Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

5 King's College Rd.
Toronto, ON M5S 3G8

mie.utoronto.ca

momentum

Alumni & Industry Magazine
Mechanical & Industrial Engineering
University of Toronto

Volume 2, Issue 1
Engineering the Future

"There are no easy solutions. The point of research is to create more, and hopefully better, options."

Momentum
Alumni & Industry Magazine

Volume 2, Issue 1
Engineering the Future

—

EDITOR
Nina Haikara

ASSISTANT EDITOR
Shannon Osborne

FEATURE WRITERS
Prof. Mark S. Fox
Nina Haikara
Mark Witten

ART DIRECTION & DESIGN
Mark Neil Balson R.G.D.

PHOTOGRAPHY
Jacklyn Atlas

THANK YOU
Liz Do

—

Department of Mechanical
& Industrial Engineering
University of Toronto
5 King's College Rd.
Toronto, ON M5S 3G8

momentum@mie.utoronto.ca
mie.utoronto.ca

—

Printed in Canada by Somerset Graphics Co. Ltd. using VOC Free UV Inks on Mohawk Options PC100. PC100 is made from 100% Post Consumer Waste using wind generated electricity and is FSC Certified.

Cover image is from the solids, fluids, & vibrations laboratory.

In This Issue

03 Message from the Chair
04 Ri$ky Business
06 Revolutionizing Health Care & Biomedical Engineering
11 Honours & Awards
14 Meet the Combustion Expert
16 Smart Cities
18 Facts & Figures
20 Free Falling

Message from the Chair

"While we strive to be leaders in both education and research, the successes we discover on this path can be revolutionary."

In the Department of Mechanical & Industrial Engineering (MIE), we are privileged to have 53 world-class faculty members, plus several emeritus faculty, conducting innovative research for the betterment of our future.

Supported by the dedication and expertise of more than 480 graduate students, the results are remarkable. From optimizing operating-room scheduling, to designing a mechanical heart valve, to reducing fuel emissions, there is perhaps no area in our daily lives left unexamined by our experts. Our second issue of Momentum features just some of the research advances we're making.

Take health care and biomedical engineering, for instance, where MIE is at the forefront. In fact, we have more than 50 health-related projects underway. With the leadership of Professor Michael Carter, we've seen an increased focus on both service delivery and human resource planning. And, knowing the impact our aging population will have on our health care system, Professor Goldie Nejat—Director of the Institute for Robotics & Mechatronics (IRM)—and her team have developed socially assistive robots for elderly home care.

We are also providing industry solutions for better fuel efficiency and alternative fuel use. Professor Murray Thomson directs the newly awarded NSERC Collaborative Research and Training Experience (CREATE) Program in Clean Combustion Engines, providing the necessary resources and training to produce the next generation of combustion experts for industry. Through their work, and through the breadth of our partnerships, we will have an impact on emissions in our daily environment.

In the future, our cities will become more self-aware, adaptive, and efficient, as described by Professor Mark Fox. Additionally, at the graduate level, Professors Chi-Ghun Lee and Roy Kwon are teaching a new Masters of Engineering (MEng) certificate in Financial Engineering, developing the know-how of future financial engineers.

While we strive to be leaders in both education and research, the successes we discover on this path can be revolutionary. Our momentum is limitless.

Jean W. Zu
Professor & Chair

Ri$ky Business

New MEng certificate develops engineering know-how for the financial sector

Image: MEng student **Layan Kutob** (IndE 1T2 + PEY)

Money is an essential part of our daily lives. You earn it, save it, or spend it. However, investing can be a risk, in the ups and downs of the stock market. Good risk management ensures financial stability, resulting in reliable pensions for workers, better endowments for universities, and most importantly, it helps a country's overall economy.

To manage financial loss, modern quantitative methods are used. Associate Professors **Chi-Guhn Lee** and **Roy H. Kwon** are Industrial Engineering researchers who believe financial tools and techniques are powerful enough to mitigate risk. But more can be done to improve.

"A financial product can be designed—engineered—to control risk, and perform to the satisfaction of the customer," says Lee.

For example, if you own a company stock, you have a physical stake in the company. Derivatives are financial contracts, typically attached to a stock, and can be traded, but have no real asset value. With the market crash of 2008, derivatives drew the ire of investors. Lee thinks the emergence of new rules and regulations since then are advancing the design of new financial products, raising the value of financial engineering as an emerging field. That's why the Department of Mechanical & Industrial Engineering created the MEng certificate in Financial Engineering—to provide U of T Engineering graduates with an advanced skill set.

Kwon cites Harry Markowitz, American economist and winner of the 1990 Nobel Memorial Prize in Economic Sciences, for first ushering in the modern financial investment with an operations research approach.

"Broadly speaking, there are mathematical models and approaches for how to invest your money in different assets," says Kwon. "And to generalize derivatives, how do you engineer a financial contract that has very specific desires and goals, for the person buying it? How does the person selling it, design it?"

