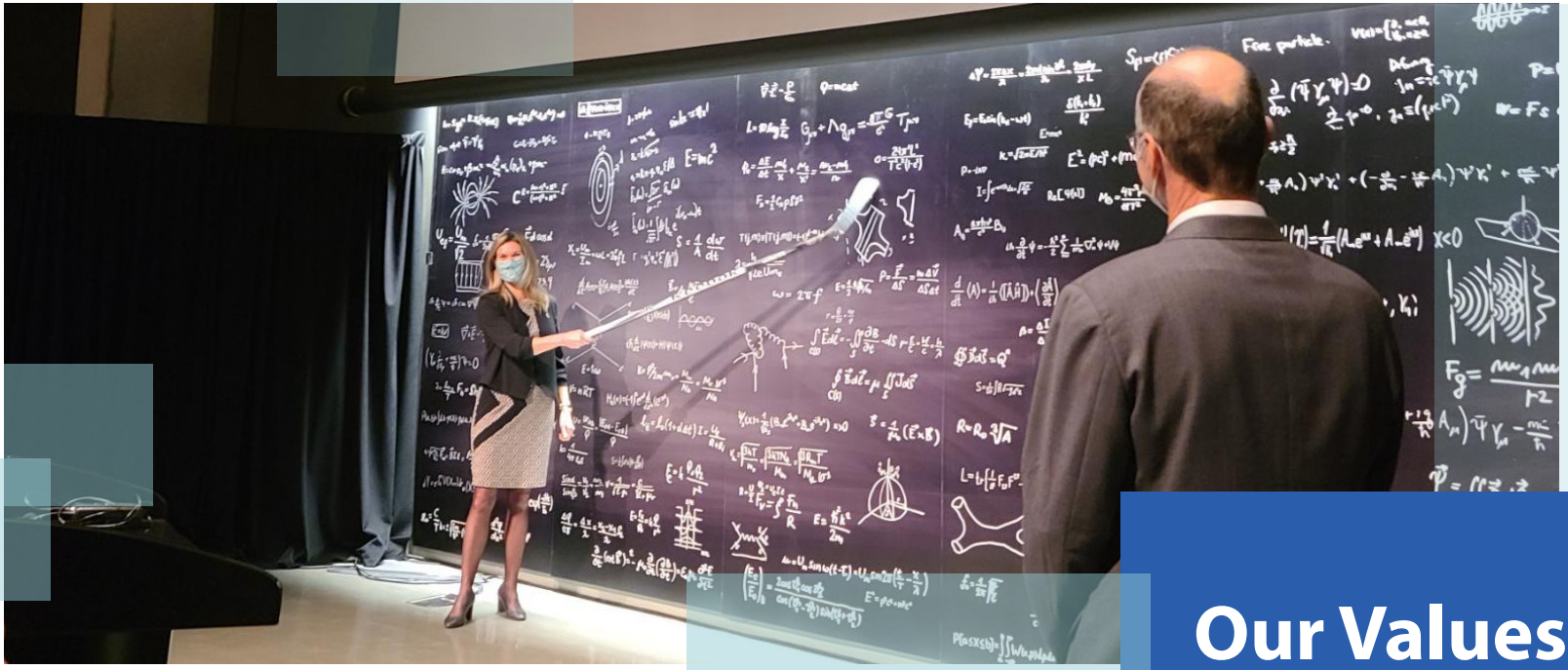
ADVANCING RESEARCH & INNOVATION IN ONTARIO

FIVE-YEAR REPORT 2015 – 2020 / 2020 – 2021 ANNUAL REPORT

Compute • Calcul Ontario



OUR VISION

Realize the full potential of digital research infrastructure (DRI) in advancing research, innovation, and creation in Ontario to support economic prosperity and improve the lives of Ontario residents.

OUR MISSION

Ensure that researchers in Ontario have access to the necessary DRI equipment, services, skills and support to advance research, discovery, and creation.

Our Values

- **Trust, Transparency & Accountability**
- **Collaboration and Partnership**
- **Innovation, Agility & Adaptability**
- **Continuous Improvement**

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Message from our Chair and CEO

Mark Daley
Chair, Board of Directors

Ranil Sonnadara
Chief Executive Officer

Advanced Research Computing (ARC) in Ontario is supported by a complex network of organizations that includes research and academic institutions, government agencies, hospitals, and private companies. These organizations provide the computing clusters, expertise, and bandwidth that we refer to as Digital Research Infrastructure (DRI). This ecosystem has grown organically over many years, and as the use of DRI has become more widespread, the need for strategic coordination and collaboration across the system has become clear. To fulfill this purpose, the Ontario government announced the creation of Compute Ontario in the spring of 2014 with a mandate to bring strategic coordination to Ontario's DRI ecosystem. Our role, as defined by the Province, is to help ensure that Ontario's researchers have access to the services and facilities they need.

In this report, you will read about the impact our work has had on the provincial research community since 2015, when Compute Ontario began operating. Clearly, these achievements are not ours alone, but reflect the work of the entire ecosystem, and in particular our consortia partners.

Compute Ontario's role is to convene and catalyze collaborative partnerships; provide expertise and occasionally hands-on support; consult and distill the range of views within the ecosystem into a coherent position that contributes to policy; and provide strategic thinking to ensure the ecosystem is funded effectively. We are grateful to our staff, and our many partners, for their support and hard work in the interests of Ontario's researchers.

This report also serves as our Annual Report for the fiscal year April 1st, 2020 – March 31st, 2021, and the period April 1st, 2021 – September 30th, 2021 (going forward, our fiscal year will start on October 1st.). The past 18 months has been a time of change and uncertainty, not only because of the global pandemic, but also because of changes in DRI at the national level. Compute Canada is in its final year of operation, and the new national federation, the Digital Research Alliance of Canada, is ramping up. Compute Ontario has focused much of its energies since March 2020 toward the Province's pandemic response and supporting the Alliance and its work towards a new funding model, whilst making sure that Ontario's researchers can still access the necessary services and infrastructure.

Meanwhile, the DRI ecosystem is becoming more complex. Researchers need integrated support and services that span data collection, computation and analysis, as well as data management and knowledge translation. Looking ahead, as we enter a new strategic planning cycle in January, we know we need to strengthen our stakeholder partnerships and our community. With this in mind, we will shortly be embarking on a series of consultations with the consortia and other stakeholders to build a unified vision and strategy for the future of DRI in Ontario and beyond.

Mark Daley
Chair, Board of Directors

Ranil Sonnadara
Chief Executive Officer

Summing Up Our Impact:

Researchers using intensive computational methods are generating ground-breaking results in every discipline, from climate science to epidemiology. Their research is producing results that fuel game-changing industrial innovation and create enormous benefits for society.

Advanced computing research can only thrive in a strong digital ecosystem that encompasses sufficient high-performance hardware, agile software development, and secure, efficient management of data. These services would not be possible without the knowledge and expertise that highly qualified personnel. Highly qualified personnel are crucial, and not just to manage hardware and write code. They train and support researchers in the development of sophisticated computing and data science skills needed to design and conduct studies that take advantage of computational methods.

As an independent organization, we are not custodians of data; we do not host high-performance computing clusters. Compute Ontario strives to understand the ecosystem clearly in its entirety and complexity, and to coordinate funding and strategy towards the best interests of the ecosystem as a whole. We advocate on behalf of the ecosystem and provide expert advice to the government to ensure the understanding of the ecosystem and its needs.

