Greetings from Houghton, Michigan, and the campus of Michigan Technological University. I am pleased to bring you the 2015 edition of the Annual Report for the Department of Electrical and Computer Engineering. This report covers all of our departmental activity for the most recent fiscal year, which runs from July 1, 2014, to June 30, 2015.

As I write this, it is a brilliant, sunny, summer day in the Keweenaw. By the time you read this, the campus may be covered with snow again. We are blessed to live and work in such a wonderful location, with its four-season climate and all the varieties of recreational opportunity that go with it.

The ECE department continues to move forward in pursuit of its strategic goals of excellence in undergraduate and graduate education, and faculty achievement in research and professional service. This year the number of undergraduates and PhD students was about the same as in past years, while the number of students in our course-only MS program is rising. Our level of research activity, measured by expenditures, publications, and supported PhD students, is holding steady in comparison to recent years. One of the things that I am pleased with right now is the number of tenured and tenure-track faculty members—19 out of 25—that have sponsored research programs. All of these research-active faculty are fully engaged in our teaching programs as well, which I believe makes for a healthy department.

The demand for our graduates continues to push all boundaries. At the Fall 2014 Career Fair, the University hosted 341 recruiting organizations, with 2/3 of those looking to hire electrical or computer engineers for full-time jobs, co-ops, and internships. This is due in part to positive changes in the U.S. economy, but it is also a reflection of the reputation and ability of Michigan Tech engineers. In my position, nothing is more rewarding than talking to promising young graduates as they begin their professional careers, especially when they tell me how Michigan Tech has changed their lives and set them on a path to make the world a better place.

With all the success that our graduates are enjoying right now, one thing that makes me lose sleep at night is the fact that only 10 percent of those students are women. We struggle to understand why this should be the case. Perhaps the answer is that many students—both men and women—are not aware of the breadth of industries and application areas where electrical and computer engineers are needed and can make their mark. With an eye toward expanding that understanding, the ECE department has recently introduced two new undergraduate concentrations, one in Biomedical Applications and one in Environmental Applications.
This year we said goodbye to two faculty members, Ashok Goel and Zhi (Gerry) Tian. Goel retired in November 2014, and Tian took a position at George Mason University, in Fairfax, Virginia. We will miss them of course, and we are grateful for their contributions during their time with us, and wish them well. Two new faculty members will take up positions with us in the Fall 2015 semester, and I will have more to say about them in the 2016 Annual Report.

As always, the ECE department is eager to maintain its ties with alumni and friends, and we encourage them to engage with the department in whatever way looks and feels right for them. We are fortunate to have many alumni who feel strongly connected to Michigan Tech and remember us financially. This year we received a generous gift from the estate of Earl and Ellanette Lind to endow a graduate student fellowship.

Many thanks for your interest in Michigan Tech and reading about the department. For more information you can visit our website at www.mtu.edu/ece, or just shoot me an e-mail at fuhrmann@mtu.edu. I look forward to hearing your comments.

Daniel R. Fuhrmann, Chair
Dave House Professor and Chair
Department of Electrical and Computer Engineering
fuhrmann@mtu.edu
Ashok Ambardar
Associate Professor
PhD, Electrical Engineering, University of Wyoming
Signal processing, medical imaging

Glen Archer
Principal Lecturer/Associate Chair
PhD, Electrical Engineering, Michigan Technological University
Image processing, security, information operations

Paul Bergstrom
Professor
PhD, Electrical Engineering, University of Michigan
MEMS, nanotechnology

Leonard Bohmann
Professor/Associate Dean, College of Engineering
PhD, Electrical Engineering, University of Wisconsin
Power systems, renewable energy

Jeremy Bos
Assistant Professor
PhD, Electrical Engineering, Michigan Technological University
Atmospheric optics, image processing, machine intelligence

Duane Bucheger
Professor of Practice/Senior Design Coordinator
PhD, Sensing and Signal Processing, Michigan Technological University
Signal processing, power electronics

Jeffrey Burl
Associate Professor
PhD, Electrical Engineering, University of California—Irvine
Adaptive control, robust control, image motion estimation

Bo Chen
Dave House Associate Professor of Mechanical Engineering and Electrical Engineering
PhD, Mechanical and Aeronautical Engineering, University of California—Davis
Intelligent mechatronics, embedded systems

Christopher (Kit) Cischke
Senior Lecturer
MS, Computer Engineering, University of Minnesota
Parallel computing and UPC

Zhuo Feng
Associate Professor
PhD, Computer Engineering, Texas A&M University
VLSI computer-aided design, multiphysics modeling and simulation

Daniel Fuhrmann
Dave House Professor and Chair
PhD, Electrical Engineering and Computer Science, Princeton University
Signal processing
Lucia Gauchia
Richard and Elizabeth Henes Assistant Professor of Energy Storage Systems
PhD, Electrical, Electronic, and Automation Engineering, University of Carlos III of Madrid, Spain
Energy storage systems, state estimation for batteries and supercapacitors

Durdu Guney
Assistant Professor
PhD, Electrical and Computer Engineering, University of California—San Diego
Metamaterials and plasmonics, quantum computing, communications and cryptography

Timothy Havens
William and Gloria Jackson Assistant Professor
PhD, Electrical and Computer Engineering, University of Missouri
Pattern recognition and machine learning, signal and image processing

Shiyan Hu
Associate Professor
PhD, Computer Engineering, Texas A&M University
Computer-aided design of VLSI circuits and combinatorial optimization

Roger Kieckhafer
Associate Professor
PhD, Electrical Engineering, Cornell University
Computer architecture, fault-tolerant computing

John Lukowski
Associate Professor
Chair, Undergraduate Programs Committee
MS, Electrical Engineering, Michigan Technological University
Power, energy, factory automation, robotics

Christopher Middlebrook
Associate Professor
PhD, Optics, University of Central Florida
Infrared detectors, optics, photonics, radiometry

Bruce Mork
Dennis Wiitanen Professor of Electric Power Systems
PhD, Electrical Engineering, North Dakota State University
Power system transients (ATP/EMTP), nonlinear dynamics and chaos theory, power system protection

Saeid Nooshabadi
Professor
PhD, Integrated Circuits (VLSI), Indian Institute of Technology Delhi (IITD)
High-performance computer architecture, embedded systems

