Strategic Plan for CMC Microsystems

Manager of Canada's National Design Network®

Lowering Barriers to Technology Adoption





2021

Table of Contents

CMC Microsystems
www.CMC.ca
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Foreword

Enabling Canadian Innovation

CMC reduces barriers to technology adoption by creating and sharing research platforms in advanced technologies. The Strategic Plan promotes Canadian research, innovation, and economic growth in alignment with the statement of vision, mission, and goals of CMC Microsystems (CMC). Canada's National Design Network (CNDN) Technology Roadmap describes strengths, weaknesses, opportunities, and threats to 2029. The focus is on foundational technologies - microelectronics, photonics, edge processing (artificial intelligence/machine learning), microelectromechanical systems (MEMS), quantum technologies, and nanotechnologies – technologies critical to enabling Canada's growing digital economy.

CMC's strategies focus on a supply chain ecosystem that:

- enables world-class industry/academic collaboration,
- expands support for industrial R&D leading to commercialization of research,
- enhances Canadian leadership in manufacturing in photonics and quantum technologies, and
- secures new products and creates jobs in Canada.

Think Global!

International technology alliances enable the CNDN to access advanced technologies to accelerate innovative research in Canada.

Contact: Gordon Harling, President & CEO, Harling@cmc.ca

Microsystems

A World of Magic & Invisible Technology

> Arthur C. Clarke, the famous science fiction writer said, "Any sufficiently advanced technology is indistinguishable from magic."

Few people realize the extent of the skills and knowledge required to create modern technology. People using their cellphone to talk, text or share video with people on the other side of the world can be unaware that their phone contains:

- sensors for acceleration, temperature, magnetic field and light,
- highly sophisticated solid-state cameras,
- advanced microelectronic computers including artificial intelligence (AI),
- very high frequency transmitters and receivers,
- mechanical packaging with tolerances smaller than a human hair, and
- nanomaterial based glass for increased robustness.

Although we accept the continual improvements in the performance of the devices we use every day, we don't appreciate how much varied expertise was required to develop and manufacture them. The most successful microsystems are invisible and pervasive.

It isn't magic, but it is complex, and requires a vast amount of training in many different technologies.

In Canada, CMC Microsystems provides tools to researchers and educators to make it easier for them to design, simulate, fabricate, and test their microsystems in a range of technologies including:

- microelectronics,
- photonics,
- mechanical sensors,
- artificial intelligence and machine learning,
- nanomaterials, and
- quantum devices.

Every year over 700 graduates use the products and services of Canada's National Design Network (CNDN), managed by CMC, to complete their thesis work and move to jobs in Canadian industry. The services of the CNDN are available to all post-secondary institutions, large and small, urban or rural, across Canada. A truly Canadian approach to providing equal opportunity and equal capabilities anywhere in the country.

CMC Microsystems is a Canadian corporation that was created in a truly Canadian way.

About CMC Microsystems

CMC Microsystems (CMC) is a not-for-profit organization founded in 1984 to facilitate access to state-of-the-art design, manufacturing, and testing facilities for microsystems technologies. With headquarters in Montreal and offices across Canada, the organization manages CNDN, Canada's National Design Network® – a Canada wide collaboration between over 65 universities and colleges to connect 10,000 academic participants with 1,000 companies (Figure 1).

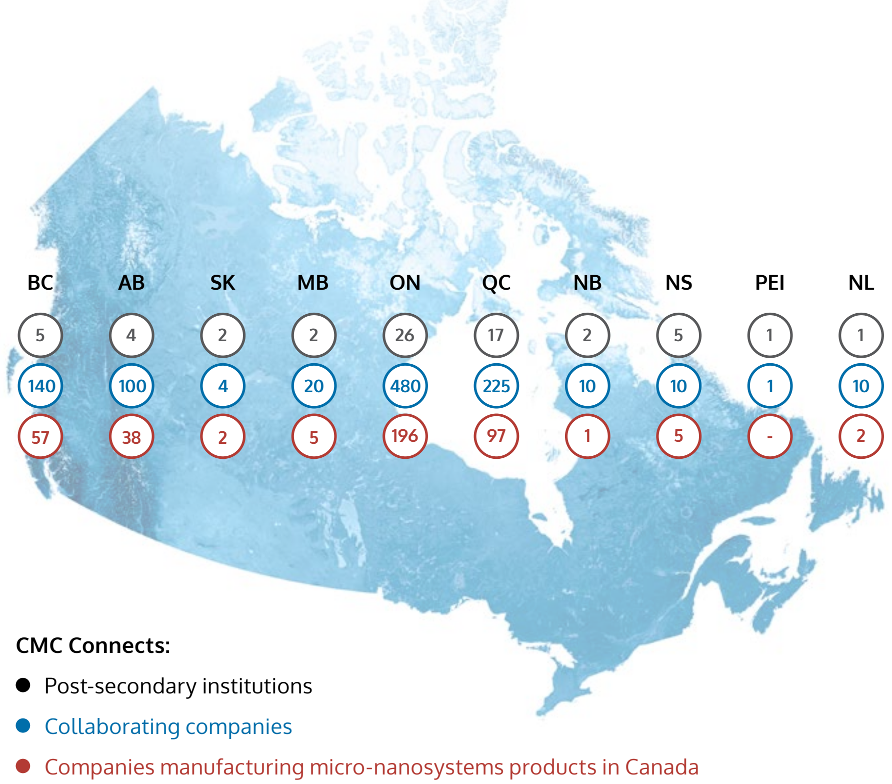
Canada's National Design Network® (CNDN)

A Canada Foundation for Innovation (CFI) Major Research Facility

CNDN's mission is to provide research infrastructure for Canada's digital economy, in support of CFI's vision that Canada's researchers lead the world in contributing to competitiveness, prosperity, and quality of life.

CMC, through the CNDN, provides access to research and manufacturing infrastructure equally to post-secondary institutions across the country and leverages the strengths of every institution working with these advanced technologies. Every student in Canada that works in some aspect of microsystems technology will encounter CMC and what it offers. As students move to industry or academia the ideas that they generate and implement through the CNDN drive the microsystems ecosystem so that Canada can participate in the almost magical developments of the modern world.

FIGURE 1: **Canada's National Design Network**



Building on Success

CMC's Strategic Direction

CMC is lowering barriers for developing microelectronics, photonics, and quantum prototypes used for research and in high technology products and services. These prototypes are normally very challenging to design, manufacture, and test — CMC plays an enabling role in providing the tools, technologies, and expertise. This advances Canada's digital economy, in which chip technologies are critical: Industry 4.0, autonomous vehicles, big data, Internet of Things (IoT), cyber defence/security, 5G, quantum computing, artificial intelligence (AI) and more (Table 1).

TABLE 1: CNDN - Critical for all Aspects of a Modern Digital Economy

CMC's Areas of Technology Application	CNDN Researcher's Interests
ICT Industries	22%
Biomed + Pharma	21%
Natural Resources + Energy	13%
Aerospace	11%
Defence + Security	10%
Automotive/Transportation	10%
Environment	10%
Agri-/Agri-food	3%
	100%

Canada's Economic Strategy Tables

- Advanced Manufacturing
- Agri-Food
- Clean Technology
- Digital Industries (ICT, digital media)
- Health & Bio-sciences
- Resources of the Future

Vision

Research in microsystems and nanotechnology expands knowledge frontiers, enables applications, and contributes to economic prosperity in Canada through advanced technology manufacturing.

Mission

Enable and support the creation and application of micro- and nanosystems knowledge and manufacturing capability by providing a national infrastructure for excellence in research through Canada's National Design Network and establishing and verifying a path to commercialization of related processes, devices, components, and systems.

Guiding Values

Research Excellence | "Honest Broker" | Benefit to Canada

CMC is Committed to the Principles of Equity, Diversity, and Inclusivity

We recognize that a breadth of perspectives, skills, and experiences contribute to excellence in research and innovation. This culture is the responsibility of every participant in the ecosystem, including employees, funders, investors, sponsors, institutions, companies, researchers, advisors, administrators, and reviewers.

