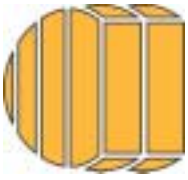
Strategies for Innovations in Research

CMC's Contribution
To
Canada's Innovation Strategy

August 29, 2002



CANADIAN MICROELECTRONICS CORPORATION
SOCIÉTÉ CANADIENNE DE MICRO-ÉLECTRONIQUE

210A Carruthers Hall
Queen's University
Kingston, ON, Canada K7L 3N6

Telephone: 613.530.4666
Fax: 613.548.8104
Web: www.cmc.ca

Table of Contents

Executive Summary

The Canadian Microelectronics Corporation (CMC) is pleased to contribute to Canada's Innovation Strategy initiated by the Government of Canada in February 2002, and described in two discussion papers – "*Achieving Excellence",* and *"Knowledge Matters."* (www.innovationstrategy.gc.ca).

This paper focuses on challenges identified in these national discussion papers, specifically

- the knowledge performance challenge,
- the skills challenge;
- and strengthening accessibility and excellence in post-secondary education.

CMC's contribution to innovation focuses upon issues impacting research, education, training and the development of highly qualified people, upon whom Canada's future livelihood increasingly depends.

CMC proposes overarching strategies together with specific recommendations (immediately following) that exploit the impact of microsystems and related disciplines as fundamental enabling technologies, essential to the creation of new wealth, improved productivity and competitiveness, and increased innovation in diverse Canadian industrial sectors. Appendix 1 sets out the specific recommendations, CMC's actions that support the recommendations and the expected results/impact.

> ***"In Canada we are already firmly into the knowledge-based economy. In this economy the key asset is knowledgeable people who are able to create both new value itself and new value-generating knowledge.***
>
> ***The development of this key asset is accomplished primarily through education and learning.***
>
> ***The competitive differentiators in the knowledge-based economy are education, the capacity for innovation and knowledge-based value creation. So education is a strategic activity for any nation."***
>
> ***"The Educational Challenges in the Knowledge-Based Economy"***
>
> ***H. Douglas Barber,***
> ***Past President and CEO, Gennum Corporation***
> ***Past Chair, Board of Governors and Distinguished Professor in Residence, McMaster University***

These strategies and recommendations aim to support and accelerate research, development and innovations that are:

- underpinned by microsystems technologies and

- leveraged by diverse industrial sectors such as telecommunications, medical, automotive, environment, natural resources, aerospace and national security.

Innovations related to microsystems technologies are pivotal to achieving our national R&D and economic potential, improving quality of life for our citizens, and increasing Canada's international ranking in R&D performance from 15th to among the top five nations in the world.

"The Government of Canada sees information and communications technologies as a cornerstone of our country's economic development. Microelectronics is a fundamental enabling technology."

The Hon. John Manley (Current Deputy Prime Minister, and Minister of Finance of Canada), when speaking as the former Minister of Industry

CMC is proud to play a key role in implementing Canada's Innovation Strategy, and in increasing the impact of microsystems research on Canadian innovation objectives, industrial and economic performance, and quality of life.

Summary of Proposed Strategies and Recommendations

Strategy 1: Integrate Canada's Innovation and Economic Strategies

Strategy 2: Identify and integrate strategic innovation-enabling technologies and multiplier organizations into Canada's Innovation Strategy

Recommendation 1: Identify and use *4th Pillar*[1] organizations strategically, particularly innovation-enabler and multiplier organizations, in the development and implementation of Canada's Innovation Strategy.

Recommendation 2: Strategically coordinate government investments in 4th Pillar organizations, especially those central to research and technological innovation.

Recommendation 3: Implement the 'CMC-model' widely for greater advantage and impact on Canada's system of innovation.

Recommendation 4: Increase strategic investment for enabling disciplines and infrastructure.

Strategy 3: Identify microsystems to be among the leading enabling technological underpinnings of Canada's future economy and ensure that supporting investments in research, education and training are managed strategically, and are fully integrated into Canada's Innovation Strategy

Recommendation 5: Develop a national strategy that ensures a sustainable approach to accelerated development of highly qualified people with microsystems expertise, acquired through development of microsystems prototypes.

Recommendation 6: Expand initiatives to foster multi-disciplinary collaboration and research.

Recommendation 7: Make innovation at the university/industry interface a priority to ensure investments in research and the development of highly qualified people fully benefit the Canadian economy.

Recommendation 8: Establish targets to improve the productivity of university researchers and the efficient development of highly qualified people through new innovations.

[1] Four pillars are essential to Canada's Innovation Strategy: industry, government, universities and 4th Pillar innovation-enabling and multiplier organizations.

1. Introduction:

1.1 About CMC

CMC is instrumental in the development of highly qualified people (professors and students) at Canadian universities.

CMC has developed unique capability over eighteen years in the effective and low-cost delivery of advanced tools and technologies that enable leading-edge microsystems research and development (see Appendix 2: Terminology) at 41 universities, coast to coast.

> ***"CMC's service is superb, efficient, and friendly…the best among similar services in Taiwan, Korea, Japan, US, and Europe."***
>
> ***Dr. James Kuo,***
> ***Canada Research Chair***
> ***and Professor,***
> ***University of Waterloo***

CMC is at the center of a highly successful national collaboration. It builds research capacity in Canadian universities of all sizes, in all parts of the country, through its National Design Network for microsystems. It capitalizes upon CMC's strategic interaction between Canadian industry and academic institutions. It facilitates regional technology clustering and associated increases in economic activity across the nation. It directly addresses Canada's goal to move from 15th to at least 5th in global R&D performance by 2010.

- The highly qualified people supported by CMC are deployed widely for increased innovation and productivity across the Canadian economy, in particular in the fast-growing knowledge industries that have provided the majority of national economic growth in recent decades. According to Industry Canada statistics[2], the compound annual growth rate for employment in the ICT sector was three times greater than that of the total economy from 1997 to 2002.

- CMC enables broad leverage of Canada's research dollars, providing microsystems researchers at both smaller and larger universities with opportunity and access to leading-edge tools and technologies.

- CMC amplifies government and industry investments many times over. For example, CMC develops a design environment once, and then delivers it to over 450 university professors and 1,100 students annually at participating universities across Canada. Effective negotiation with suppliers and large-scale purchases for the National Design Network enables CMC to deliver greater value and achieve a cost-effectiveness that would not be possible by any student, professor, university or organization acting individually. CMC also acts as a single channel for delivering tools and technologies to multiple universities, providing first line support.

