By Natalya Anderson, Sharon Aschaiek and Michael Mastromatteo

Welcoming Innovation

Engineers are inventors and problem-solvers by nature. Whether they're creating self-driving cars or revolutionary medical applications, they're changing—or will soon change—life as we know it. The eight projects we profile here are the work of Ontario professional engineers, and are just a small sampling of vital innovation in action.

Photo: Neil Ta

The Autonomoose is a Lincoln MKZ hybrid sedan that has been modified with artificial intelligence to become a self-driving car.

PUTTING AUTONOMOUS DRIVING RESEARCH INTO HIGH GEAR

Steven Waslander, PhD, P.Eng., is leading the University of Waterloo's innovative research and development of a safe and fully functioning self-driving car.

In the race to develop a fully functioning self-driving car, Steven Waslander, PhD, P.Eng., is gaining momentum with the quirkily named but very promising Autonomoose.

The Autonomoose is a Lincoln MKZ hybrid sedan that is being modified with artificial intelligence into an autonomous vehicle. The vehicle is being developed by Waslander and several other researchers at the University of Waterloo as part of a three-year research project, one of three approved by the province for its automated vehicle pilot program. The team faces many difficult engineering challenges, but they've made enough progress to test a prototype this fall on Ontario's public roads—a Canadian first.

"It's exciting to be at the forefront of this research in Canada… The complexity and intricacy of this project makes it very rewarding," says Waslander, an associate professor of mechanical and mechatronics engineering and director of the Waterloo Autonomous Vehicle Laboratory.

Waslander has studied robotic autonomy since completing his education—a bachelor's degree in applied math and mechanical engineering at Queen's University, and a master's and then doctoral degree at Stanford University in aeronautics and astronautics. The self-driving car project was greenlighted last November when Waslander and his colleagues received a $150,000 grant from the Natural Sciences and Engineering Research Council of Canada. With additional financial support from seven industry partners, the team is focusing on how to create an autonomous vehicle that is safe, fuel efficient and can operate in Canada's diverse weather conditions.

The car's development team—Waterloo faculty members from mechanical, mechatronics, electrical, computing and systems design engineering, and from computer science, as well as technicians and stu-

> "WE'RE INTERESTED IN CONTINUING TO INVESTIGATE THE HARDEST PROBLEMS TO HELP PUSH FORWARD THE DEVELOPMENT OF AUTONOMOUS CARS AND TRAIN THE NEXT GENERATION OF ENGINEERS."
> Steven Waslander, PhD, P.Eng.

dents—are creating, integrating and testing key systems and components. Chief among them are radar, sonar, lidar, inertial and vision sensors that provide comprehensive real-time information about the vehicle's surroundings, including other cars, pedestrians, lane markings, traffic lights and weather. The vehicle also receives information about the driving environment from the Internet, and all this data is analyzed by powerful computers.

"The hardest part is getting the car to disambiguate what's going on: Are there one or two cars at the stoplight? Are those pedestrians crossing the street or walking on the sidewalk?" Waslander says. "The dynamic aspects of the driving scene confound the current state of the art, so we are throwing everything we can at improving the detection of objects."

His team has tested the Autonomoose on an outdoor road test site in all types of weather, including snow and ice. The vehicle has also performed in various simulated road conditions on a dynamometer. The researchers have learned they must continue enhancing the vehicle's ability to detect the quality and quantity of ice, and to more accurately perceive objects obscured by rain or snow. While the driver can take over the vehicle if needed—a feature required by provincial law—Waslander says the goal is to offer a consistent, safe, automatic driving experience that doesn't require intervention.

The Autonomoose has been showcased on the *Rick Mercer Report* and *Daily Planet*, and at the 2017 Consumer Electronics Show in Las Vegas. The vehicle is also participating in a North American competition sponsored by General Motors and SAE International to create an autonomous driving vehicle for urban settings by 2020. However, the innovation will not be commercialized, Waslander says, but will continue serving as a research platform for determining the optimal self-driving vehicle.

Says Waslander: "We're interested in continuing to investigate the hardest problems to help push forward the development of autonomous cars and train the next generation of engineers."

FORENSIC MAPPING POISED FOR NEW ROUND OF APPLICATIONS

Eugene Liscio, P.Eng., outlines some of the capabilities of 3-D imaging at an Engineering Innovation Forum hosted by PEO.

