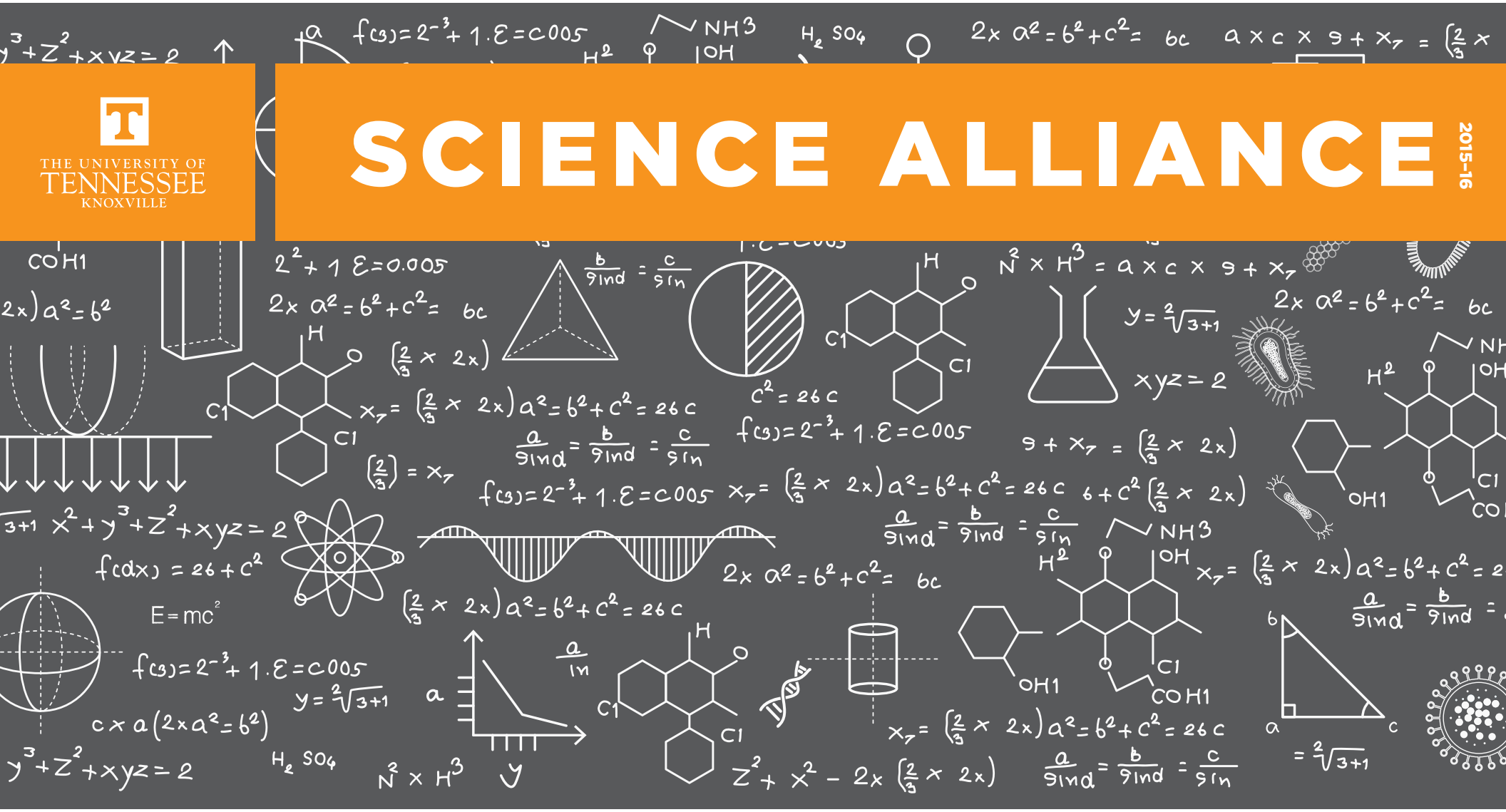
THE UNIVERSITY OF TENNESSEE KNOXVILLE

SCIENCE ALLIANCE

2015–16



SCIENCE ALLIANCE ANNUAL REPORT 2015–2016

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The Science Alliance is a Tennessee Center of Excellence established in 1984 and supported annually by the Tennessee General Assembly. The mission of the Science Alliance is to:

- Hire and support joint distinguished scientists of national note
- Create and support joint institutes
- Share resources
- Bring the University of Tennessee and Oak Ridge National Laboratory together to support technology transfer
- Build areas of common strength
- Provide incentives to attract and retain the highest quality faculty and students
- Strengthen educational opportunities
- Grow government and industrial support of the shared research enterprise

Science Alliance funding is one critical way that the partnership between UT and ORNL is further advanced. Funds support a variety of significant investments in people and collaborations.

Much of our current collaborative research emphasizes strategic areas of importance to both organizations. Advanced manufacturing, advanced materials and materials science, neutron science, computational science, big data and data science, and bioinformatics are currently among the most prominent UT-ORNL collaborative areas receiving support.

The investment made by the state each year in this important collaboration is greatly appreciated and is instrumental in allowing the Science Alliance to provide a variety of opportunities to innovative and groundbreaking collaborations between people. Great science and discovery come when people-to-people interactions are optimized, not unlike a chemical reaction. A reaction progresses because of interactions, and these funds support interactivity. They hold a decisive role in leveraging the federal investments made at ORNL and UT in our areas of collaborative research and development.

FROM THE DIRECTOR

The Science Alliance has seen exhilarating growth and collaboration between the University of Tennessee, Knoxville, and Oak Ridge National Laboratory this past year. Our two institutions have partnered on high-visibility projects and shared our teaming process with regional and national thought leaders, all while advancing the core mission. At each step of the way, the Science Alliance is spreading the message that this is the model for the future of collaboration.

Last fall, UT hosted the twenty-first general meeting of the National Academies' University Industry Demonstration Partnership, which brought together 250 attendees from universities, corporations, and Department of Energy national laboratories from across the nation to explore research engagement with national laboratories.

Our partnership is seen as the gold standard for university-national lab collaborations, producing innovations in advanced manufacturing, materials science, and neutron sciences to name a few. It is crucial that we continue to foster current areas of innovation through the Science Alliance.

In May, the Science Alliance facilitated the Southeast Regional Energy Innovation workshop in Chattanooga, Tennessee, that enabled stakeholders from several spheres (university, industry, community, legislature, and the DOE) to discuss innovative clean energy technologies and how to leverage our region's unique capabilities.

Finally, IACMI—the Composites Institute continued to gain momentum, announcing its first call for proposals last fall. Tied closely to the Science Alliance's work with advanced materials and manufacturing technology, IACMI was involved with the recent opening of the Fibers and Composites Manufacturing facility at UT.

This report is not only a summary of the past year's efforts by our distinguished scientists, Joint Directed Research Development fellows, project leaders, and team members to advance the research enterprise here at UT and with our partners at ORNL, but is also a glimpse into the future of research innovation in our nation.

—Taylor Eighmy
UT Vice Chancellor for Research and Engagement

"The partnership between the Laboratory and the University is exceptionally valuable to both of our institutions. We look forward to sustaining and extending our joint research and education programs to deliver scientific discoveries and technical innovations for clean energy and global security, creating economic opportunity for the state and the nation."