To complete the Financial Engineering certificate, students take four core courses, plus three electives, or one elective course and a MEng project on a topic related to financial engineering. **I-Chun (Tony) Chiu** (1T0 + PEY) is among the first to complete the MEng Financial Engineering certificate.

"Financial engineering is an application of operations research, where we express a real-life problem in mathematical terms, and try to solve it using various theories," says Chiu, who links his previous experience in supply-chain management and optimization in health care, to other areas of business.

> "The certificate is open to students with a general engineering background; not necessarily with financial experience"

"The Financial Engineering certificate teaches you everything, from the very fundamental, to the theoretical, to the real-world application of what businesses are practicing," says Chiu, who is interested in a career as a financial planner or portfolio manager.

"The certificate is open to students with a general engineering background; not necessarily with financial experience," says Kwon.

"Those with a general engineering background may find it the most interesting, because they may have the engineering and mathematical aptitude to be introduced to finance in a way that leverages their current knowledge. We take a very quantitative approach," says Kwon.

In 2014, Lee and Kwon hope to launch the Centre for Financial Engineering, to enhance Financial Engineering education at both the undergraduate and graduate level. They also aim to increase the profile of Financial Engineering researchers, and create linkages between the Centre, U of T, as well as Bay Street—the centre of Toronto's financial district, and essential to Canada's economy.

The Master of Engineering (MEng) program prepares graduate engineers for advanced professional practice, by completing graduate-level coursework and an optional project. Students can also specialize in Computational Mechanics, Energy Studies, Health Care Engineering, and Information Engineering. Enrollment options include full-time, extended full-time (two years) or part-time studies.

For more information, please contact meng.admission@mie.utoronto.ca.

Revolutionizing Health Care & Biomedical Engineering

Four faculty experts share their solutions for the future of your health

Image: PhD candidate **Geoffrey Louie** (MechE 1T0 + PEY) adjusts "Tangy" the robot.

Industrial Engineering Professor **Michael Carter** wants to re-engineer the health care system to do more for patients with fewer resources.

As Director of the Centre for Research in Healthcare Engineering (CRHE), Carter, faculty colleagues and research students provide health care policymakers and administrators with advice and support tools to make better informed decisions to improve quality and efficiency in the health care system.

Operations research is a branch of industrial engineering that uses a wide variety of quantitative tools to help analyze and understand real-world problems. The tools run from fairly basic performance measures and ratios, to models of mathematical equations that can be used to optimize medical procedures.

"Industrial engineering is the engineering of common sense," says Carter.

His common-sense approach involves tracking key variables and then mapping alternative scenarios to show what can be done with existing resources. The approach can be applied to problems like cutting surgical wait times, getting patients emergency care faster, ensuring Ontarians have access to timely colorectal cancer screening, and having the right number of medical professionals doing the right job, at the right time.

"We're making a difference by helping hospitals in Ontario and across the country test and implement these tools so they can deliver services better and faster," says Carter, who is also an Adjunct Scientist with the Institute for Clinical Evaluative

Sciences in Toronto, and a recently named fellow of the Institute for Operations Research and the Management Sciences (INFORMS).

CRHE, which was founded in 2008, also focuses on better predicting the spread of a pandemic disease during an outbreak in an urban setting. CRHE faculty member and Industrial Engineering Associate Professor **Dionne Aleman** developed a simulation model as a tool to help public health agencies decide which strategies are likely to be most effective in preventing further disease spread.

The Ontario Agency for Health Protection and Promotion (OAHHP) has consulted with her in developing her simulation model called morPOP (Medical Operations Research Pandemic Outbreak Planner), for pandemic planning for the Greater Toronto Area.

"We can run 1,000 what-if scenarios for a population of five million, comparable to the GTA, in under 15 minutes. This is a rapid-response, decision-making tool that can help public health officials determine if one policy is significantly better than another," says Aleman.

Her morLAB (Medical Operations Research Laboratory) also applies operations research techniques to make radiation therapy for cancer patients more precise. Aleman is collaborating with Toronto's Princess Margaret Hospital to improve Gamma Knife radiation treatments for cancer patients with brain tumours. Mathematical modelling is used to develop optimal directions for radiation beams, positioning of the patient and distributions of radiation within each beam.

"The optimization algorithms are designed to deliver the appropriate amount of radiation to the target area while avoiding sensitive healthy brain tissues, leaving the patient with a higher quality of life and fewer side effects after treatment," she says.

Carter has also developed ambitious and sophisticated tools to tackle large-scale health care problems on a province-wide basis. For example, in 2006, he created a forecasting model on how many people are going to require a certain surgery. This helped to reduce wait times in Ontario for key medical procedures, such as cataract and hip and knee replacement surgeries. Recently, he and one of his doctoral students created a queuing model to determine how long patients will have to wait to receive it.

"The baby boomers are retiring and will be creating an even greater demand on the system over the next 10 to 20 years. We can't continue doing what we currently do. We need to make some drastic changes," he says.