Since 2015, we have focused on:

Growing ecosystem resources and improving researcher access

Helping Ontario's computing consortia to increase access to computing power, software support, and data through advocacy and strategic coordination of funding investments

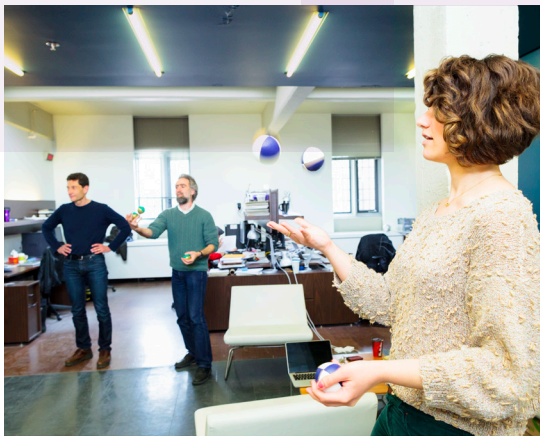
Building a cohesive DRI community

Creating the foundation for coordinated strategy, funding advocacy and synergistic collaboration across the province and amongst the regions that make up the Canadian landscape

Supporting skills development

Aiding consortia efforts to provide Ontario researchers with the skills to use advanced computing resources

Research Impact: Machine learning accelerates development of materials to make sustainable batteries and increase aircraft fuel efficiency



The Computational Materials Engineering Laboratory (CMEL) at the University of Toronto is an outstanding example of how digital research infrastructure is facilitating advances in areas critical to humankind such as climate change. The CMEL team, led by Dr. Chandra Veer Singh, Associate Professor of Materials Science and Engineering, is developing efficient machine learning models to accelerate materials development, which has historically required a slow and cumbersome trial-and-error approach.

In machine learning, "data is everything," says Abu Anand, a PhD student on the team. In collaboration with other research groups, CMEL builds quality databases related to specific materials and alloys, then applies machine learning techniques to predict material properties. Eventually, the team intends to make the databases open source, available to researchers around the globe.

The CMEL team is focused on identifying properties that can be leveraged to improve energy sustainability in a variety of ways, such as making aircraft more fuel-efficient and batteries more long-lasting. Researchers in the lab work in several areas:

- Graphene and other two-dimensional materials
- Batteries and energy materials
- Alloy design
- 'Meta' materials (materials whose structure has been changed to reduce weight while retaining strength)

From left to right: Dr. Zhiwen Chen, Adwitiya Rao, Jonathan Shan, Prof. Chandra Veer Singh, Sahar Choukir, Eric Nicholson, Abu Anand, Dr. Shwetank Yadav, Farzin Najafi, Hema Rajesh Nadella, Pedro Guerra Demingos, Zhuole (Joller) Lu, Szu-Jia (Jessica) Liu, Dr. Lixin Chen, Xiang Ni.

Anand's research focuses on high-entropy alloys. This field has emerged relatively recently. High-entropy alloys, which can withstand extreme temperatures, are of high interest in the automotive and aerospace sectors. Once perfected, these alloys will be 'game-changers', Anand says. "This is like the development of steel 100 years ago. These are the materials of the future."

While some projects at CMEL are still in the data-building stage, others are beginning to produce results. Last October, for example, Singh, Zhuole Lu, and Dr. Zhiwen Chen published a paper in the journal *Matter* to share significant findings related to the use of high-entropy alloys as catalysts for reactions. Such reactions include splitting water atoms to release hydrogen, which enables the use of hydrogen as a clean fuel. Using alloys as catalysts can potentially speed up and fine-tune chemical reactions, but the same complex combination of properties that allows them to do so also makes them difficult to research without the assistance of machine learning and sophisticated data management.

Anand says that he alone generates 1.5 terabytes of data every couple of months — data which then must be skillfully boiled down to 100 gigabytes without losing any important information. That's where SciNet, the advanced computing centre led by University of Toronto, comes in. SciNet provides access to high-performance computing cycles and supports post-processing of data and secure file management with their expertise.

Growing Ecosystem Resources and Improving Researcher Access

Researcher demand for advanced computing resources and support — including training, software development, and data management expertise — increases significantly every year. In fiscal 2020-2021, Ontario researchers drew on provincial and national ARC resources for 1.8 times more CPU cycles and 3.1 times more GPU cycles than they used in 2015 (see **Figure 1**).

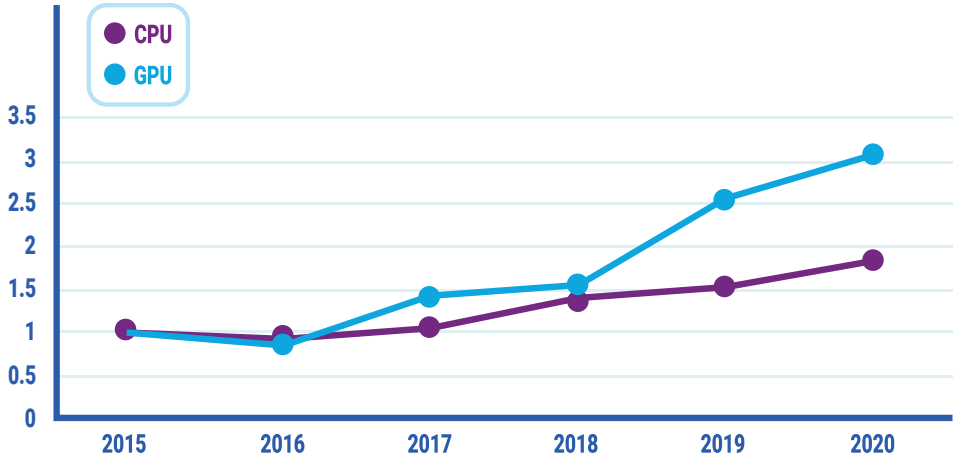


Fig. 1 Growth in CPU and GPU usage by Ontario researchers

Compute Ontario continues to advocate for, and coordinate, the funding and delivery of DRI resources to ensure researchers have access to these powerful tools. We have, to a degree, been successful, as evidenced by the increase in high-performance computing capacity in Ontario since 2015. Between March 31st, 2015 and March 31st, 2021, Ontario more than doubled its supply of high-performance computing cycles (see **Figure 2**). However the demand for ARC resources continues to outstrip supply. In 2021, the annual Research Allocation Competition (RAC), which distributes CPU and GPU access nationally, was able to grant Ontario researchers only 40% of the CPU time and 22% of the GPU time they requested.