—Thom Mason
ORNL Director

COLLABORATIVE COHORT

The Collaborative Cohort program, introduced by Science Alliance in the fall of 2013, is a two-year program designed to nurture collaboration between underrepresented UT junior faculty and ORNL junior scientists. Eligible faculty members include those within ten years of their initial appointment at UT who are working within the STEM disciplines, with a focus on underrepresented groups as defined by UT—including women and ethnic or racial minorities, veterans, and individuals with disabilities. Cohort fellows from UT work closely with the ORNL Liane B. Russell Fellows.

In 2013, ORNL introduced the fellowship, which honors Liane Russell's groundbreaking research in genetic science. This highly competitive fellowship recognizes and promotes diversity across all fields of research relevant to the missions of ORNL and the US Department of Energy (DOE). A select number of fellowships are awarded annually to candidates who have shown outstanding potential to conduct research of the highest quality and impact. The Russell Fellowship provides funding support for three years along with formal mentorship to facilitate successful integration of Russell Fellows' research with DOE programs and long-term careers with ORNL.

As a whole, the Collaborative Cohort is focused on enabling discovery and scholarly development, collaboration, team building, graduate student mentoring, and obtaining funding from a variety of sources, including the Science Alliance JDRD, ORNL, and DOE programs. The entire cohort convenes a minimum of six times per year at ORNL for site visits, introductions, meetings, planning, and mentoring.

Tessa Burch-Smith

Relationships are vital in every field of study. Connections to other professionals play a large role in generating new ideas and solving persistent problems. For Tessa Burch-Smith, assistant professor in the Department of Biochemistry and Cellular and Molecular Biology, these relationships were the most important part of her time as a member of the Collaborative Cohort.

Burch-Smith studies intercellular signaling in plants. Her work as a cohort fellow adapted several of the tools from her existing research to study Crassulacean acid metabolism (CAM) photosynthesis. CAM photosynthesis is performed by plants in the Crassulaceae family, including succulents and other desert plants that thrive in water-stressed environments. Understanding how these plants work is key to the development of hardy, drought-resistant crops.

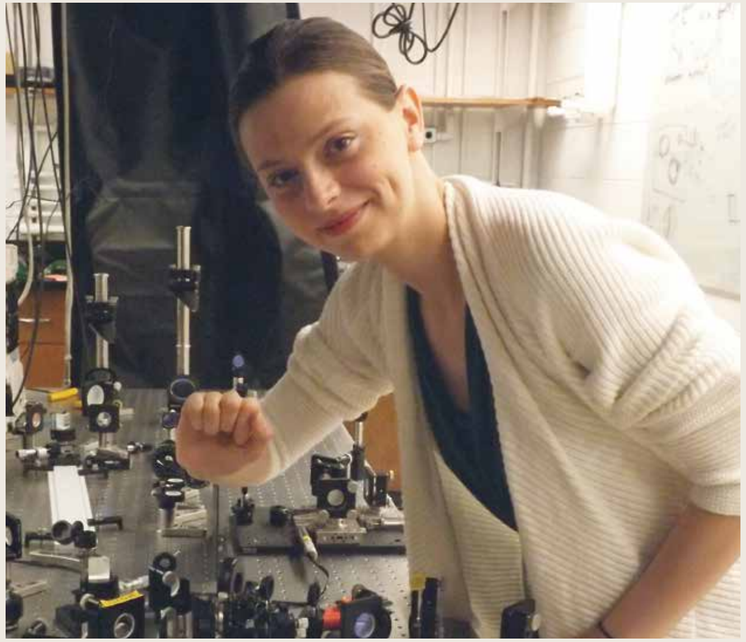
For Burch-Smith, participation in the Collaborative Cohort program provided an opportunity to work with ORNL scientists who are part of an international symposium interested in CAM photosynthesis. Collaborating with these professionals on her existing project has given Burch-Smith access to the bioinformatics and gene studies conducted by the symposium and allowed her to become involved with other areas of the CAM project.

Once her term with the Collaborative Cohort is over, Burch-Smith intends to continue her work with the goal of providing a framework for encouraging CAM photosynthesis in other families of plants.

Tessa Calhoun

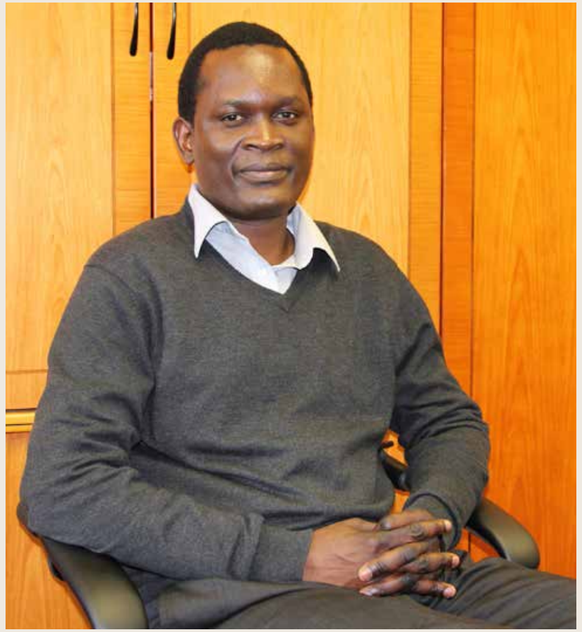
Tessa Calhoun of UT's Department of Chemistry has focused her research on nonlinear microscopy. Recently, as a part of the JDRD program, Calhoun constructed a new microscope for use in nanoparticle interfacial chemistry. As a Collaborative Cohort Fellow, Calhoun has focused her efforts on transient absorption microscopy. The results of her research have the potential to shed light on drug interactions with cell membranes.

The goal of Calhoun's work as a cohort fellow is to use advancing imaging technology to image small molecule drugs as they interact with the membranes of living cells. Observing a molecule's interaction with a cell membrane has most commonly relied on fluorescence, exciting the molecule with a single pulse of light and waiting for it to spontaneously emit. Unfortunately, not all systems fluoresce.



To bypass this difficulty, Calhoun uses transient absorption, a method that adds a variable second pulse of light, to stimulate a response. This particular technique has been used before, but rarely with biological systems.

In addition to expanding her research, Calhoun says the Collaborative Cohort fellows formed a helpful community of cross-disciplinary scientists who were able to share information with each other on a variety of topics. She added that regular meetings between the cohort fellows have opened the door to possible future collaborations.



Joshua Sangoro

Joshua Sangoro, assistant professor in the Department of Chemical and Biomolecular Engineering, has spent his term in the Collaborative Cohort working with polymerized ionic liquids. Part of a new class of polymer electrolytes, these liquids have the potential to serve as replacements for the less stable electrolytes currently in use in a variety of technologies, such as lithium ion batteries.

Through his affiliation with the Collaborative Cohort, Sangoro was connected with several ORNL scientists, including Kunlun Hong of the chemical sciences division, who have synthesized some of the liquids for Sangoro's research. Additionally, Hong has supervised graduate student Thomas Kinsey at the Center for Nanophase Materials Sciences in his work on the project, allowing Kinsey to split his time between UT and ORNL labs.

A first time faculty member, Sangoro believes the Collaborative Cohort provided a solid framework for professional development, allowing him to focus his work.

"When I began I had goals that were not very realistic and would have required a much larger team, but it got me to think in the right direction," Sangoro said. "The goal has now become to get preliminary results and secure funding to create a project that can sustain itself."

The project has, in fact, yielded some preliminary results since Sangoro began his term as a member of the Cohort, which led to a proposal submitted to the Army Research Office. Additionally, he secured a National Science Foundation grant and published several articles as a result of his work during this time.