An Ontario engineer with expertise in forensic mapping and 3-D reconstruction is optimistic that something as basic as a digital camera could lead to improvements in assessing structural safety of buildings and other structures.

Eugene Liscio, P.Eng., president of the AI2-3D company in Woodbridge, Ontario, says that while forensic mapping and related technology is generally associated with crime investigation and accident reconstruction, there is potential application in new areas, including building safety work.

AI2-3D specializes in forensic mapping, analysis and 3-D reconstructions of crime and accident scenes. Its personnel assist police, attorneys and experts with rebuilding a case to test different theories and scenarios. "3-D technologies have played a very important part in the accuracy and level of detail that can be captured for crime and accident scenes or even large disaster scenes such as explosions and building collapses," Liscio explains. "It's the kind of technology that merges well with other data types, such as photographs, video, photogrammetry, total station, thermal and alternate

Eugene Liscio, P.Eng., prepares a scan at an underground tunnel to gather data on a mining accident. It was part of an exercise on lighting and digital imaging in extreme environments.

light sources. By combining these data types, it opens the door to new types of analyses that were not possible previously. In some cases, it's simply not possible to do the same types of analysis without 3-D."

Liscio is also past president of the International Association of Forensic and Security Metrology, a US-based organization promoting the development and use of precision measurement systems, techniques and software in the generation of two- or three-dimensional coordinate spatial data.

Liscio believes the technology is poised to take off in other areas, including architecture and construction. For engineers concerned with innovative ways to consider building and structural safety, it could also lead to collection of important new data.

"For example," Liscio says, "ensuring you have captured the 'as built' model of a historical building and being able to check for the flatness and level of concrete can save tons of time and avoid lengthy civil litigation. I wonder if collapses like the [Algo Mall] Elliot Lake event could have been avoided if 3-D tools were employed over time to look for and detect shifting structures."

While the use of forensic mapping and related technology holds promise in terms of preventing disasters, it is still used primarily as a way to determine what went wrong after the fact.

"Most of my work is crime scene related, although I still do civil cases such as accident reconstruction," Liscio says. "We are often called upon by the police to assist on cold cases and during the investigation phase for any number of reasons, but often it's to look at patterned evidence or reconstruct scenes from video."

Liscio is occasionally called on as an expert witness in crime investigation cases, and some of his testimony and investigative work has been featured on *48 Hours* and *Dateline NBC*.

One of the most direct advantages of laser scanning, he says, comes in the areas of crime scene investigation and car accident reconstruction. Liscio said 3-D laser scanning and visualization give a tremendous boost to traditional investigation methods and have become a key tool in documenting and validating evidence. Even bullet trajectories, he says, can be pieced together more accurately based on information obtained via laser imaging.

Although some of the work may be morbid, it still holds fascination for engineers and other investigators in getting to the essential causes of an incident, accident, crime or disaster.

"There is new equipment, which is higher accuracy, and the workflows have been streamlined. There have also been some other technologies that are integrating with laser scanning, such as thermal technologies, panoramic cameras, alternate light sources and even drones," Liscio adds.

LISCIO SAID 3-D LASER SCANNING AND VISUALIZATION GIVE A TREMENDOUS BOOST TO TRADITIONAL INVESTIGATION METHODS AND HAVE BECOME A KEY TOOL IN DOCUMENTING AND VALIDATING EVIDENCE.

CANADIAN SCIENTISTS USE ENGINEERING TECHNOLOGY TO CREATE HUMAN ORGANS

Milica Radisic, PhD, P.Eng., and her team hope to use their "organ-on-a-chip" technology to grow various living organ tissue for use in drug development and testing.

A team of Canadian scientists has applied intricate engineering techniques to create miniature hearts and livers, and these living organs are revolutionizing drug testing globally.

Principal investigator Milica Radisic, PhD, P.Eng., and her team at the University of Toronto's Laboratory for Functional Tissue Engineering have grown swatches of living heart tissue that contain muscle and "blood vessels" and beat like a human heart. Rather than working with traditional, flat-surfaced petri dishes, the team aimed to create an environment that more resembles the human body. By applying technology commonly used to create computer chips, Radisic began growing heart cells on a chip—a kind of 3-D scaffold comprised of biodegradable polymer that is malleable.