Equity: All potential users of CMC services will have the opportunity to access and benefit from our programs through our fair and impartial practices.

Diversity: CMC values attributes that allow researchers and entrepreneurs from any background and any region to succeed, attributes such as race, gender, language, culture, religion, age, and career stage; institutional and company attributes such as size, type, and location; and research spanning the entire spectrum of basic to applied and across all disciplines and industrial sectors.

Inclusivity: CMC respects and values all individuals for their contributions and our culture encourages collaboration, partnership, and engagement among diverse groups of people, institutions, and areas of research to maximize the potential of Canada's research and innovation ecosystem.

Strategic Goals

The strategic goals for the CNDN, reviewed annually as part of CMC's planning processes, are as follows:

Research & Commercialization

Enable transformative micro-scale and nano-scale research leading to materials, processes, devices, components, and integrated microsystems including software.

- By 2025: 50 research projects (academic, industrial) building quantum devices.
- By 2025: CMC a world leader in multi-project (MPW) services for quantum deivice fabrication.
- By 2029: 200 photonics prototypes manufactured annually (2020-21 actual: 70).
- By 2029: 10% of microelectronics prototypes incorporate AI or CMC open-source IP.
- By 2029, CNDN grows to 1,000 academic Subscribers. Growth is in disciplines associated with nano, AI, quantum, and photonics.

Innovation & Entrepreneurship

Accelerate the commercialization of new microsystems knowledge through joint efforts with Canadian partners.

- Beginning in 2027, CMC technology development spins off one start-up per year.
- By 2025, 50% of CNDN platform technologies used by academics are commercial-ready for entrepreneurial purposes.
- By 2029, the Virtual Incubator Environment (VIE) will be host to 100 start-ups in Canada.
- Partner with investment community as advisors to de-risk technology investments and accelerate timelines and revenues: 2023.
- Proposal in development: 300+ industry (ISED-SIF funding proposal) FABrIC user groups investing over $1B in R&D expenditure: 2027.
- Annually three entrepreneurship training and networking events for accelerating development of prototypes that attract seed investment.

Advanced Technology Supply Chain

Deliver efficient access to technologies and services that enable leading research and innovation.

- By 2026: 25 new Made-in-Canada manufacturing processes in niche technology areas that are Canada's strengths: photonics, specialty semiconductors & quantum, and MEMS.
- By 2023: CMC is Canada's go-to organization for support of IoT and Edge AI research and training via custom hardware, dedicated hardware platforms.
- By 2023: CMC is Canada's leading research infrastructure organization for microelectronics, MEMS, photonics, and nanotechnologies.

Highly Qualified Personnel (HQP) Development

Enable training of highly qualified personnel involved in microsystems research and encourage innovation at post-secondary institutions, industry, government, and others.

- By 2029: 1,000 trained students moving to industry in Canada annually.
- 10% annual growth in graduate students receiving hands-on training in advanced technologies.
- By 2026: educational initiatives for 1,000 K-12 students and 6,000 undergrads annually.
- By 2024: introduce workforce of the future skills enrichment program for industry.

Stakeholder Investments in the Mission

Ensure maximum benefits are derived from the significant investments in CNDN capabilities and in microsystems laboratories in post-secondary institutions.

- **Secure CFI-MSI funding** for university-facing operations: 2022
- **Pursue federal and provincial funding** for industry-facing operations: 2023
- CMC is **50/50 CNDN/externals** (foreign academics, entrepreneurs) by number of clients: 2029
- Annual revenues:
  - **$9M** CFI-MSI
  - **$20M** Government Funding
  - **$20M** sales: 2029

What We Do

CMC offers researchers technical support for:

- **CAD**: Access to state-of-the art commercial software tools for design and simulation
- **FAB**: Cost-sharing for commercial fabrication processes for microsystems
- **LAB**: Technology platforms to mitigate risk and accelerate research and innovation

CMC's technical staff support microelectronics, Micro Electro-Mechanical (MEMS), photonics, optics, quantum and system integration. These are the underlying technologies enabling biomedical devices, autonomous cars, wearable technology, remote health diagnostics, 5G networks, AI-driven data processing, and quantum computing.

Researchers can use industrial-grade software provided by CMC to design their microsystems and use CMC-brokered access to commercial fabrication facilities to build prototypes. Electronic and photonic sensors are used in handheld and mobile devices for point-of-care medical testing, environmental monitoring, and structural monitoring.

CAD

State-of-the-art software for successful design

- Computer-aided design tools and design environments
- A secure, distributed private cloud for hosting
- User guides, process design kits (PDKs), application notes, training materials, courses

www.CMC.ca/CAD

FAB

Simple access and reduced cost for working prototypes

- Multi-Project Wafer (MPW) services through a global supply chain
  - Microelectronics down to 12nm
  - Silicon photonics
  - MicroElectroMechanical Systems (MEMS)
  - Nanofabrication
- Expert assistance for first time right designs
- Packaging and assembly services

www.CMC.ca/FAB

LAB

Tools for test and demonstration

- Platform technologies to speed up your research
- Test equipment loans for short term needs
- Technical contract services including quantum coding
- Constructing research networks
- International partnerships for unique needs

www.CMC.ca/LAB

CMC's Effectiveness Criteria for Resource Allocation

CMC's guiding principles are summarized in the Effectiveness Criteria used in selection of projects and resource allocation.

- Realized or potential economic and social benefits to Canada.
- Demonstrated industrial relevance of research.
- Contribution made to maintaining or promoting the standard and status of microsystems research and technology development that has the potential to be exceptional by international standards.
- Contribution to the education of highly trained people for industry, research, and education in the field of microsystems.
- Demonstrated need for requested resources (such as fabrication, test access, development hardware, intellectual property (IP), etc.) for microsystems research, technology development, and education.
- Broad and sustained research and technology development collaboration among researchers, research institutions, disciplines, and sectors.

Impact

Access to leading-edge technologies enables researchers to push the frontiers of science and engineering.

CMC enhances research capability to Canadian universities and start-ups and supports development of highly qualified people essential to Canada's competitiveness. These internationally competitive technologies enable thousands of researchers to improve the quality of life of Canadians.

Impact 2020/21

Research Outcomes

1,995	Journal Publications
2,035	Other Publications
75	National Awards
75	International Awards
325	Graduate Student Courses
485	Undergraduate Student Courses

Commercialization Outcomes

14	Start-up Companies
245	Patents (applied for/issued)
50	Licenses
355	Interactions with industry in Canada, valued at **$34.3M**
75	Interactions with foreign industry, valued at **$5.4M**

Outcomes published annually. Unless otherwise indicated, all dollar amounts referred to in this Strategic Plan are expressed in Canadian dollars.

CMC uses a performance measurement framework with a Logic Model to align activities with strategic direction and to demonstrate accountability to stakeholders.

Logic Model: www.CMC.ca/Corporate-Reports.

The Return on Investment

Benefits to Canada

Based on strategic and operating plans, this strong national network of researchers will deliver globally competitive, industrially relevant research and innovation. Outcome forecasts, the results coming from the efforts of the researchers, are shown in Table 2.

CMC collaborates with many peer organizations provincially, nationally, and internationally.

TABLE 2: Projected Impact of CNDN Users

Outcomes	2021/22	2024/25	2028/29
Awards	180	200	225
Publications	4,300	4,680	5,275
Patents - Applied for & Issued	275	295	335
University Collaborations with Industry in Canada	495 [$38.5M]	540 [$42.1M]	605 [$47.4M]
HQP Movement to Industry in Canada	680	735	835

Users	2021/22	2024/25	2028/29
Professors (Subscribers)	700	800	1,000
HQP	9,885	10,765	12,095

Global Partners

Enabling Internationally Competitive Research and Innovation

CNDN researchers benefit from simplified and cost-shared access to products and services sourced from CMC's unique world-wide industrial supply chain of more than 100 organizations. We are proud to play an important role in Canada's research and innovation microsystems and nanotechnology ecosystem and are well placed to take our country's best to the next level.