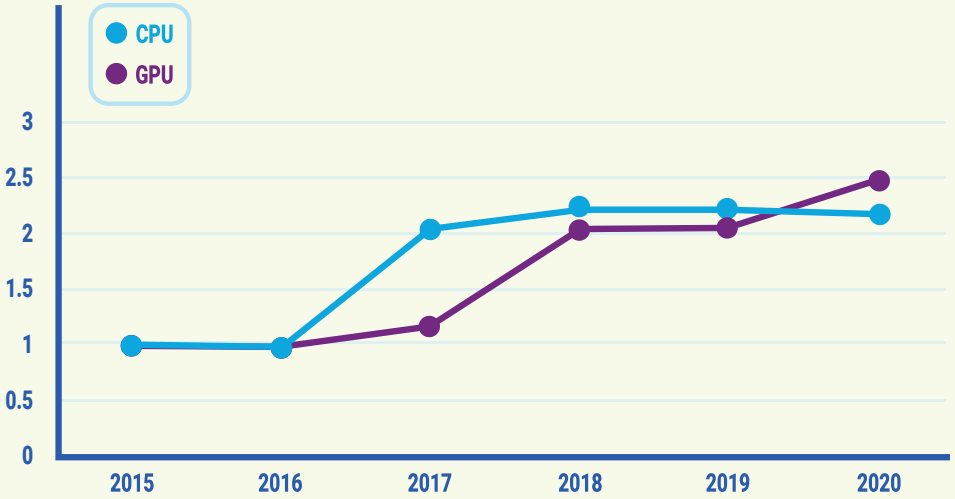


Fig. 2 Growth in CPU and GPU Cycles provided by Ontario-based systems

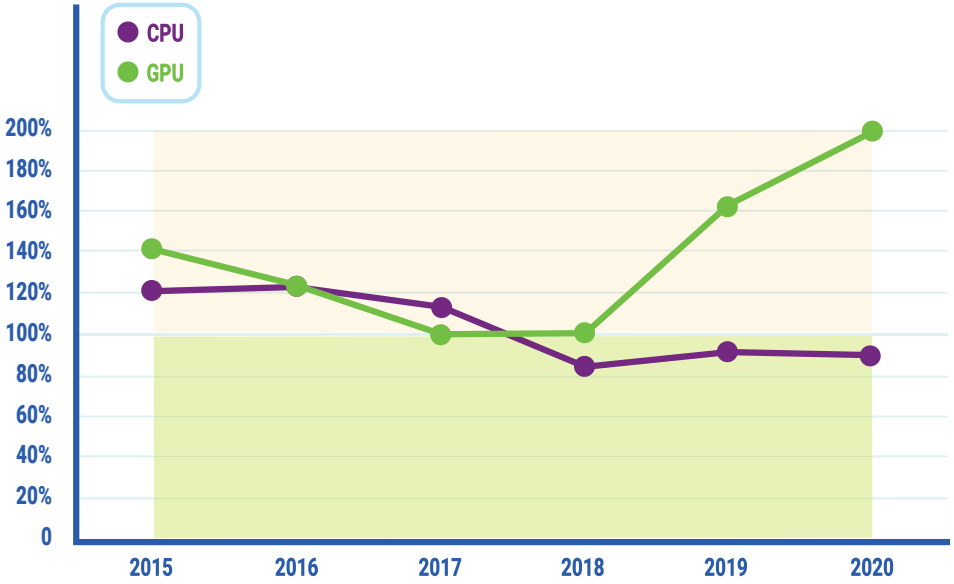


Fig. 3 Ontario usage relative to Ontario resources

It's important to note that both the compute needs of researchers and compute technology continues to evolve. The DRI ecosystems in Ontario and at the national level are interdependent, and comprise a federation of multiple systems, procured at different times, which can respond to changing trends. For example, in recent years, the GPU needs of many researchers across the country have increased significantly. The national DRI platform has responded to these needs by incorporating more GPUs in systems bought after Graham and Niagara were installed in Ontario (in 2017 and 2018). **Figure 3** illustrates how the changing demands of Ontario researchers have been accommodated by systems across the country.

Research Impact: Dedicated Research Software Support Speeds Pandemic Forecasting Model

Every three weeks, the Ontario Modelling Consensus Table (MCT) meets to review COVID-19 forecasting scenarios from several different research teams and create a consensus view to help the Ontario government make decisions about health care. The Mac-Theobio Research Group at McMaster University is one of the research teams creating these scenarios using sophisticated mathematical modelling.

"We began developing our software, the McMasterPandemic R Package, in March 2020, specifically to support governments and public health authorities in making epidemic-related decisions," says Dr. David Earn, Professor of Mathematics and Faculty of Science Research Chair in Mathematical Epidemiology at McMaster University. McMasterPandemic has also been adopted by the Public Health Agency of Canada.

Dr. Earn leads the Mac-Theobio team jointly with McMaster professors Dr. Ben Bolker (principal architect of McMasterPandemic) and Dr. Jonathan Dushoff. For decades, Earn, Bolker and Dushoff have been using mathematical modelling to study epidemics, whether that be the global spread of measles in the 20th century or the spread of bubonic plague across the 14th to 17th centuries — a project that required extensive resources to uncover and digitize records dating back nearly 700 years.

The team, which includes post-doctoral fellow Dr. Irena Papst and adjunct assistant professor Dr. Michael W.Z. Li, now produces COVID-19 forecasts for governments and public health authorities across Canada and in other countries. But their ability to provide this crucial service in a timely manner has been constrained until recently by the many hours it takes to recalibrate the model every time the ever-expanding data streams are updated.

Left to right: Dr. David Earn with former graduate students Dr. Chai Molina (middle) and Dr. Dora Rosati, discussing infectious disease modelling

Enter SHARCNET, a consortium of 19 academic institutions that provides researchers with access to advanced computing resources and services via the national advanced research computing platform. SHARCNET provided half-time programming support from Weiguang Guan, a C++ programmer who worked with the McMaster team's principal data scientist, Dr. Steve Walker, to speed up the software package by a factor of ten — a huge increase that will allow the team to move with greater agility and speed to support pandemic response in Ontario and elsewhere.

Growing Ecosystem Resources: Key Accomplishments

2017 SUPPORTED
the launch of Graham supercomputer at the University of Waterloo.

2018 SUPPORTED
the launch of Niagara, the most powerful supercomputer in Canada.

2018 – 2019 SECURED $10 MILLION
to fund network upgrades (100 G), 27 petabytes of archival storage capacity and a secure cloud-based data platform to support HAIDAP (see below).

2018 – 2019 LED THE DEVELOPMENT
of Health Artificial Intelligence Data Analytics Platform (HAIDAP), in partnership with the Vector Institute for Artificial Intelligence, HPC4Health, and ICES. HAIDAP is a supercomputing platform with a private cloud enabling researchers to securely access vast amounts of longitudinal health data.

2020 – 2021 LED THE DEVELOPMENT
of the Ontario Health Data Platform, which built on HAIDAP to create a federated data platform offering researchers the potential to anticipate epidemiological trends, generate new clinical insights and develop treatment innovations to aid in the fight against COVID-19.

The Hon. Jill Dunlop, Minister of Colleges and Universities, shared details of province's investment in research, on Nov. 9, 2021. Left to right: Dr. Clarence Virtue, Executive Director, SNOLAB; Minister Dunlop; Dr. Ranil Sonnadara, CEO, Compute Ontario

2021 SUCCESSFULLY ADVOCATED
for additional funding of $12 million to the Ontario ARC ecosystem to cover operational costs.

2021 FUNDED DEVELOPMENT
of encrypted Global Unique Identifiers (eGUIDs) to allow project teams to access data securely via unique, auditable, linking of data elements (a collaboration among University Health Network, Indoc and ICES).

2021 FUNDED DEVELOPMENT
of an open-source metadata template to standardize environmental microplastics data management and enable data sharing across the world (a collaboration among the University of Waterloo, Portage, Free University of Amsterdam).