"We call it Biowire, or biological wire, and it's a small piece of human tissue that we build in the lab using microfabrication technologies from the semiconductor industry and electrical stimulation," explains Radisic, a University of Toronto professor and Canada research chair in functional cardiovascular tissue engineering. "We rely a lot on techniques that are established in engineering. We build a small, chip-like environment that enables the cells to come together and beat together, like in a real heart."

Radisic and her team saw the potential for a few applications and have quickly produced more platforms for cell maturation. Along with Biowire, which matures heart cells, they have also created AngioChip, which enables the researchers to build a family of vascularized tissues to grow both human liver and human heart.

The implications are dramatic for treating life-threatening diseases in terms of safer, more effective drug development and testing. "All drugs have to go through cardiac safety testing, regardless of their ultimate use," says Radisic, who has won, among a multitude of awards, the 2011 Ontario Professional Engineers Awards (OPEA) Young Engineer Award, and the 2015 Hatch Innovation Award from the Canadian Society of Chemical Engineers. "In the current drug-testing paradigm, a drug encounters human tissues and cells for the first time in Phase I clinical studies. That's when it's given to the human for the first time. With our technology, people will be able to assess effects in human cells much earlier—before a drug is given to a real person."

Radisic says the applications will also enable scientists to discover new medicinal products that are personalized or tailored to specific subsets of patients. She can, for example, work with patient cells and build patient-specific heart tissues—a project that is already underway with her colleagues at Toronto General Hospital. Says Radisic: "We

can build human heart tissue for the patient, and then ask, 'What causes the disease at the molecular level, and how can I use this knowledge to develop better drugs for a specific group of patients?' It's along the idea of precision medicine or personalized medicine. In the past, before these human tissues were available, everything was done in large clinical trials. Now you can tailor the drug to a specific [subset] population. A drug may work beautifully in a subset of patients, but not so well in other patients, and these emerging technologies with human tissues on a chip will enable us to delineate better which genetic backgrounds certain drugs would be good for."

With a company she co-founded, TARA Biosystems, Radisic's innovations are already exploring their lifesaving potential. "This is happening now, right now, through our start-up company, TARA," says Radisic. "Pharma is accessing this human heart tissue, biological wire, and there are projects the start-up is [collaborating on] with pharma companies."

TEACHER LOOKS TO BREAK NEW GROUND IN PREPARING NEXT GENERATION OF ENGINEERS

Professor Nancy Nelson, P.Eng., FEC, has introduced several innovative teaching methods at Conestoga College and is also co-developer of an educational authoring software.

Engineering innovations are often thought of in terms of products, devices, systems or processes, so it's something of a departure to highlight a teaching approach as a form of innovation. But Conestoga College professor and academic coordinator Nancy Nelson, P.Eng., FEC, comes highly recommended as a subject for a discussion of what's new and exciting in preparing engineering undergraduates to make a difference in their professional careers.

A member of the Conestoga teaching staff since 1984, Nelson spearheaded the college's electronic systems engineering program and introduced a number of innovations in the classroom, including flipped learning, where the focus moves from teaching to learning by changing when, where and how learning occurs; gamification, where elements of game theory are added to the curriculum to help increase student engagement, collaboration, communication and improve knowledge retention; and project-based learning, where students work on authentic projects integrating cross-course and cross-discipline knowledge and skills.

Her teaching efforts have not gone unnoticed. This year, she won CICan's Gold Award in Leadership Excellence for Faculty, in 2016 she claimed the Engineers Canada Medal for Distinction in Engineering Education, and in 2003 she won Conestoga's top teaching honour, the Aubrey Hagar Distinguished Teaching Award.

But being an innovative educator obviously means more than claiming awards. Nelson is keenly interested in how students—engineering or otherwise—actually learn material, absorb information and acquire the patience, experience and confidence to perform in the professional world.

It's probably more than coincidence that Nelson wound up on the faculty of the first college (as opposed to a full university) to obtain accreditation of its engineering program from the Canadian Engineering Accreditation Board (CEAB). Nelson was closely involved in accreditation of the school's electrical systems engineering program—she led curriculum review and redesign as preliminary steps in the eventual CEAB accreditation.

