3

Our approach to research is defined by ambition, innovation, multidisciplinary collaboration and strong partnerships with industry, non-profit organizations and community groups. Enabled by the rich entrepreneurial ecosystem at U of T — including our own campus-linked accelerators and our vibrant alumni network — our professors and students translate their innovations from the lab to the global marketplace.

U of T Engineering is home to 120 chairs and professorships, and more than 25 multidisciplinary research centres and institutes. In 2016–2017, the most recent year for which data is available, we attracted research operating funds of $74.4 million, a 17% increase over the previous year and a 62% increase over the past decade. Our funding comes from a range of sources, including federal government (NSERC, CIHR, SSHRC and National Centres of Excellence) grants and scholarships, provincial research grants, industrial research partnerships and philanthropic support. Each year, we collaborate with more than 400 external partners, from major global corporations to local hospitals and startups.

In the past year, our faculty and students created flexible heart repair kits that could save and extend human lives, as well as leading-edge techniques for storing energy from intermittent sources such as solar and wind, among many other innovations. They are also developing the technologies that will drive new business models, including in advanced manufacturing, artificial intelligence and robotics.

Through initiatives such as EMHSeed with U of T's Faculty of Medicine and a new agreement with the Faculty of Arts & Science, we bring together principal investigators from a wide range of fields. We have also been successful in obtaining a number of prestigious NSERC Collaborative Research and Training Experience (CREATE) grants, which enable our graduate students to gain relevant experience in their chosen industry.

The Myhal Centre for Engineering Innovation & Entrepreneurship, which opened this year, will enhance our research in many ways. It significantly expands our Faculty's fabrication and prototyping facilities, and provides a new home for our Centre for Global Engineering, Institute for Robotics & Mechatronics, Institute for Sustainable Energy and Institute for Water Innovation. It also strengthens our connections with alumni and partners, enabling us to leverage our global network to address challenges and create new technologies.

Selected Highlights Organized by Research Theme

Data Analytics and Intelligent Systems

U of T attracts Fujitsu Co-Creation Research Laboratory

A new multidisciplinary research hub, created in partnership with Fujitsu Laboratories Limited, will accelerate collaborative work in fields including machine learning, quantum computing, smart cities, advanced health care and financial technology. The seeds of the collaboration were planted in 1998 when Professor Ali Sheikholeslami (ECE), then a PhD student, completed a six-week internship at the company's headquarters in Tokyo. That work grew into a collaboration that has lasted more than 20 years, and culminated in the Fujitsu Co-Creation Research Laboratory, which will be led by Sheikholeslami. A global delegation led by Tatsuya Tanaka, President of Fujitsu Laboratories Limited, met with U of T leaders and researchers in March 2018 to celebrate the agreements and tour the new Myhal Centre for Engineering Innovation & Entrepreneurship. Fujitsu plans to work with U of T to accelerate the practical use of quantum computing technologies that can reach beyond the limitations of today's supercomputers. For example, such technologies could help health-care professionals more precisely calibrate the dosage and angle of beam radiation needed to shrink tumours and kill cancer cells with little to no damage to surrounding healthy tissue. The Fujitsu Co-Creation Research Laboratory includes partnership agreements with U of T Engineering professors Alberto Leon-Garcia (ECE), Shahrokh Valaee (ECE), Taufik Valiante (Department of Surgery, ECE) and Yuri Lawryshyn (ChemE), each of whom will work with Fujitsu to introduce quantum computing technology into their respective areas of research expertise.

U of T Engineering spinoff Deep Genomics raises US$13 million to fund expansion

Deep Genomics, an artificial intelligence-powered health startup co-founded by Professor Brendan Frey (ECE) has raised US$13 million from a Silicon Valley venture capital firm. The startup, launched in 2015, combines artificial intelligence (AI) and genomics research to help develop genetic medicines to treat a myriad of disorders — everything from autism to cancer. At the heart of the company is a set of machine learning algorithms capable of harnessing the massive amount of genetic data that has become available since the human genome was sequenced in 2001. Unlike traditional drug discovery algorithms, which focus on a particular protein involved in a disease, Deep Genomics focuses on the genetic mutations that are the source of the problem. Researchers can then use this information to screen giant libraries of chemical compounds — tens of billions of molecules — to generate compounds that can lead toward new therapeutics. In addition to being the CEO of Deep Genomics, Frey is a founding member of the Vector Institute for artificial intelligence research, an academia-industry-government centre that solidifies Toronto's position as a global hub for AI research and development. With over $200 million in funding, the institute builds on U of T's longstanding strength in branches of AI such as deep learning, machine learning, neural networks, augmented reality, autonomous vehicles and robotics.

U of T Engineering spinoff LegUp Computing secures seed funding from Intel Capital

LegUp Computing Inc., co-founded by Professor Jason Anderson (ECE) with alumni Andrew Canis (CompE PhD 1T5), Jongsok Choi (CompE MASc 1T2, PhD 1T6) and Ruolong Lian (CompE 1T3, MASc 1T6) announced in February that it closed a seed funding round led by Intel Capital. Anderson's research area is computer hardware design, focusing on field-programmable gate arrays (FPGAs): programmable and reprogrammable computer chips that can be configured by the end user to implement any digital circuit. While FPGAs have been traditionally used for specialized functions — such as network switches — more recently they have been deployed by a number of cloud service providers. But servers based on FPGA chips come with a challenge: the difficulties of designing hardware can be an impediment to their adoption. LegUp Computing, founded in 2015, provides users with a cloud platform that enables software developers to program, scale and manage FPGA devices for accelerating high-performance applications. The company received early funding from UTEST, a University of Toronto accelerator partnered with MaRS Innovation.

Data in this chapter are presented for the 2016-2017 grant year (April to March). This is the most recent year for which complete data are available. Highlights are from July 2017 to June 2018.

Advanced Materials and Manufacturing

Natural fibres: New yeast strains could turn plant waste into fabrics

Nylon is used in everything from clothing to car parts to toothbrush bristles, but it is derived from oil, a nonrenewable fossil fuel. A team of researchers from U of T Engineering is working on a way to make the same chemical from a renewable source: plants. Professor Krishna Mahadevan (ChemE) and his collaborators are engineering strains of yeast that can make hexamethylene diamine and adipic acid — the two precursors of the nylon polymer — from sugar. The sugar, in turn, will be derived from cellulose, the major component of bark, corn stalks, leaves, corn cobs and other biomass that is most often discarded as waste. The project's partners include BioAmber, a company that uses yeast to turn corn sugar into a chemical called succinic acid on the industrial scale at its Sarnia, Ont. plant, and FPInnovations, which has developed a process to turn bark and other forestry waste into sugars. Over the past few years, the project has received more than $10 million from a variety of sources, including NSERC, the Ontario Ministry of Research and Innovation and Genome Canada.

New smart material from U of T researchers aids in the fight against tooth decay

When patients go to the dentist to fill a cavity, they are trying to solve a problem — not create a new one. But many dental patients get some bad news: bacteria can dig under their tooth-coloured fillings and cause new cavities, called recurrent caries. Recurrent caries affect 100 million patients every year and cost an additional US$34 billion to treat. In a paper published this year in *Scientific Reports,* professors Ben Hatton (MSE), Yoav Finer (Dentistry) and PhD student Cameron Stewart (IBBME) proposed a novel solution: a filling material that slowly releases antimicrobial drugs throughout the lifetime of the patient. The material is made from a combination of drugs and silica glass. These materials organize themselves on a molecule-by-molecule basis to maximize drug density, with enough supply to last years as opposed to the weeks provided by more traditional materials. The team plans on testing these new drug-storing particles in dental fillings, monitoring their performance when attacked by bacteria and saliva in the complex environment in the mouth. If successful, this new material could create a stronger filling and fewer trips to the dentist.

Sustainability

Artificial photosynthesis gets big boost from new catalyst

A new catalyst created by U of T Engineering researchers brings them one step closer to artificial photosynthesis — a system that, just like plants, would use renewable energy to convert carbon dioxide (CO_2) into stored chemical energy. Phil De Luna (MSE PhD candidate) and his co-lead authors Xueli Zheng (ECE PhD 1T7), postdoctoral fellow Bo Zhang and Professor Ted Sargent (ECE) created a new catalyst for a chemical reaction that splits water into protons and oxygen gas: this reaction is one half of the artificial photosynthesis system. Unlike previous catalysts which required high pH levels to work, this one is highly active at neutral pH, increasing the overall efficiency of the system. The catalyst is made of nickel, iron, cobalt and phosphorus, all elements that are low-cost and pose few safety hazards. The research was published in *Nature Chemistry*.

Elements of bio-mining: Engineering collaboration aims to turn mine waste into valuable metals

Professors Vladimiros Papangelakis (ChemE) and Elizabeth Edwards (ChemE) are leading the Elements of Bio-mining project. The initiative is a multidisciplinary collaboration between U of T Engineering, Laurentian University, and the University of British Columbia (UBC), as well as a number of technology, engineering and mining companies, including Glencore, Vale, Teck, Barrick and Hatch. Together, the team is developing ways to process a number of different types of materials left over from mining activities across Canada, from nickel mines in Sudbury, Ont. to coal mines in British Columbia. They aim to understand how native microorganisms at these sites convert chemicals from one form to another, and how they might encourage certain beneficial reactions while discouraging others. For example, there may be up to $7 billion worth of nickel alone locked in the tailings from Sudbury's mines. The Elements of Bio-mining project aims to determine whether this value could be recovered in a way that makes the treatment and remediation process economically viable. In addition to the universities and industrial partners, the project has attracted support from a number of research funding agencies, including NSERC, Genome British Columbia and Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). Most recently, the project received $4 million from the Ontario Research Fund.