[2] Key Indicators on ICT Infrastructure, Use and Content, July 2002, Industry Canada, page 2

"CMC's infrastructure is an excellent resource and is the "glue" for the research development of graduate students. I have been able to capitalize on the availability of CMC tools, design kits, tutorials and IC fabrication to increase students' learning…. I consider CMC's tutorial to be the entry point to design. The tutorial is totally enabling and without it students would not be able to perform their research. Once the students' skills are developed from using the tutorial, their design time is accelerated through use of CMC's design flows. Without CMC infrastructure, the same level of research could not continue, especially in smaller universities. The burden of setting up the design infrastructure and the legal and administrative framework for fabrication access would be simply too much…without CMC, a minimum of one full-time person dedicated to performing normal CMC functions would be required to simply maintain the same level of activities presently in place."

Dr. Rick Hobson
Professor of Computing and Engineering Science, Simon Fraser University

- CMC stimulates the development of highly qualified people with microsystems expertise. It facilitates essential multidisciplinary and collaborative research across disciplines, where microsystems increasingly enable the actual realization, use and benefit of new devices from emerging technologies. These new approaches to collaboration are essential to make advanced research effective, overcoming the barriers presented by cost and complexity, in the interests of the largest number of scientists possible.

- CMC is a not-for-profit corporation supported by technology, services and cash from 25 industrial partners and numerous suppliers, with matching funding from the Natural Sciences and Engineering Research Council. CMC also provides professional management of grants from the Canada Foundation for Innovation and the Ontario Innovation Trust through Queen's University to deliver research infrastructure for System-on-Chip investigations at 30 Canadian universities; and to enable the testing of high-performance microsystem designs through the National Microelectronics and Photonics Testing Collaboratory.

- CMC's integration of industrial technologies and government resources helps to place Canadian university research at the global forefront, and to produce individuals with the finest knowledge and skills in microelectronics, emerging areas of photonics, optoelectronics, embedded software, micromachining, and progressively nano-scale phenomena.

"I have not found any other country that offers the same level of research infrastructure, provided by CMC. This makes Canada a very attractive country for business development. It is hard to find qualified people with microsystems skills and experience in other countries - CMC helps to produce them in Canada."

Dr. Mourad El-Gamal,
Professor, Electrical & Computer Engineering,
McGill University

1.2 Why are Highly Qualified People in Microsystems Important?

Microsystems enable numerous scientific disciplines and industrial sectors, with a direct impact on Canada's industrial competitiveness and productivity. Highly qualified people with microsystems skills are deployed throughout telecommunications, automotive, resource, health care, aerospace, agriculture, forestry and other industries.

Microsystems are everywhere information must be collected, managed and manipulated for decision-making; everywhere that innovation is key to productivity and competitiveness. Even emerging fields such as biotechnology and molecular engineering depend heavily on microsystems skills and technologies at both the research and commercialization stages of their evolution, as will more speculative research in areas such as quantum computing. It is these highly qualified people who are enabling our collective future:

"Microsystems enable new innovations for machinery used by every farmer, creating opportunity for increased productivity and cost-effectiveness in the agricultural community. Common agricultural applications include diesel equipment, computerized engines and positioning systems, drawing upon scientific disciplines such as computer design, ranging and control theory. New ground-based equipment guidance systems are being developed to control and locate farm vehicles such as tractors that do not require a driver. These systems will provide new functionality, such as "auto-steering", to help to eliminate common problems such as skipping and overlap when ploughing fields. This will help save the Canadian farmer time and money."

Dr. Ron Palmer, Professor,
Faculty of Engineering,
University of Regina

- Microsystems-intensive corporations generate $500,000 revenue per employee (average of public company members of Strategic Microelectronics Consortium (2001), CMC and Micronet). Every highly qualified person with a post-graduate degree in a microsystems discipline is estimated to generate $2 million in future revenues annually.

- Since 1997, Canada's microsystems-intensive Information and Communications Technologies (ICT) sector has produced four times the rate of GDP growth relative to the economy as a whole. The ICT sector accounts for 46% of Canada's private sector R&D, of which 60% (28% of private sector R&D) is attributable to microsystems-intensive companies.

The facts are convincing. The Information and Communications (ICT) sector is underpinned by microsystems technologies. It is the most innovation-intensive sector in Canada, undertaking close to half of all R&D in the private sector.

Microsystems technologies are ubiquitous and pervasive. They also have an impact well beyond the ICT sector and have become indispensable to the operation and competitiveness of all forms of industry and commerce. Almost half of all ICT professionals in Canada (46% in 2000 according to Industry Canada) are employed ***outside the ICT sector***, enabling countless industrial applications in automation, instrumentation, sensing, medicine and other sectors. According to Industry Canada statistics[3], Canadian Medical Specialists rank second in the world for utilization of electronic medical records. This is just one example of how electronics enable greater productivity in different sectors.

> ***"Recent studies project that electronics will constitute as much as 40 percent of a vehicle's value by 2010. The automotive electronics industry comprises a wide range of microelectronics and related technologies including MicroElectroMechanical Systems (MEMS) systems, photonic devices, wireless communications, networking, power electronics and related embedded software. These core enabling technologies have provided enhanced intelligent functionality to powertrain components, safety systems, environmental systems, navigation, collision avoidance systems, and multimedia systems so as to fuel the mobile electronics revolution."***
>
> ***Dr. Frank J. Ewasyshyn***
> ***Senior Vice-President,***
> ***Advanced Manufacturing Technology,***
> ***DaimlerChrysler Corporation***

The impact of highly qualified people with microsystems expertise across Canada's industrial, university and public sectors is illustrated by the success stories emerging from CMC's national research community. This includes research and innovation relying upon microsystems in fields such as biotechnology and medicine that will directly impact quality of life. CMC is proud to help facilitate such research across Canada, including École Polytechnique de Montréal, the University of Calgary, and Dalhousie University.

Dr. Mohamad Sawan and the Polystim research team at École Polytechnique de Montréal want to help improve the quality of life for people with brain-related injuries using microsystems innovations. Working with the Montreal Neurological Institute at McGill University, CMC, and experts from many scientific disciplines, the team is targeting delivery of implantable smart medical devices within the next five to ten years to help people with a range of medical problems, including loss of organs or chronic illness. Dr. Sawan's team has developed several biomedical innovations to help restore or enhance lost sensory ability or bodily functions. This includes innovations related to the cochlear implants, the cardiac pacemaker, the bladder controller for those who have incurred spinal cord injuries, and several other sensors and catheters.