Her focus on innovative teaching methods has generated at least one commercial opportunity. She is co-developer of Private School Interactive, an educational authoring software. "This commercial product was the result of my graduate work, which is where I really became interested in the effects that teaching has on learning," Nelson reveals. "My husband, who is also an engineer and professor, and I worked together on this project. He wrote the front end and I wrote the intelligence engine that monitored the way the student approached their learning experience, analyzed these patterns with respect to how well the student mastered the content, and modified the way the computer-based content was presented to the learner to help achieve optimal learning. It also allowed faculty to easily produce learning packages for their own courses."

The software, which won a McGraw-Hill Ryerson Education Innovation Award, has been used to create multimedia learning packages for educators, industry, and even at the US space agency NASA.

Ignac Kolenko, P.Eng., chair of the School of Engineering and Information Technology at Conestoga College, is proud to have Nelson on staff. "From day one, I have witnessed Nancy's passion for quality education, and her innovative approaches to content delivery have taken her into areas like online learning/testing, flipped (inverted) classrooms and our unique brand of project-based learning that we practice in our electronic systems engineering degree at Conestoga," he says. "There can be no doubt that Nancy has been an educational innovator for most of her career, especially in regard to engineering education."

Kolenko adds that Nelson gives back to the educational community regularly and shares her teaching skills and techniques annually as part of the college educator development program. "Our next generation of educators pick up and master some of these same techniques that have made Nancy such a noted innovator in the classroom."

HER FOCUS ON INNOVATIVE TEACHING METHODS HAS GENERATED AT LEAST ONE COMMERCIAL OPPORTUNITY. SHE IS CO-DEVELOPER OF PRIVATE SCHOOL INTERACTIVE, AN EDUCATIONAL AUTHORING SOFTWARE.

The emphasis on improving teaching performance is especially apt as the engineering profession looks to prepare the next generation of practitioners. It's a challenge that innovative educators like Nelson find especially compelling. "This change is absolutely crucial and is the main reason that I'm continuing my studies in engineering education," she told *Engineering Dimensions*. "I've done a lot of work related to faculty development over the last 10 years and it is extremely important that opportunities for teaching-related professional growth are available. Faculty must be encouraged to stretch their comfort zones, be supported during that process, and be recognized for their efforts to improve their teaching practice. Regulatory bodies and accreditation boards must also be willing to recognize and accept the value and richness that innovative teaching strategies and methods can add to the student experience and learning as they prepare for the practice of engineering."

DRONE TECHNOLOGY IMPROVES EFFICIENCY IN CONSTRUCTION INDUSTRY

Enaeria co-founders Daniel Matzeg, P.Eng. (left), and Zachary Feld, P.Eng. (right), are bringing drones to the forefront of the construction industry.

A few brainstorming sessions with his best friend was all it took for Zachary Feld, P.Eng., to realize that aerial surveying and inspection could be achieved locally to reduce the immense time, and financial and environmental burdens of the global construction industry.

"We were thinking about ways we wanted to try our hand at entrepreneurship," explains Feld, who, along with fellow University of Waterloo engineering graduate Daniel Matzeg, P.Eng., founded Enaeria in October 2015. "Ultimately, we decided we wanted to explore use of drones—not just for photography or videography, which we knew a lot of people were doing—but more so for an industrial application."

While the concept of using unmanned aerial vehicles (UAVs) industrially is not entirely new, the technology is still in its infancy in terms of what applications might be possible. Feld says this has allowed him and Matzeg to bring the concept to a new wave of contractors in Ontario.

"We'll fly a drone in a particular pattern, depending on what the application is, ultimately to collect data about the environment from a variety of perspectives," explains Feld. "Using the information we collect, we triangulate data points we see from various perspectives to be able to identify where in 3-D space any particular point is located… Just doing that millions of times using a computer algorithm is sort of the brain behind it all."

During the second quarter of 2017, Statistics Canada reported that investment in non-residential building construction totalled $12.4 billion. Ontario reported the largest upturn in spending on institutional, industrial and commercial buildings. For Enaeria, that means more clients looking to reduce cost.

FELD SAYS HE CAN DO SITE SURVEYS IN A FRACTION OF THE TIME OF TRADITIONAL METHODS WITH MORE ACCURATE RESULTS, WHICH TRANSLATES INTO COST SAVINGS.