Crunching the numbers on Toronto's King Street transit pilot

Toronto's one-year King Street transit pilot project, launched in November 2017, involves altering traffic patterns on the stretch of King Street from Bathurst Street in the west to Jarvis Street in the east to prioritize through-traffic from streetcars, cyclists and pedestrians. It aims to improve transit reliability, speed and capacity, along with a number of other measures included in a comprehensive evaluation and monitoring program. For a team of researchers including Professor Marianne Hatzopoulou (CivMin), it also presents an ideal opportunity to study the effects — both direct and indirect — of traffic changes on air and noise pollution, public health and commuter decision-making. Hatzopoulou and her team are using portable exposure monitors that measure traffic-related air pollution such as small inhalable particles and soot on simulated visits through the area via several modes, such as cycling, walking, riding the streetcar or sitting in a coffee shop. Postdoctoral fellow Cheol-Heon Jeong (ChemE) and Peter Murphy (ChemE MASc candidate) of the Southern Ontario Centre for Atmospheric Aerosol Research (SOCAAR) at U of T Engineering have also installed several of its stationary AirSENCE™ monitors throughout the pilot project area, as well as air quality monitors on two TTC streetcars dedicated exclusively to King Street routes for the duration of the project. These devices measure ozone, carbon monoxide, carbon dioxide, ultrafine particles, black carbon and PM 2.5, a measure of airborne particulate matter. In December 2017, the researchers met with representatives from the City of Toronto's Transportation Services and Public Health teams to discuss coordinated data collection, information sharing, survey design and next steps.

U of T Engineering spinoff Appulse Power acquired by Silanna Semiconductor

In March 2018, Appulse Power Inc., a startup company founded by U of T Engineering alumni Ahsan Zaman (ElecE 0T9, ECE MASc 1T2, PhD 1T5), Behzad Mahdavikhah (ECE PhD 1T4), Aleksandar Radić (ECE PhD 1T4) and Professor Aleksandar Prodić (ECE), announced its acquisition by the multinational Silanna Semiconductor. Appulse designs application-specific integrated circuits to allow devices, including smartphones and tablets, to charge faster and consume less power. Its innovations enable more efficient charging and smaller components both within and outside its devices — shrinking the footprint required for power management and downsizing clunky chargers and adapters. Appulse has 13 employees across two offices in Toronto and San Diego, Calif., all of whom are staying with Silanna and will operate as an independent business unit within the company. The Toronto office will become Silanna's first Canadian location, in addition to hubs in San Diego; Raleigh, NC; Brisbane and Sydney, Australia; and Singapore.

CERT team advances to finals of Carbon XPRIZE

In April 2018, a U of T Engineering-led team working to capture greenhouse gas and recycle it into useful chemicals advanced to the finals of the international NRG COSIA Carbon XPRIZE. The competition challenges teams to capture carbon emissions from power plants and efficiently convert them into valuable chemical products. Carbon Electrocatalytic Recycling Toronto (CERT) is a team of two dozen multidisciplinary researchers working with Professors Ted Sargent (ECE) and David Sinton (MIE). They are among the five teams from around the world to make it into the third and final round in the natural gas plant stream of the competition. CERT leveraged the team's expertise in electrocatalysis to develop nanoparticle-based catalysts that use clean electricity to recycle CO_2 into valuable carbon-based products. They demonstrated they could convert kilograms of CO_2 into carbon monoxide, a widely utilized industrial chemical. They also achieved significant scale-up: in just one year, they advanced their technology from a catalyst the size of a fingernail in a beaker to a continuous flow system the size of a small car. By advancing to the finals, the team earned US$500,000 to continue their research. The final winner will receive a US$7.5-million grand prize.

Engineering and Human Health

Injectable tissue patch could help repair damaged organs

A team of U of T Engineering researchers is mending broken hearts with an expanding tissue bandage a little smaller than a postage stamp. The team, which includes IBBME PhD candidate Miles Montgomery and Professor Milica Radisic (IBBME, ChemE), built their scaffold out of POMaC, a polymer that is both biodegradable and biocompatible. Its physical shape enables it to match the mechanical properties of the target heart tissue, and gives it the required shape-memory behaviour: as it emerges from a needle, the patch unfolds itself into a bandage-like shape. Similar tissue scaffolds have been proposed as a treatment for heart attacks before, but the method by which they are implanted — open-heart surgery — usually poses more risks than the potential benefits of the device. By creating a patch that can be injected rather than implanted, Radisic and her team are aiming to offer a more realistic solution that can improve the lives of heart attack patients around the world. The research was published in *Nature Materials*.

Searching for toxins in the aftermath of the Fort McMurray wildfire

The wildfires that raged through northern Alberta in the summer of 2016 are estimated to be the most costly natural disaster in Canada's history, destroying approximately 2,400 homes and forcing the evacuation of nearly 90,000 people.

But the ash left behind by the fire can continue to affect people's health long after the flames have gone out. Professor Arthur Chan (ChemE), along with postdoctoral researcher Lukas Kohl (ChemE) and undergraduate student Cynthia Jing (Year 2 EngSci) created the Fire Ash Characterization and Evaluation of Toxicity (FACET) study to assess the human health hazards posed by this ash. They are gathering dust from the homes of people affected by the fires and analyzing it for a variety of substances, including heavy metals such as lead, a potential neurotoxin, and organic chemicals such as polycyclic aromatic hydrocarbons (PAHs), which have been associated with cancer. More than 60 homes were sampled three times throughout the summer and fall of 2017 and the winter of 2018. Results are expected to be published later this year.

U of T Engineering researchers develop handheld 3D skin printer

U of T Engineering researchers have developed a handheld 3D skin printer that deposits even layers of skin tissues to cover and heal deep wounds. The team believes it to be the first device that forms tissue *in situ*, depositing and setting in place in two minutes or less. Their research, led by Navid Hakimi (MIE PhD candidate) under the supervision of Professor Axel Guenther (MIE, IBBME), and in collaboration with Dr. Marc Jeschke, director of the Ross-Tilley Burn Centre at Sunnybrook Hospital, was recently published in the journal *Lab on a Chip*. The current preferred treatment for deep skin wounds is called split-thickness skin grafting, where healthy donor skin is grafted into the surface epidermis and part of the underlying dermis. This requires enough healthy donor skin to traverse all three layers of skin — the epidermis, dermis and hypodermis — and sufficient graft skin is rarely available. The research team believes their in-situ skin printer is a platform technology that can overcome these barriers, while improving the skin-healing process. Resembling a white-out tape dispenser, the handheld device uses vertical stripes of "bio ink." This ink is made up of protein-based biomaterials including collagen, the most abundant protein in the dermis, and fibrin, a protein involved in wound healing. Working with Jeschke's team at Sunnybrook Hospital, the team plans to perform more *in vivo* studies. They hope that one day they can begin running clinical trials on humans, and eventually revolutionize burn care.