To support this growing need, Mechanical Engineering Associate Professor **Goldie Nejat** (MechE 0T1, MechE PhD 0T5) is developing socially assistive robots.

By 2030, about 20 per cent of Canadians will be over 65. Interactive robots like Nejat's Brian, Casper and Tangy, could provide social and cognitive stimulation, helping prepare meals, and leading group recreational activities for millions of seniors in long-term care facilities, retirement residences and private homes.

"As baby boomers age and there are fewer people in the workforce to take care of them, assistive robots could be used by staff to help with various tasks and improve services," says Nejat. "The robots we're developing are human-like — but not intended to replace a human."

Brian, the first social, human-like robot she developed, has a silicone rubber face and synthesized voice that allows him to display and express emotions such as happy, neutral and sad. He has the ability to monitor and interpret a person's emotional state through vocal intonation, body language and facial expressions. He can also act as a social motivator, prompting and encouraging people with cognitive impairments to perform tasks or participate in activities.

In studies at local Toronto-area, long-term care facilities, Nejat showed that Brian effectively promoted the engagement of participants in eating meals and memory card games.

"We observed that people speak to the robot like they would to a person. On a social level, they're accepting of the robot and enjoy the interactions," says Nejat, also an Adjunct Scientist at the Toronto Rehabilitation Institute and recipient of the 2013 Engineers Canada Young Engineer Achievement Award.

Casper is a mobile, interactive personal robot designed to assist people with daily activities, such as preparing meals, by helping to choose recipes, store and retrieve food items, and remind them when to eat. Tangy is designed to facilitate group recreational activities, like Bingo or sing-a-longs, at long-term facilities, which may improve skills such as naming, recognition and recall, and provide a social benefit.

"Casper makes sure people make a meal and that they eat it," says Nejat, who builds these robots with off-the-shelf parts to make them affordable. "Our overall goal is to see if robots like Brian, Casper and Tangy can be used as tools in cognitive/social interventions to help people with dementia maintain or sustain their social and cognitive abilities."

As an engineer applying the principles of biomechanics, **Craig Simmons** (PhD MechE 0T0), Mechanical Engineering Associate Professor and Canada Research Chair in Mechanobiology, has brought a unique perspective to the medical mystery of heart valve disease.

Simmons began by looking for possible differences in the expression of thousands of genes in aortic heart valves with good mechanical properties, compared to those with poor mechanical properties, to pinpoint a cause.

"We discovered one molecule the aortic heart valve makes naturally, called C-type natriuretic peptide (CNP), which has a protective effect that keeps the valve healthy. People with less of it may be more prone to heart valve disease," says Simmons, a recipient of the 2012 McLean Award for recognition as an emerging research leader.

Today, patients with a failing aortic valve typically have to undergo surgery to replace it with a mechanical valve, which requires blood thinners, or an animal tissue valve that wears out faster. His goal is to identify a therapeutic target for prevention and treatment of heart valve disease as an alternative to surgical replacement.

"About one in four people over 65 have early heart valve disease. In the future, people at risk of heart valve disease may be able to pop a pill that mimics the effects of CNP," says Simmons, who is cross-appointed to the Institute of Biomaterials and Biomedical Engineering (IBBME), and the Faculty of Dentistry.

His research group in the Cellular Mechanobiology Lab is also doing promising tissue engineering research to replace and regenerate damaged heart valves. Collaborating with scientists at the Hospital for Sick Children, they are engineering tissue to repair heart valve defects in infants and young children.

"When a baby with a heart defect is born, we plan to take cells from the umbilical cord to create a patch from the patient's own cells to avoid rejection," says Simmons. "The ideal solution in the future would be to replace the valve using a living tissue that would grow with the child and adapt as the child grew."

Such revolutionary developments in biomedical engineering and health care will improve the lives of Canadians and patients, globally. For Professor Aleman, motivation can be drawn from her own family's experience with cancer.

"The satisfaction of this work is that I can use my skills to help people have healthier lives," she says.

"We're making a difference by helping hospitals in Ontario and across the country"

Mark Witten is a freelance health and science writer in Toronto.

Health care engineering improves the delivery of related services, whereas biomedical engineering is improving health through the development of new devices and procedures. Department researchers are investigating more than 50 projects that seek to engineer service, diagnosis, treatment, care, and more.

Here are just a few examples:

Improving the way defibrillators are located in public settings for use in cardiac emergencies is a project led by Assistant Professor **Timothy Chan**.

Professor **Mark Chignell** and graduate student Tiffany Tong are working with clinicians at Sunnybrook Health Sciences Centre to develop new forms of cognitive assessment for the risk of delirium onset in the emergency room.

Assistant Professor **Birsen Donmez** is working with Toronto General Hospital to study interruptions experienced by ICU nurses.

Already at the stage of human trials, Professor Emeritus **Andrew Goldenberg** is working with University Health Network to develop a MRI-guided robot for prostate treatment.