Feld says he can do site surveys in a fraction of the time of traditional methods with more accurate results, which translates into costs savings. "Even more impressive is that instead of getting a data point manually one point at a time, spaced out every five or 10 metres, we can get upwards of—depending on the project—spacing of data samples every four millimetres," says Feld. "So, you're not missing any nuances in the ground because of how coarse your data sampling is."

His approach also reduces safety concerns in undeveloped or more challenging areas. "We've done bridge inspections where we're able to obtain measurements of hard-to-reach areas that would either cost a lot of money or would potentially put someone in a vulnerable position to obtain those measurements," explains Feld.

Minimizing environmental impact is also a benefit, says Feld, because they're not disturbing wildlife or other natural or undeveloped areas when they're flying over them as opposed to walking through them. "Effectively we're able

Daniel Matzeg, P.Eng., holds one of the drones so integral to surveying, mapping and inspections.

to give our clients a more accurate understanding of what they have on their particular sites," says Feld. "That way they can make decisions with a higher degree of accuracy that is less detrimental to the environment."

Inevitably, security and trust are of huge importance to Feld and the company. "The biggest concern people have is flying in locations or in manners where you're not legally allowed—flying close to airports or no-fly zones or flying at altitudes you're not supposed to be flying at," says Feld. "We don't take on projects where we find that what our customer is asking of us would teeter on the side of inappropriate."

With UAV demand on the sharp rise (*Fortune* reported last year that analysts estimate the commercial drone industry will reach $5 billion US by 2020), companies like Enaeria are in the unique position of being able to evolve organically. "There are tons of applications for this," says Feld. "To be quite honest I don't think we've even scratched the surface."

PUTTING SOFTWARE BUGS ON NOTICE

Lin Tan, PhD, P.Eng., is the award-winning creator of a novel computer program that can automatically detect and fix flaws in software code.

With a breakthrough approach to addressing software defects that has attracted extensive government funding and industry interest, Lin Tan, PhD, P.Eng., is helping to make computing much more effective.

The University of Waterloo professor has created a novel program that can automatically detect and fix flaws in software by analyzing developers' commentary accompanying their code. Her method involves comparing lines of code with their related comments to identify and adjust discrepancies in meaning. Tan is the first researcher to tackle software glitches in this way, and her innovative tools have proven more efficient at predicting, finding and repairing bugs, and even at preventing them in the first place.

"Either we can find and fix bugs that other tools cannot, or we can fix them more accurately," says Tan, the Canada research chair in software dependability and winner of the 2016 OPEA Young Engineer Award. "We are helping to push forward the state of the art and offer better solutions to software developers."

It's a topic Tan began investigating for the computer science doctoral thesis she completed at the University of Illinois in 2009, and that she has studied ever since joining Waterloo later that same year. She has learned that often the instruction in a line of code will not match information described in its comment, and this could indicate an error in the software. As well, in software documentation, such as menu pages and bug reports, there are often discrepancies between their instructions and what's in the code. She says developers' unclear use of the English language—spelling mistakes, incomplete sentences, missing or incorrect punctuation—and the inclusion of other languages besides English in the code commentary and documentation make it difficult to analyze computer code commentary.

"Software text is a free form, there is no template for writing it, and English is a complex language. So the quality of the text and its clarity varies a lot from developer to developer," Tan says.

She and her team—faculty members at Waterloo and at academic institutes worldwide, plus many students—rely on natural language processing, machine learning and various program analysis tools to systematically identify and understand these errors. So far, Tan has created dozens of automated and semi-automated software testing tools that can more effectively detect and repair software bugs. She primarily studies open-source software, but has also conducted research for and received funding from Google, IBM and other technology companies. Tan has also received more than $1.3 million in government research funding from sources such as the Natural Sciences and Engineering Research Council of Canada and the Ontario Centres of Excellence.

Tan understands the high stakes of her research: her efforts could save software companies millions of dollars, ease frustrations for computer users, and even save lives by improving the reliability of software in safety critical systems in cars, airplanes and medical devices.

"If we can improve the dependability of software and make it easier to use," Tan says, "we can reduce security problems and safety failures, and make a better world for everyone."

