang Lu and Lixin Sun won Graduate Student Awards at the 2017 Spring Materials Research Society conference.

Alexander Creely and Cody Dennett received the Manson Benedict Award, presented to a graduate student for excellence in academic performance and professional promise in Nuclear Science and Engineering.

Patrick Everett received the Roy Axford Award for academic achievement by a senior in Nuclear Science and Engineering.

Logan Abel received the Irving Kaplan Award for academic achievement by a junior in Nuclear Science and Engineering.

Ka-Yen Yau received the Outstanding UROP Award for outstanding contributions to a research project by a junior or senior in Nuclear Science and Engineering.

Jared Conway received the Outstanding UROP Award for outstanding contributions in an NSE project by a freshman or sophomore in Nuclear Science and Engineering.

Lixin Sun received the Outstanding Teaching Assistant Award for exceptional contributions as a teaching assistant in Nuclear Science and Engineering.

Hin Yeung Lee received the Outstanding Grader of the Year Award, presented by the student chapter of the American Nuclear Society.

Will Boyd, Cody Dennett, and Pablo Ducru received Outstanding Student Service Awards in recognition of exceptional service to the department.

Yang Yang won two awards for presentations of his doctoral research at the 2017 American Nuclear Society Student Conference in April 2017. Yang's podium presentation, "The Necessity of Full-3D Monte Carlo Simulations for Ion Irradiation," won the Best in Materials Science and Technology Award. His summary paper on the same topic won the Best Overall Research Award.

Guanyu Su won the 2016 Young Professional Thermal Hydraulics Research Competition at the November meeting of the ANS Thermal Hydraulics Division in Las Vegas, NV, for his presentation, "High Resolution Measurements Reveal Transient Boiling under Exponential Heat Inputs."

Artyom Kossolapov and Andrew Richenderfer received an award for best research poster at the Conference on Computational Fluid Dynamics for Nuclear Reactor Safety Applications for their work concerning an experimental breakthrough in boiling heat transfer visualization.

Zhaoyuan Liu won a best student paper award at the ANS Mathematical and Computational Methods 2017 topical meeting held at Jeju Island, South Korea.

Derek Gaston won a best poster presentation award at the ANS Mathematical and Computational Methods 2017 topical meeting at Jeju Island, South Korea, for "Verification of MOCkingbird, an Unstructured-Mesh, Method of Characteristics Implementation Using the MOOSE Multiphysics Framework."

Matthew Ellis and Colin Josey received a best paper award from the Reactor Physics Division at the ANS winter meeting, held in Las Vegas, NV.

Norman Cao was selected as a festival fellow for the Ninth Festival de Theorie in France.

Pablo Ducru received a second-place award ($5,000) from *The Economist*'s NRG Energy Case Study Competition 2017, with the MIT three-student team called The Beetles.

Dennis G. Whyte
Department Head
Hitachi American Professor of Engineering