Lab-on-a-chip delivers critical immunity data for vulnerable populations

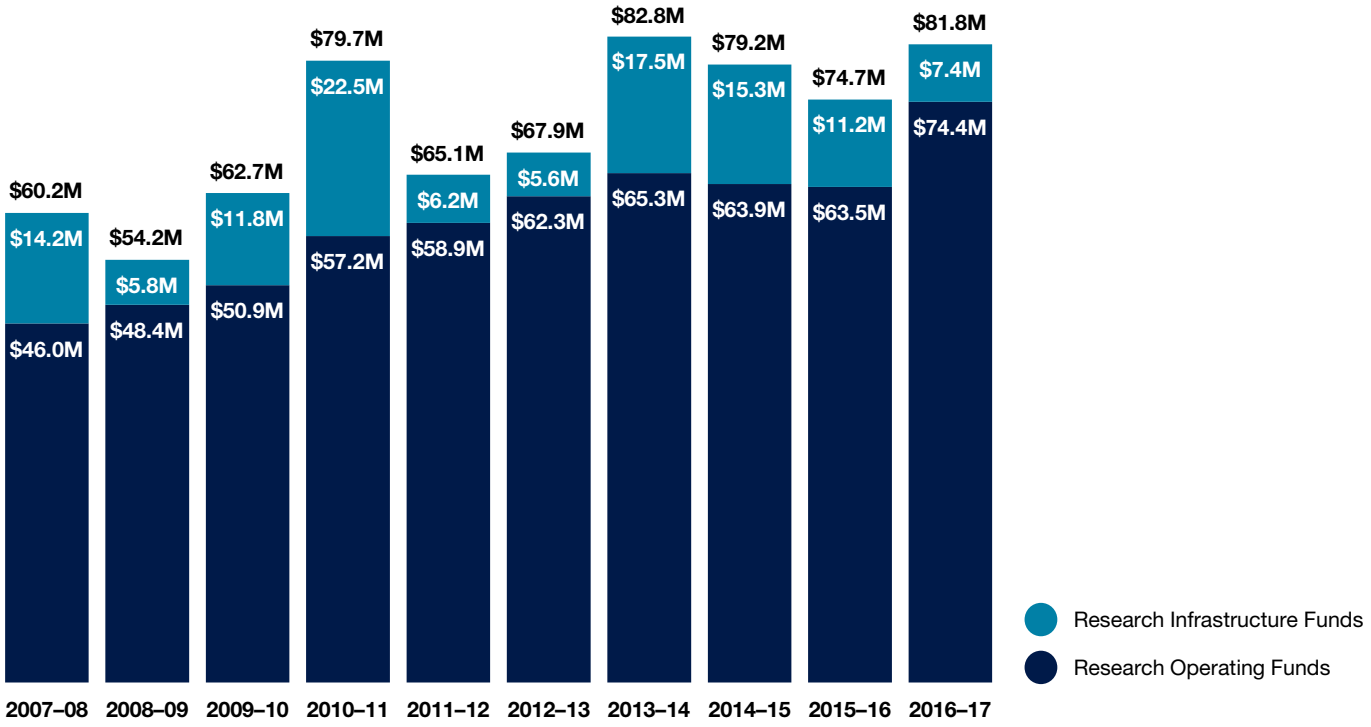
A team of U of T Engineering researchers has applied a hacker mentality to developing a portable, reconfigurable lab-on-a-chip diagnostic platform and field-tested the system in remote Kenya. Their validated platform can gauge the level of immunity to vaccine-preventable diseases among vulnerable populations. The work was done by Alphonsus Ng (IBBME PhD 1T5) and Ryan Fobel (IBBME PhD 1T6), who were supervised by Professor Aaron Wheeler (Chemistry, IBBME). It leverages digital microfluidics, a technique used to move, split, recombine and mix miniscule droplets of liquid, all on a tiny 'chip.' The chips are made using low-cost fabrication techniques such as ink-jet and 3D printing, and the droplets are controlled by applying electrical signals to different electrodes. In June 2016 four members of the Wheeler Lab travelled to the Kakuma refugee camp in northwestern Kenya to validate their platform, dubbed the MR Box — a desktop lab the size of a toaster oven configured to test for measles and rubella. They arrived in Kakuma following a massive public-health immunization campaign and tested hundreds of children and their caregivers for the presence of molecular markers indicating disease immunity. They sent their samples to the Kenyan Medical Research Institute national laboratory in Nairobi for validation. The final results were published in April 2018 in the journal *Science Translational Medicine*.

Research Funding and Partnerships

The amount of research funding we attract reflects the strength of our innovative and collaborative approach to research, including our industrial partnerships. In 2016–2017, the most recent year for which data is available, we earned research operating funds of $74.4 million, our highest level to date. This is equivalent to $326,344 per faculty member, a 17% increase over the previous year. Research funding per faculty member has grown 48% since 2008.

Our total combined research operating and infrastructure funding reached $81.8 million. This funding came from a variety of sources, including federal and provincial granting councils and corporate partners.

Figure 3.1a **Research Infrastructure Funding and Research Operating Funding, 2007–2008 to 2016–2017**



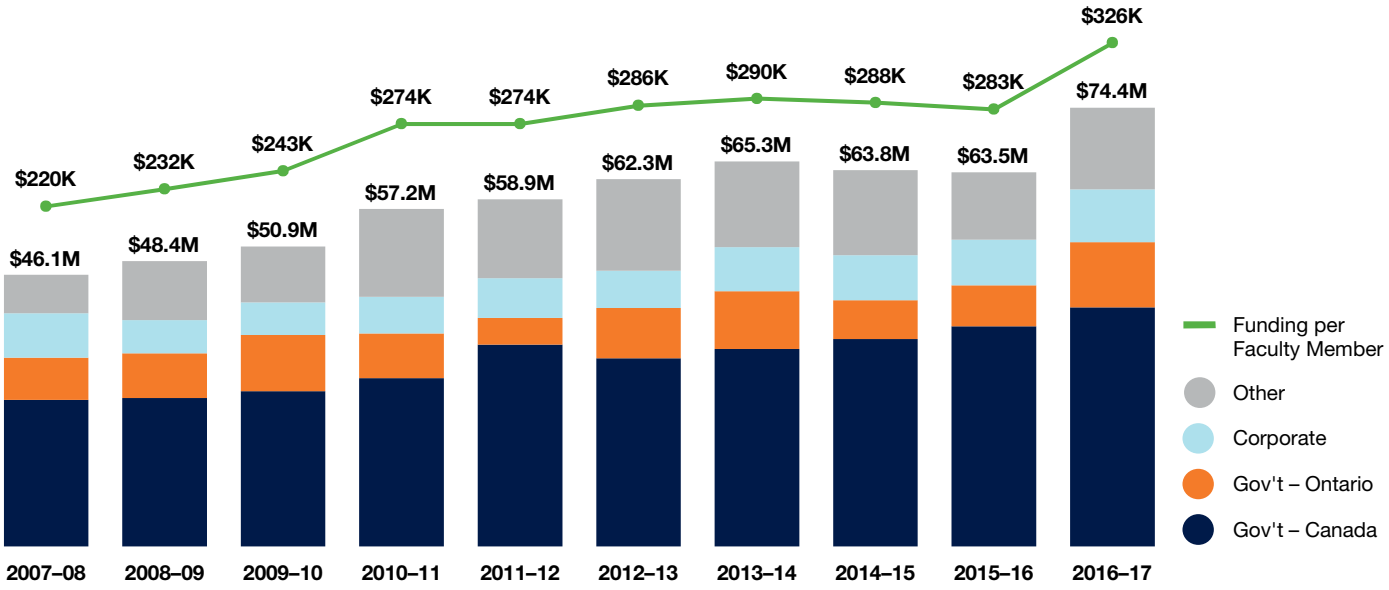
As of the completion of Academic Plan 2011–2016, we had surpassed our revised federal funding (NSERC, CIHR, SSHRC and National Centres of Excellence) goal of $32 million, reaching a total of $35.3 million. The majority of our Tri-Agency funding continues to come from NSERC, and industrial partnership programs continue to account for a major proportion of this funding, comprising 42%. In particular, funding from collaborative research and development grants is 28.7% higher than the previous year, reflecting continued interest from industrial partners in our world-leading research.

One hundred U of T Engineering researchers, including 65 professors and 35 graduate students and postdoctoral researchers, received a total of $12.8 million in research funding and scholarships awarded by NSERC, announced in September 2017. Three faculty members received prestigious Discovery Accelerator Supplements designed to maximize the impact of those researchers with highly original and innovative programs and who show strong potential to become international leaders in their field:

- Professor Brent Sleep (CivMin) — Thermally enhanced remediation of groundwater contamination
- Professor Roman Genov (ECE) — Transport-aware image sensors
- Professor Masayuki Yano (UTIAS) — Adaptive high-fidelity computational fluid dynamics

Note 3.1: The figures in this chapter report research funding the Faculty received in 2016–2017. Because it takes some time after the completion of a fiscal year for research funding data to become final, this is the most recent year for which data are available.

Figure 3.1b **Research Operating Funding by Year, Source and Funding per Faculty Member, 2007–2008 to 2016–2017**



	Funding per Faculty Member	Gov't – Canada	Gov't – Ontario	Corporate	Other	Total
2007–08	$220,370	$24,841,761	$7,168,950	$7,520,781	$6,525,854	**$46,057,346**
2008–09	$231,579	$25,145,331	$7,618,346	$5,640,631	$9,995,737	**$48,400,045**
2009–10	$243,390	$26,302,896	$9,562,402	$5,540,382	$9,462,900	**$50,868,580**
2010–11	$273,841	$28,528,383	$7,574,798	$6,210,621	$14,918,995	**$57,232,797**
2011–12	$273,861	$34,238,056	$4,538,965	$6,702,822	$13,400,263	**$58,880,106**
2012–13	$285,684	$31,922,907	$8,511,024	$6,315,707	$15,529,396	**$62,279,034**
2013–14	$290,218	$33,470,711	$9,814,984	$7,490,891	$14,522,410	**$65,298,996**
2014–15	$287,586	$35,192,451	$6,556,483	$7,658,869	$14,436,376	**$63,844,179**
2015–16	$283,319	$37,328,850	$6,955,835	$7,731,492	$11,447,261	**$63,463,438**
2016–17	$326,344	$40,568,381	$11,054,213	$8,956,135	$13,827,596	**$74,406,325**

