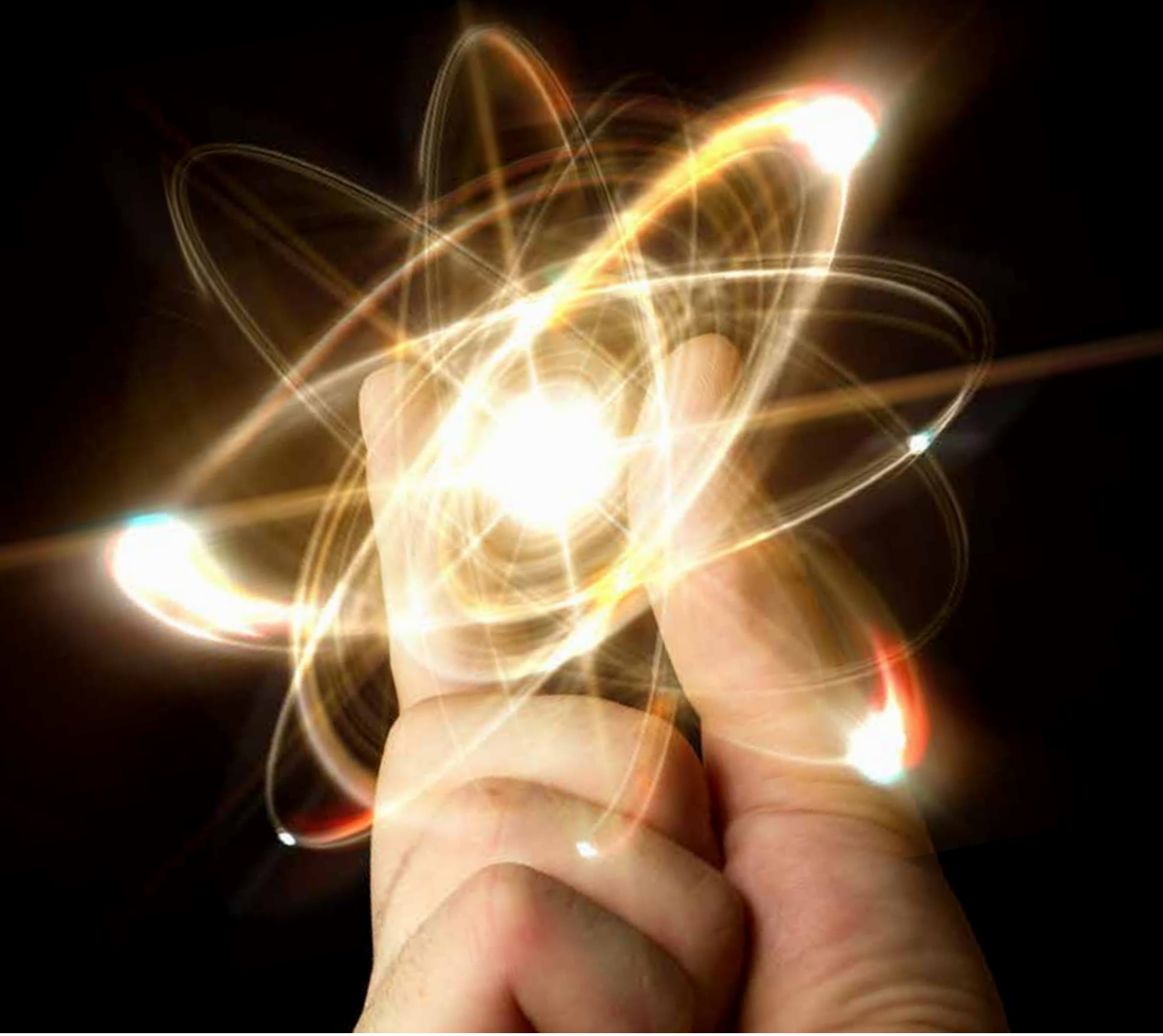

Quantum Canada

Survey overview

March 2017

Canada NRC·CNRC

NSERC CRSNG

CIFAR CANADIAN INSTITUTE FOR ADVANCED RESEARCH | ICRA L'INSTITUT CANADIEN DE RECHERCHES AVANCÉES

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OVERVIEW

Context

Quantum Canada is a national initiative to grow coherence in Canada's vibrant quantum ecosystem.