[3] Key Indicators on ICT Infrastructure, Use and Content, July 2002, Industry Canada, page 28

Dr. Karan Kaler is zeroing in on the genetic signature of cancer. For over twenty years, he has developed biomedical tools and instrumentation to probe and quantify the state and properties of biological living cells. Working with a research team at the University of Calgary, Dr. Kaler relies upon leading-edge CMC microsystems tools and technologies for the research required to "fingerprint" and analyze unhealthy cells in the human body. The ability to manipulate and interrogate human cells is fundamental to discover new methods of early detection, more effective treatments, and potential cures for deadly diseases like cancer. Dr. Kaler and his research team are focused on developing diagnostic tools and methods like his microchip-based "Planar DEP Levitator" that will help the medical community identify and understand the properties of diseased cells.

Dr. Ted Hubbard, Dr. Marek Kujath and their research team at Dalhousie University are building tiny electrical machines and robots that could improve health care and help save human lives. The research team is developing micro-robots, motors and mechanical "grippers" to manipulate human cells and living bacteria - not one cell at a time, but thousands of cells at a time. This could enable greater efficiency and productivity in medical screening, help keep Canada's national blood stock safe, enable doctors to diagnose patients faster, and allow researchers to isolate diseased cells when working towards a cure for the world's most common diseases. This is research on micromachining or MEMS (MicroElectroMechanical Systems): small devices manufactured with dimensions of less than 1 millimetre, with feature sizes on the order of 0.001 millimetre. The team is designing and manufacturing bio-chips using MEMS technology with research infrastructure provided by CMC.

The global success of many Canadian industries relies upon the capability that CMC provides to universities, and by the highly qualified graduates they produce. Research and innovations produced by these highly qualified men and women contribute to the development of new Canadian start-up enterprises, patents, R&D productivity and the attraction and retention of talent. This is evidenced by high employability rates, improved ramp-up, and high productivity of "CMC graduates" as articulated by leaders of Canada's fabless semiconductor industry.

"CMC has supported the high quality training of future employees for Canada's semiconductor industry for over 18 years. Companies such as PMC-Sierra and others have been able to capitalize on the highly skilled workforce CMC has enabled. CMC's integrated circuit development infrastructure for Canadian universities is both "leading edge" and reflective of industry "best practice". These high quality graduates are ready to innovate, implement their ideas, and increase Canada's leadership and competitiveness in the global microelectronics market."

Kevin Huscroft, Vice President, Research & Development & Chief Technology Officer, PMC-Sierra, Inc.

"I am privileged to have worked with CMC for over 15 years. CMC is a unique Canadian jewel that has enabled microsystems in a way that is unparalleled anywhere in the world. It has put Canada at least ten years ahead of any other country in regards to its research programs and infrastructure. The high quality people CMC helps to produce offer companies faster time to profitability, and employee ramp-up that would typically take three years to meet industry standards."

***Nick Deeble, Account Director, Canada,* Cadence Design Systems (Canada), Inc.**

Strategic partnerships with industry allow CMC to integrate industrial leading-edge technologies and government resources to place Canadian university research at the global forefront and to produce individuals with the finest knowledge and skills in microelectronics, emerging areas of photonics, optoelectronics and micromachining, and nano-scale technologies.

Given CMC's pivotal role in the development of highly qualified people in microsystems disciplines, it is essential that CMC be a full participant in the development and implementation of Canada's Innovation Strategy. CMC is a Canadian innovation in itself.

"Have said to many groups that CMC's model is one to emulate for distributed research."

Brian Moore,
Founder and Chief Technology Officer,
BigBangwidth Inc.

2. Strategies and Recommendations

Strategy 1:

Integrate Canada's Innovation and Economic Strategies

Canada's Innovation Strategy discussion papers, "*Achieving Excellence"* and *"Knowledge Matters",* emphasize the importance of bolstering knowledge, skills, research and development, entrepreneurship and other capacities. It is critical that the national discussion and actions related to these innovation-centric matters connect explicitly to Canada's economic strategy.

As Canada strives to build excellence through investment in people, knowledge, skills development and opportunity, it is to ensure that our standard of living and quality of life are the best they can be. To do so requires increased investment that must be derived from the new knowledge-intensive sectors of the economy. There is, therefore, a strong connection between the realization of Canada's innovation goals and targets, and the performance of the economy.

For example, one key innovation target is to improve Canada's international R&D performance ranking from 15th to among the top five nations in the world. This is to be measured by the gross expenditure on research and development per capita. It is estimated that $100's of billions of new private sector revenues will be needed to achieve this target. Ensuring the continued growth of knowledge-intensive companies engaged in global trade with higher than average revenues for their employees represents an effective means to achieve these revenues.

Should Canada adopt an economic strategy that maintains traditional economic sectors, while stimulating economic growth and innovation through knowledge-intensive export sectors, it would stimulate discussion on key issues that impact innovation. Such issues include: investment in education, the linkage between education, research, development and commerce, the stimulation of entrepreneurship and global trade, and the role of manufacturing vs. service sectors.

The most important element in the innovation-economic equation is the availability of highly qualified people who drive improved economic and innovation performance in Canada. CMC is a key participant in Canada's system of innovation focusing on the development of highly qualified people. A focus on the natural sciences and engineering, particularly enabling disciplines such as microsystems, will realize major impact on Canada's future innovation-driven economy.

Strategy 2:

Identify and integrate strategic innovation-enabling technologies and multiplier organizations into Canada's Innovation Strategy

For Canada to achieve its economic and innovation goals it is essential to facilitate the highest degree of effectiveness, efficiency and leverage from and across individuals, organizations and governments.

Innovation-enabling disciplines, technologies, and multiplier organizations merit strategic attention in Canada's Innovation Strategy. These organizations provide focus and leverage that delivers higher return on investment across the entire economy.

In addition, the coordination of federal and provincial R&D investments directed towards the development of highly qualified people will bring about major rewards.

These perspectives are discussed within the context of the following recommendations that are action-oriented and emphasize the benefits of early implementation. They support CMC's perspective that Canadians have demonstrated consistent leadership in discovery, but have struggled to acquire equal credibility and proven track record through all aspects of innovation, action and risk-taking.

Recommendation 1:

Identify and use *4th Pillar* organizations strategically, particularly innovation-enabler and multiplier organizations, in the development and implementation of Canada's Innovation Strategy.