Stephanie TerMaath

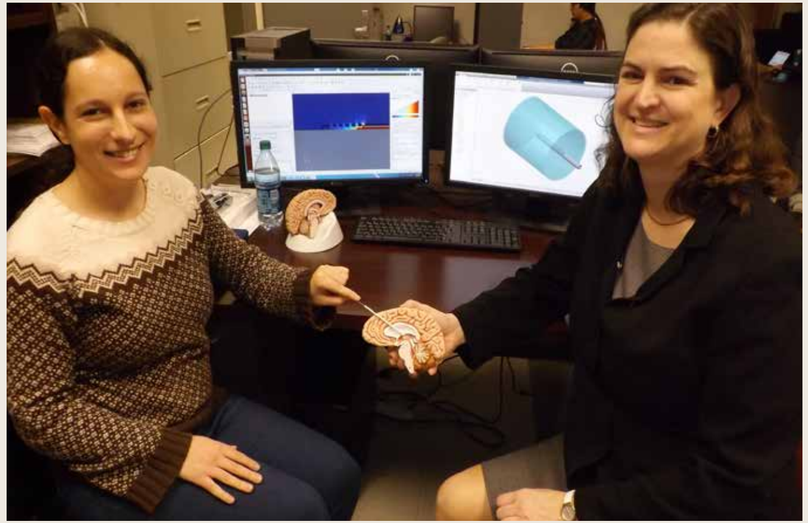
In 2014, the Science Alliance unveiled the Collaborative Cohort program. Designed to nurture collaboration between underrepresented UT faculty and ORNL scientists, the program launched with an inaugural class of four, including Stephanie TerMaath of the UT Department of Mechanical, Aerospace and Biomedical Engineering.

During her two years with the cohort, TerMaath's work has centered on advances in the treatment of hydrocephalus, a debilitating disorder caused by an accumulation of cerebrospinal fluid (CSF) in the brain. Currently the only treatment available to patients suffering from hydrocephalus is invasive surgery to implant a cerebral shunt.

The shunt is inserted into the patient's ventricle, a cavity within the brain, where it diverts the excess CSF fluid to another part of the body to be absorbed. Unfortunately, these shunts have a high failure rate and need to be replaced multiple times over the course of a patient's life, requiring as many as two to four surgeries every ten years.

These flaws are TerMaath's focus as her cohort work has sought to improve the shunt's design through modeling and computational fluid dynamics.

TerMaath's work thus far has yielded a model she and her team will use to address what they believe to be a possible cause of the failures in existing shunts. She has plans to continue her work past the end of her cohort term and credits her time in the program with providing the opportunity to forge the relationships and collaborations needed to do so.



UNIVERSITY-INDUSTRY DEMONSTRATION PARTNERSHIP

The University-Industry Demonstration Partnership (UIDP) was created as a forum to facilitate university-industry relations and collaborations. As a member, UT is joined by major corporations such as Boeing, Coca Cola, and Lockheed Martin, as well as prominent educational institutions including the Massachusetts Institute of Technology, Tufts University, and Stanford University.

UIDP convenes regular meetings at locations across the country to allow participants to better understand the tactical side of university-industry partnerships. Meetings often engage members in discussions of initiating collaborations and lessons learned from previous partnerships, providing valuable insight for emerging affiliations.

In October 2015, UT and ORNL hosted one of these meetings. Conducted at the Hilton Downtown Knoxville and the ORNL campus, the meeting included speakers from seven of the DOE's national laboratories as well as professors and administrators from notable universities.

"Our partnership with Oak Ridge National Laboratory not only puts UT in elite company nationally, it has a profound impact on the state, the nation, and the world," said UT System President Joe DiPietro. "I'm proud of that partnership and honored that we're able to share our insight with this distinguished group."

The meeting was facilitated by the Science Alliance as part of its core mission to promote and support collaborations between UT and ORNL. Each JDRD project and Distinguished Scientist appointment funded by the Science Alliance contributes to the culture of collaboration between the two organizations and serves as a model for other university-industry partnerships across the country.

"Many UIDP members have long been interested in learning more about effective engagement with national labs," said Tony Boccanfuso, president of UIDP. "Because of the strong strategic relationship between UT and ORNL, we wanted to bring our members together in Knoxville to experience this relationship in action."

KEPPENS TO LEAD JOINT INSTITUTE

Veerle Keppens has been named the new director of the UT-ORNL Joint Institute for Advanced Materials (JIAM). Currently the head of UT's Department of Materials Science and Engineering, Keppens brings an abundance of experience in the field.

"Keppens carries a wealth of materials science knowledge to this position along with a passion for broadening our understanding in these areas of research," said UT Chancellor Jimmy G. Cheek. "She has worked well in research partnership with ORNL and will be a strong leader of the institute."

A regular recipient of Science Alliance JDRD awards, Keppens also served as the senior faculty mentor to the most recent class of Collaborative Cohort fellows. Several years prior to her arrival at UT, Keppens served as a Fulbright Fellow at ORNL.

"Materials research has impacted much of what we take for granted in our everyday world," said Keppens. "Everything from construction to transportation, from information technology to life-saving medical devices, owes its improvements to the knowledge gained in advanced materials."

Keppens will succeed George Pharr at the recently opened 144,000-square-foot facility at Cherokee Farm, UT and ORNL's research and development park.

SOUTHEAST REGIONAL ENERGY INNOVATION WORKSHOP

On May 23, 2015, UT and ORNL co-hosted the Southeast Regional Energy Innovation Workshop in Chattanooga, Tennessee. The workshop is a forum with the express purpose of advancing clean energy technology innovation in the region.

"Our region has a clear advantage on clean energy technology innovation given our focus on materials science for energy storage, advanced manufacturing, solar, and nuclear," said Cheek. "Our close partnerships with ORNL and with many industries here in the Southeast allow us to help advance the clean energy technology ecosystem."

The forum addressed key priorities for innovation and how to build on current DOE programs and models. Panel discussions featured representatives from Boeing, GE, Southern Power, TVA, and Volkswagen America.

The Southeast region is optimally situated for such innovation with nuclear power, natural gas, and carbon capture research already taking place in both academic and industrial arenas. Additionally, the support available from ORNL as a national laboratory provides a leg up to the region as a whole, with opportunities for collaboration and access to state-of-the-art facilities.

"The opportunity to accelerate the transition of innovative technologies to the marketplace is critical to our mission as a DOE national laboratory," said Thom Mason, ORNL director. "We have dedicated user facilities, scientific staff, and strategic partnerships with industry and universities that can contribute to energy innovation here in the Southeast."

The workshop was attended by close to 150 representatives from universities, industry, and federal agencies, as well as elected officials. Representatives from two of the eight National Network for Manufacturing Innovation (NNMI) institutes were also in attendance, along with a panel of graduate students, many from the UT-ORNL Bredesen Center.

"As we look to the future, it is critical to establish the partnerships that accelerate clean energy technology innovation" said Taylor Eighmy, vice chancellor for research and engagement at UT. "The nexus of public-private partnerships involving the deep collaboration between federal government, national labs, industry, and universities is the best way to accelerate innovation and to keep the innovation in the region."