Figure 3.1c **CIHR, NSERC and NCE Funding, 2007–2008 to 2016–2017**

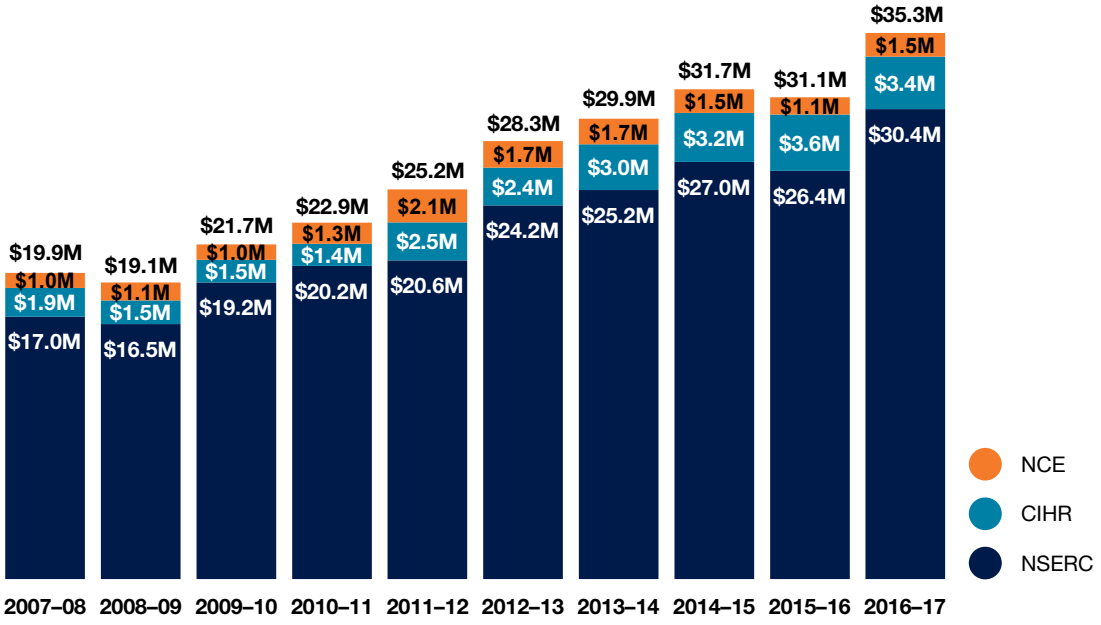
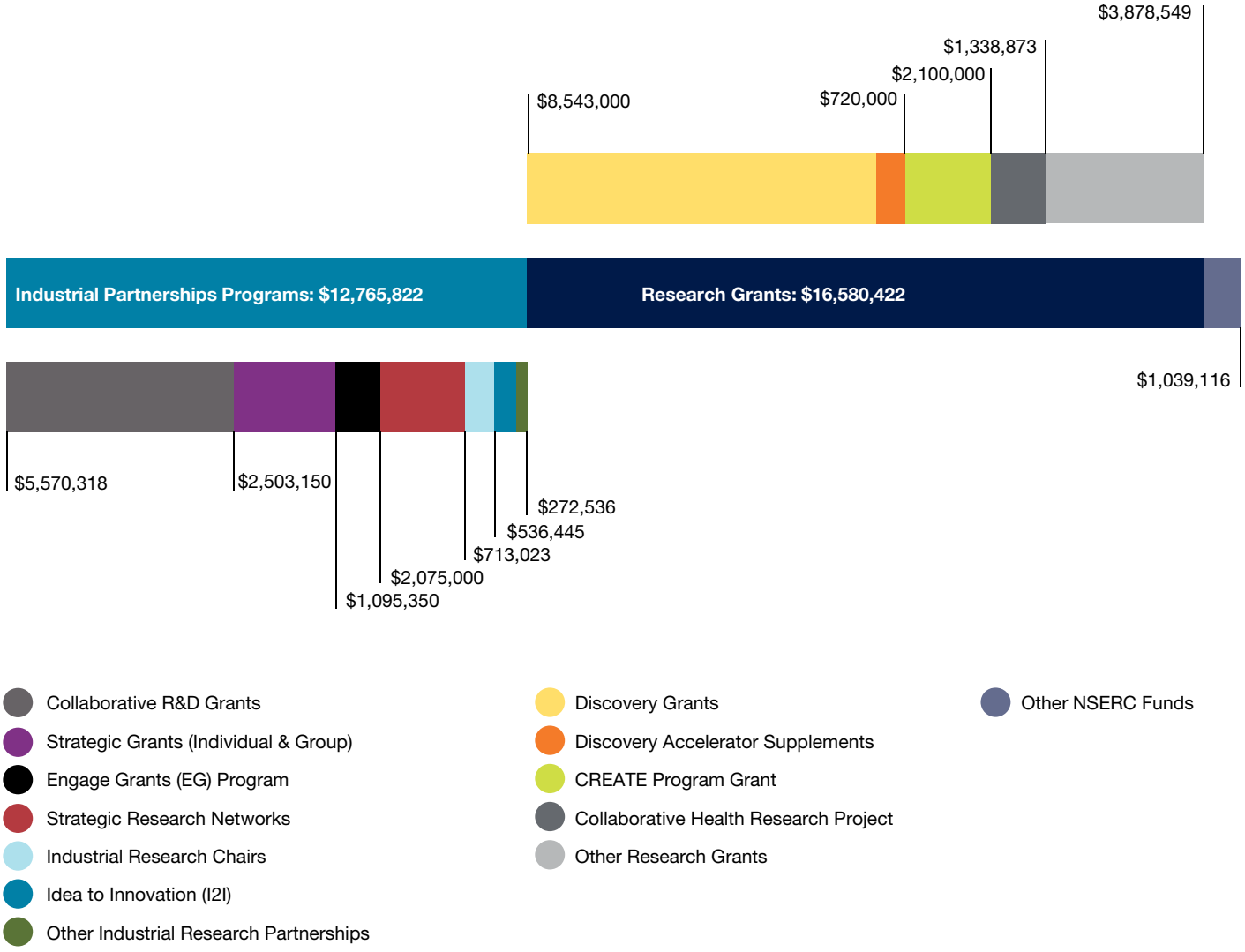
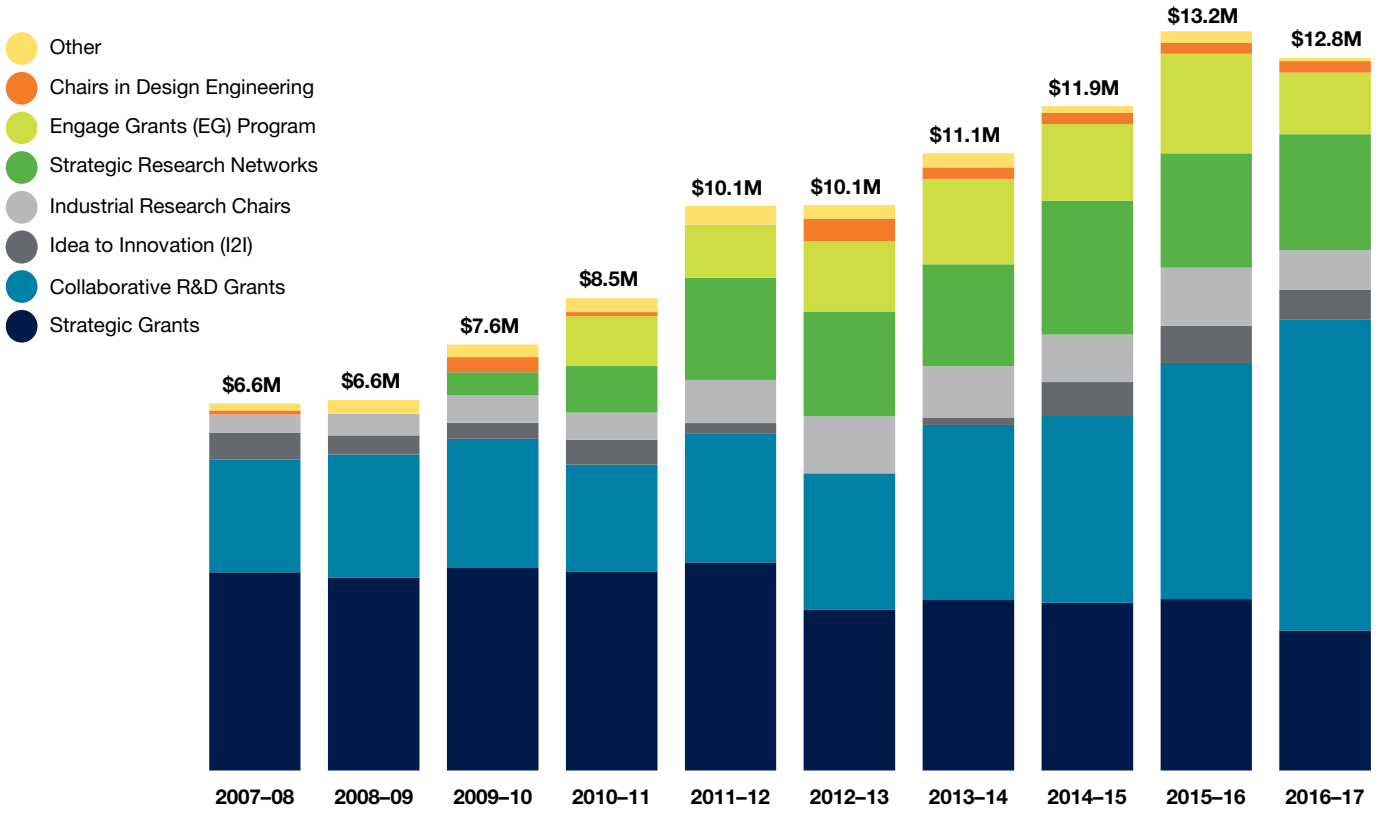