Four pillars are essential to Canada's Innovation Strategy: industry, government, universities and 4th Pillar organizations. It is imperative that 4th Pillar organizations play a greater role in Canada's innovation strategy and heighten the contribution currently implied in the national discussion papers.

In the present context, 4th Pillar organizations are defined as innovation-enabler and multiplier organizations. They build upon the contributions of business, government and the universities by bringing together diverse stakeholder groups to focus on important science and technology-based opportunities.

- 4th Pillar organizations serve communities of common interest. They complement the work of governments, universities and the private sector, and often bring together and channel individual and organizational

interests, commitment, and competence towards focused group-based action. They are effective instruments to bridge sectoral, geographical and governmental divides.

- 4th Pillar organizations are often structured as not-for-profits, agencies of government or associations, and manifest the competence and conscience of governments, the universities and the private sector. They are differentiated from governments and universities through their ability to be agile and focused, to develop consensus quickly on specific issues, and to take immediate and concerted action in the interests of their constituency.

- 4th Pillar organizations perform exceptionally well when transition, innovation and change are prevalent. This increases their relevance and potential for impact on Canada's Innovation Strategy.

- 4th Pillar organizations such as CMC demonstrate the ability to readily adapt and respond to change, to take action and deliver the greatest value to the constituents they serve. This is evidenced by CMC's recent update its strategic direction, which outlines CMC's increasing role as a facilitator of collaboration and multi-disciplinary research across microsystems disciplines. With growth in emerging sectors such as the biosciences, cross-fertilization through microsystems will be essential to strengthen the application and impact of research and innovation in Canada. CMC has updated its strategic direction to adapt to Canada's current innovation requirements, target future industrial and economic needs, and contribute greater value to the national system of innovation.

As Canada proceeds to implement its Innovation Strategy, the ability to meet the distinct challenges across stakeholder groups will ultimately determine its success. The federal government will address Canadian citizens in a broad-based fashion, while private sector companies will focus upon their individual commercial objectives. The 4th Pillar organizations are designed to act as 'change-management' agents, exactly the type of role required now, to facilitate the collaboration required to achieve Canada's common innovation objectives. This role is required for the successful implementation of Canada's Innovation Strategy. Examples of 4th Pillar organizations include the CMC (Canadian Microelectronics Corporation), the Canadian Institute for Advanced Research, CANARIE Inc., PRECARN Inc., and PAPRICAN. There are many others, operating both nationally and provincially.

"For the past 18 years, CMC has provided a unique service to Canadian university researchers not found anywhere else in the world. With a national System-on-Chip Research Network in place, I believe that Canada is well equipped to take a leadership role in the global race of SOC design technology."

Dr. Jianwen Zhu, Professor,
Electrical and Computer Engineering
University of Toronto

How can 4th Pillar organizations contribute to Canada's Innovation Strategy? As Canada strives to become a more innovative nation, to increase its international research investment from 15th to among the top 5 in the world, and to direct investments to priority areas, 4th Pillar organizations are 'at the ready', with established public, private and university channels of communication in place. They are the organizations addressing the challenges of federal/provincial boundaries, and bridging communities for a greater common good. National benefit will be derived from the strategically planned and concerted action of 4th Pillar organizations.

CMC has updated its strategic direction (www.cmc.ca/about/corporation/strategic_plan/). As a 4th Pillar organization, it will support broader multidisciplinary microsystems-oriented research and development at Canadian universities, while responding immediately to new innovation challenges as they emerge.

Recommendation 2:

Strategically coordinate government investments in 4th Pillar organizations, especially those central to research and technological innovation.

Canadians have been disadvantaged by the absence of strategic policies and practices pertaining to investments in science and technology. Although there has been benefit from specific initiatives, there is greater opportunity for optimization and impact of government investments. As an example, the Canada Foundation for Innovation (CFI) investments have been welcomed by research organizations, and are essential to the improvement of infrastructure in Canada's universities and other organizations. On the other hand, university researchers and funding agencies face unnecessary challenges when striving to establish responsible constructs of research programs because of the lack of coordination with research program grants at both the federal and provincial levels. For example, synchronizing program and infrastructure grants at the project level is cumbersome, resulting in research initiatives that may be infrastructure rich and program funding poor, or vice versa. The impact of Canadian science will improve with increased harmonization, coordination and cooperation among federal and provincial research funding agencies and governments.

As another example, the Government of Canada's commitment to innovation in photonics and nanoscience through the National Research Council (NRC) is to be applauded. This commitment is demonstrated by the launch of the Canadian Photonics Fabrication Centre and the cooperation engendered between the Government of Alberta and NRC in the development of the National Institute of Nanotechnology (NINT). Yet, major investments in science and technology being made by Provinces, and in provinces by the federal government, can be made much more effective with better coordination through federal/provincial cooperation. It is most important that Canadian investment in science and

technology support collaboration among researchers to enable truly world-class work and reduce potential for duplication, rather than division engendered by disparities among federal and provincial funding programs.

To achieve the objectives of Canada's Innovation Strategy, CMC recommends the harmonization of federal/provincial investments in science and technology directed towards both regional and national interests. Such an approach will responsibly foster 'hot spots' of science where clusters of expertise currently exist or are beginning to form. The NINT provides an excellent example of how such expertise may be cultivated, and provide a national focus.

Similarly, with respect to the 4th Pillar organizations that the Government of Canada supports, CMC recommends that investments be stewarded strategically by one agency. This may involve creation of a new agency with A-line budget appropriation ensuring sustainable but managed investment in cornerstone 4th Pillar institutions such as CMC, CANARIE Inc., PRECARN Inc., and others required to implement national innovation strategies. This approach may include innovation-intensive agencies of the federal government currently distributed across numerous government departments.

CMC will leverage new initiatives and innovations to ensure all regions of Canada are actively engaged in the information exchange essential to the effective positioning and delivery of CMC's products and services.

CMC will broaden its partnerships and research-funding base in cooperation with governments, universities and the private sector.

CMC will link its program to performing sectors of the economy and to the participation of contributing industrial partners.

"The Canada Foundation for Innovation is pleased to support Queen's University in its collaboration with CMC to deliver state-of-the-art research infrastructure through the deployment of Canada's System-on-Chip Research Network and the upcoming National Microelectronics and Photonics Testing Collaboratory. These projects will strengthen Canada's capacity to compete globally by providing universities with the tools to attract and retain talented faculty, and to train the next generation of researchers."