SHULL WOLLAN CENTER

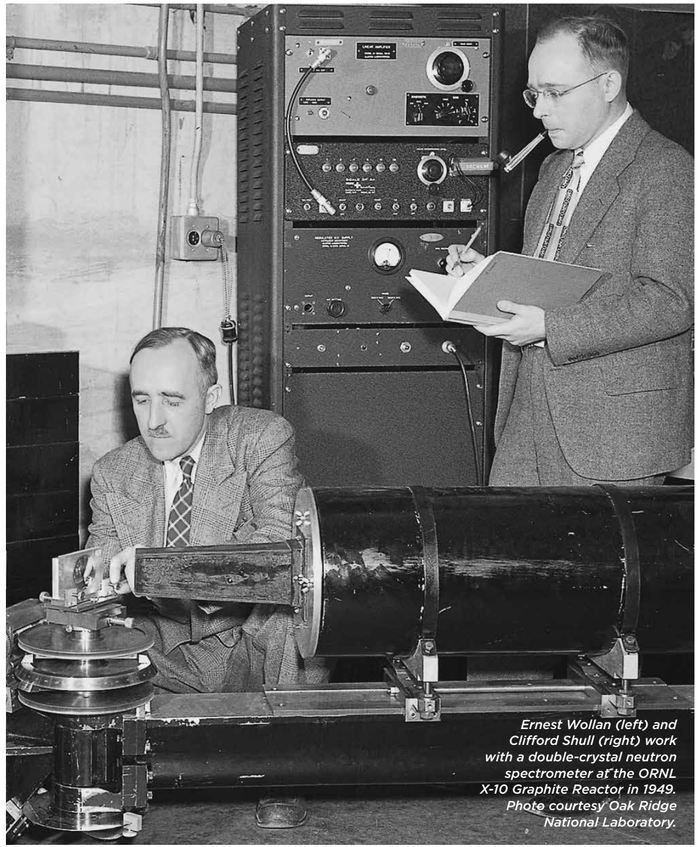
The UT-ORNL Joint Institute for Neutron Sciences was established in 1998, tasked with promoting worldwide neutron scattering collaborations among researchers in a variety of fields. Additionally, the institute provides workspace and programmatic support for scientists conducting research at the High Flux Isotope Reactor and the Spallation Neutron Source, both located at ORNL.

This year, the Joint Institute for Neutron Sciences was renamed the Shull Wollan Center in honor of two pioneering physicists in the field of neutron scattering. Clifford Shull and Ernest Wollan were researchers at ORNL in the 1940s and worked together on the X-10 Graphite Reactor. After the Manhattan Project, the two continued work that established neutron diffraction as a quantitative research tool.

"Naming our neutron science facility after Clifford Shull and Ernest Wollan seems only appropriate, because their collaboration around the development of neutron diffraction, recognized by the Nobel committee, is emblematic of the discovery enterprise we will further nurture," said Taylor Eighmy, UT vice chancellor for research and engagement.

Neutron scattering continues to be a vital implement in the research tool kit for scientists seeking to understand material properties on the atomic scale. This technique has been instrumental in advancements in a variety of fields including clean energy, pharmaceuticals, healthcare, nanotechnology, and IT.

By providing access to ORNL and UT's world-leading capabilities, the Shull Wollan Center allows scientists from diverse backgrounds and fields of research to use neutrons to address compelling scientific questions.



Ernest Wollan (left) and Clifford Shull (right) work with a double-crystal neutron spectrometer at the ORNL X-10 Graphite Reactor in 1949. Photo courtesy Oak Ridge National Laboratory.

UT NAMED AS LEAD INSTITUTION FOR IACMI

In January of 2015, President Barack Obama announced that UT would become the lead institution of the newly formed Institute for Advanced Composites Manufacturing Innovation (IACMI). Focused on the advancement of composites manufacturing, IACMI is tasked with growing research in the use of composites in a variety of areas, including automobiles, wind turbines, and compressed gas storage tanks.

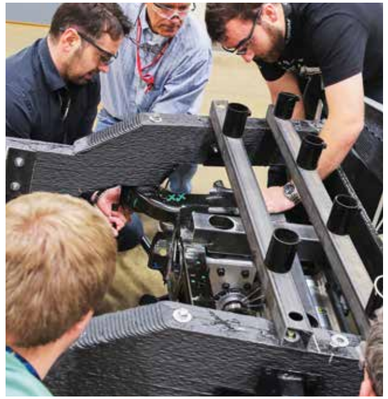
"The project will accelerate the development of an advanced manufacturing system in East Tennessee, particularly around automotive manufacturing and materials development," said Eighmy.

Advanced composites manufacturing is the creation of composites via the use of new materials such as carbon fibers or methods such as 3-D printing. Composites are created by combining a polymer resin with strong reinforcing fibers such as glass or carbon. This process yields a new composite material with improved performance, strength, and stiffness.

IACMI comprises three composite application centers, in Michigan, Colorado, and Ohio, and technology centers in Indiana and Tennessee. These five states, along with Kentucky, form the six core partners of IACMI, which also includes a 122-member consortium of industry leaders, universities, and national laboratories.

IACMI will receive $189 million in funding from several sources, including the DOE, the Science Alliance, and many of the affiliated industry partners. Volkswagen, Ford Motor Company, Boeing, Lockheed Martin, and Dow Chemical are just a few of the industry leaders participating in the consortium.

"Being the lead institution on this project is a testament to the ideas, research, and faculty that we bring to the table" said Wayne Davis, dean of UT's College of Engineering. "From our expertise in developing the materials of the future to our work in advanced manufacturing techniques and 3-D printing, our college has a wealth of expertise that we can share with the institute and that really shows in our selection to lead that enterprise."



JOINT DIRECTED RESEARCH DEVELOPMENT

The Joint Directed Research Development (JDRD) program offers an opportunity for collaborative research with ORNL.

A dual UT and ORNL venture, JDRD complements the Laboratory Directed Research Development (LDRD) program and ORNL Seed Money Fund. The LDRD is a US Department of Energy program that encourages multiprogram DOE laboratories such as ORNL to select a limited number of projects with the potential to position the lab for scientific and technical leadership in future national initiatives.

The ORNL Seed Money Fund provides a source of funding for innovative ideas that have the potential to enhance the laboratory's core scientific and technical competencies and provide a path for funding new approaches that fall within the distinctive capabilities of ORNL but outside the more focused research priorities of existing major initiatives. The JDRD program identifies and supports corresponding areas of research at UT, and projects approved for the program have both a UT and ORNL component.

JDRD awards run for up to two calendar years. A progressive assessment at the end of year one determines if second-year funding will be awarded, based on partnership development and research progress. In FY 2016 the Science Alliance funded nine first-year JDRD projects and three second-year projects.

Francisco Barrera

Much as the walls of a house protect the people and objects within from the outside, cell membranes surround and protect individual cells. Also known as the plasma membrane, the cell membrane serves as a barrier to the external environment and is involved in a number of complex cellular processes, including cell signaling.

Cell signaling is the system of communication by which cells perceive and respond to their environment. Miscommunications in cell signaling and information processing are thought to be responsible for autoimmune diseases, cancer, and diabetes. Cell membranes regulate this entire process, but much of how and why membranes are organized is unknown.

Francisco Barrera, assistant professor in UT's Department of Biochemistry and Cellular and Molecular Biology, seeks to change that. Barrera's JDRD project is focused on the formation of lipid domains, or groupings of lipids, in the cellular membrane and how proteins impact them. Lipid domains, once formed, are known to be attractive targets to many viruses that attack cells.

Barrera's JDRD team hopes to characterize how proteins affect these domains by using a very simple synthetic protein which they believe will disrupt the formation of the domains, thereby failing to create those attractive targets to viruses.