Aurenice Oliveira
Associate Professor
PhD, Electrical Engineering, University of Maryland, Baltimore County
Optical fiber communications, automation, wireless communication

Sumit Paudyal
Assistant Professor
PhD, Electrical Engineering
University of Waterloo, Canada
Smart-grid technologies, optimization techniques in power systems

Joshua Pearce
Associate Professor
PhD, Materials (Engineering option)
The Pennsylvania State University
Photovoltaic materials, photovoltaic device physics, photovoltaic systems

Warren Perger
Professor/Chair, Graduate Programs Committee
PhD, Physics, Colorado State University
Theoretical atomic physics, electrophysics

Michael Roggemann
Professor
PhD, Electro-Optics, Air Force Institute of Technology
Optics, image reconstruction and processing, pattern recognition

Timothy Schulz
Professor
DSc, Electrical Engineering,
Washington University in St. Louis
Statistical signal processing, computational photography

Elena Semouchkina
Associate Professor
PhD, Materials (Engineering option), The Pennsylvania State University
Electromagnetic metamaterials, computational electromagnetic analysis

Chee-Wooi Ten
Assistant Professor
PhD, Electrical Engineering, University College Dublin
Power infrastructure cybersecurity, future control center framework, SCADA/EMS/DMS applications

Zhaohui Wang
Assistant Professor
PhD, Electrical and Computer Engineering, University of Connecticut
Communications, signal processing, communication networks, and network security

Wayne Weaver
Dave House Associate Professor of Electrical Engineering
PhD, Electrical Engineering, University of Illinois at Urbana-Champaign
Power electronics systems, microgrids, hybrid and electric vehicles

Seyed (Reza) Zekavat
Professor
PhD, Communication, Colorado State University
Wireless localization systems, wireless power transfer, statistical signal processing
ECE FACULTY AWARDS

The ECE faculty participate in the various forms of service for the profession, and are often recognized for their excellence in teaching and research. We are proud of their many contributions and accomplishments.

Promotion and Tenure

Zhuo Feng was promoted from Assistant Professor to Associate Professor with tenure.

Awards and Honors

Kit Cischke was nominated to the Dean’s Teaching Showcase, sponsored by Michigan Tech’s William G. Jackson Center for Teaching and Learning.

Shiyan Hu was elected Fellow of the Institute of Engineering and Technology (IET), and was named a distinguished speaker of the Association for Computing Machinery (ACM). He was among 62 researchers invited from the European Union and the United States to attend the National Academy of Engineering Frontiers of Engineering symposium.

Zhaohui Wang was named an Outstanding Reviewer by the IEEE Journal of Oceanic Engineering.

Professional Service

Leonard Bohmann was appointed as the finance committee chair of the IEEE Education Society for 2015.

Bo Chen is the guest editor of the special issue on mechatronic and embedded systems and applications in intelligent transportation systems for the IEEE Transactions on Intelligent Transportation Systems. She was also a member of the technical program committee for the 2014 IEEE Conference on Intelligent Transportation Systems (ITSC14).


Shiyan Hu is a founding co-chair for the IEEE Technical Committee on Cybernetics for Cyber-Physical Systems (CPS), within the IEEE Society for Systems, Man, and Cybernetics (SMC). This is the first CPS-related technical committee among all IEEE societies.


Mike Roggemann serves on the editorial board of Applied Optics as topical editor for Wave Propagation and Imaging through Atmospheric Turbulence.

Reza Zekavat was an organizer and co-chair of the Wireless Power Transfer Workshop, held in September 2014 in conjunction with the 2014 IEEE Annual International Symposium on Personal, Indoor, and Mobile Communications (PIMRC’14). He also served on the PIMRC’14 organizing committee as finance co-chair.

Timothy Havens was honored as Professor of the Year presented by the Michigan Tech chapter of Eta Kappa Nu, the student honor society of IEEE. He was selected by a vote of ECE students for all-around excellence in teaching. Havens was also a winner in the Jackson Center for Teaching and Learning’s Creative Canvas Course Contest for his course CS5821, Computational Intelligence—Theory and Application. Pictured is Havens receiving his award from HKN’s Alexandra Roche.
Michigan Tech and Google’s Advanced Technology and Projects (ATAP) group have signed an open-ended research agreement which will make it possible for Tech faculty and students to work directly on a variety of research and development projects with the Silicon Valley powerhouse.

The agreement is known as the Pilot Multi-University Sponsored Research Agreement, or MURA. Google ATAP has similar partnerships with about 30 other universities in the U.S. and abroad. The MURA concept is part of Google ATAP’s effort to use and promote the technological talent and innovation on America’s university campuses to help strengthen its own technology portfolio. The ATAP division at Google is headed by Regina Dugan, former director of the Pentagon’s Defense Advanced Research Projects Agency, or DARPA.

Not surprisingly, the ATAP model looks a lot like what one finds at DARPA: high-risk, high-impact projects with a short two-year timeline and a team of researchers from multiple institutions working with intense focus on results. The idea is to develop a breakthrough innovation that may or may not fit within other Google business units, and at the end of the two-year period either take it internally for further development and commercialization, spin it off, or scrap it.

The MURA is a single contract between Google ATAP and Michigan Tech which serves as a vehicle for multiple projects as they become available. An individual project is defined using a Statement of Work (SOW) and a budget, and after a brief negotiation the project can be added to the master contract. The aim is to shorten the lead time between initial contact and getting started with research.

The first Michigan Tech project under the MURA is being led by Professor and Department Chair Daniel R. Fuhrmann, along with ECE colleagues Saeid Nooshabadi and Aurenice Oliveira, on a technology development program that has not yet been publicly released.

"I am thrilled to be a part of this new relationship," Fuhrmann said. "We are grateful that Google has put their faith in Michigan Tech, and we will do everything we can to earn that trust."
The Sound Beneath the
Learning more about acoustic properties underwater — and specifically under the ice — is important for designing acoustic communication networks and quiet underwater vehicles. These networks and vehicles have a range of applications, including naval, subsea oil/gas exploration and drilling, and environmental monitoring. The latter encompasses everything from ice movement to the habits of aquatic critters to keeping tabs on water qualities. Although the applications are broad, studying acoustics all comes back to sound: Beeps and chirps for network signals, the glassy crinkle of floating ice and even the underwater reverberation of a snowmobile passing by. Each sound tells a story; each narrative helps researchers understand the icy-cold depths we can’t normally see.