Dr. David Strangway,
President and CEO, CFI

Recommendation 3:

Implement the 'CMC-model' widely for greater advantage and impact on Canada's system of innovation.

CMC's stakeholders indicate the CMC-model could be used more widely in Canada's system of innovation, based upon its best-in-class support of national

university-based research and education. CMC recently engaged government, academic and industry stakeholders in 15 cities across Canada during a strategic planning process. The results are pertinent to Canada's Innovation Strategy.

Figure 1 shows stakeholder responses on the benefits of using the CMC-model more broadly to support increasing complexity in research at Canadian universities. This consensus is particularly important for policy makers, governmental and industrial investors in R&D, and for CMC.

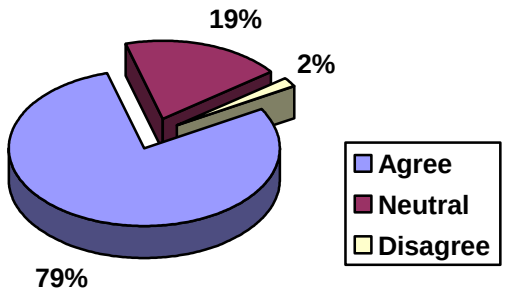


Fig. 1: Beneficial to Use CMC-Model More Broadly To Support Research at Canadian Universities

The following characteristics and core competencies of the CMC-model reveal broader opportunity for government/private sector collaboration in support of research and the development of highly qualified people. They emphasize the potential to leverage professionally managed organizations such as CMC to foster research and educational initiatives in Canada.

Characteristics of the CMC-Model:

- Government funding is matched by private sector investments directly focused on university research and the development of highly qualified people.
- Investments are directed to a focused set of disciplines that are linked to present and future needs of industry – microsystems.
- Investments result in internationally recognized and industrial-class capability made available to university laboratories across Canada.
- Researchers benefit from collaboration within a non-exclusive national network developed to produce prototypes of sophisticated microsystems.
- Specific research infrastructure investments are determined by joint university/industry committees, and thereby enable the highest quality research outcomes and graduate student capability.
- Professional management ensures research investments are optimized to have the highest efficiency and impact, with proactive strategies for key issues such as intellectual property protection, negotiation with suppliers and responsiveness to both university researchers and private sector companies.

Building upon innovative approaches such as the CMC-model will be essential to achieve the objectives outlined in Canada's Innovation Strategy.

These include:

- Vastly increasing public and private investments in knowledge infrastructure to improve Canada's rank in R&D performance to the top five countries in the world by 2010,
- Providing internationally competitive research opportunities in Canada,
- Responding to the inherent challenges of increasing the admission of M.Sc. and Ph. D. students by 5% per year through to 2010,
- Building collaborative networks across government departments, universities, non-government organizations and the private sector.

"Please consider yourself as an infrastructure model that could be extended to other sectors and as a way of fostering partnerships that are the basis of clusters."
Frank Huntley, President,
The Software Factory

CMC will be an active supporter and implementation organization for initiatives that engender national public/private collaboration in the provision of research support at Canadian universities where association with microsystems is apparent.

Recommendation 4:

Increase strategic investment for enabling disciplines and infrastructure.

Microsystems are enabling technologies. Broadband networks, themselves enabled by microsystems, are an example of enabling infrastructure. When brought together, they provide the opportunity for innovation in research, the development of new products and services, and ultimately fundamental shifts in industry.

The impact of microsystems and broadband technologies is evident enabling fields such as medical telemetry where doctors in remote regions have the increasing ability to conduct examinations, perform surgical procedures, and transmit data through a high-speed network to patients at a distance. Microsystems technologies are at the heart of such enabling fields, and help turn innovative concepts into the valuable applications that improve the quality of human life.

More specifically, microelectronics technology enables the enablers' such as intelligent systems, optoelectronics, wireless, and biotechnology. Microelectronics is also projected to play a pivotal role in linking macro, micro

and nano-scale processes, enabling the full industrial potential of nanotechnology in the decades ahead.

Strategic support of enabling technologies and research infrastructure offers increased leverage and high potential for return on investment, as they in turn enable many disciplines and impact many industrial sectors. Enabling technologies are the key to Canada's future and require all possible investment to improve the competitiveness of Canadian industry, national productivity and economic performance.

> ***CMC's core strength, expertise and credibility in design of complex systems should be applied to newly emerging areas such as micro/ nano, molecular, and quantum technologies."***
>
> ***Leo Derikx,***
> ***Former Director General, Research Partnerships, NSERC***

CMC will contribute to Canada's research and innovation objectives through continued development of its current program; the introduction of support for new microsystems and related research areas; and an increased contribution to government and industry policy discussions.

Strategy 3:

Identify microsystems to be among the leading enabling technological underpinnings of Canada's future economy, and ensure supporting investments in research, education and training are managed strategically, and fully integrated into Canada's Innovation Strategy

Microsystems are principal enablers of research, development and innovation in the private and public sectors, and increasingly provide a strong foundation for Canada's economy. Given this critical role, support for research, education and the commercialization potential of microsystems must be embedded within Canada's Innovation Strategy.

Canada is the only G-7 country without major semiconductor manufacturing facilities. Further, recent evidence emerging from international meetings on microsystems shows Canada to rank about 15th with respect to advancements in microsystems R&D. For Canada to fully benefit from advancements of this enabling field, novel approaches are required to support microsystems researchers. This is strategic to ensuring attraction, retention, and the overall availability of highly qualified people with microsystems expertise who are essential across the Canadian economy.

Canada's Innovation Strategy must also account for the special role that Canadian universities play in Canada's system of innovation relative to other countries. Comparatively, Canadian universities are performing a relatively

larger portion of national R&D, in addition to a larger portion on behalf of the private sector. Increased focus on the university/industry interface, heightened collaboration and multidisciplinary research within universities, and improved productivity of university researchers are essential to performance of Canada's innovation-driven economy.

Recommendation 5:

Develop a national strategy that ensures a sustainable approach to accelerated development of highly qualified people with microsystems expertise, acquired through development of microsystems prototypes.

Canada has achieved global distinction in its approach to fostering leading-edge microsystems research though university/industry/government collaboration. This unique collaboration is facilitated by CMC and supported by the Natural Sciences and Engineering Research Council (NSERC) and the private sector. It enables university professors and students across the country to realize their research ideas through the construction of actual microchip prototypes. This distinction has helped Canada to acquire global recognition and success in the fabless semiconductor industry, in addition to the broader Information and Communications Technology sector. Global leadership in this field has been pivotal in the attraction and retention of highly qualified people with microsystems expertise.