Barrera's team is partnering with Xiaolin Cheng, Fred Heberle, and John Katsaras at ORNL, and methodology designed by Katsaras and Heberle is being used in Barrera's experiment. Additionally, Barrera, Katsaras, Heberle, and Cheng are active participants in a recently launched biomembranes initiative developed by the Joint Institute for Biological Sciences, a UT-ORNL institute designed to provide new research and training opportunities for UT faculty and students and ORNL staff.

Subhadeep Chakraborty

Since their introduction, Google self-driving cars have traveled more than 1.7 million miles in a very public series of test drives and have been in only eleven accidents. Most of these collisions were a result of the driverless vehicle being rear-ended by a human-controlled car.

The human element is an important consideration in the development of autonomous vehicle technology. Subhadeep Chakraborty, assistant professor with UT's Department of Mechanical, Aerospace, and Biomedical Engineering, has focused his JDRD project on this element with connective vehicle technology that asks how it's possible to drive as a group in a way that is best for everyone.

Connective vehicle technology, as the name suggests, gives vehicles on a given section of road the ability to communicate with each other, with traffic signals, and with a variety of sensors. This communication would allow vehicles to make real-time adjustments to create the best possible driving environment with the other vehicles in range.

This lofty goal comes with a multitude of complex research questions, not the least of which is how much distance should be maintained between cars to keep the people in them from panicking. To answer these questions, Chakraborty's team is approaching this project with a multiplatform method.

The team has outfitted a donated Humvee with a series of sensors that feed data from the vehicle, as it is being driven, into a simulation they've created. The simulation allows Chakraborty's team to study the data and use it to address the effect of the human element in connective vehicle technology.

Brett Compton

Throughout history, people have turned to nature for inspiration. Van Gogh painted sunflowers, Vivaldi composed an ode to nature in his piece "Spring," and Henry David Thoreau wrote *Walden* after two years on Walden Pond. In recent years, scientists have turned to nature for that same spark of creativity. Biomimicry—modeling design on biological entities and processes—has become an important source of inspiration for many scientists and engineers, including Brett Compton, assistant professor with UT's Department of Mechanical, Aerospace, and Biomedical Engineering.

Compton has focused his JDRD project on bio-inspired hybrid materials created with 3-D printing, using natural materials and structures as a source for design.

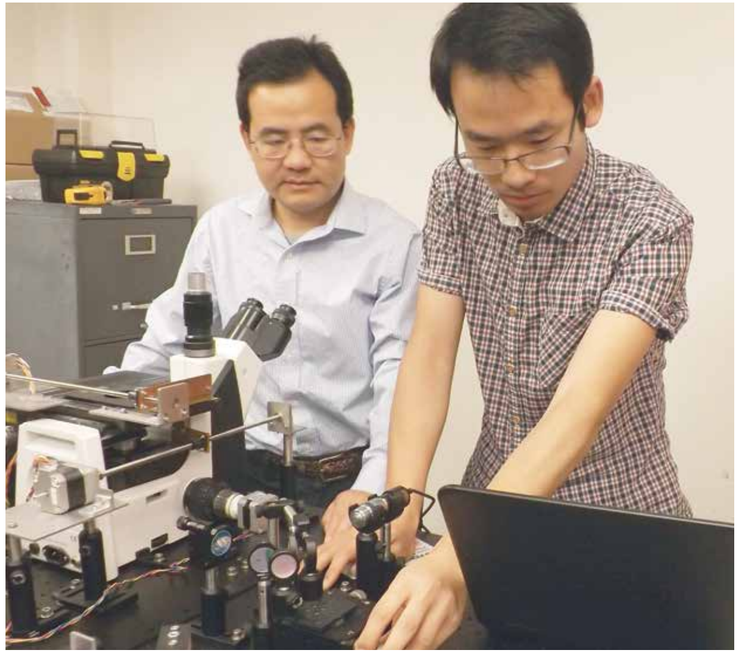
"There's one part of a seashell called nacre, or mother of pearl. It's comprised of very tiny ceramic platelets that are stacked together in a staggered way. Throughout and connecting them all is a very gooey and pliant biopolymer," said Compton.

This microstructure is similar to what one would see looking at a cinder block wall and is known as a brick-and-mortar structure. In seashells, this network of 95 percent ceramics and 5 percent polymer creates a structure a thousand times more resistant to cracking than ceramic alone. Compton plans to leverage this design to create a ceramic plate for the High Flux Isotope Reactor that can be made through a more efficient and cost effective process.

Compton's ORNL partner, Kurt Terrani, is providing the last piece of the puzzle by taking the printed structures and consolidating them to full density with secondary heating equipment available in Oak Ridge. Compton hopes his JDRD research can be built into opportunities for bringing external funding into UT.

Anming Hu

Nanotechnology is poised to revolutionize modern science. With possible applications in medicine, computing, renewable energy, and a number of other fields, nanotechnology development will impact daily life like few other areas of study. Before it can do that, however, nanotechnology must be manufactured.



Nanoscale manufacturing, or nanomanufacturing, is the production of nanoscale materials which may then be used in the creation of nanotechnology. Unfortunately, current methods for nanomanufacturing such as electron beam lithography can be cumbersome, requiring a number of special considerations.

Anming Hu, assistant professor in UT's Department of Mechanical, Aerospace, and Biomedical Engineering, wants to find an easier way. Hu's JDRD project is focused on a new, less restrictive methodology for creating nanomaterials.

His team is attempting to replace an electron beam with two incredibly fast interferenced laser beams and create a similar processing resolution.

The array with which Hu's team is working must be calibrated with exact precision to achieve this, a process taking a great deal of time. They have, however, already achieved some success in this area and hope to submit a proposal to the National Science Foundation in conjunction with Hu's ORNL partner, Benjamin Lawrie.

Hu's research will have far-reaching effects in the field of nanomanufacturing. Discovering a method that allows manufacturers to forego generating a vacuum, having perfectly sterile work environments, and creating cryogenic temperatures will reduce the complexity and difficulty of the process.

Steven Johnston

Humans are creatures of habit. They enjoy consistency and can be resistant to change and disorder, and how a person responds to that disorder can reveal a bit about them. Consider a coffee shop during morning rush hour: Patrons line up and give their orders one by one. The orders are then filled by employees as they are received. Now imagine that a new customer enters the store, sees the line, and chooses to walk to the front of it. An observer would likely see several different reactions from the customers in line. One may huff, one may politely attempt to correct the offense, and one may yell, revealing a bit of their personality in their behavior.

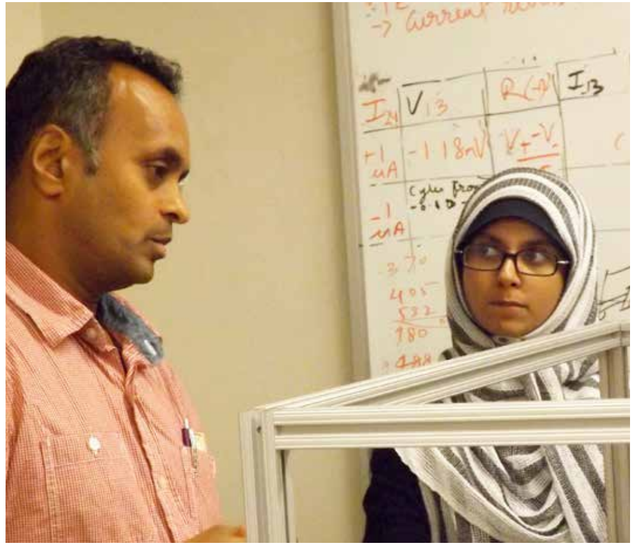
In research, investigators often find themselves studying disorder to develop a clearer understanding of a subject. Such is the case with Steven Johnston, assistant professor in UT's Department of Physics and Astronomy. Johnston's team is studying the orbital freedom of electrons in iron pnictide superconductors.