North America

Canada
12 CAD | 10 FAB | 7 LAB
14 Systems & Components
42 University MNT Labs

USA
16 CAD | 7 FAB | 4 LAB
4 Systems & Components

Europe

Austria
1 FAB

Belgium
1 CAD | 2 FAB

France
3 FAB

Germany
2 CAD | 1 FAB

Ireland
1 FAB

Netherlands
2 FAB

Sweden
1 CAD

Switzerland
1 FAB

UK
1 CAD
1 Systems & Components

Asia

Israel
1 FAB

Japan
1 Collaborative Organization

Singapore
2 FAB

South Korea
1 Collaborative Organization

Taiwan
2 FAB | 7 LAB
2 Systems & Components
1 Collaborative Organization

Australia

1 Collaborative Organization

FIGURE 2:
Global Supply Chain to Enable Internationally Competitive Research and Innovation

CMC's International Partners – Peer Organizations Around the World

Internationally, CMC has well-established relationships with organizations in the US, Europe, Australia, and Asia that have similar mandates to accelerate innovation.

ANFF	CMC Microsystems	cmp	EUROPRACTICE IC SERVICE	VDEC	IDEC	TSRI
Australia	Canada	Europe	Europe	Japan	South Korea	Taiwan

CMC

Opportunities & Threats Demand Strategic National Action

Strengths

- Unique delivery model for research infrastructure across Canada
- Respected organization, well-connected nationally and internationally
- Continual 5% growth of subscriber base. 10,000 researchers as of 2020
- Expert domain knowledge internally, technical teams cover a wide range of technologies
- Well-managed global supply chain
- 67% of staff are from equity seeking groups

Weaknesses

- Piecemeal funding from multiple sources, most are shorter than the timescale to obtain an advanced degree
- Connection with 1,000 companies in CNDN is indirect, through the academic users

Opportunities

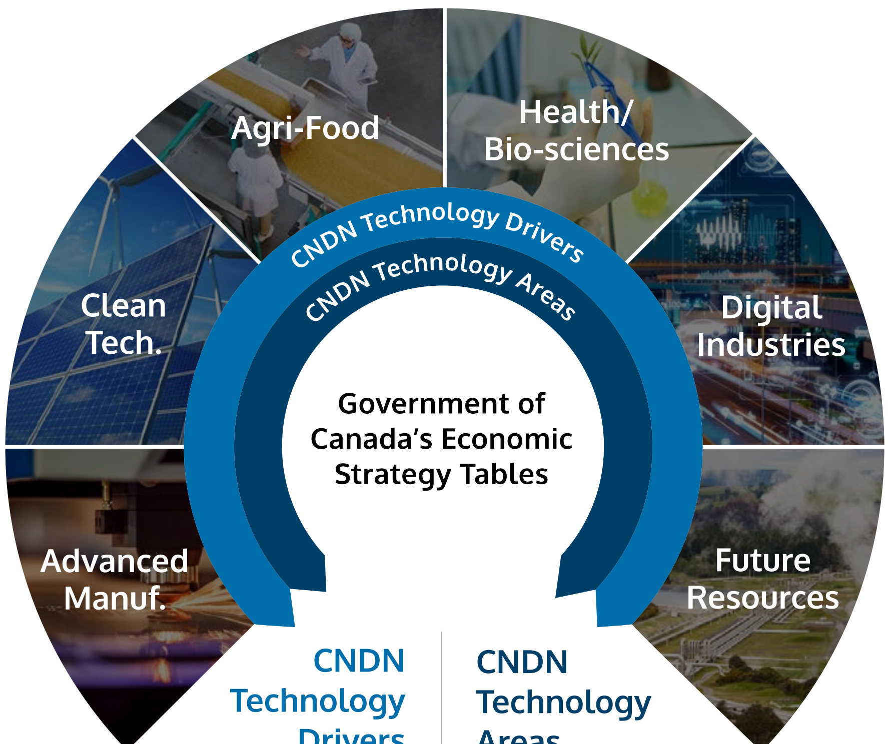
- Microsystems are increasingly relevant for a vibrant digital economy in all Canadian sectors (IoT, 5G, MedTech…)
- Microelectronics and photonics are foundational to quantum computing and AI
- Lower costs, improved services by including foreign users without subsidization
- Increase impact by supporting start-up companies in Canada

Threats

- Lack of sources of capital for equipment, CFI IF funding is in competition with our clients
- Increasingly restrictive licensing practices and export controls
- Cybersecurity costs and risks are increasing

Technology Development for Strategic Sectors

The facility enables users to support innovation in sectors identified by the federal government's Economic Strategy Tables (Figure 3) through research and development spanning multiple technology drivers, including the Internet of Things (IoT), 5G, and Artificial Intelligence (AI). CNDN foundational technology areas are critical to enabling Canada's growing digital economy.



CNDN Technology Drivers	CNDN Technology Areas
Pervasive Computing & AI	Microelectronics
Ultra-High Speed Communication	Photonics
Energy Management	IoT & Edge AI
Biophotonics, Bioelectronics	MEMS, Nanofabrication, Integration
Industry 4.0	Quantum Computing

FIGURE 3: **Fuelling Innovation and Competitiveness Across Strategic Sectors**

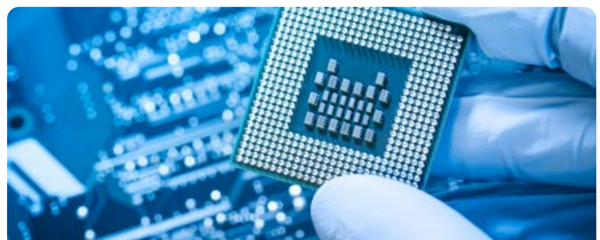
Foundational Technologies

The CNDN technology drivers are underpinned
by the following technology areas:

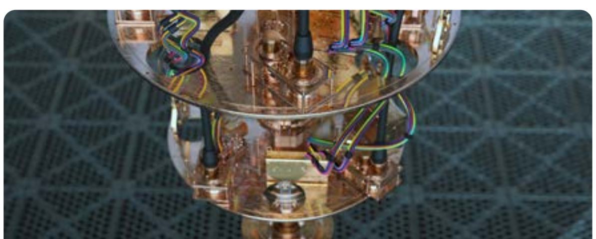
Microelectronics

Photonics

IoT & Edge AI



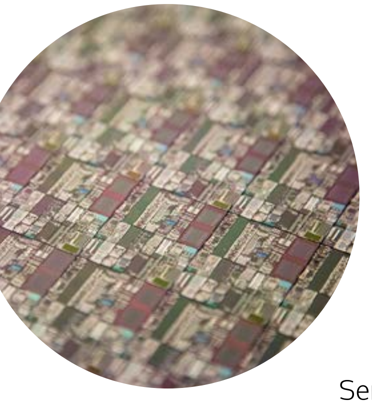
Micro Electro-Mechanical System (MEMS), Nanofabrication and Integration



Quantum Computing

Spotlight on Foundational Technologies

The following pages define market opportunities and SWOT (Strengths, Weaknesses, Opportunities, Threats) in each area. The CMC Advisory Committee, a committee of CMC's Board of Directors with representation from industry, academia, and government, is a key contributor to the formation of this strategy and plans for the years ahead.



Spotlight on Microelectronics

The semiconductor industry is moving toward a "silicon to services" model that spans from data center to mobile edge applications, with artificial intelligence (AI) integrated in every aspect from product development to service delivery. This Platform as a Service (PaaS) model includes open-sourced Intellectual Property (IP) and facilitates use of heterogeneous technologies via chiplets and other techniques.

According to the 2021 Global Semiconductor Industry Outlook[1] from KPMG and the Global Semiconductor Alliance, the semiconductor industry remained resilient, **finishing 2020 with revenue growth of 6.5% despite the pandemic**. Every application market is expected to grow, led by the IoT, AI and computing, wireless, automotive, and consumer electronics markets.