"IF WE CAN IMPROVE THE DEPENDABILITY OF SOFTWARE AND MAKE IT EASIER TO USE," TAN SAYS, "WE CAN REDUCE SECURITY PROBLEMS AND SAFETY FAILURES, AND MAKE A BETTER WORLD FOR EVERYONE."

ENTREPRENEUR FINDS BUSINESS OPPORTUNITY WITH FIBER OPTIC GAUGES

Nick Burgwin, P.Eng., co-founder of Fibos Inc., developed new fiber optic sensors that he hopes will become the standard for advanced optical measurements and sensing.

Last October, PEO's York Chapter invited members to attend a special presentation on the advances in fiber optic sensors as an affordable and technically advanced alternative to traditional electrical sensors now in use in various industrial and manufacturing settings.

The speaker at the York Chapter event was Nicholas Burgwin, P.Eng., co-founder of Fibos Inc., an exciting new start-up looking to fill a unique niche in the optical gauge sensor and transducer marketplace.

Burgwin was an inspired choice for the presentation because of his experience in industry and his involvement with Ryerson's Centre for Engineering Innovation and Entrepreneurship (CEIE), a new institution that helps bring engineering and technological innovation to commercialization.

Ryerson's CEIE brands itself as an institution offering students a systematic process to become entrepreneurs. Its "incubation zone" aims to bring engineers together with experts to form start-up companies dedicated to developing innovative products, processes and systems.

After graduating in electrical engineering from the University of Toronto in 2010, Burgwin entered industry where he found work in the consumer electronics, aerospace and automotive sector. During this time, Burgwin worked with a number of traditional sensors and came to understand some of their limitations.

With a determination to research and develop a more efficient sensor product, Burgwin enrolled in Ryerson University's master's degree program with a focus on replacing electrical strain gauges with fiber optic alternatives.

The end result was the creation of Fibos Inc. to manufacture and market the Optical Gauge Sensor and Optical Gauge Amplifier to provide "plug-in-and-play" replacements for traditional electrical strain gauges.

Burgwin and his co-founding partner Michael Bakaic, also a University of Toronto engineering graduate, tout the virtues of optics that provide the technical advantages within their products.

"I recognized how fiber optic sensors are intrinsically safe and offer advantages over electrical sensors," Burgwin says. "Fiber optics are less sensitive to electromagnetic interference, and can be used in harsh environments. These sensors can be applied to measure mechanical forces, such as strain and temperature."

Burgwin suggests the most innovative feature of his company's optical sensing solution is the ability to monitor mechanical forces, such as pressure, temperature, load and vibration in harsh environments. These include extremely high temperature environments, up to 1000 degrees C,

BURGWIN ENROLLED IN RYERSON UNIVERSITY'S MASTER'S DEGREE PROGRAM WITH A FOCUS ON REPLACING ELECTRICAL STRAIN GAUGES WITH FIBER OPTIC ALTERNATIVES.

which is almost doubling any other technology available, intrinsically safe environments or high electromagnetic or ionization radiation areas.

"We're effectively replacing what's now used in the electrical strain gauge area with advanced and affordable optical sensors," he says.

The Fibos main product line to date includes the optical gauge sensor and amplifier. The sensor, or OGS, is what is bonded or attached to a mechanical component that is experiencing a force, such as pressure, load or vibration. The amplifier (OGA) is the device that converts the optical signal into useful data that can easily be integrated into existing data logging systems.

Most often, traditional sensors use foil strain gauges to monitor mechanical deformation. These electrical-based sensing elements cannot survive at elevated temperatures, are susceptible to electro-magnetic interference and ionizing radiation, and are not inherently intrinsically safe.

"Our optical sensors solve all of these issues without sacrificing accuracy, opening up an endless number of new applications in which our sensors can be utilized," Burgwin says.

In addition to researching a new product's technical advantages, Burgwin also had to contend with such marketing constraints as affordability and reliability. To this end, Burgwin's involvement with Ryerson's CEIE paid quick dividends.

"The Centre for Engineering Innovation and Entrepreneurship from Ryerson manages the Norman Esch Awards," Burgwin recalls. "I won all three stages, which totalled $38,000. It was instrumental towards developing and testing prototypes. For the award applications, I had to develop my business plan and through market research, validate the market fit for the product. Mentors were available to help guide and focus my thoughts."