Now in its second year of funding, Johnston's JDRD project began with the creation of a computational model. With that model completed and generating meaningful results, Johnston is moving forward by introducing atoms with impurities and observing the behavioral changes of the affected electrons on extended clusters.

Data gathered by Johnston's team has been shared with his ORNL partner Thomas Maier, whose work focuses on neutron scattering in strongly correlated and disordered materials.

Ramki Kalyanaraman

Research doesn't always meet expectations. On rare occasions it can, however, exceed them. The members of Ramki Kalyanaraman's JDRD team are experiencing that very phenomenon as they move forward with their research. Currently in its second year, Kalyanaraman's project has yielded not only his expected outcome but an unforeseen discovery.



Kalyanaraman's team began their JDRD project by attempting to improve the materials used for optical sensor applications. Optical sensors are finding their way into a variety of modern technologies, including motion sensing, medical applications, and even chemical-detecting technology.

When Kalyanaraman, professor in UT's Department of Materials Science and Engineering, began his research, the most effective element for these sensors was silver, which unfortunately degrades rapidly once exposed to air—sometimes within a matter of hours. Over the course of the first year, his JDRD team found a way to mitigate this degradation and simultaneously discovered a new material. Since then, Kalyanaraman has filed an invention disclosure and ORNL is preparing to file a joint UT-ORNL patent.

In the meantime, Kalyanaraman's team has accomplished exactly what his project proposed. By combining silver with cobalt, they have improved the rate of degradation by more than 250 percent. As a result of that work, Kalyanaraman published a paper in January in the journal *Scientific Reports*, and he plans to submit proposals to the National Science Foundation in the fall.

His research has also led to further NSF support for a graduate student who is being supervised by Kalyanaraman's ORNL partner, Raphael Pooser. Additionally, new collaborations have been formed with ORNL scientist Benjamin Lawrie, who was recently named a joint faculty member in UT's Department of Chemical and Biomolecular Engineering.

Veerle Keppens

Transistors are found in nearly all modern electronic devices. From radios to computers, transistors have been credited with revolutionizing electronics, making portable devices possible. Their size, however, is quickly becoming problematic as modern science is approaching the limit of how small transistors can be made while maintaining effectiveness.

Veerle Keppens, professor and head of UT's Department of Materials Science and Engineering—also serving as an associate dean in the College of Engineering and director of JIAMS—seeks to address this with her JDRD project. Working with graduate student Amanda Haglund, Keppens is exploring the use of new materials for making smaller, more efficient transistors.

One of the problems cited with semiconductor transistors is energy consumption. When the materials in transistors are shrunk to a certain point, they become impossible to switch on and off, essentially leaking current constantly. Keppens's project is addressing this issue with liquid ionic gating, which can be used to make insulating materials into conducting materials, an effective on-off switch for smaller materials.

Haglund is mining the history books for magnetic semiconducting materials that were placed aside for lack of application in decades past. Working backward from papers and available research, she is attempting to recreate the structure of these materials and test their effectiveness in transistors.

This area of study in materials is just beginning to develop, and Keppens expects this research to serve as a catalyst for the study and creation of ionic liquid field-gated devices. Keppens's ORNL partner, Thomas Ward, is focusing his work on the ionic liquids utilized in Haglund's work. In turn, the material Haglund grows presents new areas of opportunity for Ward's research.

DID YOU KNOW?

Since 2010, the Science Alliance has provided support for more than seventy-five Joint Directed Research Development Projects and eight Distinguished Scientist appointments. Fields of study have included physics, geology, advanced materials science, and high-performance computing.

Anahita Khojandi

Green infrastructure has been a part of public consciousness for a number of years. Studies have shown urban green spaces can significantly contribute to stormwater management and flood prevention while improving the health of city dwellers and the local environment. Because green infrastructure is a fairly new consideration for urban development, however, there is no existing method for strategic placements to maximize its use.

Anahita Khojandi, assistant professor in UT's Department of Industrial and Systems Engineering, plans to remedy this issue. Khojandi's JDRD project, carried out with ORNL partners Xueping Li and Olufemi Omitaomu, is focused on creating a multimethod framework to aid midsize cities in considering the possible impacts of climate change extremes on infrastructure.

Parks and urban forests aid in controlling rainfall runoff by absorbing more water directly into the ground. Green roofs have the potential to conserve a building's energy—and when partnered with solar panels, they can simultaneously improve the efficiency of the panels to generate additional energy. While each of these components has notable benefits, mid-size cities have struggled historically with deciding where to locate them.

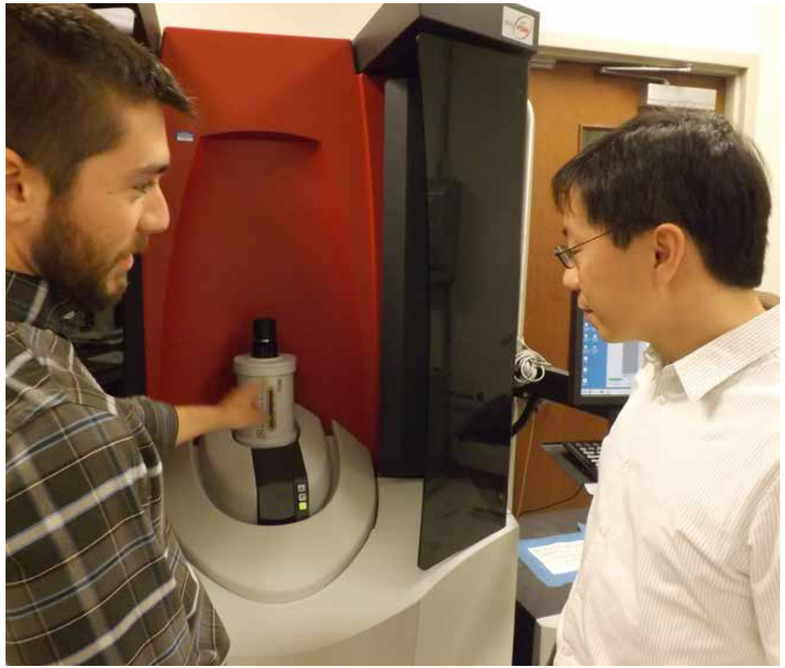
Khojandi's JDRD team is currently working on formulating a method for deciding where and how to incorporate green infrastructure into urban development in the most effective way possible.

Working in conjunction with ORNL's recently formed Urban Dynamics Institute, Khojandi, Li, and Omitaomu have presented some of their work to Knoxville city planners, who will use it to inform local urban development. They also hope the results of their research can be used in creating policies encouraging better, more proactive planning of urban development.

Jian Liu

What do baseball and computers have in common? According to Jian Liu, assistant professor in UT's Department of Physics and Astronomy, the answer is spin—or, more precisely, spin-orbit coupling.