Leading edge microelectronics technology is critical to researchers. CMC will enable affordable access through our established Multi-Project Wafer (MPW) model and our deep partnerships with world class suppliers and foundries.

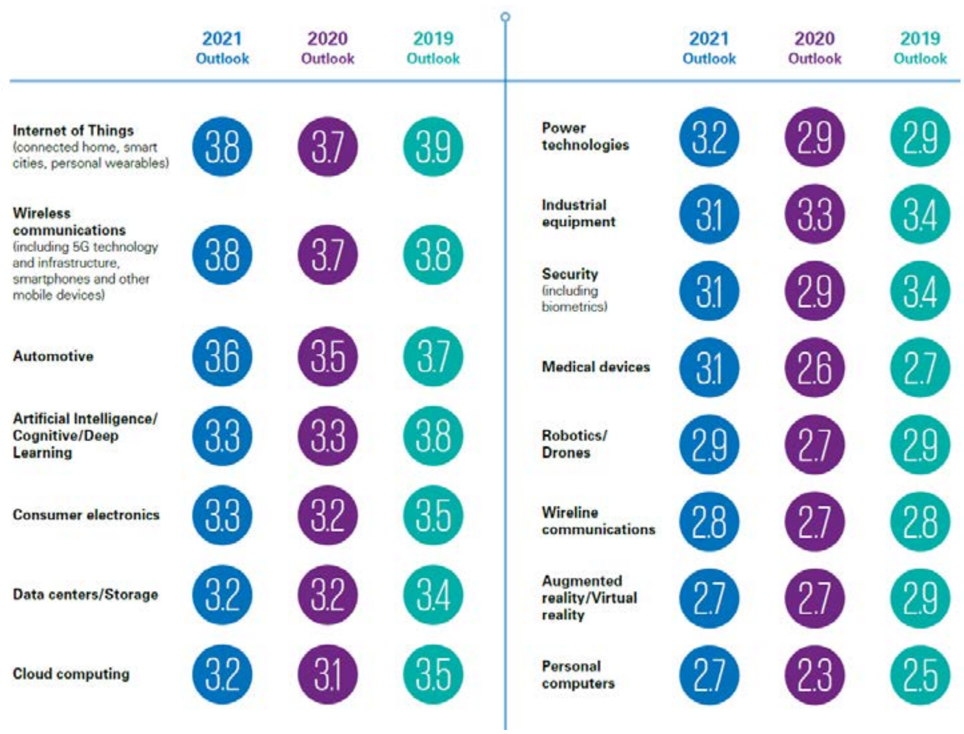


FIGURE 4: Applications driving semiconductor revenue over the next year

(Averages on a 1 to 5 scale with 1=Not at all important and 5=Very important.)

2021 (n=156); 2020 (n=195); 2019 (n=149)

Source: KPMG Global Semiconductor Industry Survey findings, 2021

[1] home.kpmg/us/en/home/insights/2019/03/semiconductors-the-backbone-of-the-connected-world.html

Strengths

CMC has access to a variety of technology nodes across various foundries including Taiwan Semiconductor Manufacturing Company (TSMC), GlobalFoundries (GF), and STMicroelectronics through global partnerships. This portfolio supports researchers across a variety of growth areas, including Analog, RF, Mixed signal, RF, Digital and Optoelectronics as indicated in Figure 5. IP partnerships such as the one with OpenHW.org for open-RISC-V hardware allow CMC to provide implementation support to researchers.

Weaknesses

Access to state-of-the art foundries and CAD tools continues to grow in difficulty and cost. FinFET and future Nanosheet and GAA (Gate All Around) technologies require extraordinarily complex photolithography and a new generation of tools to accurately model, layout and simulate designs in 12nm and below. More than ever, the tools aggregation and the manufacturing cost reductions available through MPW services such as those from CMC are critical for academics, start-ups, and small and medium-sized companies to access leading-edge technologies.

	2021 Outlook	2020 Outlook
Sensors/MEMS	3.8	3.7
Analog/RF/Mixed Signal	3.7	3.5
Microprocessors (GPU/MCU/MPU)	3.6	3.2
Optoelectronics	3.3	3.1
Memory (Flash, DRAM)	3.3	3.0
Other Logic	3.0	2.8
Discretes	2.9	2.6

FIGURE 5: Products representing growth opportunity for the semiconductor industry over the next year

(Averages on a 1 to 5 scale with 1=Not at all important and 5=Very important.)

2021 (n=156); 2020 (n=195)

Source: KPMG Global Semiconductor Industry Survey findings, 2021

Opportunities

The May 2021 report by Yole Développement (Figure 6) showed the rapid growth in GaN as a key enabling technology for Wireless Communication, Efficient Energy, Automotive and Consumer Markets. The Automotive and Consumer markets also bring an increased need for image processing. CMC will engage with new foundry partners such as UMS (GaN), XFAB (High-Voltage control circuitry) and Tower Semi (CMOS Image Sensors) to support researchers in these areas.

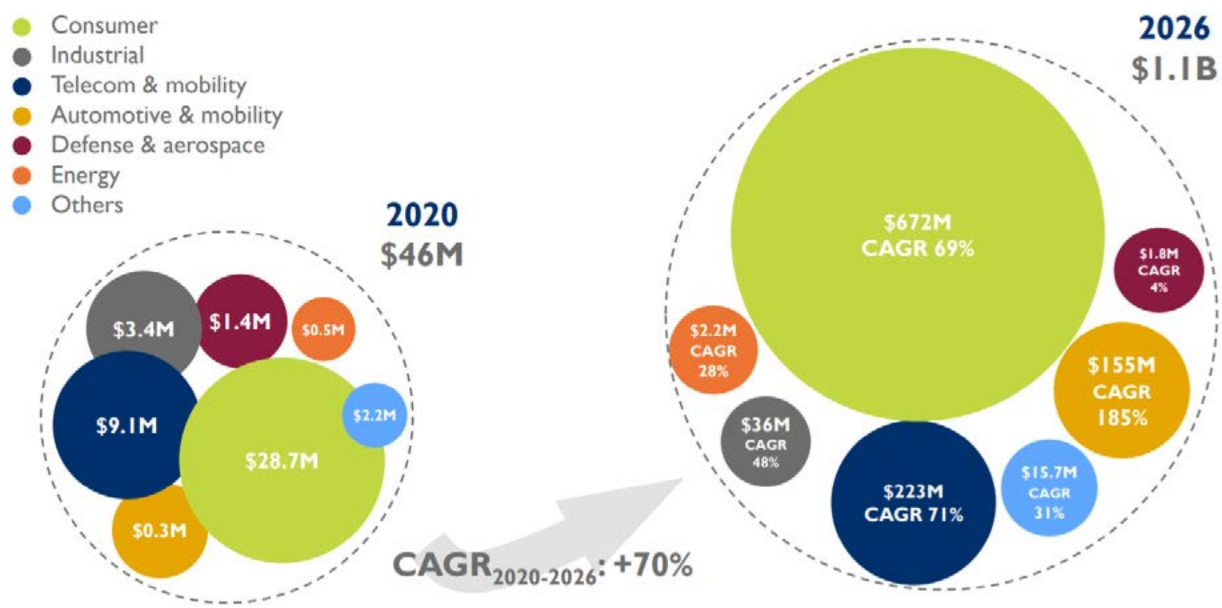


FIGURE 6: 2020-2026 power GaN market forecast split by application

Source: GaN Power 2021: Epitaxy, Devices, Applications and Technology Trends , Yole Développement | www.yole.fr | ©2021

Threats

Difficulty in accessing CAD Tools and design kits for more advanced technology affects CMC ability to make these technologies generally available. In addition, the overall industry talent shortage and supply chain churn, as identified in the KPMG study referenced in Figure 7, are making it more difficult to find and retain the right human resources to support and sustain growth. Supply chain disruption further directly impacts CMC's ability to procure services such as device fabrication, packaging, or testing for both researchers and for future manufacturing volumes as that research is commercialized.