Zhaohui Wang, assistant professor of ECE, studies underwater wireless communication networks. She, alongside other researchers at the Great Lakes Research Center, has taken advantage of having a perfect testing bed in the Keweenaw Waterway and Lake Superior.

Within underwater acoustic networks, information delivery is key, whether it’s about the condition of nodes along a pipeline, naval command control, or the frolicking behavior of seals.

“There are a wide range of applications,” says Wang.

For networks above water, radio waves connect the wi-fi in our homes and favorite coffee shops — along with cell phones, televisions and car stereos. Wang’s network, however, has to adapt to being underwater.

“Radio signals attenuate very fast under water,” Wang says, explaining the radio waves weaken and disperse more quickly in water. “We have to use acoustics as the information carrier.” Particularly, underwater acoustics is the only option for autonomous vehicles with ice cover, since they cannot surface to access satellite services.

However, underwater acoustics is not as quick as the radio signals we’re used to: In 1.3 seconds, sound can transmit 2 kilometers, and within that time, the radio signal from Earth has reached the moon. This speed bump makes underwater acoustic networks more challenging than their terrestrial radio counterpart.

Wang makes do with the limitations. “My goal is to design communication algorithms and network protocols that allow nodes to communicate with high data rate and energy efficiency,” Wang says, explaining that this gets complex as more nodes are added to the network. All the nodes have to coordinate for transmitting and receiving.

Starting last August, Wang and her research group conducted several underwater communication tests. They went out in March — and found some benefits to ice cover. Her team was able to send a signal over four kilometers away, which came in handy when their cell phones died. Testing also proved much easier, since the team could just walk out on the lake.

“We went out in May and repeated the experiment at the same site after the ice was gone,” Wang says. “The signals received at different test distances became weaker compared to those in the March experiment with ice cover.”

However, the underwater nodes still could communicate over a distance of 15 km. The team believes that the communication distance with ice cover will be more than 15 km— during the March experiment, they could not go as far walking on the ice as they would have liked and only reached a test distance of 4 km. They are planning to bring a snowmobile for the under-ice experiments to be conducted this winter.

“There is very little under-ice communication data available,” Wang says. “We need to take advantage of the unique features of this area and run under-ice experiments.” Wang and her colleagues plan to continue developing this body of under-ice research along with their all-season underwater acoustic tests. The work will keep maximizing the advantages of Michigan Tech’s location, providing yet another reason to appreciate having Lake Superior out our backdoor.
Advancing Microgrid Deployment
On the battlefield, a reliable, easy-to-maintain power source is essential with danger lurking just beyond the base walls. A flexible, efficient and reliable tactical microgrid is very important to today’s modern military. But microgrids, covering a small area, face problems that a large national grid wouldn’t face. ECE faculty member Wayne Weaver, the Dave House Associate Professor of Electrical Engineering, is currently work to stabilize the microgrid solution with an interdisciplinary team of researchers at Michigan Tech.

A war zone is rarely stable, and a disaster scenario most likely has very limited resources. This means that the old, inefficient way of overpowering a microgrid to gain stability is frequently not an option. Additionally these operations do not have highly trained power engineers to set up, operate, and maintain the needed systems. With these challenging requirements, the most important function is to keep critical power loads reliably supplied with power. This type of microgrid needs is to be smarter, to use fewer resources, and to be flexible to operate in unforeseen circumstances.

Weaver, along with Assistant Professor Laura Brown (CS) and Professor Gordon Parker (MEEM), co-director of the Agile and Interconnected Microgrids Center at Michigan Tech, are working on a smart power system that uses adaptive, predictive, and decision-making algorithms that can learn system behavior. These technologies allow the reliable use of energy storage and renewables in small grids, and allow the power grid to grow through the ability to chain multiple microgrids together. This enables distributed control over a larger power network for vastly improved reliability of the power supply and significant fuel consumption reduction.

Creating these technologies requires research into key areas of control theory, adaptive algorithms, and model-based predictions. Research and analysis of techniques in learning behavior and artificial intelligence for system control are being conducted to provide the ability to reduce the need for human oversight of power grid systems. These systems will monitor and react to external inputs including current and forecasted weather events and operational and logistical support data that can provide the critical information to make decisions and support system learning.

“The weather forecast might be very sunny for the next week,” Weaver explains. “Then the grid can run more on solar energy, making the smart controller be as efficient as possible. That is something we are currently working into the microgrid system.”

What complicates matters is that these controls need to be flexible enough to work with a variety of electrical equipment. The military has a vast number of bases with many different solutions deployed in the past.

“We have to integrate these smart controls into the existing hardware,” Weaver says. “They can’t just replace all of their gear. To do so would be prohibitively expensive.” The research has just moved out of the lab and into the test field. Once ready, the new smart microgrid system will provide a more reliable, efficient, and secure way to provide power for military operations.
The road near the horizon seems to shimmer, giving the impression of water always just beyond the reach of your car. That light is playing a trick on you: light from the sky is reaching the surface and being bent by a temperature inversion. It's propagating in a way that's counter to how we would imagine.

The path that light travels is of particular interest to Mike Roggemann. A professor in the ECE department, the retired Air Force officer studies the way light behaves in the atmosphere with respect to optical communication.

“There are several uses for this kind of technology,” Roggemann explains. “Astronomers have a strong interest, of course, as it would help them to see the universe through distortion in our atmosphere.

“I work more with free-space optical communication. It’s horizontal rather than vertical.”

Fiber optic networks operate by sending light signals through fibers between pieces of equipment. Free-space optical communication simply removes the fibers, sending out light through the atmosphere. That’s where turbulence can become an issue.

“Over a short distance, these networks can run at a good speed,” he says. “Over longer distances, with the signal having to travel through more and more atmosphere, there’s more turbulence and distortion. That slows the communication down quite a bit.”

The challenge, then, is to find ways to counteract that turbulence so a consistent, strong signal can carry vital communications. A sensor at the receiving station can keep track of atmospheric conditions and train the station to compensate for the noise and distortion. In other words, it is precompensating for transmission errors.

“Having reliable communication is important in a disaster,” Roggemann says, giving an example for when this technology might be deployed. “Or up and down a mountain, places where you can’t run fiber.”