Associate Professor **Chi-Guhn Lee** has developed a statistical algorithm to detect acute hypertension episodes in intensive care units.

Professor **Viliam Makis** and graduate student **Akram Khaleghei** are collaborating with colleagues at Medical Biophysics at U of T and the Ontario Cancer Institute, to determine breast cancer risk through modelling breast tissue transformation information.

Professor **Andreas Mandelis** is developing a new laser photothermal biosensor for non-invasive blood glucose monitoring in collaboration with the Diabetes Center, Samuel Lunenfeld Research Institute, and for in-vehicle blood alcohol monitoring in partnership with Alcohol Countermeasures Systems, Inc.

Professor **Javad Mostaghimi** is collaborating with Mount Sinai Hospital to develop antibacterial coatings that will reduce health care associated infections.

Professor **Hani Naguib** (MechE PhD 0T1) is engaged in a collaborative project with University Health Network (UHN). The goal is to create polymeric devices, known as phantoms, to mimic human tissues and organs. Phantoms can be scanned using CT and MRI imaging and act like a calibration unit to give medical practitioners a better idea of the intensity of treatment needed.

Professor **David Sinton** (MechE 9T8, MechE PhD 0T3) is developing a method to select sperm with high DNA integrity for fertility treatment.

Working with colleagues at Johns Hopkins Hospital and the National Institutes of Health (NIH) Professor **David A. Steinman** (MechE 8T7, MechE MASc 8T9, MechE PhD 9T3) is determining whether the shape of an individual's artery geometry predisposes them to increased risk of atherosclerosis and stroke.

Professor **Yu Sun** is working with Mount Sinai Hospital to develop micro devices for blood cell testing and cancer diagnosis.

Assistant Professor (status-only) **Sharareh Taghipour** is collaborating with the Centre for Maintenance Optimization and Reliability (C-MORE) and faculty members from the Dalla Lana School of Public Health to model the progression of breast cancer and optimizing breast cancer screening policies.

Assistant Professor **Edmond Young** (MechE PhD 0T8) is working with hospitals in Thailand to develop a microfluidic technology for testing drug effectiveness on tuberculosis patients.

Honours & Awards

Award period of December 2, 2012 to December 1, 2013.
We apologize if your award is not listed.

Please contact us at momentum@mie.utoronto.ca with details about your award and we will add it to our online record.

Alumni

International

George Washington University: Outstanding Young Researcher & Outstanding Young Teacher, School of Engineering & Applied Science
Pinhas Ben-Tzvi (MechE PhD 0T8)

National

Canadian Academy of Engineering (CAE): Fellow
William (Bill) Buckley (MechE 7T1)
Chris Twigge-Molecey (MechE MASc 6T9 PhD 7T2)
Suong Van Hoa (MechE MASc 7T3 PhD 7T6)
James Wilcox (MechE 5T9)

Government of Canada: Order of Canada
Anne Sado (IndE 7T7, Doctor of Laws, honoris causa 1T1)

Women's Executive Network™ (WXN): Canada's Top 100 Most Powerful Women for 2013
Anne Sado (IndE 7T7, Doctor of Laws, honoris causa 1T1)

Regional: Provincial & City-wide

Privacy Commissioner of Ontario: Privacy by Design Ambassador Designation
Reza Samavi (MEng 0T7, IndE PhD 1T3)

University of Toronto

Arbor Award
Ted Maulucci (MechE 8T9)

Faculty of Applied Science & Engineering

Engineering Alumni Association (EAA): The L.E. (Ted) Jones Award of Distinction
Ryan Alafriz (IndE 1T2 + PEY)

Faculty

International

American Society of Mechanical Engineers (ASME): Fellow
David Sinton
Yu Sun

American Society of Mechanical Engineers (ASME): Heat Transfer Division – 75th Anniversary Medal
Cristina H. Amon
Javad Mostaghimi

Hispanic Engineer National Achievement Awards Corporation (HENAAC): Hall of Fame Inductee
Cristina H. Amon

Institute of Industrial Engineers (IIE): Fellow
Andrew K.S. Jardine

Institute for Operational Research and the Management Sciences (INFORMS): Fellow
Michael W. Carter

International Society of Engineering Asset Management (ISEAM): Lifetime Achievement
Andrew K.S. Jardine

Faculty

National

Canadian Academy of Engineering (CAE): Fellow
Andrew K.S. Jardine
Andreas Mandelis

Canada Science and Technology Museum: Canadian Science and Engineering Hall of Fame Inductee
Professor Arthur Porter (1910–2010)

Canadian Society for Mechanical Engineering (CSME): Robert W. Angus Medal
Javad Mostaghimi

Engineers Canada: Young Engineer Achievement Award
Goldie Nejat

Engineering Institute of Canada (EIC): Sir John Kennedy Medal
Andrew A. Goldenberg