FIGURE 7: Top issues facing the semiconductor industry over the next three years

Multiple responses allowed; percentages do not sum to 100%. Partial list of responses shown.

Source: KPMG Global Semiconductor Industry Survey findings, 2021

Looking Ahead

CMC will work with academic, industry and foundry partners and collaborate as opportunities permit, to lower the barriers to entry and to execute on the following plan:

- Create PaaS for RISC-V, digital designs using AI for architectural exploration, device development and test, and novel drive and readout electronics for innovative sensor designs.
- Partner with GF and Cadence, Synopsys, Siemens, and others on CAD tools and PDKs to increase the number of students trained to use technologies, and increase awareness about CMC's capabilities in CAD and FAB both in Canada and internationally.
- Work with peer organizations and suppliers worldwide to mitigate supply chain threats.

Targeted growth of 10% per year in activity and outcomes.

Spotlight on Photonics

Photonics technology is widely used in modern systems, where it delivers many essential functions ranging from data transmission to sensing. The datacenter & telecom photonic components market alone had a value of $21B in 2018 and is forecasted to grow to $44B by 2025.[2]

Photonics is a systems-enabling technology. The trend toward higher levels of integration naturally favours the adoption of silicon photonics. Yole Développement predicts that the value of the silicon photonics market will grow from US$480 million in 2019 to US$3.9 billion in 2025. This represents a 42% CAGR. For this level of growth to be realized, access barriers and costs need to be reduced so that silicon photonics can become universal and fully integrated with other high-performance technologies. Market penetration will go beyond current deployments in datacenter and telecom markets to include health, automotive and instrumentation.

CMC will enable more photonics integration with a strong emphasis on putting more photonic functionality onto each chip, integrating photonics with other technologies including microelectronics, and using both hybrid and monolithic approaches. Greater design automation and verification capability will enable larger and more complex designs.

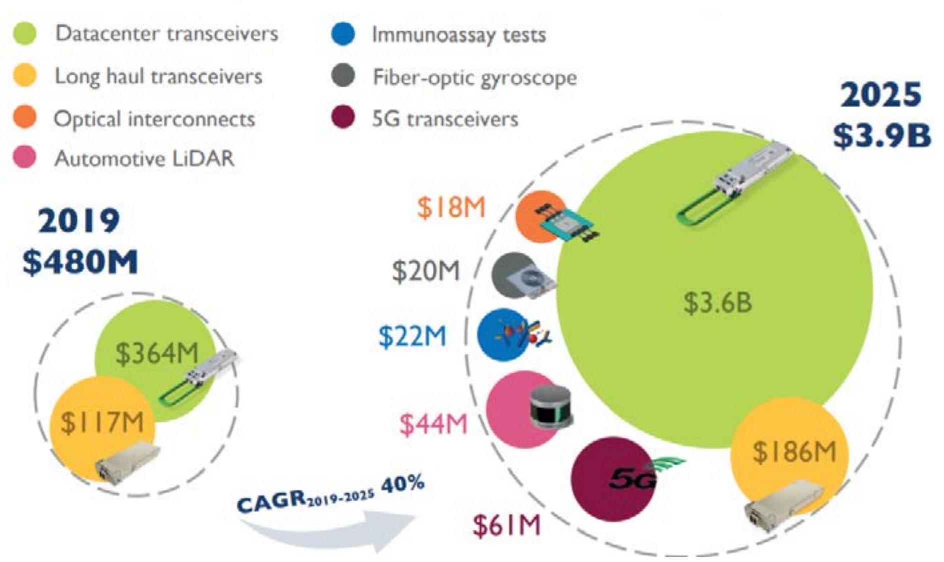


FIGURE 8: Silicon photonic 2019-2025 market forecast by application

Source: Silicon Photonics 2020 report, Yole Développement | www.yole.fr | ©2020

[2] Lightwave Logic Inc. as quoted in IPSR-I 2019

Strengths

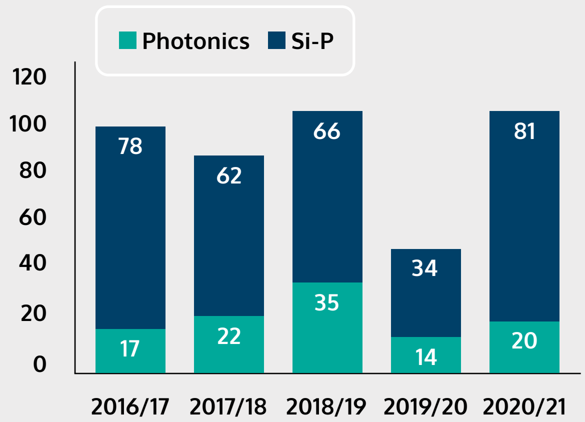
Canada has well-established photonics expertise, dating back to the Nortel days, and currently residing in organizations like NRC and INO, numerous university research groups, and companies including Ciena, NeoPhotonics, TeraXion, Ranovus, and Aeponyx. CMC and Canada's National Design Network currently deliver a program that includes fabrication access to silicon photonics platforms for chip-level monolithic integration, methodologies for scalable integrated photonics design, and graduate-level training in the design, fabrication and testing of photonic integrated circuits.

950 photonics & optics designs fabricated (since 2007/08)

CMC's strategic investments give Canada a competitive advantage

- **120** (of 950) were III-V photonics technology
- Over **690** (of 950) were CMC-brokered silicon photonics (Si-P)

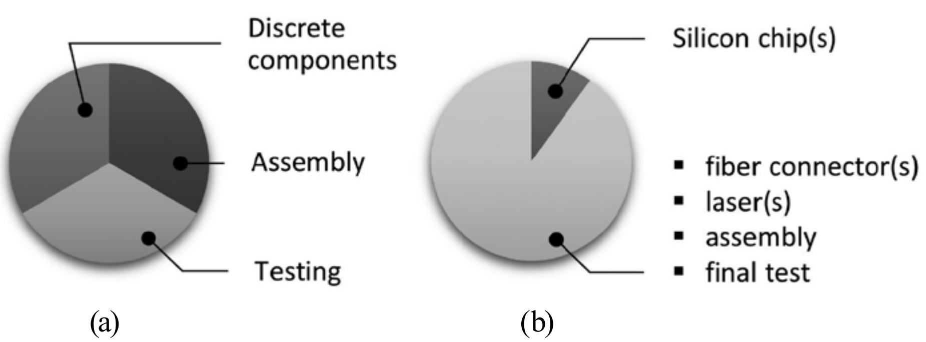
5-year Highlights: Photonics Designs



Weaknesses

Currently, there are a small number of research and industrial foundries, which can provide medium-to-high volume access to silicon photonics technology. MPW access has low barriers, but long cycle times. The silicon photonics PDKs offered by foundries are not manufacturing hardened increasing the risk that results will not be repeatable or consistent. There is a lack of solutions for cheap, automated packaging, particularly for fine-pitch packaging (Figure 9 below).

Design verification remains a challenge. In contrast to microelectronics, it is still a highly manual and labour-intensive process, and not easily scalable to larger and more numerous designs.



Schematic representation of the cost structure of (a) legacy optical devices and (b) silicon photonic devices. The total cost of silicon photonic devices is substantially lower than of legacy devices and is dominated by anything but the Si chips. To fulfill the potential of Si photonics, disruptive improvements in cost and scalability of its packaging are required.

FIGURE 9: A Novel Approach to Photonic Packaging Leveraging Existing High-Throughput Microelectronic Facilities

Source: Barwicz et al, IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 22, NO. 6, NOVEMBER/DECEMBER 2016 | researcher.watson.ibm.com/researcher/files/us-tymon/TBarwicz_Photonic_Packaging_JSTQE2016.pdf

Opportunities

CMC is well positioned to lower barriers to access, e.g. by developing PDKs and helping to develop re-usable intellectual property through collaborations with foundries and other players in the ecosystem. Anticipated developments in artificial intelligence (AI) are expected to lead to improvements in design automation and design verification capabilities.