The way light can be distorted can also be used to an observer’s advantage. Recently, Roggemann and some of his students have ventured north to the tip of the Keweenaw Peninsula, trying to catch a glimpse of a freighter below the horizon, using the same temperature inversion principles we see in a mirage.

“We know where the freighters are thanks to digital tracking, and we can keep a good eye on the weather,” Roggemann says. “It’s just a matter of bringing the equipment with us and everything lining up just right.”

It’s this temperature inversion, common in mountainous areas, that makes the famous Paulding Light possible. While car headlights being bent downward off the clouds and through trees explains the light’s origins, Roggemann and his team also offer some room for those who support the local legend.

“If someone says the light is extraterrestrial or supernatural, our research doesn’t prove that it isn’t.”
The entire west wall of the Power and Energy Research Lab is lined with outlets and switches. The array simulates a power grid operating board, a lab version of what would be the beating heart of a power plant.

What most people take for granted in the easy flip of a switch is the complexity it takes to run a system like this. Bruce Mork, the Dennis Wiitanen Professor of Electric Power Systems, and his research group of ECE faculty and students, know what it takes to bring power to your home or business and protect the path in which it travels.

Elizaveta Egorova, an electrical engineering PhD candidate, is studying power transformer protection, specifically internal faults under Mork’s direction. “Transformers are one of the main components in power grids,” Egorova says. “This type of equipment is used in every country of the world, and research for power transformers is never ending.”

“With a long time in service, transformer insulation deteriorates, and internal faults can occur,” she says. “The faster a fault is detected, the less damage to a transformer will be inflicted—and for such an expensive piece of equipment, in the range of $1-7 million, it should always be well protected from possible damages.”

Mork explains that smart grid technologies can make it possible to more closely monitor and optimally compromise between system operation needs and transform Loss of Life—how much operational life is used. In addition, advancements in fundamental protection technologies can help in the development of smart grid strategies.

This work is supported by a consortium of energy-company partners who know that this kind of research is crucial for maintaining infrastructure and transitioning into more efficient smart grid set-ups. Partners include: Bonneville Power, American Transmission Company, Great River Energy, Semiconductor Energy Laboratory, and Wisconsin Public Service.

This past summer, three students from Brazil joined the group as part of the Institute for International Education (IIE) exchange. One of the students, Gabriel Sousa, spoke of his interest in protective relays, the first line of defense to protect electrical equipment.

“Without an effective protection scheme, a complex and high cost power system could be easily damaged in electric fault events,” Sousa says. “This research is a great opportunity for me to learn about the most effective and reliable methods to guarantee a power system integrity.”

The two other students, Junior Castro and Matheus Freitas, share the same enthusiasm for making their work matter.

“As an electrical engineering student concerned with society’s development, I think that working in this area will help me to build structures and systems that will improve my country and the world,” Castro says.

Freitas agrees that his experience at Michigan Tech has influenced how he sees his career in electrical engineering. “The chance to study in the United States has made me realize the importance of the power system field,” he adds.

ECE’s power and energy research group brings together faculty, graduate and undergraduate students, along with industry, to help solve critical issues that go along with the use of new smart grid technology.
ECE FACULTY PUBLICATIONS


X. Li, and S. Zekavat, “Number of clusters formed in an emergency cognitive radio network and upper bound of network simultaneous transmission capacity,” *IET Communications*, vol. 8, no. 14, pp. 2516-2527, September 2014.


**Book Chapters**


**Books**


ECE GRADUATE STUDENT HIGHLIGHTS

ECE Doctoral Degrees: August 2014 to May 2015

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<tr>
<th>PhD Graduate</th>
<th>Advisor</th>
<th>Dissertation Title</th>
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<tbody>
<tr>
<td>Kaitlyn Bunker</td>
<td>Wayne Weaver</td>
<td>Multidimensional Optimal Droop Control for Wind Resources in DC Microgrids</td>
</tr>
<tr>
<td>Fang Chen</td>
<td>Elena Semouchkina</td>
<td>Near-Field Coupling and Homogenization in All-Dielectric Metamaterials and their Effects on Applications</td>
</tr>
<tr>
<td>Yonghe Guo</td>
<td>Chee-Wooi Ten</td>
<td>Cyberdefense Framework for Electrical Distribution Grid</td>
</tr>
<tr>
<td>Mohamed Hanafy</td>
<td>Mike Roggemann</td>
<td>Characterization of the Atmospheric Effects on the Transmission of Thermal Radiation</td>
</tr>
<tr>
<td>Weston Thomas</td>
<td>Chris Middlebrook</td>
<td>Multi-Wavelength Speckle Reduction for Laser Pico-Projectors Using Diffractive Optics</td>
</tr>
</tbody>
</table>

Graduate Student Awards:

Zagros Shahooei—Jonathan Bara Award for Outstanding GTA

Xiaohui Wang—Matt Wolfe Award for Outstanding GRA

Details regarding the students and awards are located on the ECE website at: www.mtu.edu/ece/department/student-awards

Electrical and Computer Engineering Graduate Student Fellowship Recipients 2014-2015

House Professorship Fellows

Marco La Manna, PhD Candidate
Expected graduation: Spring 2016
Advisor: Daniel Fuhrmann

Amir Rezaei, PhD Candidate
Expected graduation: Fall 2015
Advisor: Jeffrey Burl

Jackson Professorship Fellow

Dereck Wonnacott
Expected graduation: Summer 2015
Advisor: Timothy Havens
The Electrical and Computer Engineering Department is pleased to welcome Chito Kendrick as the new Managing Director of the Microfabrication Facility (MFF).

Kendrick completed his PhD in Electrical and Electronic Engineering at the University of Canterbury in New Zealand. His research focused on the growth of III-nitride thin films by molecular beam epitaxy. He moved to the United States in 2008 for a postdoctoral position at Penn State. His research at Penn State involved the growth and fabrication of silicon wire photovoltaic cells. He then moved to the Colorado School of Mines as a research assistant professor in the Department of Physics, working on quantum-confined nanocrystalline silicon, a hybrid material that may allow for the fabrication of an all-silicon multiple junction photovoltaic cell or a photovoltaic cell that allows for hot carrier collection.