Canada must build upon this success to create greater opportunity for innovation and competitiveness. The importance of microsystems prototype creation for researchers has become increasingly important to biomedicine and other disciplines. Microsystems now play a key role in sensing and diagnostics in areas ranging from the environment, to forensics, security and social policy.

It is therefore imperative that microsystems research and prototype development at Canadian universities be addressed as a strategic component contributing to Canada's knowledge base and industrial future. Without this ability, research ideas cannot be validated and the value of the research is severely reduced. This often compromises the potential for publication, and impairs the ability for further development and commercialization of university-based research.

"My main benefit from CMC is the access to CAD tools, support of those tools, computing and test equipment, access to fabrication, and the support that is needed to access the fabrication before and after the chip is fabricated. If CMC did not exist, I would probably do research in a different area, or in a different place (not in Canada)….also, my current situation, on leave at a startup company, can be attributed to the fact that CMC helped to fabricate a large device that was a key factor in the origins of this company…… if I were to be starting in the current day climate I probably would not even consider working in the area without the support of CMC…. Another way to look at it is that I could not afford to be in the business without CMC."

Dr. Paul Chow, Associate Professor,
Electrical and Computer Engineering, University of Toronto;
Director of ASIC Technology, AcceLight Networks

To further illustrate this point, CMC stakeholders were asked about the value of using simulation or actual hardware prototypes to prove their work. The results are shown in Figure 2, illustrating the value and preference for hardware (e.g. microchips) prototypes to professors and students.

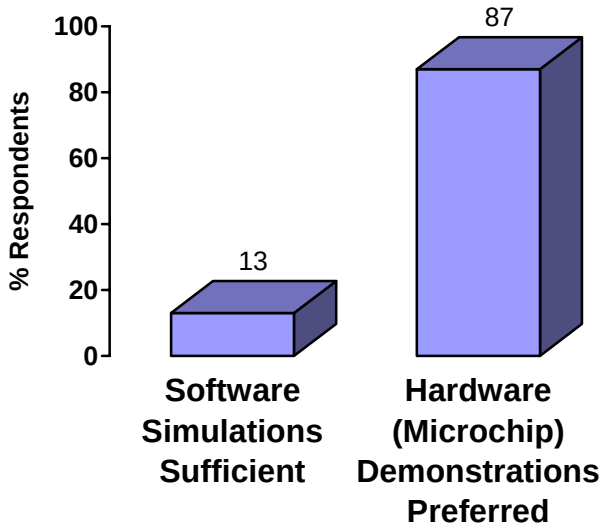


Fig 2: Preference in demonstrating the functionality of new hardware designs using simulation or actual hardware for research pursuits

Prototype development costs borne by NSERC and the private sector have risen dramatically in recent years. These costs have been exacerbated by the loss of valued in-kind contributions from Nortel Networks and ST Microelectronics in providing 'deeply discounted' access to manufacture of many prototypes in Canada. Because these company's manufacturing facilities have closed, and Canada remains the only G-7 nation without major semiconductor manufacturing facilities, Canada must now pay fully for access to microchip manufacturing offshore.

To ensure that Canadians can fully participate in the pervasive development and use of products and services that depend upon microsystems, a national strategy is needed to support the microsystems prototype developments of university researchers. This strategy requires extensive collaboration and involvement of key agencies of the Government of Canada including the Natural Sciences and Engineering Research Council (NSERC), the Canada Foundation for Innovation (CFI), the National Research Council (NRC), the Canadian Institutes of Health Research and Industry Canada.

CMC is prepared to lead the development of a national microsystems prototype development strategy on behalf of the Government of Canada, to ensure a sustainable approach for accelerated development of highly qualified people with microsystems expertise.

Recommendation 6:

Expand initiatives to foster multidisciplinary collaboration and multidisciplinary research.

New approaches to collaboration are essential to make advanced research effective, overcome the barriers presented by cost and complexity, and enable the largest number of scientists possible. It is essential to foster extensive collaboration among peers on a local, national and international scale to acquire the greatest benefit from top Canadian researchers, their innovations, and the global research community. CMC connects to over 1,500 professors and students on an annual basis. It supports Networks of Centres of Excellence (NCE) that are critical to microsystems research in Canada, including Micronet, the Institute for Robotics and Intelligent Systems (IRIS), the Canadian Institute for Photonic Innovations (CIPI), and the Canadian Institute for Telecommunications Research (CITR). Researchers voice consistent interest in effective collaboration. Innovative collaboration, coupled with increased research funding, will create an appealing research environment that is internationally competitive in the retention and attraction of key knowledge workers.

Canadian governments and national institutions such as CMC have a special role to play, not only in enabling infrastructure for collaboration, but also in facilitating multidisciplinary research. Examples to be followed are the specific multidisciplinary international initiatives of the federal Networks of Centres of Excellence and the Canada Foundation for Innovation.

Stimulating collaboration will enable researchers in diverse Canadian communities to achieve objectives that would otherwise be impossible to attain independently. While it is a laudable objective of governments to 'stimulate the creation of more clusters of innovation at the community level', it is also evident that not all communities will have the capability to respond. Moreover, for Canada to fulfill its innovation goals, the linkage between individuals and groups from diverse clusters will be essential to avoid 'Balkanization', so as to derive full benefit from regional innovations. Collaboration must be fostered across Canada just as CMC fosters collaboration through its National Design Network on behalf of microsystems researchers.

From an industrial perspective, the increasing functionality and commercial value of systems continues to be achieved through greater integration. Over the past several decades, microsystems integration was reflected in the increasing density of 'transistors' on a single chip. Today, this phenomenon is characterized by the development of electronic systems on a chip, an area in which Canada and CMC are recognized as world leaders. In the future, integration will be manifested through co-existing microelectronic, photonic, optoelectronics and nano-scale devices and systems requiring collaborative multidisciplinary approaches.

> ***"Microsystem interfaces between nanoscience and human beings will provide the foundations of a new Canadian economy…. By optimizing medical interventions through more precise and faster medical testing, high quality health care becomes more affordable, providing significant economic benefits while maintaining Canadian social values."***
>
> ***Dr. Andrew Belch, M.D., Head, Division of Medical Oncology, Cross Cancer Institute, Edmonton Alberta.***

New partnerships, novel approaches to investment, and broader recognition of the impact of multidisciplinary-based, multifunctional microsystems on diverse areas of science and industry are essential to enabling Canada's future innovation economy. CMC will address this need through national delivery of world-class technology that encourages a multidisciplinary and systems-oriented environment for Canadian university researchers.