2021 FUNDED A PROJECT
to georeference 1:50,000 series of Canadian topographic maps and make these available to researchers on Scholars GeoPortal and Dataverse Canada as a unified collection with support for searching, online viewing, and bulk downloading (a collaboration between University of Toronto Library and Scholars Portal).

2021 FUNDED INITIAL WORK
on the creation of a data repository to share research on the impact of arts participation on health and wellness, with special emphasis on community-based activities (Laboratory for Artistic Intelligence).

2020 – 2021: Creating a secure data platform for pandemic researchers

Rapidly following the World Health Organization's declaration of a pandemic, the Ontario Ministry of Health announced plans for a province-wide health data platform that would link large health datasets from a variety of sources to create an unprecedented volume of rich, connected data. Coupled with massive computing power, this federated data platform would offer researchers the potential to anticipate epidemiological trends, generate new clinical insights and develop treatment innovations to aid in the fight against COVID-19.

As a trusted advisor to the Government of Ontario, Compute Ontario was asked to lead the initial stages of this initiative, now known as the Ontario Health Data Platform (OHDP). The OHDP launched on schedule in July 2020 with the initial system leveraging the Health Artificial Intelligence Data Analytics Platform (HAIDAP) that had earlier been developed jointly by Compute Ontario, ICES and HPC4Health (a partnership between SickKids and Princess Margaret Cancer Centre). The second component launched on schedule in November 2020.

> "OHDP offers the ability to bring a massive amount of data together and analyze it without risking privacy or security."
>
> *— Dr. Bo Wang*

With the platform deployed and Compute Ontario's responsibilities completed on time and on budget, operational responsibility for OHDP was assumed by ICES, a not-for-profit analytics and research institute, and Indoc Research, a not-for-profit corporation that helps medical research teams manage, share and analyze their data.

OHDP involved more than 100 people from at least a dozen different organizations and is a testament to the power of bringing together consortia partners, stakeholders and researchers to solve real-world problems, and to support provincial and national priorities.

Research impact: Leveraging OHDP to understand COVID-19 mortality factors in long-term care residents

Managing COVID-19 in long-term care settings has been a high-profile concern during the pandemic, and for good reason. Long-term care residents are highly vulnerable to the disease's worst effects. An Ontario research team recently made a significant contribution to this area by using machine learning to study predictors of mortality in LTC residents with COVID-19.

The results, recently published in the **Journal of American Geriatrics*, concluded that functional status measures are key predictors of mortality, even after considering age, comorbidities and routine biochemical tests. "The results point to the need for sustained vigilance in long-term care settings," says Dr. Douglas Lee, co-author of the study, "especially regarding those with functional limitations, who are at exquisite risk." Precautions to minimize transmission of COVID-19 should continue to be employed, even when residents have been vaccinated.

The study was a collaboration between the clinical research team led by Lee, cardiologist and clinical epidemiologist at University Health Network's Peter Munk Cardiac Centre and the cardiovascular program leader at ICES, and the computational team led by Dr. Bo Wang, Lead Scientist of the Artificial Intelligence Team for Peter Munk Cardiac Centre. Wang's lab develops integrative and interpretable machine learning algorithms that can help clinicians with predictive models and decision support.

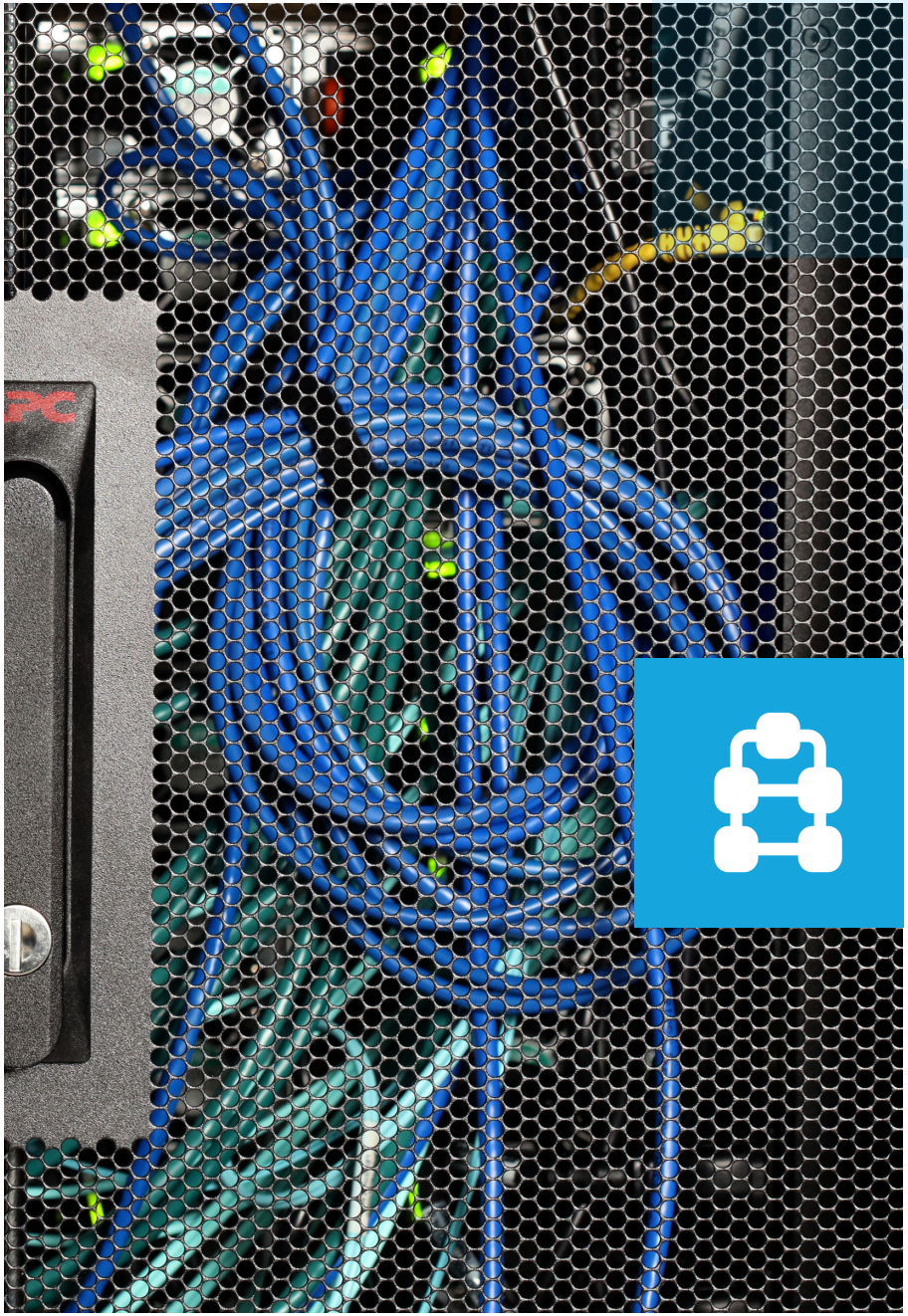
The two teams analyzed massive amounts of data housed on the Ontario Health Data Platform (OHDP), running on the high-performance computing cluster maintained by HPC4Health, a partnership between SickKids and the Princess Margaret Cancer Centre. The combination of a vast data set linked to powerful analytical resources enabled the teams to apply machine learning algorithms to investigate no less than 304 potential predictors of mortality, by analyzing more than 500,000 health records (approximately 65,000 patients). "This was unprecedented, not just in the scale of the data but also in the depth," says Wang, noting the team analyzed records going back nearly twenty years to include data from the first emergence of SARS in 2002.