Kendrick relocated to Houghton in 2014 with his wife, Yvette Dickinson, assistant professor of Forest Resources and Environmental Science. He took a part-time position as research assistant professor with a joint appointment in the ECE department and the Department of Material Science and Engineering. During that time he began working with Prof. Joshua Pearce, also in the MSE and ECE departments, on the growth of strain-free gallium nitride on silicon. Chito taught EE4231, Physical Electronics, in Fall 2014.

In Spring 2015, Kendrick was selected as the new MFF Managing Director following an extensive search to fill the position formerly held by William (Bill) Knudsen for ten years prior. According to Prof. Paul Bergstrom, MFF director and search committee chair, “Dr. Kendrick’s strong qualifications and the depth and breadth of his experience in materials processing and device characterization at the micro and nano scale made him an ideal choice to move the Microfabrication Facility to the next level of capability.”

The MFF was founded in 2000 by Prof. Bergstrom under a multi-university NSF grant. Operations began in 2003 and the facility was made available to all researchers on campus in 2006. The facility has a range of capabilities including thin film deposition of metals and dielectrics, wet and dry etching, photolithography, thermal diffusion furnaces for the fabrication of p-n junctions used in diodes, photovoltaic cells and transistors, wafer dicing, and electrical testing of fabricated device structures. In 2014 the MFF was named a Michigan Tech Core Facility by the Office of the Vice-President for Research.

Kendrick will be involved with the daily operations of the facility, training new users, and developing the MFF equipment to allow for a research space that PIs and students across campus can utilize to develop their research programs. Currently the MFF is being used for a range of projects including improving photovoltaic cells, biological and biochemical sensors, and photonics. A priority for Chito’s effort over the next year will be the re-introduction of chemical vapor deposition process capabilities.

Kendrick will teach EE5471, Microfabrication Laboratory, on a regular basis beginning this fall. This course is designed to give students hands-on experience in the MFF and allow for the fabrication of their own devices. Chito also plans to develop an intensive laboratory short course where K-12 teachers and others with an interest in solar energy can learn what goes into the fabrication of a photovoltaic cell.

When he is not at the MFF, or continuing his photovoltaic cell research, he can be found on the streams and lakes in the Upper Peninsula fly fishing for trout, bass, and pike. He is also a keen fly tier, tying both modern flies and fully dressed classic salmon flies.

STAFF DIRECTORY

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joan Becker</td>
<td>ECE Graduate Program Coordinator</td>
</tr>
<tr>
<td>Judy Donahue</td>
<td>ECE Undergraduate Advisor</td>
</tr>
<tr>
<td>Trever Hassell</td>
<td>CpE Undergraduate Advisor and Instructor</td>
</tr>
<tr>
<td>Lisa Hitch</td>
<td>Business Manager and Technical Communications Specialist</td>
</tr>
<tr>
<td>Michele Kamppinen</td>
<td>Staff Assistant</td>
</tr>
<tr>
<td>John Kolacz</td>
<td>Research Associate</td>
</tr>
<tr>
<td>Chuck Sannes</td>
<td>Laboratory Supervisor</td>
</tr>
<tr>
<td>Mark Sloat</td>
<td>Research Associate</td>
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ECE CREATES NEW CONCENTRATIONS

Biomedical Applications and Environmental Applications within the Bachelor of Science in Electrical Engineering

One challenge we face as educators in electrical engineering is raising awareness of the breadth of opportunities to our own current and prospective students. Many come into the field, if they come at all, with at most vague notions of what electrical engineering is and what an electrical engineer can be. We need to help students make good choices about the fields or sub-fields that they may enter, and then provide them with the tools they need to be competitive in the job market that they choose to enter. With that as our primary motivation, the ECE department has created two new concentrations, one in Environmental Applications and one in Biomedical Applications, within the Bachelor of Science in Electrical Engineering.

The Biomedical Applications concentration is for those students whose primary interest is in electrical engineering, and who seek to apply their skills in the healthcare field. Examples of such applications include biomedical instrumentation, biomedical signal processing, and medical imaging.

The Environmental Applications concentration is intended for those students whose primary interest is in electrical engineering, but who seek to apply their skills in environmental quality assurance and remediation. Examples of such applications include environmental remote sensing, water treatment, and industrial controls for manufacturing, and energy generation.

A secondary motivation for the establishment of these concentrations is to attract and retain more women into electrical engineering. This motivation is consistent with the University’s 2035 Portrait, which includes a female undergraduate population which is 40 percent of the total, the College of Engineering’s former strategic goal of being among the 10 largest engineering programs in the nation for women, and the ECE department’s strategic goal of having undergraduate women make up 20 percent of our enrollment by 2020. Given the current level of interest among women in biomedical and environmental fields in general, we feel that making clear the strong connection that exists between these fields and electrical engineering is one good strategy towards meeting those goals.

BME Department Chair Sean Kirkpatrick and CEE Department Chair David Hand were very supportive of the new concentrations during the proposal process.

“Thank you to the ECE department for their vision and leadership,” said Kirkpatrick. “This concentration will offer new opportunities to students in both EE and BME disciplines as they prepare themselves to be productive and highly employable engineers.”

Hand explained, “For a long time, electrical engineers, environmental engineers and scientists have been developing sensing devices to track and monitor the physical, chemical, and biological characteristics of the built and natural environment to help balance the needs of mankind while minimizing the impact on the world in which we live. The environmental applications concentration will only strengthen the importance of balancing these needs.”

The new concentrations, available Fall 2015, will open up the career possibilities in electrical engineering to those students, both men and women, who have a focused passion for human health and well-being and our shared environment.
SLAM SYSTEMS  Mapping—and more—in real time

Let’s say you’re walking around a new building,” says Joshua Manela, an undergraduate researcher in the Michigan Tech Intelligent Robotics Lab (IRL). “Inherently whether you know it or not you’re figuring out where you are. You see a bunch of walls, doorways, and usually when you look around you get a general idea of what your environment looks like. You are simultaneously localizing yourself and mapping your surroundings without even knowing it. In the robotics world, this is known as SLAM—simultaneous localization and mapping.”

Manela, an electrical engineering major, is working with a research team in the IRL with director Tim Havens to develop a sensor pod for UAVs that will combine information from LiDAR, camera, and sensors to measure 3D information about road and bridge surfaces for the Michigan Department of Transportation.