Engineering Institute of Canada (EIC): K.Y. Lo Medal
Chul B. Park

Engineering Institute of Canada (EIC): Fellow
Yu Sun

Natural Sciences and Engineering Research Council of Canada (NSERC): CREATE Program in Clean Combustion Engines
Murray J. Thomson

Natural Sciences and Engineering Research Council of Canada (NSERC): Discovery Accelerator Supplement
Aimy Bazylak
Shaker A. Meguid

Natural Sciences and Engineering Research Council of Canada (NSERC): E.W.R. Steacie Memorial Fellowship
Yu Sun

Natural Sciences and Engineering Research Council of Canada (NSERC): Strategic Project Grant
Andreas Mandelis

University of Toronto

Connaught Innovation Award
Ridha Ben Mrad
Axel Guenther
Pierre E. Sullivan
Yu Sun

Connaught New Researcher Award
Aimy Bazylak

Distinguished Professor Award in Plasma Engineering (Renewed)
Javad Mostaghimi

Global Cities Institute (GCI): Senior Urban Fellow
Mark S. Fox

Inventor of the Year Award
Axel Guenther
Andreas Mandelis

McLean Award 2012
Craig A. Simmons

McLean Award 2013
David Sinton

Sustainability Office Green Ribbon Award
Jason Bazylak

Faculty of Applied Science & Engineering

Early Career Teaching Award
Timothy C.Y. Chan

Mechanical & Industrial Engineering

MIE Early Career Teaching Award
Timothy C.Y. Chan
Birsen Donmez

MIE Sustained Excellence in Teaching Award
Beno Benhabib

MIE Teaching Award
Markus Bussmann

Staff

University of Toronto: Excellence Through Innovation Award
Tomas Bernreiter, Laboratory Manager and Engineer

Students

International

Human Factors & Ergonomics Society (HFES): Gold Award
MIE Human Factors Interest Group

National

Health Council of Canada: Health Innovation Challenge
Mary Qiu (IndE 1T3 + PEY)

Canadian Society for Mechanical Engineering (CSME): Gold Medal Award
Zhi Quan (Ernest) Seow (MechE 1T3)

University of Toronto

Gordon Cressy Student Leadership Award
Yi-Wei Ang (IndE 1T2 + PEY)
Michelle Cho (MechE 1T2 + PEY)
Shailin Gosalia (MechE 1T2 + PEY)
Huda Idrees (IndE 1T2 + PEY)
Layan Kutob (IndE 1T2 + PEY)
Abhishek Mathur (MechE 1T2 + PEY)
Prachy Mohan (MechE 1T2 + PEY)
Donnie Yee (MechE 1T2 + PEY)
Peter Zhang
(EngSci 1T0 + PEY, MechE MASc 1T3)

Faculty of Applied Science & Engineering

Faculty of Applied Science & Engineering: Teaching Assistant Award
Aaron Persad

Hatchery Orozco Prize
Denis Loboda (MechE 1T3)
Neil Sharma (MechE 1T3)

Department of Mechanical & Industrial Engineering

Barbara and Frank Milligan Graduate Fellowships 2012–13
Tsoleen Ayanian
Phoenix Qing Ba
Amanda S. Bell
Hootan Kamran Habibkhanient
Eunji In
Richard King Keung Tam
Shefali Kulkarni-Thaker
Mike Kwon
Haijiao Liu
Houra Mahmoudzadeh
Elnaz Shokrollahi
Neda Tamannaee

Barbara and Frank Milligan Graduate Fellowships 2013–14
Michele Bergevin
Carlton Hoy
Karl Price
Xiao Li
Jun Wen
Joseph Robert Brooks
Edem Dovlo
Owais Muhammad Khan
Hoda Maleki
Thomas Moore

Bill Shaw Memorial Graduate Fellowships
Mohammadreza Sharifi

Bert Wasmund Graduate Fellowships in Sustainable Energy Research
Milad Abolhasani

Chalmers Design Award
Daniel Fonseca (MechE 1T3)
Anthony McLeod (MechE 1T3)
Serhiy Naumenko (MechE 1T3)

David Sanborn Scott Graduate Fellowship
Vahid Amani
Nickolas Eaves

Glynn Williams Fellowship
Pedro Isaza
Katelyn Adrienne Seaborn

John W. Senders Award
Hue Lamp (Helane) Chan (MechE 1T2 + PEY)
Michelle Cho (MechE 1T2 + PEY)
Reagan Sun (MechE 1T2 + PEY)
Stephen Yang (MechE 1T2 + PEY)

Neil Duncan Thompson Fellowship
Manuel Jose Matos Graca Ramos

Pierre Rivard Hydrogenics Graduate Fellowships
Francisco Jose Contreras Cordero

Ron D. Venter Graduate Fellowship
Armin Veshkini

Russell A. Reynolds Graduate Fellowships in Thermodynamics
Seyed Hadi Zandavi

Meet the Combustion Expert

The NSERC CREATE Program in Clean Combustion Engines ignites

Image: Bio-oil and ethanol flame in a swirl burner.
Research image by graduate student Dylan Kowalewski.