Figure 3.2a **NSERC Funding, 2016–2017**



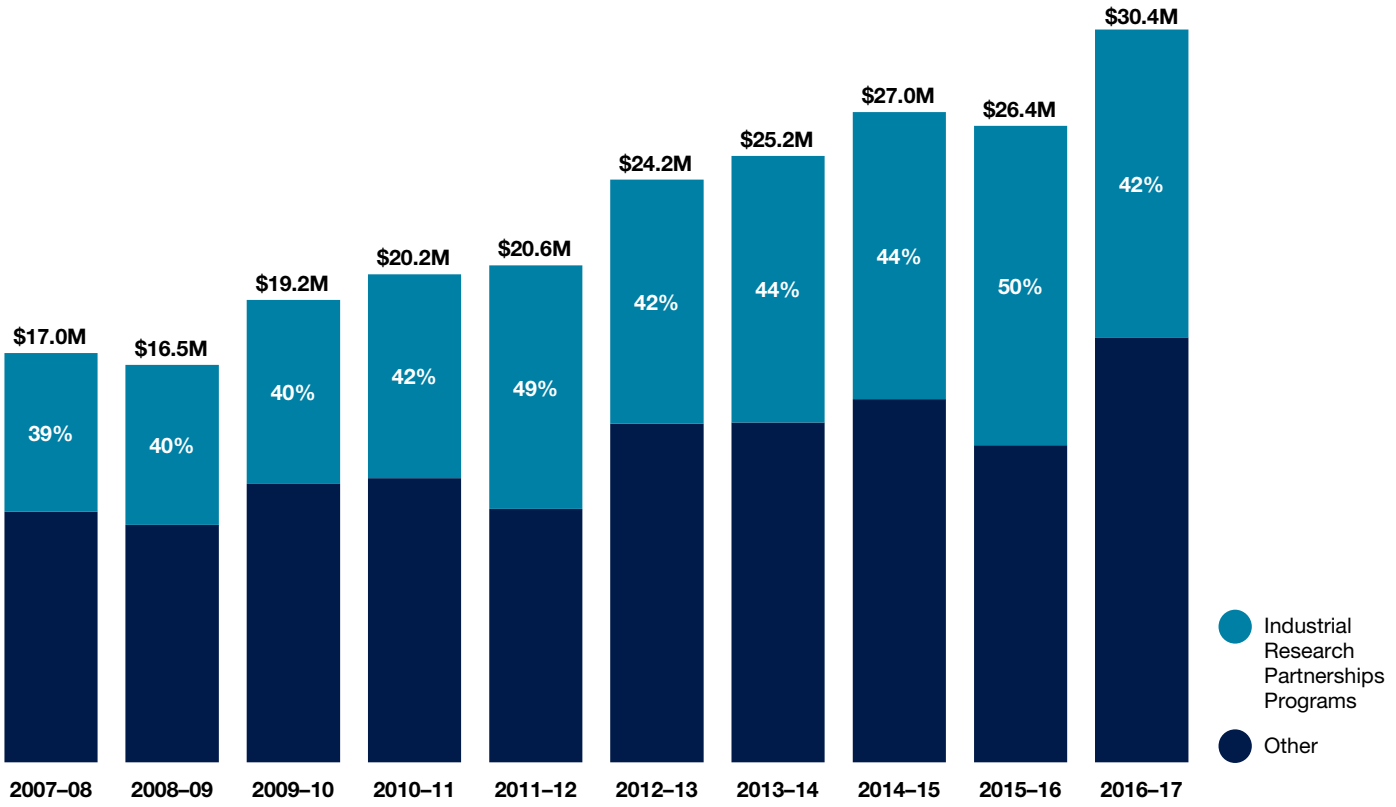
Note 3.2a: Data current as of May 2017 and based on grant year (April to March).

Figure 3.2b **NSERC Industrial Partnership Funding by Program, 2007–2008 to 2016–2017**



	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17
Other	$130,000	$247,392	$230,000	$251,770	$328,780	$246,790	$258,882	$119,531	$203,803	$61,036
Chairs in Design Engineering	$69,076		$267,173	$69,076		$400,000	$200,000	$200,000	$200,000	$200,000
Engage Grants (EG) Program				$897,114	$960,531	$1,254,468	$1,533,924	$1,375,371	$1,784,319	$1,106,850
Strategic Research Networks			$417,293	$832,697	$1,826,000	$1,879,000	$1,824,940	$2,400,000	$2,050,000	$2,075,000
Industrial Research Chairs	$329,834	$390,667	$493,197	$485,711	$773,964	$1,025,031	$918,349	$847,278	$1,040,762	$713,023
Idea to Innovation (I2I)	$483,200	$339,200	$287,417	$448,612	$195,000		$133,750	$608,417	$669,364	$536,445
Collaborative R&D Grants	$2,015,904	$2,203,103	$2,313,127	$1,909,431	$2,301,643	$2,445,210	$3,137,628	$3,347,888	$4,226,332	$5,570,318
Strategic Grants	$3,549,374	$3,457,330	$3,625,317	$3,567,277	$3,725,049	$2,875,127	$3,050,467	$3,001,610	$3,070,314	$2,503,150
Total	**$6,577,388**	**$6,637,692**	**$7,633,524**	**$8,461,688**	**$10,110,967**	**$10,125,626**	**$11,057,940**	**$11,900,095**	**$13,244,894**	**$12,765,822**

Figure 3.2c **Industrial Partnerships as a Proportion of Total NSERC Funding, 2007–2008 to 2016–2017**



Last year, our Faculty collaborated with more than 400 external research partners. In addition to these, many more companies hire our students through the Professional Experience Year Co-op Program, work with them on multidisciplinary capstone projects or provide philanthropic support.

Figure 3.2d **Industry Partners, 2017–2018**

- ABB Group
- Advanced Measurement and Analysis Group Inc.
- Advanced Micro Devices Inc.
- Advanis
- Aerodyne
- Afsan Engineering Co.
- AGFA
- Agnico-Eagle Mines Ltd.
- Agrium Inc.
- Airbus SAS
- AISC
- Alcan Aluminum International
- Alcohol Countermeasure Systems
- Altera Corp.
- AMAG Ltd.
- AMEC Foster Wheeler
- Americas Styrenics LLC
- Analog Devices Inc.
- Andec Manufacturing Ltd.
- Andritz Group
- Anemoi Technologies Inc.
- Angstrom Engineering Inc.
- Antex Western
- Apotex Inc.
- Applanix
- Apple
- Aquafor Beech
- ArcelorMittal Dofasco
- Armacell
- Artium Technologies
- Arup Canada Inc.
- Atomic Energy of Canada Ltd.
- AUG Signals Ltd.
- Autodesk
- AV Nackawic Group
- Avalon Rare Metals
- Avertus Epilepsy Technologies Inc.
- Babcock & Wilcox Ltd.
- BaoWu Steel Group Corp.
- Barrick Gold Corp.
- Bell Helicopter Textron Inc.

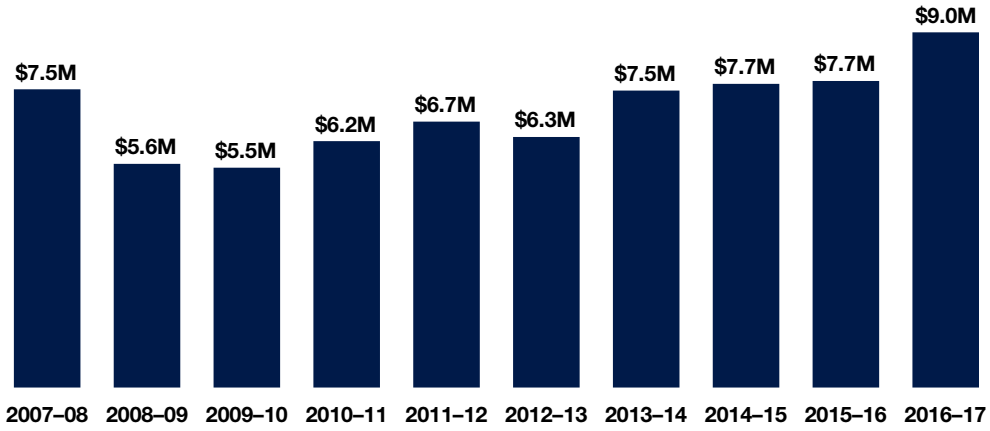
Note 3.2d: The list above includes companies from U of T's Research Information System, along with collaborators that fund research through a number of industrial research consortia, including those associated with many of our Industrial Research Chairs. It does not include companies that hire our students through the Professional Experience Year Co-op program, work with them on Multidisciplinary Capstone Projects, or provide philanthropic support.