He points out that deploying artificial intelligence in health care is complicated because of the critical need to keep data private. "OHDP offers the ability to bring a massive amount of data together and analyze it without risking privacy or security," he says. He also noted that OHDP provides researchers with expert data management support to prepare and harmonize data from a vast array of sources, enabling greater accuracy in results.

Dr. Bo Wang
Lead Scientist of the Artificial Intelligence Team, Peter Munk Cardiac Centre

Dr. Douglas Lee
Cardiologist and Clinical Epidemiologist, University Health Network's Peter Munk Cardiac Centre

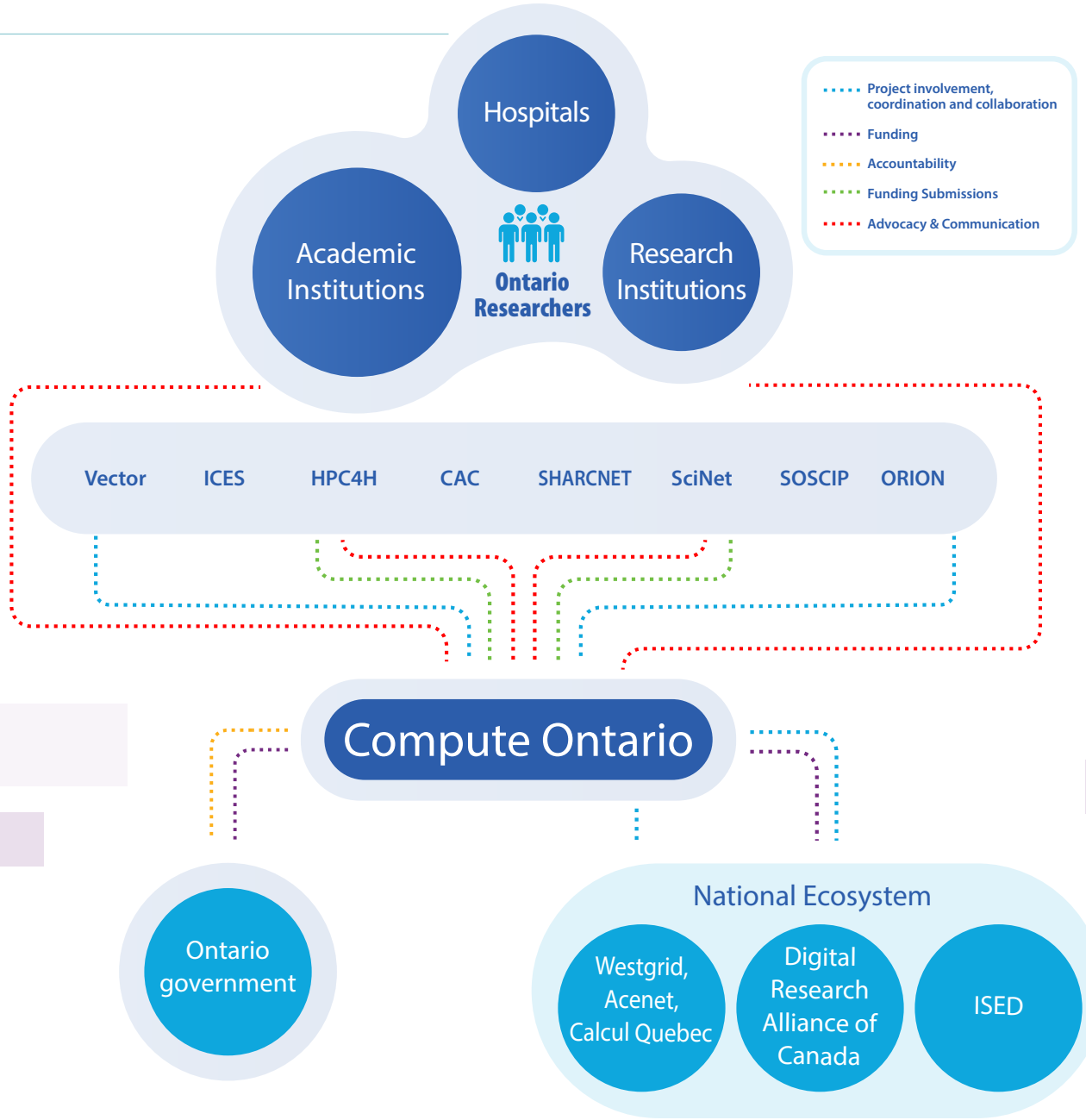
***Predictors of mortality among long-term care residents with SARS-CoV-2 infection,** first published 19 August 2021. Authors: Douglas S. Lee ,MD, PhD; Shihao Ma, BASc; Anna Chu, MHSc; Chloe X. Wang, BSc; Xuesong Wang, MSc; Peter C. Austin, PhD; Finlay A. McAlister, MD, MSc; Sunil V. Kalmady, PhD; Moira K. Kapral, MD, MSc; Padma Kaul, PhD; Dennis T. Ko, MD, MSc; Paula A. Rochon, MD, MPH; Michael J. Schull MD, MSc; Barry B. Rubin, MD, PhD; Bo Wang, PhD; CORONA Collaboration.



Building a Cohesive DRI Community

Advanced Research Computing (ARC) in Ontario is supported by a complex network of organizations that includes research and academic institutions, government agencies, hospitals, and private companies. These organizations provide the computing clusters, expertise, and bandwidth that we refer to as Digital Research Infrastructure (DRI). It's an ecosystem that has grown organically over many years, and is becoming more complex. Researchers need integrated support and services that span data collection, computation and analysis, data management and knowledge translation. A key aspect of Compute Ontario's role is to facilitate collaboration and alignment across the ecosystem.

Ontario's DRI Community



Building Community: Key Accomplishments

2016 NEGOTIATED

interregional service level agreement on behalf of Ontario.

2016 – 2018 CONSULTED

across the province regarding national coordination of DRI resulting in a published report on Ontario researchers' technology infrastructure needs.

2016 FUNDED

the Data Safe Haven project to inform health sector data strategy and planning.

2017 CO-HOSTED

the High-Performance Computing Symposium with Queen's University.

2018 COMMISSIONED

The Evidence Network to conduct impact studies to evaluate Compute Ontario effectiveness.

2018 ORGANIZED

and hosted Ontario Advanced Research Computing Congress with 130 participants

2018 LAUNCHED

Regional Information Exchanges, ongoing quarterly information-sharing and strategy sessions with our consortia partners.

2019 CREATED INAUGURAL

Compute Ontario Research Council and Technical Advisory Council to embed research and technical perspectives into our governance model.

2019 PUBLISHED

Smart Cities data governance report and use cases, developed through collaborative workshops with stakeholders from research, industry, government and other communities.

2020 COMMISSIONED

a Brookfield Institute demographic study of ARC-skilled personnel in Ontario, to inform recruiting and training strategies.

2021 SUPPORTED

the transition from Compute Canada to NDRIO (now Digital Research Alliance of Canada) including providing strategic leadership and financial services to development of a new national-provincial funding model and staff transition plan, providing input and leadership around the national service model, and providing research and analytical services to support NDRIO's needs survey.