The combustion of fuels provides 91 per cent of the world's energy supply. Such global demand causes many to predict that we will soon run out of oil, but Mechanical Engineering Professor **Murray Thomson** sees the future differently.

"The idea that we will soon run out of fuel is false. We are more than a hundred years away from running out of fossil fuels, and new, unconventional sources, are constantly being discovered," says Thomson. "The real issue is climate change. Reducing carbon emissions without economic disruption is a difficult challenge."

For Thomson, one smart, short-term action is to improve fuel efficiency as much as possible. Recently, the U.S. government mandated a 5 per cent increase each year in the fuel efficiency of cars until fuel efficiency has doubled. Engine designers are developing new strategies to achieve this goal while reducing pollutant emissions and keeping costs reasonable.

Another approach has been to convert biomass into biofuels such as ethanol and biodiesel. Currently ethanol is produced from sugarcane or corn, and biodiesel is processed from vegetable oils and animal fats. As a member of the Research Management Committee and a Theme Leader of the BiofuelNet Canada NSERC National Centre of Excellence, Thomson notes that second-generation biofuels from waste cellulose — such as straw, saw dust and tree branches — are currently being developed, although they come with a cost.

"The real issue is climate change. Reducing carbon emissions without economic disruption is a difficult challenge."

Alternatively, natural gas prices have plunged as new reserves in Canada and eastern U.S. have been discovered. But, fracking — the process of extracting natural gas from shale — has raised concerns over groundwater contamination. Without government mandates for industry to switch to biofuels, the alternative, natural gas, remains a player in the combustion game. Thomson says it's dramatically cleaner, with lower smog and greenhouse gas emissions.

"There are no easy solutions," says Thomson. "The point of research is to create more, and hopefully better, options."

To help fuel Canadian research in engine development and alternative combustion fuels, the Natural Sciences and Engineering Research Council of Canada (NSERC) has injected $1.65 million over six years to support the Collaborative Research and Training Experience (CREATE) program in Clean Combustion Engines (CCE). NSERC CREATE programs provide a pathway for improved communication, collaboration and professional skills development for students, through coordinated mentoring and training opportunities in both academic and industry-based environments.

As CCE Director, Thomson is enthusiastic about collaborations between U of T and colleagues at the University of British Columbia, McGill, Ryerson, and the University of Windsor. Their industry collaborators include every major engine design company in Canada. Pratt & Whitney, based in Toronto, designs jet engines; Westport in Vancouver, BC, develops engines that run on natural gas; Rolls-Royce Canada in Montreal builds gas turbine engines for power generation; and Ford Canada builds and tests engines in Windsor, Ont., for the automotive sector.

New computer modelling and optical measurements have also let engine researchers look inside the engine, and advanced how researchers test alternative fuels, reduce emissions and improve efficiency.

"For example, using computational fluid dynamics modelling, pollutant emissions from gas turbine jet engine combustors can be predicted. This enables the engine designers to optimize the engine for low pollutant emissions," says Thomson, who says they can take a systems approach and no longer look at combustion alone.

"UBC is investigating fuel injection strategies and its effects on emissions. At Windsor, they're looking at developing new engine concepts that improve fuel efficiency while lowering emissions. And my Department colleague and CREATE co-applicant, Professor **Jim Wallace**, is directly measuring the health effects of engine exhaust," says Thomson, who also sits on the Board of Directors for the Canadian Section of the Combustion Institute.

A feature of the CREATE program is their annual week-long Combustion Summer School, which will include training in technical and professional skills, before trainees complete an internship at a combustion-related partner company.

"Students who register with CCE have an opportunity to connect with every major engine design company in Canada," says Thomson. The CCE program is an educational program under the Institute for Sustainable Energy (ISE), already home to the NSERC CREATE program in Distributed Generation for Remote Communities (DGRC), seeking to integrate clean energy technologies in remote areas of Canada.

"I've had the privilege to work with many graduate students who have gone on to do research and development in industry and government," says Thomson. "With the CREATE program funding, we have an excellent opportunity to provide collaborative, world-class training for Canadian students."

Smart Cities

Today, the majority of the world's population lives in cities, and it is estimated to reach 80% by 2050. In order to sustain this rapid urban growth, the cities of the future will have to operate "smarter."

By smarter, cities will have to be "self-aware", sensing their environment and monitoring their performance. For example, more and more cities are using sensors to monitor traffic flow and use that information to dynamically control traffic lights and traffic routings to minimize travel time.

Cities will be adaptive, modifying how they deliver services as the needs of a city's citizens and corporations change and the environment evolves. As populations shift within a city, where, when and how services are provided must also adapt. The delivery of social services within the city of the Toronto has experienced a shift over the last 20 years, and so have the locations and methods of delivery along with them.

Our cities will also be efficient, optimizing the allocation of resources and delivery of service. The present method of providing sewage processing, fresh water, power, and more, relies upon a very large investment in infrastructure. Such infrastructure can be added incrementally, along with population growth, at a cost that is the same or less.