Last summer Manela worked in the lab full-time as a summer undergraduate research fellow, which gave him the opportunity to write SLAM algorithms for testing purposes. He used those algorithms to map out random areas with a UAV, scanning 3D environments such as hallways and intersections. Havens and Manela also drove downstate to fly the UAV across a bridge over a major highway, then went back to the lab and recreated the bridge in 3D space with the team.

Manela also helped design the LiDAR sensor system for the team’s UAVs along with PhD student Dereck Wonacott and another undergraduate researcher, computing engineering major Tim Bradt. “LiDAR is like radar on an airplane but uses lasers instead of radio waves,” he explains.

“Application-wise, the possibilities are infinite. Consider a robot that can walk through a building and create a floor plan in real time to help law enforcement officers enter an unfamiliar, dangerous area. Consider autonomous vehicles, how do you think they know how to get around? They use SLAM. That little rotating sensor on the top of the Google car is actually a laser scanner, which grabs all the points in the surrounding area. Being able to match up those points with points around it allows the car to know exactly where it is down to the centimeter, while also giving it a clear map of its surroundings.”

Staying up-to-date with the newest technologies is the most challenging aspect of the work. “The research we’re doing in the IRL is the stuff you see in comic books and science fiction movies. The idea behind research is to try and find the next coolest thing that can revolutionize your field, and help everyone else at the same time. Basically I love seeing the future and trying to invent past it,” he says.

Manela plans to attend graduate school and wants to become a professor. “The two things I love in life are teaching people and doing cool stuff, which is exactly what being a professor entails. I taught robotics camps and classes to K–12 students for a couple of years, and I’ve been hooked on teaching ever since. I just like to do cool stuff and help other people do it.”

This story originally appeared in the 2015 College of Engineering compendium of undergraduate education.
UNDERGRADUATE STUDENT AWARDS:

ECE Departmental Scholar: Joshua Manela

ECE Woman of Promise/Martha Sloan Scholarship: Alexandra Roche and Andrea Henry

Carl S. Schjonberg Award for Outstanding ECE Undergraduate Student: Jordan Grider

Details regarding the students and awards are located on the ECE website at: www.mtu.edu/ece/department/student-awards
Our Discover-Design-Deliver philosophy is at the core of our Senior Design program, where students experience a project’s entire design process as it would be in industry. Students enrolled in Senior Design work as teams on client-based engineering projects in consultation with a client representative and the direction of a faculty advisor. Our Department’s Senior Design experience spans a full year, by the end of which a team has delivered design reviews, a final report, a formal presentation, and an end product to the client. The following are our Senior Design Teams for the 2014-2015 academic year.

<table>
<thead>
<tr>
<th>Projects</th>
<th>Sponsor</th>
<th>Advisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Tool to Develop Equivalent Circuit Motor Parameters</td>
<td>American Transmission Co.</td>
<td>Trever Hassell</td>
</tr>
<tr>
<td>MAP Determination of Intake Cam Centerline Phase II (Software)</td>
<td>Fiat Chrysler Automobiles</td>
<td>Duane Bucheger</td>
</tr>
<tr>
<td>Front End Protection for Data Acquisition</td>
<td>ECE Department</td>
<td>Duane Bucheger</td>
</tr>
<tr>
<td>Substation Automation Standards</td>
<td>DTE Energy</td>
<td>John Lukowski</td>
</tr>
<tr>
<td>Geomagnetically-Induced Current Monitoring</td>
<td>ITC Holdings Corp.</td>
<td>John Lukowski</td>
</tr>
<tr>
<td>Smart Bin for Real-Time Waste Monitoring in a High-Speed Manufacturing Facility</td>
<td>Kimberly–Clark</td>
<td>Don Moore</td>
</tr>
<tr>
<td>dSpace Hardware in the Loop Development and Testing</td>
<td>Nexteer Automotive</td>
<td>Jeff Burl</td>
</tr>
<tr>
<td>Production End of Line Noise Test Certification</td>
<td>Nexteer Automotive</td>
<td>Jeff Burl</td>
</tr>
<tr>
<td>Smart Grid Home Energy Management Application</td>
<td>Consumers Energy</td>
<td>Don Moore</td>
</tr>
<tr>
<td>System to Measure the Effectiveness of a Rail Shunt</td>
<td>Union Pacific Railroad / NURail Center</td>
<td>Duane Bucheger</td>
</tr>
</tbody>
</table>
Wireless Communication Enterprise

Wireless Communication Enterprise (WCE) focuses on providing a friendly yet business-like environment for a wide variety of available projects. We pride ourselves on the bonds our members often form over the course of a semester as we all progress through the year and the consistent high quality of our work product. Over the past two years, our Enterprise has doubled in size to 68 students. We attribute this to the quality work we do on all of our projects. This year we worked on the Michigan Tech Broomball Scoreboard project, making progress toward a functional electronic scoreboard. We also have two electric vehicle projects with Ford involving scalable battery pack monitoring and driver efficiency training systems. Finally, we are completing a project with Kyocera that integrates wireless technology with multifunction printers to develop a new campus tour application. WCE Advisor: Kit Cischke

<table>
<thead>
<tr>
<th>Projects</th>
<th>Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design, implement and validate a capacitive proximity sensor, replacing</td>
<td>Funovation, Inc</td>
</tr>
<tr>
<td>current solution</td>
<td></td>
</tr>
<tr>
<td>Broomball Scoreboard</td>
<td>IRHC Broomball</td>
</tr>
<tr>
<td>Home Automation, design of keyless door knob opener</td>
<td>As a Texas Instruments competition</td>
</tr>
<tr>
<td>iBeacon, design of campus tour application</td>
<td>Kyocera</td>
</tr>
<tr>
<td>Big Brother, design of wireless security camera with multi-axis control</td>
<td>For a Texas Instruments competition</td>
</tr>
<tr>
<td>Husky LED, project design helped to reinforce skills in PCB design and</td>
<td>ECE</td>
</tr>
<tr>
<td>soldering</td>
<td></td>
</tr>
<tr>
<td>OSIRIS, develop a simulator unit that interfaces with the company's</td>
<td>Open Systems International</td>
</tr>
<tr>
<td>remote terminal unit (RTU) titled OSIRIS. The OSIRIS RTU assists in</td>
<td></td>
</tr>
<tr>
<td>smarter monitoring and control of power systems, water utilities, oil/</td>
<td></td>
</tr>
<tr>
<td>gas, and various other industries.</td>
<td></td>
</tr>
<tr>
<td>Progressive Brake Lights</td>
<td>ECE</td>
</tr>
<tr>
<td>Robotics, develop a small robotic car with on-board sensor systems that</td>
<td>ECE</td>
</tr>
<tr>
<td>has the ability to automatically detect and evade obstacles with 10cm</td>
<td></td>
</tr>
<tr>
<td>effective range</td>
<td></td>
</tr>
<tr>
<td>Ford EV Coach, design of smartphone app that tracks driver performance</td>
<td>Ford Motor Company</td>
</tr>
<tr>
<td>and provides suggestions on how to improve efficiency score.</td>
<td></td>
</tr>
</tbody>
</table>
Blue Marble Security
Blue Marble Security is a virtual company of undergraduate students focused on securing the future through thoughtful use of technology. Our student-led company combines a rich educational experience in engineering design, team building, project management, and original product development. Current projects involve the design of an electro-mechanical braking system, stereoscopic image analysis to classify metal fractures, rail system monitoring and security, autonomous ground vehicle development, and outreach at both the community level and larger scale to garner STEM/ECE interest among youth.