Spin-orbit coupling is the interaction that occurs between an object's spin and its motion or trajectory. In baseball, the pitcher is always propelling the ball forward toward the catcher. However, the spin applied to the ball as it makes its way to home plate will affect the way the ball behaves as it travels. Spin applied in one direction can result in a curveball and in another direction can create a screwball.



In Liu's JDRD project, spin-orbit coupling presents a new way to tackle speed and efficiency in computers.

"In computers, the basic idea is you switch between two states, zero and one. How fast a computer can go or how much data it can store depends on how well it can switch between these two states," said Liu.

Magnetic materials are commonly used for this function, and application of an alternating magnetic field induces the changing state by flipping the direction in which the electrons are spinning within the materials. According to Liu, this method requires a great deal of electric current and, as a result, consumes a great deal of energy. The goal of his JDRD project is to increase the speed with which these changes are made while using less energy.

Liu's work could lead to major advances in electronics technology. Hard drives could store more, devices could perform faster on less energy, and entirely new devices could be created.

Nicole McFarlane

The earliest known image captured by a camera, from the Burgundy region of France, dates back to 1826. The photo itself is dark and grainy, barely hinting at the shape of several buildings visible from the photographer's upstairs window. In the nearly 200 years since then, specialized imaging devices have been developed for studying a variety of subjects, ranging from distant galaxies to subatomic particles.

Nicole McFarlane, assistant professor in UT's Department of Electrical Engineering and Computer Science, seeks to improve the imaging technology used for neutron detection through the creation of a complementary metal-oxide semiconductor (CMOS) chip. Her JDRD team is now in its second year of funding.

Neutron detection is a popular imaging method that is used at ORNL for a variety of materials, from strands of DNA to chunks of rock. This imaging is currently performed with cameras using photomultiplier tubes, which are large and expensive.

McFarlane's CMOS chip lets electronics and diodes exist on a single chip, creating a less expensive, smaller product. This proximity allows the chip to communicate and generate information more quickly. A first generation of the chip has already been fabricated and is awaiting testing at ORNL's Spallation Neutron Source.

If testing yields positive results, McFarlane is hoping to test the chip against commercial silicon photomultiplier arrays for efficiency and full range detection.

Liem Tran

The concept of sustainable development came into public awareness in 1987, when the Brundtland Commission, convened by the United Nations to address the depletion of natural resources, presented a report titled *Our Common Future*. The report coined the term *sustainable development,* defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

One of the key components of sustainable development is the unification of environment and development, a concept advanced by the Brundtland Report. In keeping with this idea, the National Science Foundation released a call for proposals to explore the nexus of these areas. Liem Tran's JDRD project seeks to do just that.

According to Tran, an associate professor in UT's Department of Geography, most contemporary sustainability assessments evaluate water availability separately from the interconnection with human infrastructure and development across geographic regions. His project proposes to use network analysis and graph theory to link these different areas, capturing their interaction at a number of levels.

Tran's JDRD team includes Hyun Kim, an assistant professor in the Department of Geography. Kim specializes in the network analysis that Tran's project will use to create a scalable methodology for observing these system interactions.

Tran and Kim are working on models for a regional scale but plan to create a flexible system adaptable to a variety of confines. Their ORNL partner, Ryan McManamay, will use the methods and results generated by the JDRD to study the footprint of urban energy systems on river networks.

Xiaopeng Zhao

The first intensive care unit (ICU) is believed to have been established in Copenhagen, Denmark, in 1953. Since that time ICUs have become a standard feature in hospitals, constantly updating the lifesaving techniques and equipment at their disposal. Xiaopeng Zhao, associate professor in UT's Department of Mechanical, Aerospace, and Biomedical Engineering, hopes to add to that list with the results of his current research.

Zhao's JDRD project is focused on taking all the unstructured data generated by ICU patients and organizing it into a scalable infrastructure of patient care management. ICU patients generate a huge amount of data, from the information collected by monitors to observations made by hospital staff.

One of the challenges with ordering this data is how variable it is. One ICU patient may have data from a cardiac monitor, while another has data from a blood test. Monitors used and tests performed will vary based on the patient's condition. Additionally, there is a great deal of opportunity for human error in the data collection and entry.

The goal of Zhao's JDRD team is to create a tool for structuring this data, which can then provide hospitals and doctors with useful information to inform their practices and individual patient care.

"If we can look at the ICU record to determine which patients have a higher risk of mortality, we can say those patients may need more intensive care or some special treatment," Zhao said.

Zhao's ORNL partner Georgia Tourassi has focused her work on big data management. The techniques developed in her corresponding LDRD project will be useful for Zhao's work, which will in turn provide a test bed for Tourassi's work.

"The goal is to look at the patient's data and understand the structure and information in the data and produce something useful so that the information can be used for patient management," Zhao said.

DISTINGUISHED SCIENTISTS

The Science Alliance Distinguished Scientist program supports high-profile joint leadership in research areas where UT and ORNL share complementary strengths. It has been the anchor program of the Science Alliance since 1984.

Distinguished Scientists hold tenured professorship at UT; most also hold a Distinguished Scientist appointment at ORNL, nominally half time at each institution. Appointments include an ongoing discretionary research fund equal to twelve months' salary.

In the future, we intend to explore Distinguished Scientist positions that are co-supported by endowments from our corporate research and development partners. This structure may allow us to amplify the investments made by the state and ORNL in areas of interest to our key industrial research and development partners.

Elbio Dagotto

Elbio Dagotto primarily uses computational techniques to study transition metal oxides, oxide interfaces, and the recently discovered iron-based high-temperature superconductors. These materials, and others studied by his group, show promise for both technological applications and advancement of fundamental concepts in condensed matter physics.

Dagotto has several active collaborations with ORNL scientists working with materials from manganese oxides to iron-based high-temperature superconductors. Additionally, he serves as principal investigator of a US Department of Energy field work proposal, Theoretical Studies of Complex Collective Phenomena, which secured a grant from the DOE that awarded $1,992,999 over eighteen months to ORNL.

Takeshi Egami

The physics of liquids is much less developed than the physics of solids. Takeshi Egami explores liquids and gases using computer simulation, including quantum mechanical calculations, and neutron and synchrotron x-ray scattering experiments.

Egami is currently participating in a number of active collaborations with ORNL scientists, including DOE projects whose fiscal year budgets total more than $2.7 million.

Egami was recently named an Aris Phillips Lecturer by Yale University, the most prestigious award given by their Department of Mechanical Engineering. Additionally, Egami has served as editor for *Advances in Physics* since 2011 and as divisional associate editor in condensed matter physics for *Physical Review Letters.*

Bob Hatcher

A structural and tectonics geologist, Bob Hatcher studies the processes that create and evolve Earth's continental crust. His team conducts detailed field and laboratory studies of the Appalachians and other ancient and modern mountain chains worldwide, as well as related studies that try to answer the question of why there are earthquakes in the eastern United States.

Hatcher is currently serving as principal investigator on a project, supported by the US Nuclear Regulatory Commission, studying paleoseismology of the East Tennessee seismic zone. His collaborations with scientists at the University of Memphis and the US Geological Survey have yielded important information about seismic hazards in East Tennessee.

In 2014 he was the recipient of the Marcus Milling Legendary Geoscientist medal, and he was recognized along with scientists from six other countries at the Geological Society of America Penrose Conference.

David Joy

David Joy's research helps create accurate microscopic and nanoscale imaging techniques, including the new, superior helium ion beam microscope which is more flexible and powerful than electron microscopy and could ultimately offer direct, high resolution imaging at subatomic and subnanometric scales.