Threats

Interruption in silicon photonic technology access, inability to access devices integrated with silicon photonics, difficulty exchanging IP such as CAD tools and design kits, and international competition for key photonics HQP could significantly impact Canada's photonics ecosystem.

Looking Ahead

CMC will work with academic, industry, and other partners, and collaborate as opportunities permit, to lower the barriers to entry and to execute on the following plan:

- Develop a proposal for "made in Canada" solutions for silicon photonic chip fabrication, module assembly and packaging.
- Work with partners in Canada and Europe to develop hybrid integration techniques.
- Attract international customers to help make MPW runs more affordable and frequent for our Canadian customers.

Targeted growth of 10% per year in activity and outcomes.

Spotlight on IoT & Edge AI

The rise of the Internet of Things (IoT), artificial intelligence (AI) and machine learning (ML), and 5G have driven demand for power-efficient, secure computing at the network edge. Applications such as wearables, biomedical monitoring, autonomous driving, and precision agriculture are producing an unprecedented amount of data from sensors. This growth in data together with the exponential increase in AI/ML complexity are spurring a need for new computing architectures and system integration technologies.

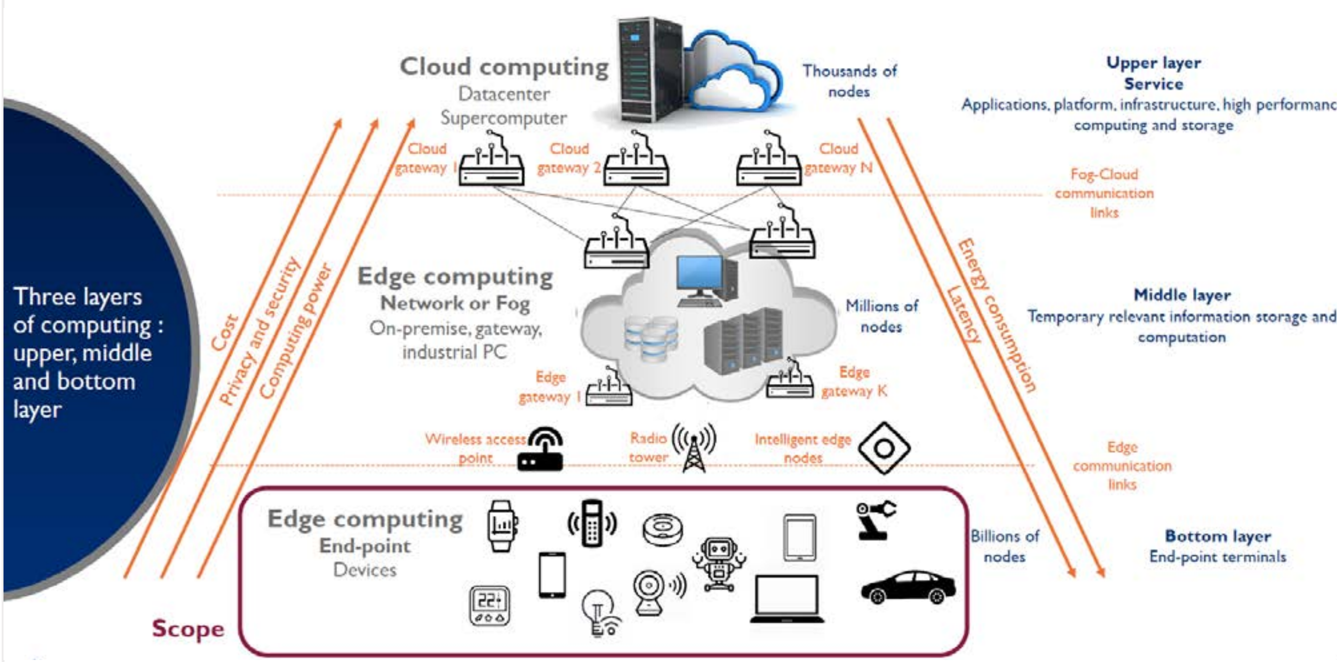


FIGURE 10: **Focus on Edge Computing**

Source: Computing and AI technologies for mobile and consumer applications,
Yole Développement | www.yole.fr | ©2021

CMC will enable critical research in AI and ML, edge computing, and IoT for researchers and industry by providing access to world-class tools, platforms, technologies, expertise, and industrial capabilities.

Strengths

Canada has a strong international reputation due to institutions such as Toronto's Vector Institute and Next AI, Edmonton's Alberta Machine Learning Institute (AMII), the Institute for Data Valorization (IVADO) in Montreal and the Montreal Institute for Learning Algorithms (MILA). The Pan-Canadian AI Strategy was renewed in 2021 with a $443.8 million commitment over 10 years starting in 2021-22. There is strong interest and R&D investment in Canada by large, multi-nationals: AMD, Intel, Google, NVIDIA, Qualcomm, and others. CMC's access to industry grade tools, open source RISC-V and IoT Mote, specialized AI compute resources including accelerators, FPGA and GPU clusters, and other diverse platforms allow it to enable a wide range of AI research.

Weaknesses

IP blocks that are not open-source and technology-specific analog/mixed-signal blocks can be critical to system implementation but are expensive or have restricted use/security requirements that can limit research and commercialization opportunities. Open source hardware IP may be difficult to widely deploy due to concerns about quality or the lack of a vibrant user community for support and evolution.

Opportunities

CMC's broad technology expertise and access supports AI research in domains beyond digital including analog, photonic, and quantum. CMC is a founding member of the OpenHW Group which curates and supports verified, silicon-proven RISC-V cores for commercial and academic use. New interposer manufacturing platforms can shrink system size and power for IoT devices enabling ultra-low power edge AIoT.

Threats

International competition for scarce AI/ML HQP may leave Canada without the relevant skills and experience in prototyping machine learning and embedded systems to ensure Canada remains competitive in this critical area.

Looking Ahead

CMC will work with academic, industry, and other partners, and collaborate as opportunities permit, to lower the barriers to entry and to execute on the following plan:

- Build partnerships with Canadian AI research facilities (AMII, MILA, Vector Institute) to enhance cloud-based AI training and inference infrastructure, and ensure Canada maintains AI leadership.
- **Partner with OpenHW Group to make open source silicon-verified RISC-V platforms available to academics and industry.**
- Build a full set of IP including analog/mixed-signal blocks and high-quality domain-specific AI datasets to provide a more complete system prototyping environment for academics.

Targeted growth of 10% per year in activity and outcomes.

Spotlight on MicroElectro-Mechanical Systems (MEMS), Nanofabrication, Integration

The importance of MEMS technology is growing as AI and data collection grows at the Edge. Market priorities no longer aim at brute miniaturization but qualities like integration, intelligence, and power efficiency. Growth continues in traditional MEMS applications in civil aerospace, automotive, and consumer markets, and demand is surging for environmental monitoring, health screening and diagnostics. Altogether, global MEMS revenue is forecast to grow from $11.5B in 2019 to $17.7B in 2025 at 7.4% CAGR.[3]