Canada has invested over $1B in quantum research and development (R&D) over the last decade, and is currently a global leader in this emerging field. As quantum technologies increasingly disrupt current approaches, Canada is well positioned to leverage its strengths in quantum R&D and its industrial base for global research leadership and long-term economic prosperity.

With other countries already executing their national quantum strategies, there is a sense of urgency to seize the opportunity now. Quantum technologies are perhaps the greatest disruptive innovation opportunity for which Canada can have global leadership in the next decade.

Quantum Canada brings together the key quantum stakeholders in Canada, from individual researchers across different sectors, to large companies, and publicly-funded organizations to deliver a cohesive vision for Canada's national interests in quantum, and to ensure that Canada maintains and expands its present-day advantage in this emerging sector.

Quantum Canada is supported by the Natural Sciences and Engineering Research Council (NSERC), lead investor of the academic community and a major investor in academic-industry research partnerships; the Canadian Institute for Advanced Research (CIFAR), which supports global networks of leading researchers doing fundamental research across a broad spectrum of disciplines, with two long-standing programs in quantum science; and the National Research Council of Canada (NRC), the federal government's premier research organization.

The first major deliverable of Quantum Canada is a set of recommendations for a national quantum strategy, scheduled to be released in Fall 2017.

Survey Objectives

The Quantum Canada survey was launched in September 2016 with the following objectives:

- Identify existing Canadian quantum R&D activities, defense activities, and commercialization efforts; and,
- Determine strengths, weaknesses, opportunities, and threats of Canada's quantum ecosystem, including infrastructure, human resources, standards initiatives, defence activities, partnerships, clusters, commercialization, and funding mechanisms.

"As an individual researcher, I want federal funding to hire students with whom to work and to attend conferences with fellow researchers. As a teacher, I want to provide my students with useful skills. As a citizen, I want to contribute to a healthy Canadian economy. To achieve these things, most immediately I need federal research funding and provincial support of universities. However, I also need Canadian industrial research and development to be strong and ways of meeting people working in industry to learn what they do and how I and my students can contribute."

- University professor

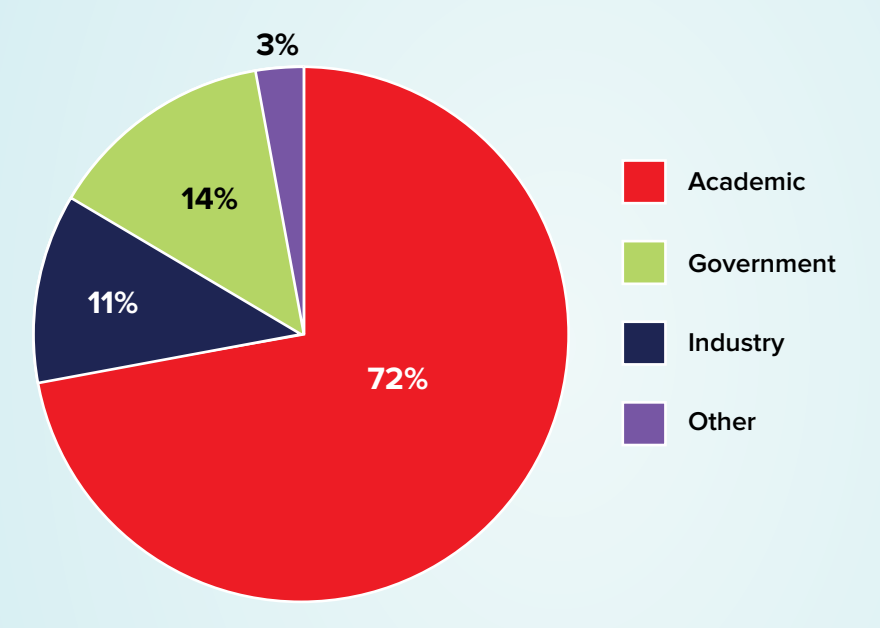


Figure 1: Quantum Canada Survey - Respondents by Type of Organization

Figure 2: Quantum Canada Survey – Map of Respondents

Respondents

- The following survey overview includes data from over 350 respondents.
- Respondents were primarily affiliated with universities, followed by government departments, and industry (Figure 1), likely reflecting the current distribution of the quantum ecosystem.
- Geographically respondents were located in major centres across Canada, demonstrating a vibrant ecosystem coast-to-coast (Figure 2).