BMS Advisor: Glen Archer

<table>
<thead>
<tr>
<th>Project</th>
<th>Sponsor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop a prototype for an electro-mechanical braking assist system</td>
<td>Halla Mechatronics</td>
</tr>
<tr>
<td>Ductility of Steel Samples</td>
<td>ArcelorMittal</td>
</tr>
<tr>
<td>Autobot (for Intelligent Ground Vehicle Competition at Oakland University)</td>
<td>ECE sponsored</td>
</tr>
<tr>
<td>Advisor: Jeff Burl</td>
<td></td>
</tr>
<tr>
<td>Rail Systems, developed a mobile sensing system to monitor the structural integrity of US freight train’s wheels and bearings using thermal, audio, and visual components. Advisors: Pasi Lautala and Tim Havens</td>
<td>NURail Research Center</td>
</tr>
<tr>
<td>Macro Outreach— The BMS Outreach team received the 2015 Industry Innovation Award selected by the ECE External Advisory Committee (EAC).</td>
<td>ECE sponsored</td>
</tr>
</tbody>
</table>

The BMS Outreach team hosts multiple events each semester, both to foster an interest in STEM among the youth in the community and to spark an interest in electrical engineering among the first year students at Michigan Tech. The team’s main project is a heart rate monitor circuit board, now used to teach soldering and basic circuitry to all ages. In the fall semester, the team also completed one-on-one customer interviews, market analysis, and value proposition validation for new outreach products, creating business model canvases and conducting research to determine viable products for the market. They improved the quality of their activity manuals and have several designs for additional STEM outreach projects under development.
Hybrid Electric Vehicle

The HEV Enterprise is a collaborative activity between the ECE department and the Department of Mechanical Engineering-Engineering Mechanics (MEEM). The goal is to develop skills applicable to the design of advanced hybrid vehicles, which are known to be fuel-efficient and environmentally friendly. The 40+ member enterprise comprises various teams for accessory drives, battery, control systems, engine modeling, platform, and transmission. HEV Advisors: John Lukowski (ECE) and Robert Page (MEEM)

The central project within HEV is a three-year program to research, design, build, and test a state-of-the-art hybrid electric vehicle, by retrofitting a 1949 Chevrolet truck with modern technology. Sponsors include General Motors, Engineered Machined Products, Martin Collision, Idsilt Inc., American Powertrain, Ride Tech, InfinityBox, and Kramer Metal Fabrication. Students work on projects such as designing and implementing power distribution, component mounting, and thermal management solutions. HEV Enterprise also incorporates Senior Design projects as well. Members of the Hybrid Electrical Vehicle Enterprise also took part in a competition to see who could disassemble and rebuild a 5-horsepower Briggs & Stratton engine. The event took place at Michigan Tech’s Advanced Technology Development Center (ATDC). For some team members, this was the first time they encountered such a task. For others, it was an opportunity to share their skills. This experience was beneficial to the team by giving members a more practical view of how engines are put together and controlled. This competition also provided some hands-on experience working with tools and handling parts, which will be necessary for creating a hybrid vehicle.
The mission of the committee is to serve the Department of Electrical and Computer Engineering in an advisory capacity, providing counsel to the department chair and the faculty from the viewpoint of industry. The aim of these activities is to improve the quality of electrical and computer engineering education at Michigan Tech and provide ECE graduates who are valuable assets to industry employers.

In Memory of Larry Kennedy, 1957–2015

Larry Kennedy, Chair of the ECE External Advisory Committee (EAC) since 2012 and EAC member since 1997, passed away suddenly on January 23, 2015. The faculty and staff of the ECE department and Larry’s colleagues on the EAC were shocked and saddened by the news and extend their condolences to his family.

Larry was born in Saginaw, Michigan in 1957, and earned a BS in Electrical Engineering from Michigan Tech and an MS in Systems Architecture and Engineering from the University of Southern California. His career spanned 35 years in the fields of vehicle engineering and automotive electronics, including over 18 years in executive level positions from Chief Engineer with Delphi, Chief Technology Officer and Director with Carbon Motors Corporation, to Vice President of Engineering with Powerteq. He was a member of the International Council on Systems Engineering (INCOSE) as a certified Systems Engineering Professional Engineer. Larry was also very active in his community choir and band organizations and church. His positive energy and generous spirit were a blessing to all who worked with him.

Part of the job of the EAC is to evaluate our Senior Design projects in the ECE department. These are industry-sponsored projects that students work on throughout the academic year, in teams of four to six, leading up to their final report and a presentation given during the time the EAC is on campus. The EAC selects the top project of the year, and gives an award which includes recognition at the annual Senior Banquet and a modest cash award for all the team members.

As a tribute to Larry and all that he has meant to the ECE department over the years, the EAC has decided to name this award the Larry Kennedy Innovation Award, in perpetuity.
The ECE department at Michigan Tech is busy doing its part. Our faculty, graduate students, and undergraduates work together in modern, well-equipped laboratories to bring practical solutions to real-world problems in signal processing, wireless communications, computer-aided design, energy systems, electronic materials and devices, photonics, and much more. Our research is funded by government agencies such as the National Science Foundation, the Department of Defense, and the Department of Energy, and by industrial partners such as Google, Molex, American Electric Power, Xcel Energy, Dow Corning, and Nexteer Automotive. The ECE department is eager to tackle new challenges and is always looking for new opportunities that are well matched to the interest and expertise of our faculty.