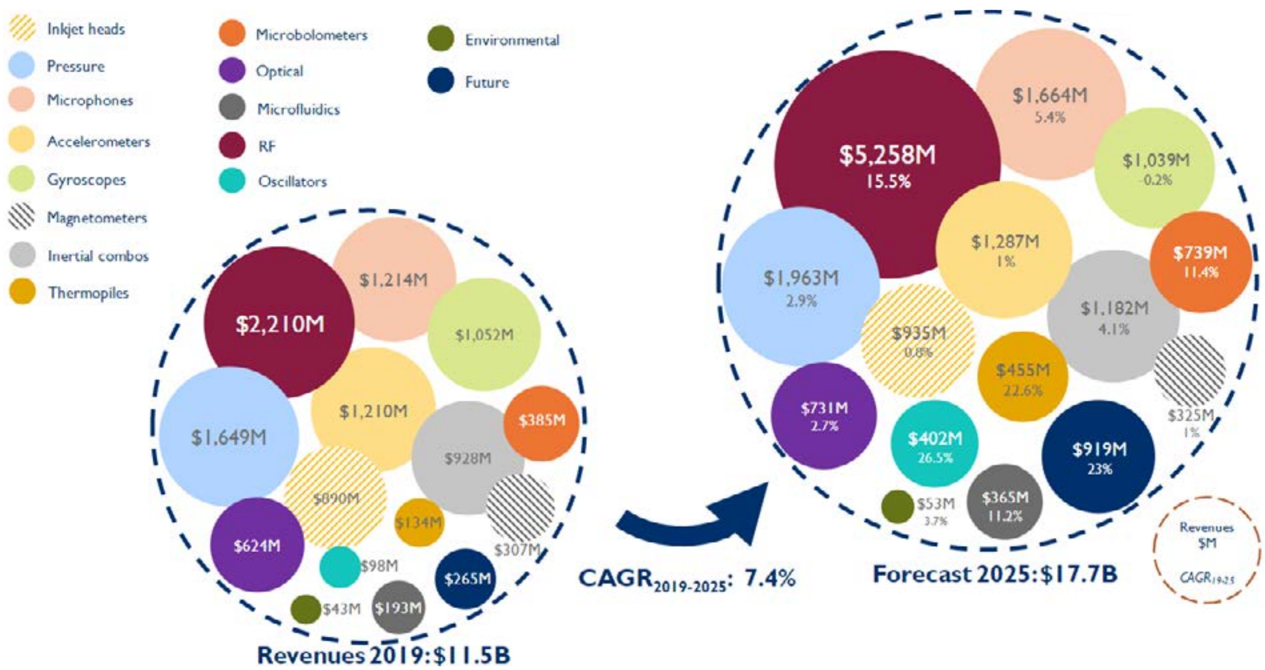


FIGURE 10: MEMS Market Dynamics by Device

Source : Status of the MEMS Industry 2020, Yole Développement | www.yole.fr | ©2020

The highly diversified MEMS market requires a wide range of process technologies. CMC will enable researchers by maintaining access to relevant technology by agilely accessing and supporting new sources of commercial and R&D fabrication, and heterogeneous integration and packaging.

[3] Status of the MEMS Industry 2020, Yole Développement

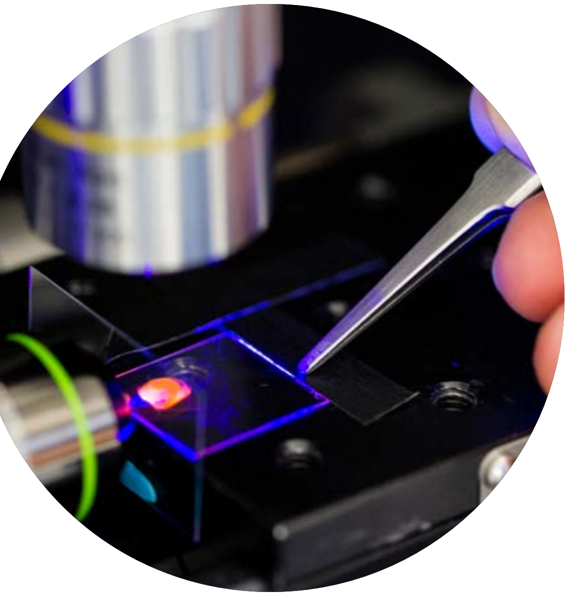
Strengths

Canada's MEMS community is strong including two MEMS foundries (Teledyne DALSA in Bromont and Teledyne Micralyne in Edmonton), centres for pilot fabrication, packaging, and system development (INO, C2MI, ACAMP), and several NRC research centres (NANO, AFT, XRCC, etc.). Additionally, some 40 nanofabrication facilities at universities are used for research and proof-of-concept demonstrations of new equipment and processes. Design activity is strong with 387 CMC fabricated MEMS designs over the last 5 years.

CNDN MEMS Design 2018/19 - 2020/21	
MEMSCAP (MPW)	121
Teledyne DALSA (MPW)	10 (80% commercial)
MNT (university labs)	88

Weaknesses

Current MEMS technologies offer limited platform potential resulting in reduced design flexibility and R&D longevity compared to microelectronics. Less frequent manufacturing runs of any given technology translates to greater unpredictability in the cycle time and quality of prototypes.

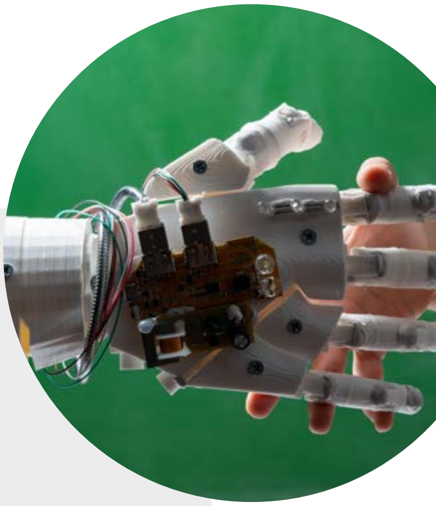


Opportunities

CMC is uniquely positioned to reduce barriers to design by distributing automated design flows and leveraging strong ties to peer organizations around the world to expand access to in-demand technologies. Multi-user interposer-type technologies can help researchers demonstrate combined sensor and actuator systems. New Basecamp workshops will help address a gap in experiential training in design, fabrication, and testing.

Threats

Growing the quality and number of Canadian HQP in this field is challenged by two gaps in the training and prototyping landscape. Graduate-level curricula do not cover the topic of microfabrication process integration in any systematic way and in the absence of a suitable MPW process, technology developers frequently prototype in university-based laboratories. Notwithstanding the benefits of such versatile facilities, technology developed there typically lacks rigorous process documentation and any path to scale-up and production. For emerging technology, an accessible small-to-medium-volume partner is essential.

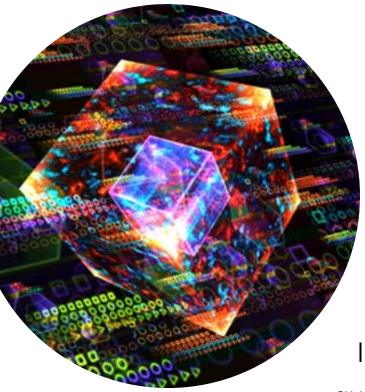


Looking Ahead

CMC will work with academic, industry, and other partners, and collaborate as opportunities permit, to lower the barriers to entry and to execute on the following plan:

- Pursue additional sources of MEMS MPW and heterogeneous integration for piezo MEMS and other researcher needs.
- Create design flows, validated templates, and reusable intellectual property as characterized designs for users to mitigate risk.
- Develop multi-user silicon interposer platforms and a versatile 3D-printed packaging service that can be used to co-package microcircuits with otherwise incompatible technologies.

Targeted growth of 10% per year in activity and outcomes.



Spotlight on Quantum Computing

Investment in quantum computing has grown significantly since the demonstration of quantum supremacy by Google Quantum AI team.[4] Revenue is now expected to reach between $5 billion and $10 billion in the next three to five years and up to $850 billion in the next 30 years.[5] Quantum technologies will impact all sectors of the economy including Communications, Computing, Energy, Finance and Pharmaceuticals.

Canada invested more than $1 billion in quantum research in the last decade,[6] 1st among G7 nations in per-capita investment.[7] The National Quantum Strategy launched in 2021 will invest a further $360M over the next seven years.