Our laboratory is undertaking several Smart City projects. In conjunction with the Global Cities Institute we are investigating the formalization, standardization and automated analysis of city performance. With assistance from the City of Toronto's 311, information and services department, we are developing a Semantic Web standard for representing information, and applying data analytics techniques to identify events and trends. Working with 211 Toronto, social services information, we are developing a smartphone app to enable caregivers and users to find the services they need, from child care, to immigration, and more.

Industrial Engineering Professor Mark S. Fox is a Senior Urban Fellow of the Global Cities Institute (GCI) at the University of Toronto, and Director of the Enterprise Integration Laboratory (EIL).

Facts & Figures

Staff 31

5 Degree Programs: BASc, MEng, MEngDM, MASc & PhD

11,800+ Active/Living Alumni

Undergraduate & Graduate Degrees Awarded (2012–2013) 377

53 Faculty Members

1,263 Undergraduates (Fall 2013)

409 Industrial Engineering Undergraduates

854 Mechanical Engineering Undergraduates

2 Advisory Boards, Alumni & Industry

U of T Engineering 1st in Canada

72% MIE Participation in Professional Experience Year (PEY)

100+ PEY Companies

8 Interdisciplinary Centres

Domestic Capstone Projects 60+

5 International Capstone Projects

Globex Summer Exchange with Peking University (PKU)

50+ Specialized Research Labs

16 International Exchange Universities

11 Research Chairs

$13.3M Total Research Funding (2012–13)

488 Graduate Students (Fall 2013)

45+ Capstone Industry Partners

Invention Disclosures in the Last Five Years 70+

50+ Student Clubs Financially Supported by MIE

UT-IMDI Industry Partners (Institute for Multidisciplinary Design & Innovation) 15

160+ Industry Partners in Research & Learning

"A space tourist will fall for 4 to 30 minutes during a suborbital flight; there is gravity in space."

Free Falling

MIE graduate student reaches for suborbital heights

Influential business mogul Sir Richard Branson is soon launching commercial spacecraft flights. Virgin Galactic's 'SpaceShipTwo' and other suborbital spacecraft from XCOR, and Blue Origin, will bring passengers 100 km above the earth so they can experience weightlessness in space. The expectation is that as the space tourism industry grows, MechE PhD candidate **Aaron Persad** (EngSci 0T6) will be on-call as an Astronaut for Hire.

Astronauts for Hire Inc. (A4H), is a non-profit corporation, whose objectives are to provide opportunities for students and professionals to develop and refine the skills necessary to become commercial astronauts. A4H's commercial astronaut candidates include accomplished scientists and engineers. Persad is one of them. He made the latest cohort of six commercial astronauts, chosen from amongst a group of 85 highly qualified candidates from 14 countries. Like other A4H, Persad will be available for contract and consulting work to design and conduct experiments on microgravity, suborbital and orbital missions.

Persad himself can hardly believe his earliest childhood dreams of going to space will be realized.

"I've been in touch with some of my friends from middle school, and they said I was always talking about going to space and living on planet Mars," he says. "It's been a dream… nothing I thought would be a serious job. I didn't think the opportunities would be there."

Unlike Commander Chris Hadfield, Canada's latest astronaut to fly the International Space Station (ISS), Persad won't have to worry about piloting the aircraft. His job on the spacecraft is to solely focus on science, as A4H streams their recruits to be specialists in research or operations.

"The idea of training as a commercial astronaut is great, because it allows me to put my full attention on research. As a commercial astronaut, space has become more accessible to me, as I'm not limited to just one space agency," says Persad.

His PhD supervisor Professor Emeritus **Charles A. Ward** hasn't been to space, but his research has. One problem Ward investigated was the stable configuration of confined fluids in space, as it's critical to know where the fuel in the spacecraft tank is located.

Ward sent glass cylinders partially filled with water on the STS-87 Space Shuttle mission and confirmed that the theoretical predictions agreed with the measured shape of the water in the cylinders. In fact, Ward was able to use the same cylinders to measure residual accelerations of spacecraft—the effect of gravity pulling on the shuttle as it orbits the Earth.