- Bickell Foundation (J. P. Bickell)
- BiomeRenewables
- Bio-Rad Laboratories Canada Ltd.
- Blackberry
- BMW
- Boeing
- Boise Cascade
- Bombardier Aerospace
- Bombardier Inc.
- Braskem
- BresoTec Inc.
- Brican Automated Systems Inc.
- Brigham & Women's Hospital
- Broadcom Corp.
- CAE
- Calera
- CalEnergy Generation
- Calgon Carbon Corp.
- Canadian Automobile Association
- Canadian Institute of Steel Construction
- Canadian Nuclear Safety Commission
- Candu Energy Inc.
- Candu Owners Group
- Candura Instruments
- CanSyn Chem Corp.
- Carbon Cure Technologies
- Cardinal Health
- Carter Holt Harvey Ltd.
- Cascades
- Cast Connex Corp.
- CD Nova
- Celestica
- CellScale Biomaterials Testing
- Celulose Nipo-Brasileira
- Cement Association of Canada
- Center for Automotive Materials and Manufacturing
- Centre Line Ltd.
- Chemetry
- Christie Digital Systems Canada Inc.
- Chrysler Canada Inc.
- Ciena Canada Inc.
- CIMA Canada Inc.
- Clearpath Robotics
- Clyde-Bergemann Inc.
- CMC Electronics
- Colibri Technologies
- COM DEV International Ltd.
- Commissariat à l'energie atomique
- ConCast Pipe
- Connaught Foundation
- Cook Medical
- Coraltec Inc.
- CPCI
- Createx Technology (Suzhou) Co., Ltd.
- Crosswing Inc.
- Curiousitate
- Cyberworks Robotics
- Daishowa-Marubeni International (DMI) Ltd.
- Dana Canada Corp.
- Daniels Group
- Dasaerospace Inc.
- Datatrends Research Corp.
- DCL International
- Defence Science & Techology Lab (UK)
- Dell
- Detour Gold Corp.
- Deveron
- Dionex
- Diros Technology Inc.
- Dongwon Technology Co. Ltd.
- Dr. Robot Inc.
- Drone Delivery Canada
- Droplet Measurement Technologies
- DSO National Laboratories
- DuPont Canada Inc.
- eCamion Incorporated
- Eclipse Scientific Inc.
- Ecobee Inc.
- Ecosynthetix
- Eco-Tec Inc.
- Eldorado Brasil
- Electrovaya Inc.
- Eli Lilly Research Laboratories
- EllisDon
- Enbridge Gas Distribution Inc.
- Energent Inc.
- Engineering Services Inc.
- ENMAX Power Corporation
- Ensyn Technologies Inc.
- ERCO Worldwide
- Ericsson Canada Inc.
- ESG Solutions
- exactEarth Inc.
- Exigence Technologies
- Expert Process Solutions (XPS)
- Explora Foundation
- Fibria Celulose
- Finisar Corp.
- Flight Safety International
- Food BioTek Corporation
- Ford Motor Company (USA)
- Ford Motor Company of Canada
- FP Innovations
- Fuji Electric Co. Ltd.
- Fujitsu Laboratories Ltd.
- Fujitsu Labs of America Inc.
- Futurebound Corp.
- Futurewei Technologies Inc.
- G. Cinelli – Esperia Corporation
- G. S. Dunn Dry Mustard Millers
- GE Energy
- GE Global Research
- GE Zenon
- Gedex Inc.
- Gener8 Inc.
- General Dynamics Canada
- General Electric Canada
- General Electric Inc.
- General Motors of Canada Ltd.
- Genpak
- Geosyntec Consultants
- Gerdau Long Steel North America
- GHGSat Inc.
- GlaxoSmithKline Inc.
- Glencore Canada Corp.
- Goodrich Landing Gear
- Grafoid Inc.
- Greencore Composites
- Groupe Mequaltech Inc.
- GTAA Toronto Pearson
- GVA Lighting
- Hanwha Solar Canada
- Hard Rock Innovations Inc.
- Hatch Ltd.
- Havelaar Canada
- Hawker Siddeley Canada
- HDR Corp.
- Hitachi High-Technologies
- Holcim Inc.
- Honeywell
- Huawei Technologies Co. Ltd.
- Hunch Manifest Inc.
- Huron Digital Pathology
- Hydro One Networks
- Hydro Quebec
- Hydrogenics
- Hyundai Motor Company
- IBI Group
- IBM Canada Ltd.
- IBM T. J. Watson Research Center
- iGEN Technologies Inc.
- IMAX Corp.
- Imperial Oil Ltd.
- Indian Oil Company
- Industrial Thermo Polymers Ltd.
- Ingenia Polymers Corp.
- Inphi Corp.
- Institute for Energy Technology (Norway)
- Integran Technologies Inc.
- Intel Corp.
- Interface Biologics Inc.
- International Business Machines
- International Paper Company
- Ionicon
- Ionics Mass Spectrometry Group Inc.
- IRISNDT Corp.
- Irving Pulp & Paper Ltd.
- JDS Uniphase Inc.
- JNE Chemicals
- Johnson Matthey
- Kapik Integration
- Kasai Kogyo Co. Ltd.
- Kevin Quan Studios
- Keysight Technologies Canada Inc.
- Kiln Flame Systems Ltd.
- Kimberly-Clark Corp.
- Kinetica Dynamics
- Kinross Gold Corp.
- Klabin
- KQS Inc
- Krauss Maffei Corp.
- Kumho Petrochemical R & D Center
- Laboratoire d'essai Mequaltech
- LaFarge Canada
- Lallemand Inc.
- Lattice Semiconductor Ltd.
- LG Chem
- Lisgar Construction Company
- Litens Automotove Group
- Lubrizol
- Lumentra Inc.
- MacDonald, Dettwiler and Associates (MDA) Ltd.
- Magellan Aerospace
- Magna Closures
- Magna Exteriors and Interiors
- Magna International Inc.
- Magna Powertrain
- Manitoba Hydro
- Mantech Inc.
- Marmak Information Technologies
- Materials & Manufacturing Ontario
- Maxim Integrated Products Inc.
- McEwen Mining Inc.
- MeadWestvaco (MWV) Corp.
- Mercedes-Benz Canada Inc.
- Messier-Bugatti-Dowty

- Messier-Dowty Inc.
- Metso Pulp, Paper and Power
- Microbonds Inc.
- Micropilot
- Millipore
- Mine Environment Neutral Drainage
- Mitsubishi Rayon Co. Ltd.
- Moldflow Corp.
- Monaghan Biosciences Ltd.
- Mr. Robot Inc.
- Nanowave
- NanoXplore Inc.
- National Aeronautical Establishment (USA)
- NatureWorks LLC
- NCK Engineering
- Nestle Canada
- New World Laboratories
- Newterra
- Nike Inc.
- Northern Yashi Engin, Const Ltd.
- NUCAP Global
- Nuclear Waste Management Organization
- NXP Semiconductors Netherlands BV
- OCMR
- Olympus Canada
- Olympus NDT Canada
- Ontario Clean Water Agency
- Ontario Power Generation Inc.
- Ontario Renal Network
- Opal-RT Technologies Inc.
- ORNGE Medical Transport
- Ossur Canada Inc.
- OtoSim
- Pall Corporation
- Perkin Elmer Canada
- Pfizer Inc. (New York)
- Philips Electronics North America Corp.
- Plasco Energy Group
- Platinum Unlimited Inc.
- Polaris Industries
- Polumiros Inc.
- Polycon Industries
- Porewater Solutions
- Potent Group Inc.
- Pratt & Whitney Canada Inc.
- PrecisionHawk
- Process Research Ortech Inc.
- Procter & Gamble
- Prothena Biosciences Inc.
- Purolator
- QD Solar Inc.
- Qualcomm Canada Inc.
- Qualcomm Technologies Inc.
- Quanser Inc.
- Quantum Dental Technologies (QDT) Inc.
- Questor Technologies Inc.
- Quorum Technologies Inc.
- RBC – Royal Bank of Canada
- Regeneron Pharmaceuticals
- RESCON
- Research in Motion Ltd.
- Resertrac Inc.
- Resonance Ltd.
- Resource Systems Group Inc.
- Rio Tinto Alcan Inc.
- Robert Bosch Corp.
- Rockwell International
- Rocscience Inc.
- Rolls Royce Canada Ltd.
- Rosellini Scientific LLC
- RWDI
- Safety Power Inc.
- Safran Electronics Canada
- Samsung Advanced Institute of Technology
- Samsung Electronics
- Sanofi Pasteur
- Saudi Basic Industries Corp. (SABIC)
- Sceye Inc.
- Schlumberger Canada Ltd.
- Sealed Air Corp.
- Semiconductor Research Corp.
- Sensor Technology Ltd.
- S-FRAME Software Inc.
- ShawCor
- Shinil Chemical Industry Co. Ltd.
- Side Effects Software
- Siemens ADGT
- Sinclair Interplanetary
- Sinclair Technologies Inc.
- Solantro Semiconductor Corp.
- Solar Ship Inc.
- Solvay Specialty Polymers
- Sony Corporation
- SPP Canada Aircraft Inc.
- St Mary's Cement Group
- Stackpole International
- Stantec Inc.
- Steel Structures Education Foundation
- StemCell Tecnologies Inc.
- StoraEnso
- Sulzer Metco
- Suncor Energy Inc.
- Sunnybrook Health Sciences Centre
- Sunwell Technologies
- Suzano Papel e Celulose
- Synbra
- Syncrude Canada Ltd.
- Teck Resources Ltd.
- Teledyne ISCO
- TELUS
- Telus Mobility
- Tembec Industries Inc.
- Tenova GoodFellow Inc.
- Tessonics Inc.
- Thales Canada Inc.
- The Iron Ore Company of Canada (IOC)
- The Miller Group
- Theralase Inc
- ThermoFisher Scientific
- Tolko Industries Ltd.
- Toronto Hydro
- Toshiba Corp.
- Total American Services Inc.
- Tower Automotive
- Tower Solutions
- Toyota Collaborative Safety Research Center (CSRC)
- Toyota Technical Center USA Inc.
- TransCanada
- Trapeze Software ULC
- TSI
- Ultrasonix
- Uncharted Software Inc.
- Unisearch Associates
- US Steel Canada
- VAC Aero International Inc.
- Vale Canada Ltd.
- Valmet Ltd.
- Vicicog
- VisImage Systems Inc.
- Volkswagen Canada Inc.
- VTT Technical Research Centre of Finland
- Westport Innovations
- Whitemud Resources
- WSP Canada Inc.
- Wugang Canada Resources Invest. Ltd.
- Wurth Elektronik eiSos GmbH & Co. KG
- Wuzhong Instrument Company
- Xilinx Inc.
- Xiphos Technologies Inc.
- XOR-Labs Toronto
- Zotefoams PLC

We received $9.0 million in direct support from our corporate and industrial partners in 2016–2017. This represents a 16% increase over the previous year and is the highest total in our history. In 2017–2018 we hosted CEOs of several international companies, some of whom signed agreements to strengthen our collaborations, including Fujitsu, Huawei and Tenova.