2021 RENEWED

the terms of reference and membership of the Technical Advisory Council (now Technical Leadership Advisory Council) to broaden representation and focus the council's work on creating a coordinated technical strategy for Ontario's DRI.

2021 COMMISSIONED

The Evidence Network Commissioned to conduct impact studies to evaluate Compute Ontario effectiveness. Results will inform our next strategic plan.

Partners and Collaborators

In Ontario, the largest providers of ARC resources are four long-established academic consortia based at universities and hospitals. These consortia have strategically built and supported ARC platforms since the late 1990s, including two of the country's current five national ARC platforms: Niagara (at the University of Toronto) and Graham (at the University of Waterloo). The academic consortia play an essential role in providing access to ARC systems, programming expertise, training and other supports to researchers in Ontario and across Canada.

SciNet is led by University of Toronto and hosts the Niagara system. SciNet provides Canadian researchers with computational resources and expertise necessary to perform their research on scales not previously possible in Canada.

CAC, the Centre for Advanced Computing, is based at Queen's University. CAC specializes in secure advanced computing resources for highly confidential data, and support for academic and medical researchers.

SHARCNET is a consortium of 19 universities and colleges, covering a geographical span of about 1800 km from Windsor to Peterborough, and St. Catharines to Thunder Bay, making it the largest HPC consortium in Canada. SHARCNET is responsible for running the Graham system which is located at the University of Waterloo.

HPC4Health is a partnership between SickKids and the Princess Margaret Cancer Centre at University Health Network, providing clinical researchers with secure cloud-computing services, while satisfying personal health information privacy requirements.

Beyond the four academic consortia, Compute Ontario works closely with:

SOSCIP, a Canadian academic-industry consortium dedicated to HPC.

ICES, a not-for-profit research institute encompassing a community of research, data and clinical experts, and a secure and accessible array of Ontario's health-related data.

ORION, the only high-speed, fibre-optic network specifically committed to supporting research, education and innovation in Ontario.

VECTOR INSTITUTE, an independent, not-for-profit corporation dedicated to research in the field of artificial intelligence (AI), excelling in machine and deep learning.

Ontario's DRI landscape also encompasses world-class research institutes and independent organizations that enable and support research in collaborative ways. These include:

CLINICAL TRIALS ONTARIO, which works collaboratively with industry, research institutes, patients and others to improve the clinical trials environment and attract investment to the province, while supporting the highest ethical and quality standards.

FACIT, which bridges cancer research and innovation to real world opportunities that benefit investors, patients and our economy.

FIELDS INSTITUTE, an international centre for scientific research in mathematical sciences at the University of Toronto.

ONTARIO BRAIN INSTITUTE, which works to establish Ontario as a world leader in brain research, commercialization and care.

ONTARIO GENOMICS, a not-for-profit organization that manages cutting-edge genomics research projects and platforms.

ONTARIO INSTITUTE FOR CANCER RESEARCH (OICR), which collaborates with partners in Ontario and around the world to accelerate new cancer research.

PERIMETER INSTITUTE, an independent research centre in foundational theoretical physics.

ROTMAN RESEARCH INSTITUTE, BAYCREST, a premier international centre for the study of human brain function.

Nationally, the **Digital Research Alliance of Canada** was launched in 2020 to coordinate and fund activities in advanced research computing (ARC), research data management (RDM) and research software (RS), working collaboratively with stakeholders across the country, including Compute Ontario and its regional counterparts in the **Compute Canada Federation**: **WestGrid** (BC, Alberta, Saskatchewan, Manitoba), **ACENET** (New Brunswick, Nova Scotia, PEI and Newfoundland and Labrador) and **Calcul Québec.**

Research Impact: Using computational methods to reclaim and revitalize Indigenous languages

Nathan Brinklow (Thanyehténhas), a PhD student at Queen's University, has been deeply involved in both community- and research-based activities designed to reclaim and revitalize indigenous languages, particularly Mohawk. In 2019, he attended a colloquium at Queen's and happened to meet Chris MacPhee, at that time the Director of Operations and Development for Queen's Centre for Advanced Computing (CAC). "Chris said, let's talk about how CAC can help you," said Brinklow. That proved to be a turning point in the way he approaches his work. "Often, the reason Humanities researchers don't take advantage of computational methods is that we don't know about what's available," Brinklow said. "CAC is enabling us to have these conversations and think about these possibilities."

Right: Community data collection: A group of Mohawk first-language speakers using plays and scripts to elicit and record vocabulary.

Photo credit: Tsi Tyónnheht Onkwawén

Left: Tyendinaga Mohawk Territory: Data collection through story-telling and discussion.

Photo credit: Tsi Tyónnheht Onkwawén

One of the possibilities involves solving the 'transcription bottleneck'. Analyzing linguistic data requires spoken and written versions of the same text, both indexed to time. While there is a wealth of language data available, most of it is either in text form with no audio or in audio form with no text. This means hiring people to read and record text or transcribe audio recordings — a time-consuming and expensive process. The lengthy recordings or transcripts that result are usually difficult to index and search. Brinklow and his CAC collaborators plan to start by creating a data management app that volunteers can use to input their work within set parameters that make it possible to more quickly digitize and index the data.

> "Ultimately, the database will be a valuable resource that can be leveraged to develop text-to-speech or speech-to-text applications, and to perform linguistic analyses, such as word frequency, which will aid in building teaching and learning tools."

Given a sufficient quantity of well managed voice and text data, machine learning can be applied to match sounds with written symbols and develop speech recognition algorithms that can then be used to automate the transcription process. Ultimately, the database will be a valuable resource that can be leveraged to develop text-to-speech or speech-to-text applications, and to perform linguistic analyses, such as word frequency, which will aid in building teaching and learning tools.

CAC's role in the project involves providing expert support around data management and security, as well as archival data storage. CAC will also be providing computing cluster support once development of the speech recognition algorithm begins. "CAC is also helping us to solve for policy issues related to Indigenous data sovereignty," Brinklow noted. CAC is helping to enable the data to be securely stored locally at the Tyendinaga Language and Culture Centre, rather than on an open cloud platform.

The project slowed to a pause during the pandemic but is restarting now, with work on data management and planning for new app-based data collection.

Supporting Skills Development

50,000
PARTICIPANTS IN ARC TRAINING

Enrollment in advanced computing training provided by Compute Ontario's consortia partners reached nearly 50,000 between 2015 and 2021. This training has tangible benefits for Ontario researchers. In a recent survey commissioned by Compute Ontario and conducted by The Evidence Network, **89%** of respondents said that the training had positively impacted their research practices by enabling them to more effectively use computing research, improve research productivity or undertake more complex research projects. **67%** identified a positive career impact. **93%** of respondents were satisfied or very satisfied with their training experience.

2017 CONDUCTED
research and developed definitions and standards to inform training and recruiting strategies.

2018 BEGAN PROVIDING FINANCIAL
planning and communications support for summer schools led by consortia.

2019 DELIVERED
Ontario Public Service (OPS) Hackathon, with consortia partners. 700 hours of cost-free training to OPS staff, who learned ARC skills hands-on while solving real problems.

2020 COMMISSIONED
Brookfield Institute research and conducted stakeholder sessions to understand demographics and develop strategies for attracting, training and retaining people with computational research skills.