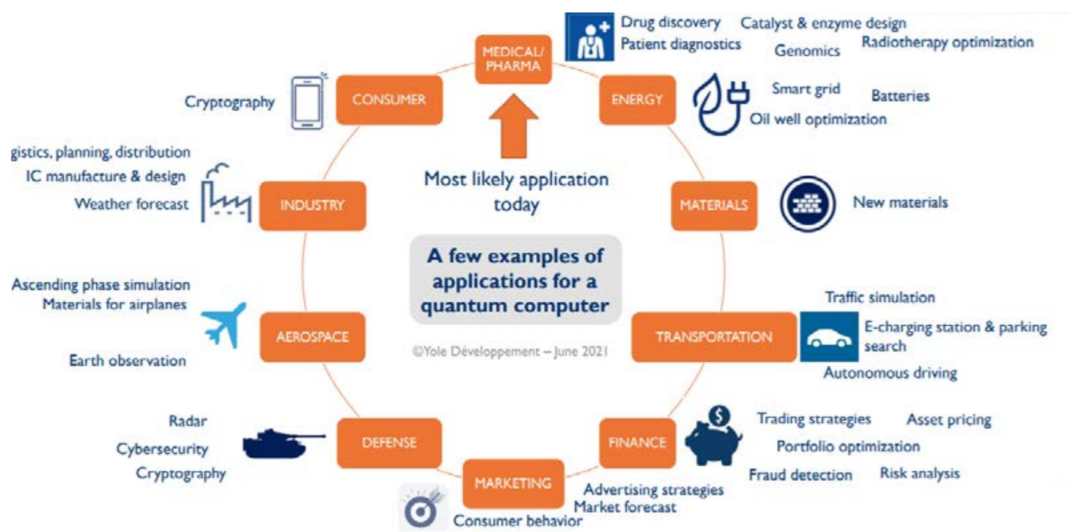


FIGURE 12: Why Quantum Computing?

Source: Quantum Technologies 2021, Yole Développement | www.yole.fr | ©2021

CMC's strategy is to democratize access to state-of-the-art quantum hardware and software technologies by lowering barriers to quantum technology through the advancement of quantum computation, MPW access and implementation of quantum hardware.

[4] Frank Arute et al., 'Quantum supremacy using a programmable superconducting processor', Nature 574, 505 (2019).
[5] www.bcg.com/publications/2021/building-quantum-advantage
[6] www.canada.ca/en/innovation-science-economic-development/news/2021/07/government-of-canada-launches-public-consultations-on-national-quantum-strategy.html
[7] Ben Sussman et al., 'Quantum Canada', Quantum Sci. Technol. 4, 020503 (2019).

Strengths

Canada has dozens of quantum software and hardware companies, start-ups, accelerators, incubators and three quantum institutes that drive quantum science and train the workforce. A 2016 assessment across G20 nations placed Canada 5th worldwide for patent filings in quantum computing and telecommunication.[8] CMC's new Quantum Computing as a Service now allows Canadian researchers to access IBM's and Xanadu's state-of-the-art quantum computers. CMC's vast network of Canadian and international partners, and expertise in MPW services will enable the introduction of cost-sharing fabrication services for superconducting quantum devices, silicon spin qubits, and silicon quantum photonics.

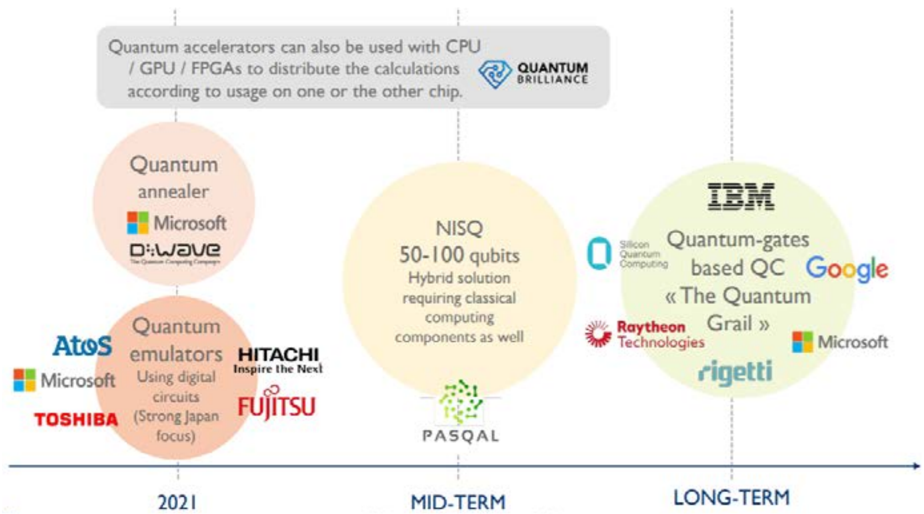


FIGURE 13: The Different Type of Quantum Computers

Source: Quantum Technologies 2021, Yole Développement | www.yole.fr | ©2021

Weaknesses

Access to quantum device fabrication is still limited to researchers with in-house facilities or with direct access to foundries. The few existing foundries are overseas, require expensive dedicated fabrication runs, and do not provide mature processes. In-house fabrication facilities, usually staffed with graduate students, are also costly with low yield, longer fabrication times, and low device quality. Lack of good EDA tools, the strong interdependence between quantum hardware and software, and the lack of a relevant quantum university curriculum further impact our progress in quantum.

[8] Ben Sussman et al., 'Quantum Canada', Quantum Sci. Technol. 4, 020503 (2019).

Opportunities

Deploying CMC's MPW model and associated tools for shared fabrication will significantly reduce the cost and increase the accessibility of quantum fabrication. Working with EDA vendors will allow us to create tools optimized for quantum hardware and device design. Working with Canadian partners to create a domestic manufacturing grade quantum process will allow us to create and maintain leadership in the development of quantum systems, retain intellectual property, and expand the quantum ecosystem in Canada. Working at both the process and software level will allow optimized quantum algorithms for world leading performance.

Threats

Termination of quantum cloud services, high costs to access both quantum software and hardware technology, and international competition for key quantum HQP could significantly impact Canada's quantum ecosystem.

Looking Ahead

CMC will work with academic, industry, and other partners, and collaborate as opportunities permit, to lower the barriers to entry and to execute on the following plan:

- Provide access to quantum computing systems and quantum software technologies.
- Provide access to mature processes and design tools to layout, design and simulate quantum hardware technologies through MPW services.
- Develop a proposal for "made in Canada" solutions for quantum device fabrication.

Targeted growth of 30% per year in activity and outcomes.

Glossary & Acronyms

AI: Artificial Intelligence

AIoT: Artificial Intelligence of Things

AMS: ams AG, formerly known as austriamicrosystems AG

ASIC: Application Specific Integrated Circuit

CAD: CMC Microsystems' product line providing Computer Aided Design (CAD) tools

CFI: Canada Foundation for Innovation

CMOS: Complementary metal–oxide–semiconductor

CNDN: Canada's National Design Network®, managed by CMC Microsystems

EDA: Electronic Design Automation

FAB: CMC Microsystems' product line providing chip fabrication services

FPGA: Field Programmable Gate Array

GaN: Gallium nitride

GF: GLOBALFOUNDRIES Inc., a semiconductor manufacturer

GPU: Graphics Processing Unit

HQP: Highly Qualified Personnel

IoT: Internet of Things

IP: Intellectual Property

LAB: CMC Microsystems' product line providing access to laboratory equipment and R&D services

MEMS: MicroElectroMechanical Systems

MIDIS: MEMS Integrated Design for Inertial Sensors, a fabrication technology from Teledyne DALSA

ML: Machine Learning

MPW: Multi-Project Wafer, cost savings via multiple customer designs in one fabrication run

MSI: Major Science Initiatives, a CFI program

NSERC: Natural Sciences and Engineering Research Council of Canada

NRC: National Research Council Canada

PaaS: Platform as a Service

PDK: Process Design Kit

PIC: Photonics Integrated Circuit

RF: Radio frequency, a wireless electromagnetic signal

SME: Small and medium-sized enterprises

SponsorChip: Industrial support and donation program administered by CMC Microsystems

TRL: Technology Readiness Level

TSMC: Taiwan Semiconductor Manufacturing Company

VIE: Virtual Incubator Environment

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