Figure 3.2e **Industry Research Funding, 2007–2008 to 2016–2017**



We partner with a number of industrial research consortia including many associated with NSERC programs or industrial research chairs (IRCs). We increased our total number of IRCs to 11 in 2017–2018 by adding four new chairs:

- Professor Nikolai DeMartini (ChemE) — NSERC Industrial Research Chair in the Role and Fate of Inorganics in the Industrial Processing of Woody Biomass
- Professor Giovanni Grasselli (CivMin) — NSERC/Energi Simulation Industrial Research Chair in Fundamental Rock Physics and Rock Mechanics
- Professor Chul Park (MIE) — Senior NSERC/NanoXplore Industrial Research Chair in Multifunctional Graphene-based Nanocomposites and Foams
- Professor Frank Gu (ChemE) — NSERC Industrial Research Chair in Nanomaterials and Nanomedicine (with Johnson & Johnson Medical Products)

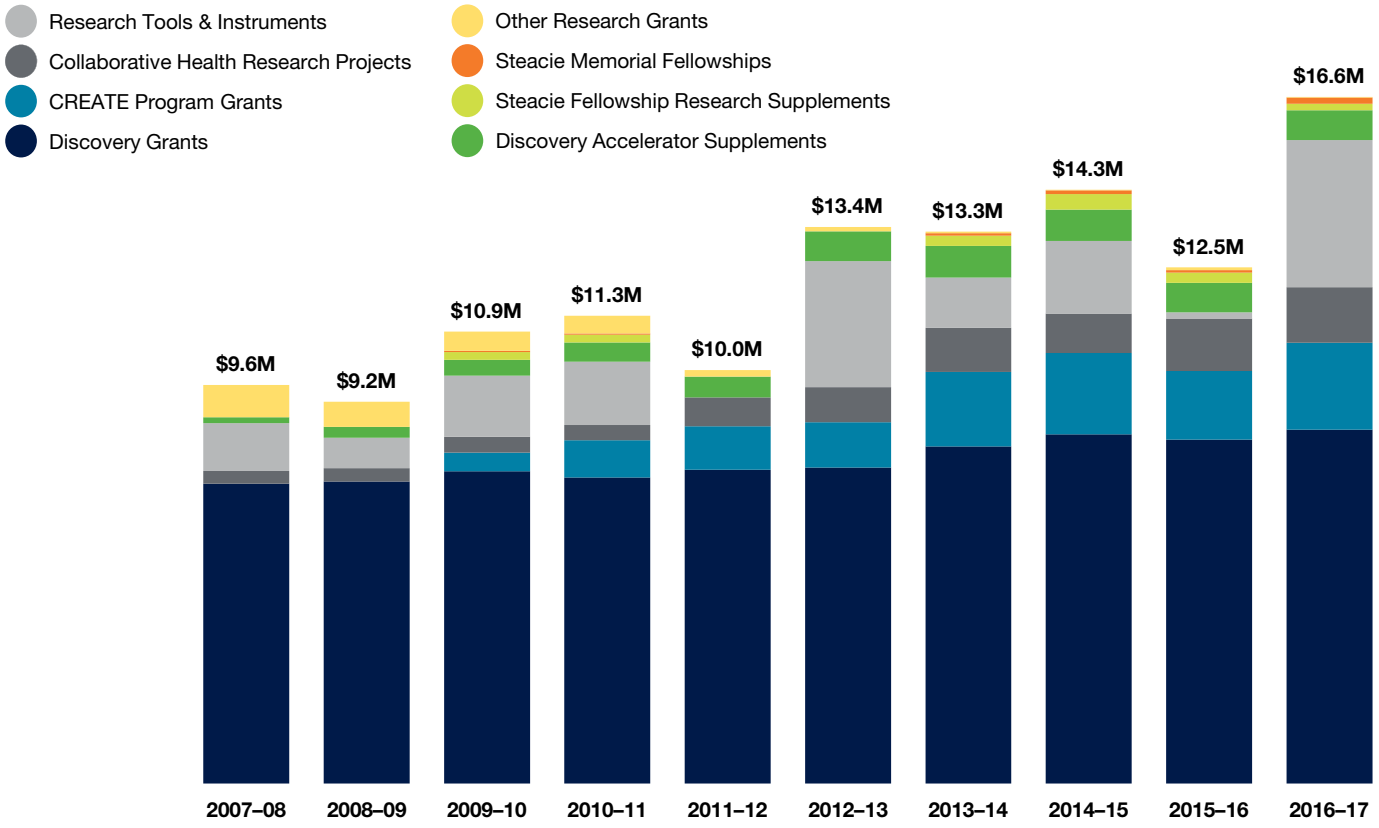
In February 2018, the Canadian federal government announced the results of its Innovation Superclusters Initiative, which provides $950 million over five years to support business-led research clusters across Canada. Two of the five superclusters — Next Generation Manufacturing Canada and the AI-Powered Supply Chains Supercluster (SCALE.AI) — leverage U of T Engineering expertise in areas such as multifunctional composites, autonomous machines and systems optimization.

Through the Vector Institute, launched in the spring of 2017, we are leveraging partnerships with government and more than 30 technology companies — including Google, Uber and Shopify — to prepare a new generation of experts in machine learning and artificial intelligence.

We received more than $6.5 million in support from the CFI Innovation Fund 2017 for the following professors and projects:

- Professor Peter Herman (ECE) — Lab-in-Fibre: Smart glass probing and distributed sensing microsystems
- Professor Alberto Leon-Garcia (ECE) — Smart city Internet of Things (IoT) testbed
- Professor Milica Radisic (IBBME, ChemE) — Ontario-Quebec centre for organ-on-a-chip engineering

Figure 3.2f **NSERC Research Grant Funding by Program, 2007–2008 to 2016–2017**



	2007–08	2008–09	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17
Other Research Grants	$781,400	$607,950	$462,319	$422,583	$162,000	$111,000	$40,000	$15,000	$67,000	$15,000
Steacie Memorial Fellowships			$30,000	$30,000			$60,000	$90,000	$60,000	$155,000
Steacie Fellowship Research Supplements			$187,500	$187,500			$250,000	$375,000	$250,000	$155,000
Discovery Accelerator Supplements	$144,000	$264,000	$383,999	$464,000	$504,000	$720,000	$760,000	$760,000	$716,285	$720,000
Research Tools & Instruments	$1,150,928	$734,572	$1,477,018	$1,533,781		$3,043,030	$1,218,077	$1,750,224	$146,900	$3,553,549
Collaborative Health Research Projects	$311,245	$326,169	$378,774	$366,899	$696,536	$846,731	$1,064,880	$950,376	$1,270,103	$1,338,873
CREATE Program Grants			$450,000	$900,000	$1,050,000	$1,096,000	$1,797,084	$1,969,779	$1,650,000	$2,100,000
Discovery Grants	$7,234,225	$7,286,804	$7,537,766	$7,385,066	$7,571,552	$7,623,942	$8,136,620	$8,427,417	$8,305,314	$8,543,000
Total	**$9,621,798**	**$9,219,495**	**$10,907,376**	**$11,289,829**	**$9,984,088**	**$13,440,703**	**$13,326,661**	**$14,337,796**	**$12,465,602**	**$16,580,422**

U of T Engineering is home to 32 Canada Research Chairs, including the following added this year:

- Professor Arun Ramchandran (ChemE) — Canada Research Chair in Engineered Soft Materials and Interfaces
- Professor Warren Chan (IBBME) — Canada Research Chair in Nanobioengineering
- Professor Olivier Trescases (ECE) — Canada Research Chair in Power Electronic Converters

In addition, five faculty members had their chairs renewed or advanced this year, including:

- Professor Ashish Khisti (ECE) — Canada Research Chair in Information Processing
- Professor Glenn Hibbard (MSE) — Canada Research Chair in Multi-Scale Materials Dynamics
- Professor Zheng-Hong Lu (MSE) — Canada Research Chair in Organic Optoelectronics
- Professor Ted Sargent (ECE) — Canada Research Chair in Nanotechnology
- Professor Yu Sun (MIE) — Canada Research Chair in Micro and Nano Engineering Systems

Please see Appendix D for a complete listing of chairholders and professorships.

We continue to earn a larger five-year cumulative share of NSERC funding than any other engineering school in Canada. This proportion is significant as it is the metric used to determine our complement of Canada Research Chairs. In 2016–2017, we earned 9.9% of all NSERC funding in engineering, just behind the previous year's record level of 10.0%.