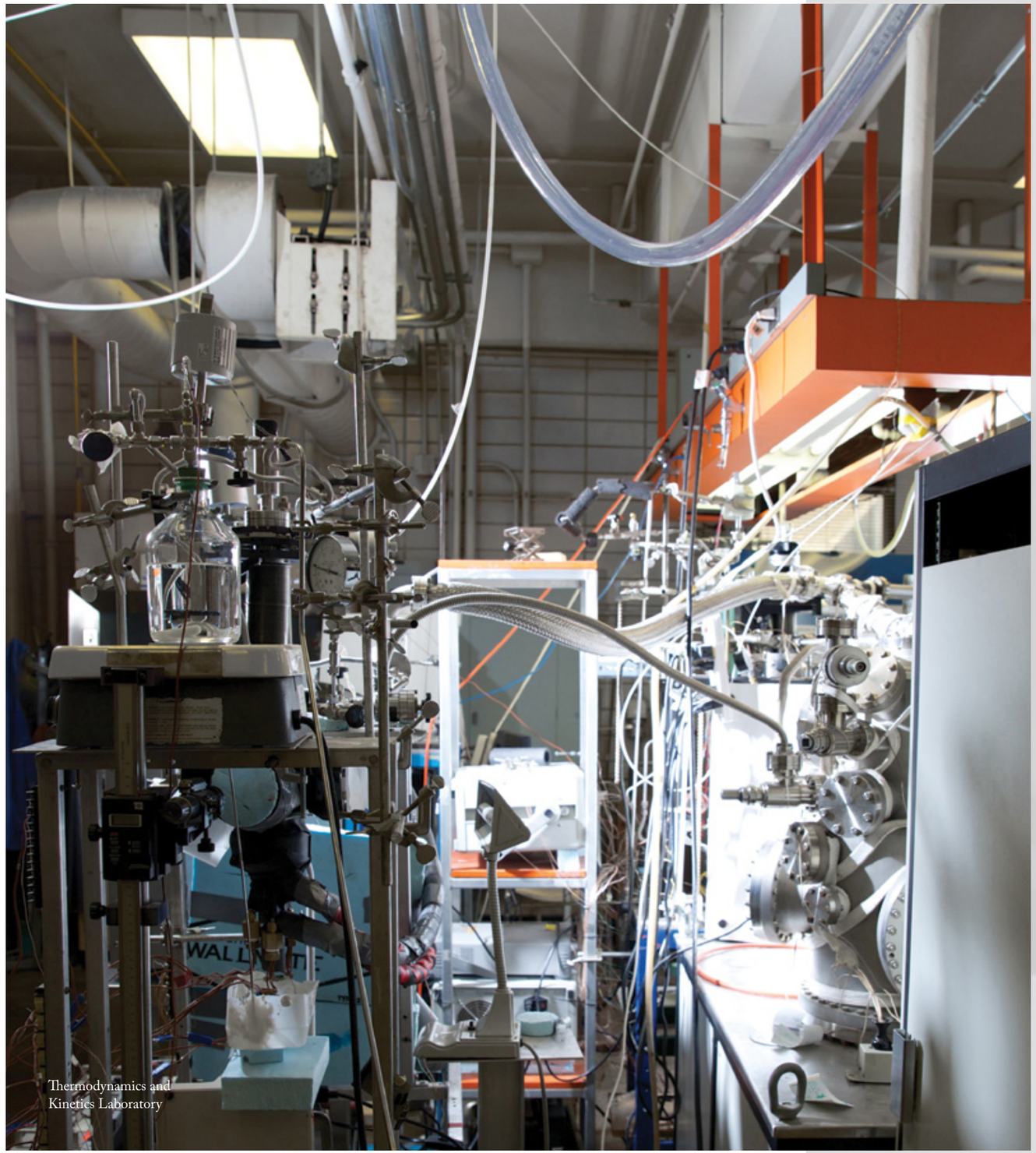
Persad whose expertise is in heat and mass transfer is currently working with Ward on two experiments for the International Space Station (ISS). In collaboration with retired Canadian astronaut Bjarni Tryggvason they will further study the liquid stability problem in greater detail. They are also working with the European Space Agency (ESA) to design experiments to measure mass and heat exchange at evaporating liquid-vapour interfaces. The results of the ESA experiments could change our basic understanding of how liquids evaporate.

"It's a misconception that we'd be working in zero gravity in space," says Persad, noting that space tourists won't be experiencing zero gravity on their suborbital flights either. "The earth is held by gravity in orbit around the sun. We'd experience weightlessness because we're a in a near-free fall environment," explains Persad. "Think of it like being in an elevator and someone cuts the elevator line. So when the elevator falls, you fall with the elevator making it seem like you're floating inside, when in fact gravity is pulling you and the elevator toward the ground. A space tourist will fall for 4 to 30 minutes during a suborbital flight; there is gravity in space."

Persad will undergo two years of training as a research specialist to be qualified for the suborbital flights, and additional physical training, including human centrifuge to experience the high-g forces of a launch, and learning how to orientate himself in a spacecraft. The costs incurred at U.S.-based space training facilities are presently Persad's own. Once hired by a unit to conduct an experiment in space, A4H provides scholarships to flight members.

The A4H program has been evolving since it was first established in 2010 and has NASA-like aspirations. As spacecraft technology develops, and space tourism takes off, Persad is looking forward to getting his first flight call.

"Space tourism may be a limited industry. Once everyone who can afford the flight goes, who will be next in line to make use of these suborbital aircrafts?" ponders Persad. "I think scientists will be next."



Thermodynamics and Kinetics Laboratory

In the next issue Engineering goes global.

If you have comments or questions please feel free to email momentum@mie.utoronto.ca