CMC will foster national opportunities for multidisciplinary research, collaboration and innovation.

CMC will undertake joint initiatives to stimulate multidisciplinary research that is pertinent to innovation in many industrial sectors. This will include but is not limited to microelectronics, related technologies and biosciences.

CMC will deliver world-class technology that encourages a multidisciplinary and systems-oriented technology environment. This in turn will help promote the development of skills and experience required by Canadian industry to establish greater global competitive capability.

CMC will maintain core competencies for the provision of research support in microsystems, while increasing its systems emphasis. It will facilitate integration of devices, components and/or scientific domains, including those that depend upon or can be enhanced by nano-scale phenomena.

Recommendation 7:

Make innovation at the university/industry interface a priority to ensure investments in research and the development of highly qualified people fully benefit the Canadian economy.

Trends in R&D funding investments and performing sectors indicate that Canada has a greater dependence upon university research, relative to other industrialized countries. This is measured by the percentage of gross expenditures on R&D performed by the higher education sector, and the share of private sector funding in research performed by universities, which continues to increase in Canada. It is essential that Canada's innovation strategy address these realities.

Increased attention to the university/industry interface is strategic for Canada. Organizations that effectively facilitate interaction at the interface include the Ontario Centres of Excellence that are focused upon specific technological and industrial sectors; and the national Networks of Centres of Excellence. These organizations support research, development and commercialization through managed government, university, and industry collaboration. CMC enables microsystems research at Canadian universities, with a model that is specifically designed to be a catalyst for the creation of research infrastructure through government, university, and industry interaction.

To achieve the national innovation objectives outlined in the federal government discussion papers, investment must not only be centred on universities and the private sector. It must also enable 4th Pillar organizations that are sufficiently agile to instigate effective and directed research initiatives with market-focused objectives. The Alberta Research Council is another model that effectively links private and public investment through professional management to realize the commercial benefits of research in the private sector.

In contrast to the examples above, Canadian universities commonly utilize Industry Liaison Offices for the commercialization of research. From a broad perspective, they resemble a technology 'push' process disconnected from industrial strategies, and operate opportunistically depending upon the availability of research results that may be transferred to industry.

Innovation at the university/industry interface or the ability to 'pull' research from universities will realize many advantages for Canada. More effective use of 4th Pillar organizations, innovative shared funding and intellectual property practices, adjustments to the taxation system, partnerships between universities and Industry Liaison Offices and others are all means by which universities can be leveraged even further in Canada's system of innovation.

"CMC as a facilitator is very important to the future of Canadian microelectronics industry…. Industry gets the benefit of students who have been trained on industry-grade tools, managing industry-grade problems, in industry-grade situations."

David Lynch, Vice President
and General Manager,
Video Products Division, Gennum Corporation

CMC will enable innovation and economic advantage in Canada at the university/industry interface, where the benefits of microsystems are evident. This will typically be fostered through partnerships, some of which may be outside of Canada.

Recommendation 8:

Establish targets to improve the productivity of university researchers and the efficient development of highly qualified people through new innovations.

The structural shortfall of skilled workers predicted in the coming decades suggests all possible actions must be taken immediately to increase the number and caliber of highly qualified people in Canada. One means to achieve higher output from Canadian universities is to reduce the administrative burdens of professors, and take steps to accelerate the graduation of students.
CMC has provided professional management that has off-loaded major administrative burdens from university professors in several ways, including the development of major research proposals, and provision of microsystems design and manufacturing capabilities. These actions have allowed professors to focus upon their research, education and training processes. CMC recommends a much wider adoption of this professional management model to support research and education activities, to acquire greater advantage from Canadian universities.

The efficiency of professors can also be improved with increased support to overcome complexities in the university research processes, particularly where laboratory methodologies are practiced. Microelectronics researchers at Canadian universities use complex computer and software systems, requiring an investment in training from the professor before research can proceed. Professors need to focus on the research task at hand rather than invest time-consuming and routine efforts on teaching students how to use complex equipment. It is much more effective to conduct this training in groups, with the training led and developed by individuals more closely suited to this task.

For graduate students in microelectronics in Canada, CMC estimates that the systematic conduct of summer 'boot camps' designed to reduce the administrative burdens of professors could decrease an M.Sc. student's time to graduation by 15-25 percent. The concomitant economic impact of earlier graduation could be realized with the wide adoption of such innovative processes. In addition, the reduction of administrative burdens will be a key factor in the retention and attraction of highly qualified people at Canadian universities. Top talent university professors are essential to fuel our knowledge-based economy.

"A single professor working in isolation, or even as part of a small team, would never be able to establish comparable research infrastructure support. Thus, it is CMC's deliverables that are empowering a professor to make novel and innovative contributions in the global microsystems area."

Dr. William Miller, Professor,
Electrical and Computer Engineering,
University of Windsor

CMC's products and services will focus on postgraduate research and training, while facilitating 'systematic trickle down' to pre-post secondary educational programs.

CMC will provide support for all of its products and services with the specific intent to reduce administrative burdens of professors, and accelerate time to graduation of post-graduate students in the area of microsystems.

3. Conclusion:

As Canada prepares to implement a national Innovation Strategy, it is imperative to improve the effectiveness of communication on research and innovation, and its relation to the economy**.** It is essential to ensure Canadian policies and practices foster improved competitiveness and productivity. It is even more important that all Canadians appreciate and understand the connection between quality of life and the knowledge-based economy.

Canada is firmly established in the knowledge-based economy. It is therefore essential to nurture our collective future through the human capital created by an exemplary educational system. To realize the benefits of human capital, Canada must engender a culture of investment in research, education and the development of highly qualified people, and foster an optimum environment for their contribution to economic growth. Strategic action is needed to consistently replenish the 'pipeline' of young students embarking on careers in related science and technology disciplines.

To sustain our future in the knowledge-based economy, citizens must be informed to make decisions that generate the greatest value to themselves, their families and the country. These may include the investment decisions of Canada's retirement community, or the future career decisions of Canada's youth.