Figure 3.3a **Canadian Peer Universities vs. University of Toronto Share of NSERC Funding for Engineering Cumulative Five-Year Share, 2012–2013 to 2016–2017**

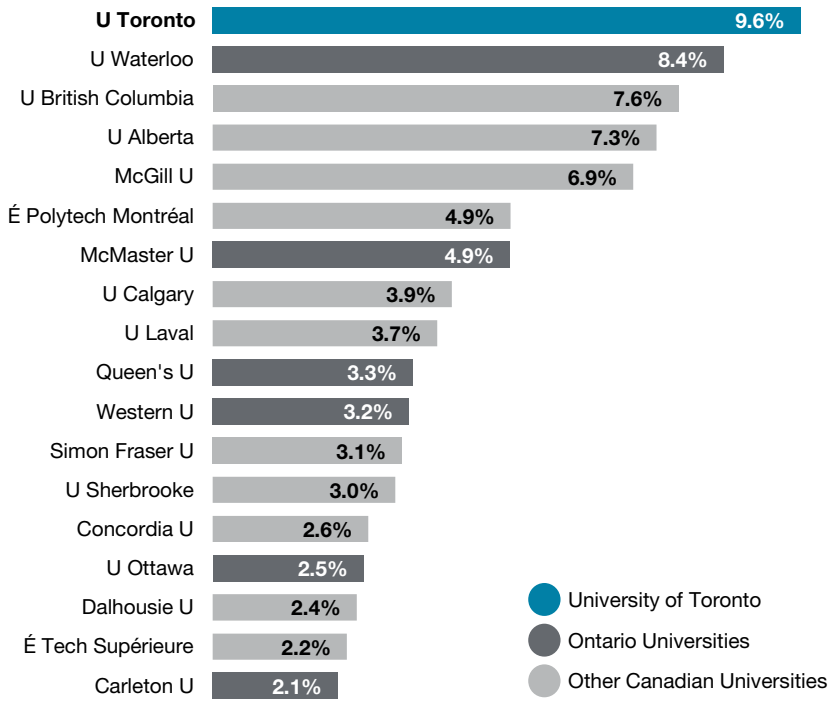


Figure 3.3b **U of T Annual Share of NSERC Funding in Engineering, 2007–2008 to 2016–2017**

2007–08	9.2%
2008–09	8.5%
2009–10	9.4%
2010–11	9.0%
2011–12	9.5%
2012–13	9.0%
2013–14	9.6%
2014–15	9.5%
2015–16	10.0%
2016–17	9.9%

Note 3.3a and 3.3b: Data are from the NSERC advanced search website and are shown by NSERC's fiscal year (April to March).

Figure 3.4a **Engineering Invention Disclosures by Academic Area, 2013–2014 to 2017–2018**

	2013–14	2014–15	2015–16	2016–17	2017–18	5-Yr Total
UTIAS	1.0		1.0	0.3	2.0	**4.3**
IBBME	5.9	6.5	7.8	5.9	4.4	**30.5**
ChemE	10.3	9.0	7.0	13.2	4.4	**43.9**
CivMin	5.0	5.0	5.0	1.7	4.0	**20.7**
ECE	16.5	41.6	23.5	34.8	38.5	**154.9**
EngSci	1.2		0.1	0.3	0.4	**2.0**
MIE	9.5	18.8	17.0	19.8	14.8	**79.9**
MSE	2.5	1.5	0.3	2.3	3.0	**9.6**
Annual Total	**51.9**	**82.4**	**61.7**	**78.3**	**71.5**	**345.8**
University Annual Total	**147.1**	**174.0**	**162.7**	**209.0**	**153.1**	**845.9**
Engineering Percentage	**35%**	**47%**	**38%**	**37%**	**47%**	**41%**

U of T Engineering continued to lead our institution in invention disclosures, as recorded by the Innovations and Partnerships Office. Our researchers accounted for 47% of these disclosures in 2017–2018 and 41% over the past five years. We also led the way in patent applications with 32 in 2017–2018, representing 54% of the University's total.

Figure 3.4b **U of T Invention Disclosures by Faculty, 2017–2018**

Figure 3.4c **U of T Patent Applications by Faculty, 2017–2018**

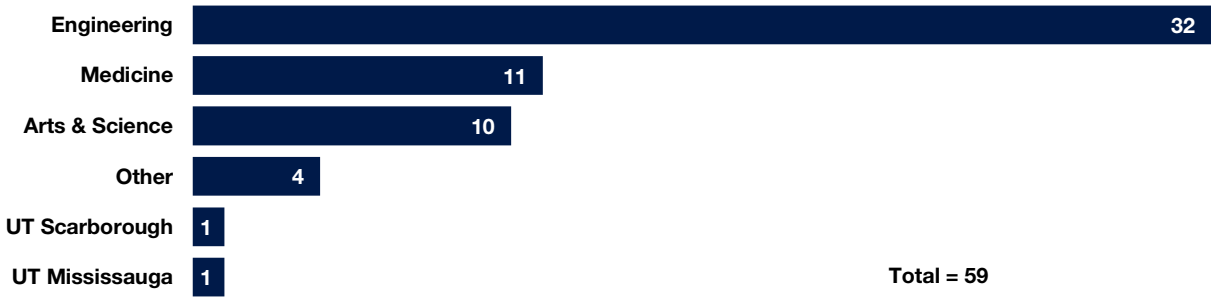
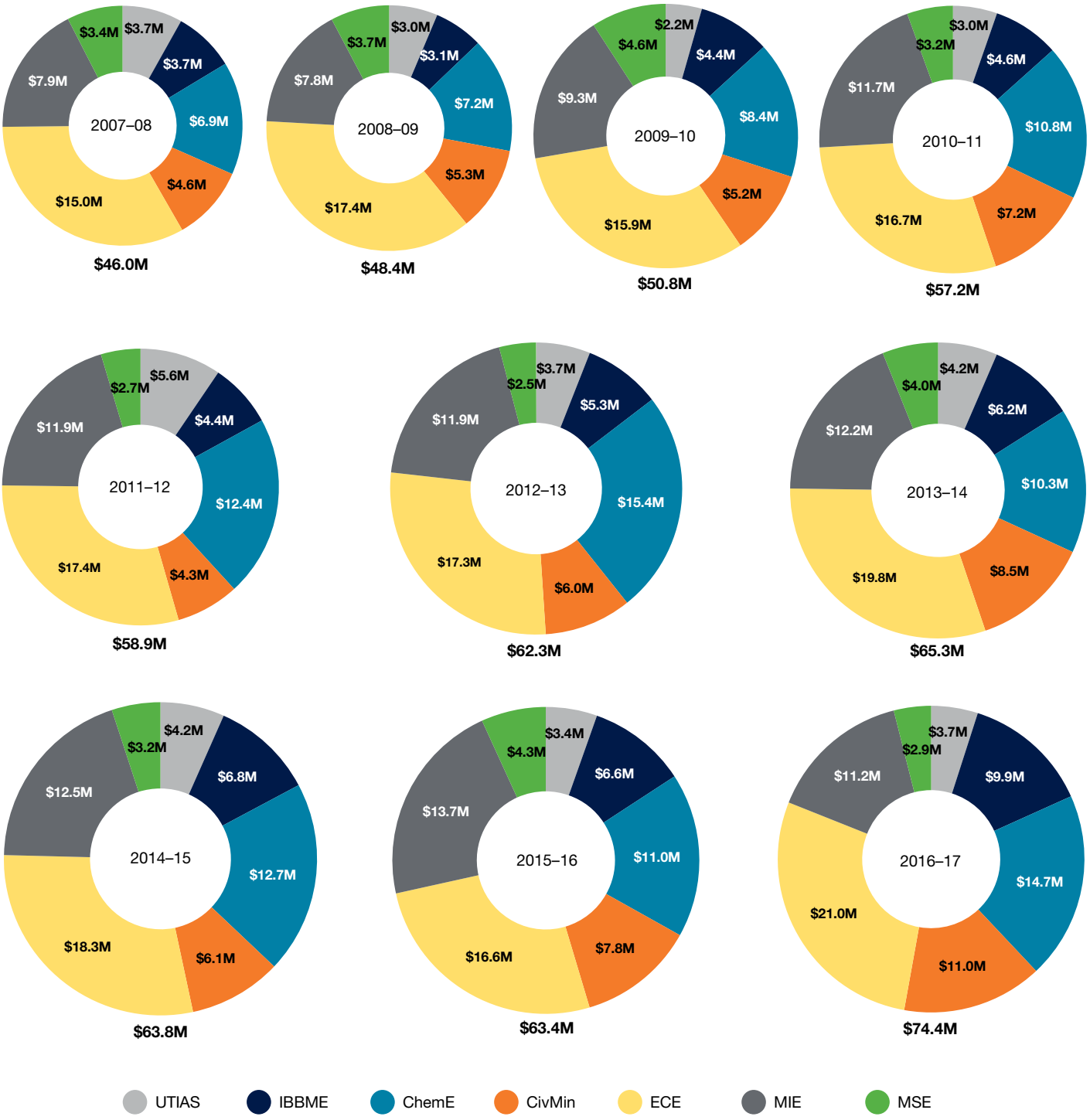


Figure 3.5 **Distribution of Research Operating Funding by Academic Area, 2007–2008 to 2016–2017**



Note 3.5: Totals include a small amount of additional funding not shown in the breakdown by academic areas. The research funding attributed to IBBME for 2016–17 represents 71% of the total funding received by core professors in the Institute. Because of IBBME's cross-disciplinary structure, many of its faculty have their research funding processed through the Medicine or Dentistry Faculties. The figure above shows only the funding that comes through U of T Engineering and is presented by grant year (April to March).