2021 FUNDED
development of free virtual training modules in secure data handling in medicine and health care (a collaboration between University of Toronto and McMaster University).

2021 FUNDED
development of free virtual training models in data handling best practices for all research disciplines (a collaboration between Ottawa Hospital Research Institute and Algonquin College).

2021 CREATED
a Training Advisory Committee to consolidate ARC training into a provincial certificate program under the Compute Ontario umbrella. Members include the consortia and e-Campus Ontario.

Credit: Bernard Clark

ARC Training April 1, 2020 to March 31, 2021

	Events	Attendees	Training hrs	Online training views	Online training video viewing hours
SciNet	180	5,112	5,626	--	--
SHARCNET	98	1,727	8,240	196,700	9,700
HPC4Health	6	146	4,455	--	--
CAC	73	1,634	6,112	--	--
Total	**357**	**8,619**	**24,433**	**196,700**	**9,700**

"I trained as an experimental researcher and had a basic education In Linux-based systems. I would not have been able to do the research I'm doing today into high-entropy alloys without advanced computing skills, which I was able to develop by taking courses through SciNet."

— Abu Anand, PhD student, Computational Materials Engineering Laboratory, University of Toronto.

Financial Statements

Financials and Metrics

Compute Ontario received its core funding from the province of Ontario to support operational expenses from April 1, 2015 to September 30, 2021. The annual costs are outlined in the following table. This does not include one-time projects (CO-ORION and OHDP) which were funded and accounted for separately.

Compute Ontario - Operational Expenses 2015-2021

Expense Category	2015-16 (Apr-Mar)	2016-17 (Apr-Mar)	2017-18 (Apr-Mar)	2018-19 (Apr-Mar)	2019-20 (Apr-Mar)	2020-21 (Apr-Mar)	2021 (Apr-Sept)	Total	Comments
Salaries, Wages & Benefits	$241,155	$617,415	$912,346	$1,030,898	$1,125,320	$549,723	$350,242	$4,827,099	CO staff positions
Staff Training	$0	$4,595	$5,761	$19,593	$8,737	$3,324	$0	$42,010	training as required
Board & Corporate Secretary	$72,240	$49,631	$0	$0	$0	$0	$0	$121,871	function absorbed by CO staff
Conferences, Meetings & Events	$14,912	$91,735	$57,547	$155,946	$173,211	($122)	$294	$493,523	conferences/workshops offered or attended
Premises	$0	$172,469	$71,319	$78,994	$82,261	$87,351	$0	$492,394	rent based on lease agreement
Strategic Initiatives	$58,228	$30,000	$387,058	$194,339	$45,340	$118,891	$349,994	$1,183,850	special projects and initiatives
Professional Services	$37,456	$358,093	$22,769	$11,996	$60,675	$12,793	$62,537	$566,319	additional administrave and communications support
Legal, HR, Procurement	$12,639	$18,674	$12,588	$18,403	$7,333	$9,126	$12,982	$91,745	legal advice, recruitment
Accounting, Financial	$10,000	$0	$0	$0	$0	$0	$0	$10,000	Western donated backend services as in-kind
Insurance	$3,078	$3,078	$5,173	$4,873	$4,873	$5,141	$8,505	$34,721	CGL, D&O, property insurance
Audit	$4,262	$11,800	$13,613	$14,127	$12,499	$14,863	$12,109	$83,273	annual audit required
IT	$542	$22,778	$27,785	$25,400	$29,311	$21,143	$23,778	$150,737	hardware, software, telephones, mobiles, annual certificates
Media & Materials	$0	$4,341	$62,845	$31,641	$6,099	$1,507	$1,091	$107,524	creative services, advertising, web design
Office Administration	$1,833	$11,384	$8,507	$5,923	$4,445	$999	$481	$33,572	supplies, printing, courier, postage
TOTAL EXPENSES	**$456,345**	**$1,395,993**	**$1,587,311**	**$1,592,133**	**$1,560,104**	**$824,739**	**$822,013**	**$8,238,638**	

Schedule of Expenditures of

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING

And Independent Auditors' Report thereon

Year ended March 31, 2021

KPMG LLP
140 Fullarton Street Suite 1400
London ON N6A 5P2
Canada
Tel 519 672-4800
Fax 519 672-5684

INDEPENDENT AUDITORS' REPORT

To the Management of Compute Ontario / Calcul Ontario and the Minister of Colleges and Universities (the "Ministry")

Report on Audit of the Schedule

Opinion

We have audited the accompanying schedule of expenditures of Compute Ontario / Calcul Ontario for the Ministry of Colleges and Universities (formerly the Ministry of Research and Innovation) (the "Ministry") funding for the year ended March 31, 2021 and notes to the schedule, including a summary of significant accounting policies (hereinafter referred to as the "schedule").

In our opinion, the accompanying schedule is prepared, in all material respects, in accordance with the financial reporting provisions in Article 7 of the agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, between Compute Ontario / Calcul Ontario (the "Organization") and the Ministry.

Basis for Opinion

We conducted our audit in accordance with Canadian generally accepted auditing standards. Our responsibilities under those standards are further described in the ***"Auditors' Responsibilities for the Audit of the Schedule"*** section of our auditors' report.

We are independent of the Organization in accordance with the ethical requirements that are relevant to our audit of the schedule in Canada and we have fulfilled our other ethical responsibilities in accordance with these requirements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Financial Reporting Framework

We draw attention to Note 2 to the schedule, which describes the applicable financial reporting framework.

The schedule is prepared to assist the Organization to meet the requirements of the funding agreement between Compute Ontario / Calcul Ontario and the Ministry as described in Note 1 to the schedule.

KPMG LLP, an Ontario limited liability partnership and member firm of the KPMG global organization of independent member firms affiliated with KPMG International Limited, a private English company limited by guarantee.
KPMG Canada provides services to KPMG LLP.

As a result, the schedule may not be suitable for another purpose.

Our opinion is not modified in respect of this matter.

Responsibilities of Management and Those Charged with Governance for the Schedule

Management is responsible for the preparation of the schedule in accordance with the financial reporting provisions in the Agreement between the Organization and the Ministry dated April 1, 2015, amended February 1, 2019 and November 9, 2020, and for such internal control as management determines is necessary to enable the preparation of the schedule that is free from material misstatement, whether due to fraud or error.

Those charged with governance are responsible for overseeing the Organization's financial reporting process.

Auditors' Responsibilities for the Audit of the Schedule

Our objectives are to obtain reasonable assurance about whether the schedule as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditors' report that includes our opinion.

Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with Canadian generally accepted auditing standards will always detect a material misstatement when it exists.

Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of the schedule.

As part of an audit in accordance with Canadian generally accepted auditing standards, we exercise professional judgment and maintain professional skepticism throughout the audit.

We also:

- Identify and assess the risks of material misstatement of the schedule, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion.

  The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Organization's internal control.

- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by management.
- Communicate with those charged with governance regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

KPMG LLP

Chartered Professional Accountants, Licensed Public Accountants

London, Canada

November 19, 2021

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING
Schedule of Expenditures

Year ended March 31, 2021, with comparative information for 2020

	Total 2021	Total 2020
Expenditures:		
Salaries, wages and benefits	$ 549,723	$ 1,125,320
Special studies	118,891	45,340
Premises	87,351	82,261
Information technology	21,143	29,311
Audit	14,863	12,499
Professional services	12,793	60,675
Legal, HR and procurement	9,126	7,333
Insurance	5,141	4,873
Staff training	3,324	8,737
Media and materials	1,507	6,099
Office administration	999	4,445
Conference, meetings and events	(122)	173,211
Total expenditures	$ 824,739	$ 1,560,104

See accompanying notes to the schedule.