It is particularly important that the role of science and technology, specifically the enabling information and communications technologies, be understood, embraced and supported in Canada's Innovation Strategy. With increasing contribution to Canada's economy and national R&D investment, the Information and Communications Technology (ICT) sector is well positioned for continued innovation leadership in Canada. The ICT sector dominates industrial R&D in Canada, outpacing other sectors in innovation. It is the pre-eminent employer of highly skilled people in Canada. These compelling facts must be communicated broadly to all Canadian citizens. The new government policies that emerge from innovation strategy discussions must be adjusted to reflect the demands for highly educated people in disciplines that are central to product development for both local and export markets.

CMC is committed to educating Canadians for the creation of a culture that fosters innovation. It will encourage and support the dissemination and exchange of technical information as a central activity. It will also communicate widely on its successes to engender knowledge, investment and support for innovation-intensive microsystems activity in Canada.

> ***"The most useful service CMC can provide is one of connectivity or networking."***
> ***David Chamberlain, Director of Research and IP, Hyperchip***

Microsystems disciplines are at the heart of Canada's knowledge-based economy. They are among the most enabling and pervasive technologies for a wide range of industries and applications impacting Canadian industry, economy and quality of life. CMC is proud to support the Government of Canada in its development and execution of the Innovation Strategy, and to contribute to the development of highly qualified people and programs that will help Canada fulfill its potential as a global leader in innovation.

Appendix 1: Summary of CMC's Recommendations, CMC's Actions, and Expected Impacts

CMC's Recommendations for Canada's Innovation Strategy	CMC's Actions to Support Recommendations	Potential Results/Impact Of Recommendation and/or CMC's Actions
Leverage '4th Pillar' innovation-enabler and multiplier organizations,	-Update CMC's strategic direction to support broader multidisciplinary microsystems-oriented research and development at Canadian universities	-Mobilization of unified action to achieve collective innovation objectives -New microsystems-based applications for increased Canadian leadership in and advancement of diverse industrial sectors (e.g., information, communications, biomedical, transportation, natural resources)
Coordinate investments in 4th Pillar organizations, especially those central to research and technological innovation.	-Actively engage all regions on the effective positioning and delivery of CMC's products and services. -Broaden CMC's partnerships and research funding -Continue linkages of CMC's program with performing sectors of the economy and contributing industrial partners	-Increased impact of research funds -Clusters of world-class microsystems expertise that may be leveraged by Canadian industry for new market opportunities -Increased industry/academic collaboration targeted to the needs of industry, and the application of research with commercial value
Implement broader use of the 'CMC-model'	-Provide support and leadership as implementation organization for initiatives that engender national public/private collaboration in the provision of research support at Canadian universities where association with microsystems is apparent	-Reduced complexity of multidisciplinary microsystems research essential for new innovations across industrial sectors - Increased number and effectiveness of public/private partnerships in R&D -More internationally competitive research opportunities -Development of larger number of highly qualified people -More effective collaboration aimed at improving Canada's international R&D performance rank
Support strategic research and infrastructure in enabling technologies	-Continue to develop the current CMC program; -Introduce additional support for new microsystems and related research areas -Increase contribution to government and industry policy discussions	-Improved return on Canada's research investment –research that adds value to diverse sectors -Increased microsystems research applications that improve quality of life (medical, automotive, environmental, etc.)
Develop a national strategy for microsystems prototype development	-Lead the development of a national microsystems prototype development strategy on behalf of the Government of Canada, to ensure a sustainable approach for accelerated development of highly qualified people	-Increased validity, value and potential application of publicly funded research -Faster time to market and industrial productivity during commercialization of microsystems innovations
Foster collaboration and multidisciplinary research	-Foster national opportunities for multidisciplinary research, collaboration and innovation -Deliver world-class technology that encourages a multidisciplinary and systems-oriented environment -Maintain core competencies for the provision of research support in microsystems, while increasing systems emphasis	-Reduce the complexity of microsystems research -Enable more Canadian scientists for increased productivity and higher volumes of research -Increased and focused development of the skills and experience required by Canadian industry to establish greater global competitive capability
Make innovation at the university /industry interface a priority	-Enable innovation and economic advantage in Canada at the university/industry interface, where the benefits of microsystems research infrastructure are evident.	-Increased commercialization of research by Canadian industry - Increased private sector investment in university research infrastructure and programs -Increased Canadian patents and intellectual property -Increased revenue generation from new applications emerging from research
Improve efficiencies in development of highly qualified people	-CMC's products and services will focus on postgraduate research and training, while facilitating 'systematic trickle down' to pre-post secondary educational programs -Provide support with the specific intent to reduce administrative burdens of professors, and accelerate time to graduation for post-graduate students in the area of microsystems	-Improved attraction and retention of top Canadian talent including professors and researchers -Increased productivity of university professors and researchers focused on new innovations -More rapid deployment of highly qualified people in Canadian industry, for improved industrial and national R&D performance

Appendix 2: Terminology

Biotechnology: The manipulation of biological organisms to make products that benefit human beings. Biotechnology contributes to such diverse areas as food production, waste disposal, technology, mining, and medicine.

Microelectronics comprises the techniques of designing and fabricating small electronic circuits whose key components measure only billionths of a metre in length. Microelectronics is the "structural steel" that supports electronic and photonic systems.

Microfluidics is a branch of physics and biotechnology that studies the behavior of fluids at the microscale and mesoscale, that is, fluids at volumes thousands of times smaller than a common droplet. It also concerns the design of systems in which such small volumes of fluids will be used.

Micromachining: Micro-Electro-Mechanical Systems (MEMS) or Micro-Machining refers to small devices manufactured with dimensions of less than 1000 microns (1 mm) and with feature sizes on the order of microns (0.001 mm). Applications include automotive accelerometers and pressure sensors, inkjet nozzles, fiber optic switching systems, and biomedical instruments.

Microsystems include microelectronics, photonics, optoelectronics, micromachining, microfluidics, embedded software and progressively nano-scale phenomena

Nanotechnology is an area of science and technology where dimensions and tolerances are in the range of 0.1 nanometre to 100 nanometre. It is concerned with materials and systems whose structures and components exhibit novel and significantly improved physical, chemical and biological properties, phenomena, and processes due to their nanoscale size.

Optoelectronics is the science and engineering concerned with electronic devices that convert electrical signals (e.g., telephone) into light (e.g. for transmission over a fibre optic communication system); and from light to electrical signals (e.g., a photo-detector).

Photonics is the technology that underlies the emergence of fibre optic communication systems as a cheap and effective way to transmit nearly unlimited amounts of information at the speed of light through thin strands of glass.

Quantum Computing: A future technology for designing computers based on quantum mechanics, the science of atomic structure and function.