Since its creation, Joy's microscope has been used consistently at ORNL. This instrument joins the Zeiss Transmission Electron Microscope, which Joy was directly responsible for acquiring, to a total benefit in excess of $5 million in microscopy alone.

Additionally, Joy serves as member of the editorial board for the *Journal of Microscopy* and is a regular reviewer for a number of major publications, including *Nature Materials*, *Physical Review Letters, Journal of Applied Physics*, and *Applied Physics Letters*.

Jimmy Mays

Jimmy Mays synthesizes new, precisely tailored polymers and examines their molecular architecture, composition, and blending capability to discover how form and structure, including their nanostructural order, might be manipulated to create useful materials.

Mays is a member of Alexei Sokolov's DOE field work proposal on polymer-based multicomponent materials, funded at $2 million annually, which Mays led prior to Sokolov's arrival. Additionally, he is serving as co-principal investigator on several ORNL-based polymer projects.

In 2014, Mays was named a fellow in the Royal Society of Chemistry as well as a guest professor at Soochow University in Suzhou, China.

Clayton Webster

The most recent addition to the program, Clayton Webster began his UT-ORNL Distinguished Scientist appointment on August 1, 2016. A professor in UT's Department of Mathematics, Webster has research interests that include approximation theory, numerical and functional analysis, and high-performance algorithms with a particular focus on large-scale applications.

Shull Wollan Center, a Joint Institute for Neutron Sciences

UT-ORNL JOINT INSTITUTES

UT-ORNL Joint Institute for Advanced Materials
The Joint Institute for Advanced Materials promotes interdisciplinary research and education related to developing new materials with superior properties, such as greater toughness and high-temperature strength, or those that can be tailored to support new technologies, such as pocket-sized supercomputers.

UT-ORNL Joint Institute for Biological Sciences
The Joint Institute for Biological Sciences supports interdisciplinary crosscutting research that accelerates progress in complex bioenergy and bioenvironmental systems. It also aids access by UT-ORNL faculty, staff, and students to state-of-the-art capability in genomic, transcriptomic, proteomic, and metabolomics analysis of biological and environmental systems.

UT-ORNL Joint Institute for Computational Sciences
The Joint Institute for Computations Sciences (JICS) advances scientific discovery and state-of-the-art engineering and computational modeling and simulation. JICS takes full advantage of the petascale and beyond computers in the DOE National Center for Computations Sciences and UT's National Institute for Computational Sciences.

UT-ORNL Joint Institute for Nuclear Physics and Applications
The Joint Institute of Nuclear Physics and Applications links UT, ORNL, and Vanderbilt University research to promote and support basic nuclear physics research and nuclear and radiological applications of common interest.

UT-ORNL Shull Wollan Center, a Joint Institute for Neutron Sciences
The Joint Institute for Neutron Sciences promotes worldwide neutron scattering collaboration among researchers in biological and life sciences, energy sciences, polymer science, condensed matter physics, and computational sciences.

STUDENT SUPPORT

Integral to the charter of the Science Alliance is this principle: Science Alliance funding will be used to "provide incentives to attract and retain the highest quality students and strengthen the educational opportunities for both UT and ORNL."

Consequently, each year a portion of the Science Alliance's funding is distributed directly to two colleges within the university with the express purpose of supporting graduate and undergraduate education and research. As a result, many students have had occasion to add significantly to the foundation of their future careers through direct support provided by Science Alliance projects:

Md Habib is a doctoral student in electrical and computer engineering working with Nicole McFarlane. Habib has focused his research on complementary metal-oxide semiconductor (CMOS) sensor design, the backbone of McFarlane's JDRD project. As a result, he has had the opportunity to design sensors for testing at ORNL's Spallation Neutron Source.

Amanda Haglund, under the direction of Veerle Keppens, has conducted extensive research into the creation of new magnetic materials for transistors. As part of her work, Haglund has gained invaluable experience in the synthesis of these materials as well as ionic liquid testing of 2-D materials.

Joshua Sangoro's undergraduate student **Konstantin Sedov** was trained extensively in experimental research and characterization using techniques such as dielectric and Fourier transform infrared spectroscopy. Sedov was also afforded the opportunity to gain experience in the use of state-of-the-art materials measurement equipment.

Brianna Watson has gained a great deal of hands-on experience while working with Tessa Calhoun's JDRD team. Watson built a nonlinear microscope and demonstrated its capabilities while serving as lead student investigator on the project. Additionally, Watson co-authored a paper currently in the process of being analyzed for publication by the *Journal of Physical Chemistry Letters*

Stephanie TerMaath's student **Sofy Weisenberg** has focused her research efforts on improving cerebrospinal fluid shunts for TerMaath's Collaborative Cohort work. As a result, Weisenberg was named one of the American Society of Mechanical Engineers' Fluids Engineering Division Graduate Scholars of the Year. Additionally, Weisenberg received a 2016 Chancellor's Award for Extraordinary Professional Promise and published a paper in the *Journal of Neurosurgery.*

Many Science Alliance–funded students are actively collaborating with ORNL scientists. They have earned additional funding for their work from a variety of sources, including the US Department of Energy, the National Science Foundation, the National Nuclear Security Administration, and the Army Young Investigator program. The contributions made by these scholars to each supported project ensure UT, as well as the state of Tennessee, a substantial foothold in the future of the nation's scientific community.

PUBLICATIONS

In the last funding year, Science Alliance-supported scientists have produced more than 130 peer-reviewed publications. Their work has been seen in high profile journals such as *Physical Review Letters*, *Nature Communications*, *American Journal of Science*, and the *Journal of Applied Physics.*

STUDENT FUNDING

Department	Total Support	Type of Support	Number of Students	Highlights
Biology	$307,408	GTA/GRA	28	About two-thirds of supported students collaborate with or are connected to ORNL. Students have co-authored nine publications and given 18 conference presentations; one was awarded Best Graduate Student Presentation at the Western Photosynthesis Conference.
Chemistry	142,879	Graduate Student Trainers	11	Most supported students work with mentors who are in ORNL collaborations. Almost half of the students receive additional support from the Army Research Office, with others earning funding from the National Science Foundation and the US Department of Energy. Students have co-authored 19 publications.
Earth and Planetary Sciences	41,423	GTA/GRA	9	More than a third of supported students have a UT supervisor with potential ORNL collaborations. Half of the students have presented at conferences, and more than 30 percent have co-authored publications.
Electrical Engineering and Computer Sciences	101,700	GTA/GRA	14	Several students are working on research in conjunction with ORNL, and more than a third are actively involved in NSF research. Students have produced numerous publications and conference presentations.
Geography	10,100	Graduate Student Fellowship	4	All supported students have active ORNL affiliations, most with the Geographic Information Science and Technology Group. Students have produced two peer-reviewed publications and five conference presentations, and one was inducted into the Gamma Theta Upsilon Geography Honors Society.
Mathematics	98,523	GTA/GRA	28	Supported students have generated six publications. More than half have made presentations at conferences, and two have internships at ORNL.
Physics	225,652	GTA	26	Nearly all supported students are being advised by scientists within the ORNL Physics Division. More than a quarter are affiliated with a UT-ORNL joint institute, including the Joint Institute for Nuclear Physics and Applications and the Joint Insistute for Advanced Materials.
Psychology	10,000	GTA/GRA	3	All supported students have supervisors with ORNL affiliations. Students have presented at multiple conferences and generated two publications. One is first author on a publication now being drafted for submission.

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