Approved on behalf of the Board of Directors:

Chair, Board of Directors

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING
Notes to Schedule of Expenditures

Year ended March 31, 2021

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1. Project Description:

Compute Ontario / Calcul Ontario (the "Organization") signed an agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, with the Ministry of Colleges and Universities (formerly the Ministry of Research and Innovation) to fund the operating costs of the Organization (the "Project").

Under the agreement, The Ministry of Colleges and Universities (formerly the Ministry of Research and Innovation) (the "Ministry") will provide a maximum of $8,500,000 cash contribution to the Project for the project period, which ends on September 30, 2021. The objective of the Project is to explore the merits of developing a high performance computing and big data strategy for the province.

The schedule of expenditures of Compute Ontario / Calcul Ontario for the Ministry of Colleges and Universities funding presents the Organization's portion of eligible expenditures incurred for the Project during the reporting period.

2. Significant accounting policies:

(a) Basis of accounting:

The schedule is prepared in accordance with the basis of accounting prescribed in Schedule F of the Agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, between Compute Ontario / Calcul Ontario and the Ministry.

The schedule has not been prepared in accordance with the presentation principles or the presentation of all the financial statements and related note disclosures required by Canadian accounting standards for not-for-profit organizations.

(b) Expenditures:

Expenditures are eligible under the Project if they were incurred in the period of the Project and are directly related to the completion of the Project.

Schedule of Expenditures of

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING

And Independent Auditors' Report thereon

Six month period ended September 30, 2021

KPMG LLP
140 Fullarton Street Suite 1400
London ON N6A 5P2
Canada
Tel 519 672-4800
Fax 519 672-5684

INDEPENDENT AUDITORS' REPORT

To the Management of Compute Ontario / Calcul Ontario and the Minister of Colleges and Universities (the "Ministry")

Report on Audit of the Schedule

Opinion

We have audited the accompanying schedule of expenditures of Compute Ontario / Calcul Ontario for the Ministry of Colleges and Universities (formerly the Ministry of Research and Innovation) (the "Ministry") funding for the six month period ended September 30, 2021 and notes to the schedule, including a summary of significant accounting policies (hereinafter referred to as the "schedule").

In our opinion, the accompanying schedule is prepared, in all material respects, in accordance with the financial reporting provisions in Article 7 of the agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, between Compute Ontario / Calcul Ontario (the "Organization") and the Ministry.

Basis for Opinion

We conducted our audit in accordance with Canadian generally accepted auditing standards. Our responsibilities under those standards are further described in the ***"Auditors' Responsibilities for the Audit of the Schedule"*** section of our auditors' report.

We are independent of the Organization in accordance with the ethical requirements that are relevant to our audit of the schedule in Canada and we have fulfilled our other ethical responsibilities in accordance with these requirements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Financial Reporting Framework

We draw attention to Note 2 to the schedule, which describes the applicable financial reporting framework.

The schedule is prepared to assist the Organization to meet the requirements of the funding agreement between Compute Ontario / Calcul Ontario and the Ministry as described in Note 1 to the schedule.

As a result, the schedule may not be suitable for another purpose.

Our opinion is not modified in respect of this matter.

KPMG LLP, an Ontario limited liability partnership and member firm of the KPMG global organization of independent member firms affiliated with KPMG International Limited, a private English company limited by guarantee.
KPMG Canada provides services to KPMG LLP.

Other Matter – Restriction on Use

Our report is intended solely for the Ministry and the Organization and should not be used by other parties.

Responsibilities of Management and Those Charged with Governance for the Schedule

Management is responsible for the preparation of the schedule in accordance with the financial reporting provisions in the Agreement between the Organization and the Ministry dated April 1, 2015, amended February 1, 2019 and November 9, 2020, and for such internal control as management determines is necessary to enable the preparation of the schedule that is free from material misstatement, whether due to fraud or error.

Those charged with governance are responsible for overseeing the Organization's financial reporting process.

Auditors' Responsibilities for the Audit of the Schedule

Our objectives are to obtain reasonable assurance about whether the schedule as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditors' report that includes our opinion.

Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with Canadian generally accepted auditing standards will always detect a material misstatement when it exists.

Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of the schedule.

As part of an audit in accordance with Canadian generally accepted auditing standards, we exercise professional judgment and maintain professional skepticism throughout the audit.

We also:

- Identify and assess the risks of material misstatement of the schedule, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion.

  The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.

- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Organization's internal control.

- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by management.
- Communicate with those charged with governance regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

KPMG LLP

Chartered Professional Accountants, Licensed Public Accountants

London, Canada

December 15, 2021

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING

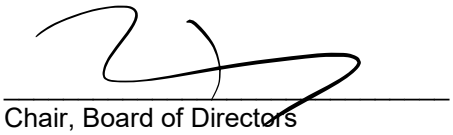
Schedule of Expenditures

Six month period ended September 30, 2021, with comparative information for twelve months ended March 31, 2021

	September 30, 2021	March 31, 2021
Expenditures:		
Salaries, wages and benefits	$ 350,242	$ 549,723
Special studies	349,994	118,891
Premises	–	87,351
Information technology	23,778	21,143
Audit	12,109	14,863
Professional services	62,537	12,793
Legal, HR and procurement	12,982	9,126
Insurance	8,505	5,141
Staff training	–	3,324
Media and materials	1,091	1,507
Office administration	481	999
Conference, meetings and events	294	(122)
Total expenditures	$ 822,013	$ 824,739

See accompanying notes to the schedule.

Approved on behalf of the Board of Directors:



Chair, Board of Directors

COMPUTE ONTARIO / CALCUL ONTARIO

MINISTRY OF COLLEGES AND UNIVERSITIES FUNDING

Notes to Schedule of Expenditures

Six month period ended September 30, 2021

---

1. Project Description:

Compute Ontario / Calcul Ontario (the "Organization") signed an agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, with the Ministry of Colleges and Universities (formerly the Ministry of Research and Innovation) to fund the operating costs of the Organization (the "Project").

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The schedule of expenditures of Compute Ontario / Calcul Ontario for the Ministry of Colleges and Universities funding presents the Organization's portion of eligible expenditures incurred for the Project during the reporting period.

2. Significant accounting policies:

(a) Basis of accounting:

The schedule is prepared in accordance with the basis of accounting prescribed in Schedule F of the Agreement dated April 1, 2015, amended February 1, 2019 and November 9, 2020, between Compute Ontario / Calcul Ontario and the Ministry.

The schedule has not been prepared in accordance with the presentation principles or the presentation of all the financial statements and related note disclosures required by Canadian accounting standards for not-for-profit organizations.

(b) Expenditures:

Expenditures are eligible under the Project if they were incurred in the period of the Project and are directly related to the completion of the Project.

Compute Ontario Board of Directors

Mark Daley
Vice-President Research CIFAR, Professor, Western University Chair

Warren Keith Helland
Vice President, DataFix
Vice Chair; Chair, Governance & Nominations Committee

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Director

Dereck Whitmell
IT Consultant
Director

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