### ECE Contracts and Grants Awarded July 2014 to June 2015

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Sponsor</th>
<th>Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware-in-the-loop (HIL) Simulation of Electric Power Steering (EPS) System</td>
<td>PI: Jeff Burl</td>
<td>Nexteer Automotive</td>
<td>$42,422</td>
</tr>
<tr>
<td>CAREER: Leveraging Heterogeneous Manycore Systems for Scalable Modeling Simulation and Verification of Nanoscale Integrated Circuits</td>
<td>PI: Zhuo Feng</td>
<td>National Science Foundation</td>
<td>$191,926</td>
</tr>
<tr>
<td>MURA/ATAP Project</td>
<td>PI: Dan Fuhrmann</td>
<td>Google, Inc.</td>
<td>$205,000</td>
</tr>
<tr>
<td>Silicon Diselenide: A 1.7 eV Solar Absorber for Tandem Silicon Photovoltaics</td>
<td>PI: Chito Kendrick</td>
<td>Research Corporation for Science Advancement</td>
<td>$24,394</td>
</tr>
<tr>
<td>Waveguide Taper and Optical Shuffle Board Connectorization</td>
<td>PI: Chris Middlebrook</td>
<td>Molex, Inc.</td>
<td>$56,088</td>
</tr>
<tr>
<td>High Linear Electro-optic Modulator for Microwave Photonic Links</td>
<td>PI: Chris Middlebrook</td>
<td>US Dept. of Defense</td>
<td>$346,268</td>
</tr>
<tr>
<td>Transformer Protection-Improved Methodologies and Engineering Tolls</td>
<td>PI: Bruce Mork</td>
<td>Bonneville Power Administration (BPA)</td>
<td>$150,000</td>
</tr>
<tr>
<td>Power System Protection in a Smartgrid Perspective-Prosmart</td>
<td>PI: Bruce Mork</td>
<td>Norwegian University of Science and Technology (NTNU)</td>
<td>$64,948</td>
</tr>
<tr>
<td>Advanced Control and Energy Storage Architectures for Microgrids</td>
<td>PI: Wayne Weaver</td>
<td>Sandia National Laboratories</td>
<td>$80,717</td>
</tr>
<tr>
<td>Collaborative Research Very Near Ground Channel Modeling: Theory and Practice</td>
<td>PI: Reza Zekavat</td>
<td>National Science Foundation</td>
<td>$360,000 ($16,000 FY15)</td>
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</tbody>
</table>
DEPARTMENTAL STATISTICS

ECE Enrollment

<table>
<thead>
<tr>
<th>Year</th>
<th>Undergraduate</th>
<th>Masters</th>
<th>PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>759</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>2011</td>
<td>747</td>
<td>70</td>
<td>112</td>
</tr>
<tr>
<td>2012</td>
<td>781</td>
<td>66</td>
<td>146</td>
</tr>
<tr>
<td>2013</td>
<td>851</td>
<td>68</td>
<td>186</td>
</tr>
<tr>
<td>2014</td>
<td>854</td>
<td>69</td>
<td>201</td>
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ECE Degrees Awarded

<table>
<thead>
<tr>
<th>Year</th>
<th>Bachelors</th>
<th>Masters</th>
<th>PhD</th>
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<tr>
<td>2010-11</td>
<td>157</td>
<td>43</td>
<td>109</td>
</tr>
<tr>
<td>2011-12</td>
<td>172</td>
<td>39</td>
<td>120</td>
</tr>
<tr>
<td>2012-13</td>
<td>167</td>
<td>53</td>
<td>103</td>
</tr>
<tr>
<td>2013-14</td>
<td>195</td>
<td>7</td>
<td>123</td>
</tr>
<tr>
<td>2014-15</td>
<td>174</td>
<td>5</td>
<td>125</td>
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ECE Research and Sponsored Programs

Expenditures in Millions

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>External Research Expenditures</th>
<th>Internal Research Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010-11</td>
<td>4.34</td>
<td>1.9</td>
<td>2.44</td>
</tr>
<tr>
<td>2011-12</td>
<td>3.83</td>
<td>1.9</td>
<td>1.93</td>
</tr>
<tr>
<td>2012-13</td>
<td>3.32</td>
<td>1.78</td>
<td>1.28</td>
</tr>
<tr>
<td>2013-14</td>
<td>3.69</td>
<td>1.81</td>
<td>1.91</td>
</tr>
<tr>
<td>2014-15</td>
<td>3.9</td>
<td>2.09</td>
<td>1.81</td>
</tr>
</tbody>
</table>
Thanks to a generous gift from the estate of Earl '50 and Ellanette Lind, an endowment fund has been established to provide annual fellowships for Michigan Tech graduate students in electrical engineering. The planned gift of $645,000 was realized in March 2014. The Earl R. and Ellanette F. Lind Memorial Endowed Fellowship will provide financial support for a graduate research assistant under the direction of their research-active advisor in the area of electrical engineering.

Dr. Earl Lind was born in Duluth, MN in 1927. After graduating from Sault St. Marie high school, he earned a BS and MS in Electrical Engineering at Michigan Tech. Earl served in the U.S. Air Force and then went on to earn his PhD in Electrical Engineering from University of Wisconsin-Madison. His career brought him to Raytheon where his work earned several patents, including one for sonar technology, before he retired as vice president and chief engineer.

In 1966 Lind married Ellanette F. Jurd. Ellanette also served in the U.S. Navy Reserve from 1944 to 1966 in aircraft and flight instrument maintenance. She continued to be of service to others including more than 1,000 hours volunteered for her local hospital. Ellanette passed away in October 2013 and Earl less than two months following in December. The couple was married for 47 years.

Graduate support from philanthropic gifts such as the Lind Fellowship are extremely valuable in helping the ECE department meet its strategic goals in the research and faculty development,” says ECE chair Dan Fuhrmann. “We use these fellowships primarily to support students working with newer faculty members whose research programs are just getting off the ground, and may not yet have a solid base of external funding. Obviously the Linds have strong ties to Michigan Tech and we are extremely grateful that they remembered us in their planned giving.”