SURVEY RESULTS

Priorities

Respondents were asked to rate the level of priority of criteria when selecting, conducting, or supporting quantum activities.

Top responses were:

- Pushing frontiers of science
- Training Highly Qualified Personnel (HQP)
- Opportunities to collaborate with other researchers
- Publications in high-profile journals
- Alignment with available funding
- Impact in Canada (innovation, job creation)
- Anticipating future technology requirements
- Technology commercialization opportunities
- Revenue generation

Resources

Respondents were asked to identify how much they rely on various sources of funding.

- 82% of respondents very strongly rely or strongly rely on federal funding.
- 42% of respondents very strongly rely or strongly rely on provincial funding.
- 18% of respondents very strongly rely or strongly rely on grants from non-Canadian funding agencies.
- 7% of respondents very strongly rely or strongly rely on funding from investors.

Respondents were asked to identify top challenges to achieving their goals.

- 59% of respondents identified federal funding as extremely challenging or very challenging to achieving their quantum goals.
- 60% of respondents identified provincial funding as extremely challenging or very challenging to achieving their quantum goals.
- 32% of respondents identified recruiting skilled human resources from Canada as extremely challenging or very challenging to achieving their quantum goals.

"Having the resources and general research environment to be able to attract top talent (graduate students and postdocs) is always difficult. Relatively limited funding opportunities in Canada have forced me to rely increasingly on funding from US agencies. The result is that I primarily collaborate with researchers in the US, as opposed to Canadian colleagues."

- University professor

"It's important to understand the multi-disciplinary nature of quantum science and technology. Quantum technologies benefit from fundamental research, and strongly rely on sophisticated engineering and development in each of the relevant platforms. For that reason, it is important for Canada to maintain its support for fundamental research in quantum information science, and at the same time invest in national infrastructures to provide support for different quantum technology platforms."

- Researcher

Quantum Research and Technology Development

Respondents were asked to identify the top 3 targets of their research, development, or technology. Top responses were:

- Basic and exploratory research
- Quantum sensing, imaging, and metrology
- Engineering and development of components for quantum applications
- Quantum-secure communications and networks
- Quantum computing and algorithms
- Exploring aspects of materials (modeling, characterization)

Respondents were asked to identify the top 3 quantum platforms involving their work. Top responses were:

- Photons
- Electronic micro/nanostructures
- Atoms and molecules
- Software
- Phonon and/or photonic micro/nanostructures

The top 3 application responses were:

- Quantum sensing, imaging, metrology
- Quantum secure communications and networks
- Quantum computing and algorithms

Respondents were asked to identify in which range of Technology Readiness Level (TRL) their organizations' work in quantum projects resides. The Technology Readiness Level scale is used to capture technology development from basic research to technology proven through successful operations (see figure 3).

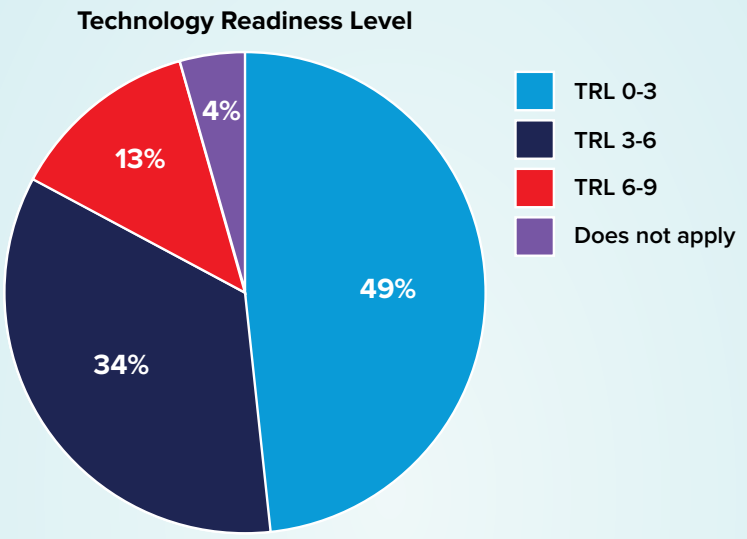
Quantum Opportunities

Respondents were asked to identify how important the following factors were to increase the commercial success of quantum technologies for Canada. Top responses were:

- Training HQP and recruiting HQP
- R&D collaboration between industry and academia
- National infrastructure development
- Financial support for small and medium-sized enterprises (SMEs) and start-ups
- National quantum R&D networks or clusters
- Early engagement of future technology adopters and receptors
- National flagship projects or technology demo projects
- Identification of standards

Respondents were asked to identify which sectors would be most impacted by quantum technologies in the next 10 years. Top sectors include:

- Information and Communication Technologies (ICT)
- Defense and security
- Health and Life Sciences
- Energy, Natural resources and Environment



Data demonstrates a healthy distribution of TRL for an emerging technology. However, SWOT data indicates barriers connecting the work of researchers in lower TRL spaces to industry in higher TRL spaces.

Figure 3: TRL breakdown of quantum technologies

"What is required is a broad strategy that secures investment for the full spectrum from basic research to the development and commercialization of applications with short and long term objectives being addressed. This includes a lifecycle approach to facilities that includes planning, construction, operation, and decommissioning."

- Professor, National Laboratory

"[Canada needs] sufficient funding, identified focused research areas (with high probability of providing game-changing operational capabilities) and the development of collaborative research activities with like-minded allied nations and defense organizations."

- Government of Canada respondent

CANADIAN QUANTUM ECOSYSTEM – SWOT ANALYSIS

Respondents were asked to perform a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the Canadian quantum ecosystem.

Strengths	Weaknesses
Canada delivers excellent scientific research	Limited and/or complex and/or difficult to access funding structures
Canada is home to world-leading researchers; strong academic community	Limited engagement with industry to inform research and increase industry investment
National infrastructure/research facilities	Lack of risk taking/risk aversion
Historic strengths in cryptography, ICT, photonics	Lack of connection between tech providers and problem owners/tech receptors
Links with international research community	Unclear mechanism for commercialization
Community cooperation/collaboration	Distance between centres of excellence – geographically difficult to collaborate
Support from government/existing GoC investment	No national strategy; lack of focus; no long term vision
Opportunities	**Threats**
More collaboration between researchers across Canada	Global competition
Canada is attractive to bring in HQP and professors, and to recruit experts and researchers from other countries	Losing Canadian HQP to other countries; Erosion of Canadian expertise; Brain drain
Opportunities for start-ups and spin-offs from the universities	Slow pace of making decisions/taking action
Global leadership	Insufficient resources and encouragement for researchers to launch spin-offs or start-ups
Training HQP and next generation of technology workers	Administrative and reporting burden on researchers
Military adoption of new technologies/ new defense capabilities	Lack of strategic prioritization
Component development for MNEs	Immigration policies to bring in HQP/students

EMERGING THEMES

Highly Qualified Personnel (HQP)

Training and recruiting HQP is identified as an essential priority when selecting, conducting, or supporting quantum activities, and is also identified as the most important opportunity to ensure Canada's commercial success in quantum technologies. Canada is currently viewed as an attractive destination, home to world-leading facilities and top researchers.

However, work permits, student visas and foreign student tuition requirements can be burdensome. Immigration processes for HQP have been identified as challenging. Canadian companies struggle to offer competitive salaries at the PhD level and top Canadian talent is being recruited by global competitors. Canadian researchers struggle to access the funding they need in Canada and are turning to foreign granting agencies to support their work – allowing other counties to dictate the research priorities of Canadian researchers and to harvest Canadian resources.

Need for National Coherence and Vision

Survey respondents came from universities, government departments, and companies across Canada. While there is undeniable scientific excellence and a general enthusiasm for the quantum opportunity, there is no clear vision for Canada's interests in quantum. A lack of national focus was identified as a weakness of the current Canadian quantum ecosystem, and global competition was identified as the number one threat. In addition, 44% of respondents identified "global competition" as extremely challenging or very challenging to achieving their quantum goals.

Respondents identified a "national quantum R&D network/cluster" as an extremely important factor to the success of quantum technologies for Canada. A "national network or flagship program" was also highlighted as an important factor.