The Norman Esch Awards support engineering and architectural science students in developing new products or technologies relevant to the Canadian economy.

Fibos Inc. now operates in open space at the Celestica property in Toronto. The partners are now engaged in centralizing manufacturing, design and product testing of their new products, while engaging with potential new customers to install evaluation units in the field.

"Engineers are most definitely on the front line of innovation, as we can take research and apply it to different problems," Burgwin says. "From universities, great new technologies are being developed in Canada, and if schools continue to support, both financially and by offering mentoring, engineers will continue to take research and apply it to industry problems."

PIONEER SEES POTENTIAL IN ASSISTIVE ROBOTIC DEVICES

Goldie Nejat, PhD, P.Eng., builds socially interactive robots that assist dementia patients with everyday activities.

University of Toronto Professor Goldie Nejat, PhD, P.Eng., has long been involved in creating robots and androids to assist seniors and other people with physical or cognitive impairments in completing everyday tasks, like eating meals and getting dressed, helping give them a sense of independence in their own homes.

A member of the university's department of mechanical and industrial engineering since 2008, Nejat is also director of the school's Autonomous Systems and Biomechatronics Lab and Canada research chair in robots for society.

Nejat is considered a world-renowned expert in developing intelligent service/personal robots for applications in health, elderly care, emergency response, search and rescue, security and surveillance, and manufacturing. A major goal of her research is to develop and integrate intelligent, socially-assistive robots for robot-human interactions.

"It's an interesting concept because we're developing a technology where we also need to understand human behaviours," Nejat says. "There's a lot of engineering that goes into the design of the robot, but there's also a lot of psychology and social/behavioural sciences and also health sciences that need to be considered, as the robots have to learn their assistive behaviours. Those assistive behaviours have to be effective, and displayed in a way the user can easily understand them. At the same time, the robot needs to recognize the user's intent in order to react to it."

To provide personalized interactions with a robot, Nejat and her team are working to have the robots display facial expressions and gestures, and even tell jokes, so the user—usually a senior with cognitive impairment—can stay focused on the tasks at hand.

"At meal time, for example, the robot focuses the user's attention on food items such as, 'This is the main dish, here is the fork to bring the food to your mouth.' We add social interactions as it's an important part of meal eating and also helps maintain a user's social networks which, as you age, are important to your health."

The simple fact of an assistive robot telling jokes allows for more interaction, Nejat says.

"Essentially, it's the robot helping them to do those repetitive actions that are needed, but also providing it in a socially engaging environment so they can eat their meal. The robot is non-contact and doesn't do any of the tasks for the person, but rather prompts them through the steps."

A great deal of engineering and creativity is involved in designing and developing the mechanical caregivers. The innovative twist for Nejat and her team of researchers is to include interactive capabilities between robot and user.

"It's very multi-disciplined in that sense," Nejat says. "We learn a lot about how people interact and communicate as well as about the diseases so we can try to adapt the robot to the user's needs. People who suffer from dementia have their own set of limitations, and no two people are alike, so the robot learns how to personalize for that specific individual."

A MAJOR GOAL OF HER RESEARCH IS TO DEVELOP AND INTEGRATE INTELLIGENT, SOCIALLY-ASSISTIVE ROBOTS FOR ROBOT-HUMAN INTERACTIONS.

Goldie Nejat, PhD, P.Eng., with two of her socially-assistive robots.

Apart from the assistive robots, Nejat is also developing service robotics, which include the time-critical urban search-and-rescue application. The MARP robot, for example, is one mobile robot in the group of rescue robots the team has developed. "Currently, we are working on multi-robot co-operation within a team of intelligent rescue robots that can be deployed in unknown and cluttered disaster environments to explore the environments in order to help find victims. The objective is that these robots can help first responders in dangerous and challenging environments."

Nejat is especially gratified to note the progress in assistive device robots over the last 15 years. "Assistive technologies exist, but the interactive ones are very new," she says. "You are adding a robot that is moving in the same space as the person and has facial expressions and gestures. We're at the stage where we've done a lot of development and then we take out the robots and do user studies with older adults, residents in long-term care facilities, get their feedback and optimize our design and focus on what the needs and wants of the population are." **e**