The community is not only asking for a national strategy to address challenges and gaps and mitigate the threat of global competition, but also for a vehicle to increase collaborations and ensure that the scientific excellence from coast-to-coast is fully leveraged.

Funding

Most researchers rely on federal and provincial funding for their work, and also identified access to these types of funding as a major hurdle.

The Canada First Research Excellence Fund is a tri-agency initiative of the Social Sciences and Humanities Research Council, the Natural Sciences and Engineering Research Council and the Canadian Institutes of Health Research. Within the NSERC mandate CFREF has allocated a combined $200M in the past 2 years to Sherbrooke University, the University of British Columbia, and the University of Waterloo for advances in quantum research, quantum materials, and quantum technologies.

The need for various types of funding was identified, with the majority of researchers highlighting a need for human resources (students, post-docs). The administrative burden in applying for funding was also noted as a challenge, with Canadian processes considered lengthier than US or European processes. A lack of funding in Canada drives researchers to apply for grants from foreign agencies, allowing other countries to attract and harness Canadian resources for their own purposes.

Respondents highlighted a need for strategic allocation of funding, from basic research to financial support of startups and SMEs. Funding was also seen as a vehicle to enable collaboration between Canadian researchers for innovation impact in Canada.

"[Canada needs] a stronger effort in recruiting more talent, more emphasis on discovery and science, with more public relations for scientists and their work in Canada. We need to be stronger in advertising and showcasing Canada's quantum science agenda, both nationally and internationally. A stronger and more streamlined effort in collaboration with academia, both nationally and internationally. This will quickly help restore Canada's reputation as a world leading research institution and attract more talent, both domestically and internationally."

- Federal researcher

"Global competition has made a difference for us in that very strong quantum programs are thriving in Australia, the UK, parts of the EEC, and the US."

- Industrial respondent

R&D Collaboration

Researchers value collaboration, and opportunities to collaborate ranks high as a decision influencer when selecting research projects. The researcher community is generally close, but opportunities are limited due to large distances between centres of excellence and competing funding priorities.

Increasing collaboration is identified as an important factor for innovation and commercial success of quantum technologies. Additional factors include "National flagship projects or technology demo project" and "National quantum R&D networks or cluster." Four distinct types of collaborations could be explored further.

"Success is a personal measure to me but in a standard societal way, we need unbiased vision, fairness, and coherent thinking to see what Canada wants out of quantum technologies. Spending money is easy but how, when, and who does what is much more important."

- Researcher

"[To be more successful I need] funding and good collaboration with Universities to develop products that can generate revenue. This is an amazing field with amazing potential. The goal is to develop products that will be used in this area – at least for my company."

- Industrial respondent

1. R&D collaborations within Canadian academic community

- R&D community is strong and active from coast-to-coast
- Previous $1M investment in Quantum Works no longer exists as national network
- Mechanism required to provide strategic direction and financial support for collaborations
- NSERC and CIFAR working as conveners of the research community

2. R&D collaborations with defense and government early adopters

- DRDC, CSE, and CSA are interested in access to new technology and the R&D community
- NRC working as a catalyst to link R&D community with government adopters

3. R&D collaborations with industry

- Future technology adopters are starting to invest in quantum (e.g. banking, energy/environment/ resources, medical) but unclear about providers
- Mechanism required to connect tech developers and future adopters; fund R&D, enhance communication, increase understanding of future requirements, improve technology handoff
- NSERC currently works with 3,600 companies who contribute $200M annually

4. R&D collaborations internationally

- CIFAR well positioned to advise on best mechanisms to support engagement
- Threat of global competition can be partially mitigated with increased international collaborations and by giving Canadian researchers access to new platforms where they can advance their research for mutually beneficial outcomes

"Top talent from Canada in application areas relevant to our technology, e.g. machine learning, are being heavily recruited by global organizations. Our ability to match compensation offers by the big players is limited. When we do find global talent that can fill requirements of our highly skilled roles, especially at the PhD level, we are frustrated by the hoops required to bring them into Canada, and the time limitations set on their stay in Canada."

- Industrial respondent

For more information, please contact **QuantumCanada@nrc-cnrc.gc.ca**