NRC·CNRC

Evaluation of the Security and Disruptive Technologies Research Centre

Office of Audit and Evaluation

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Conseil national de recherches Canada

Canada

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Abbreviations

AEP
Advanced Electronics and Photonics Research Centre

BNNT
Boron nitride nanotubes

CBI
Research centre, branch or NRC IRAP

DG
Director general

DND/DRDC
Department of National Defence (parent agency)/Defence Research and Development Canada

EDI
Equity, diversity and inclusion

FWCI
Field-weighted citation impact

GBA Plus
Gender-based Analysis Plus

HQP
Highly-qualified personnel

IP
Intellectual property

JASLab
Joint Attosecond Lab

JCEP
NRC-University of Ottawa Joint Centre for Extreme Photonics

KPI
Key performance indicator

MINK
Molecular inks

NANO
Nanotechnology Research Centre

NPO
National Program Office

NRC
National Research Council Canada

NSERC
Natural Sciences and Engineering Research Council of Canada

NQS
National Quantum Strategy

OGD
Other government department

PDF
Post doctoral fellow

PRC
Peer Review Committee

QSP
Quantum Sensors Challenge program

RCAB
Research Centre Advisory Board

RO
Research officer

SME
Small and medium sized enterprise

SDT
Security and Disruptive Technologies Research Centre

SWCNT
Single-walled carbon nanotube

TRL
Technology readiness level

Introduction

The evaluation of the National Research Council's (NRC) Security and Disruptive Technologies Research Centre (SDT) covered a 5-year period from 2017-18 to 2022-23. It was carried out in accordance with the NRC Department Evaluation Plan and the Treasury Board Policy on Results (2016). The research centre was last evaluated in 2017-18.

This report begins by providing a profile of the research centre. It then presents findings on SDT's:

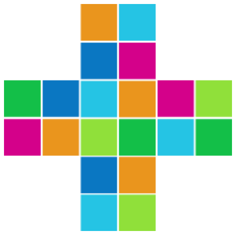
- scientific excellence and ability to advance knowledge in quantum science and technology and advanced materials science
- contributions to business innovation and government policy solutions; relevance of the research focus
- engagement with clients, collaborators and stakeholder
- and capacities, competencies and facilities

Following the evaluation findings are 3 recommendations for improvement to SDT.

In this report, you will see the following symbols:

This symbol indicates information that is useful to know to help understand the findings.

This symbol indicates a quote that helps illustrate or support the main findings.



This symbol indicates information that supports equity, diversity, inclusion and Gender-based Analysis (i.e., factors that illustrate how diverse groups may experience policies, programs and initiatives).

Source(s): These are the methods from which the findings are drawn. The sources are listed at the bottom of each page.

Evaluation approach

Approach

This evaluation used a mixed-methods approach, incorporating qualitative and quantitative data from several lines of evidence including a peer review. This allowed for triangulation and complementarity of the evaluation findings. In addition, a Gender-based Analysis Plus (GBA Plus) lens was applied to the evaluation.

Methods

The evaluation included:

- document review (incl. bibliometrics, labour market reports)
- data analysis (administrative and performance data)
- key informant qualitative research: internal interviews (n=15), external interviews (n=20), online questionnaire (n=22)
- peer review with national and international experts (n=8)

Note on scope

In November 2022, the director general (DG) of SDT assumed leadership of the Advanced Electronics and Photonics Research Centre (AEP) (minus the Canadian Photonics Fabrication Centre) and the Nanotechnology Research Centre (NANO), in addition to SDT. This change was made to identify opportunities to bring the capabilities of the 3 research centres closer together, while increasing the impact and synergies of the research teams and facilities.

On September 25, 2023 it was announced that the 3 research centres would be brought together under the new Quantum and Nanotechnologies Research Centre to be launched on April 1, 2024. This reorganization was not included in the scope of the evaluation.

Evaluation questions

1. To what extent is the research centre leading in scientific excellence and advancing knowledge in quantum science and technology[1] and advanced materials science?
2. To what extent is the research centre contributing to business innovation and government policy solutions (e.g., economic, social, and security)?
3. Is the research centre focussed on the right areas to ensure relevance in the Canadian quantum science and technology and advanced materials science ecosystems?
4. Has the research centre engaged with appropriate clients, collaborators and stakeholders in strategic and effective ways?
5. To what extent does the research centre have the capacities, competencies, and facilities to achieve its objectives moving forward?

[1]Quantum science and technology includes quantum photonics and quantum electronics.

Appendix A contains information on the methods and Appendix B includes limitations. Appendix C contains biographies of Peer Review Committee (PRC) members.

Profile

Security and Disruptive Technologies Research Centre (SDT) specializes in quantum science and technology and advanced materials science. SDT works with a wide range of clients and collaborators from numerous sectors, and other NRC research centres and programs to build new technology platforms applicable to a range of industries. The research center hosts the Quantum Sensors Challenge program (QSP) and is a key collaborator in the NRC–University of Ottawa Joint Centre of Extreme Photonics (JCEP).

Research centre overview

SDT focusses on quantum science and technology (e.g., photonics, attosecond science) and advanced materials science (e.g., security materials technology).

Vision (2019-2024)

SDT aims to be a world leader in foundational quantum science and technology and materials science. The research centre identifies emerging technology trends and translates these into disruptive technology platforms of strategic importance to build a better Canada and world. The research centre's mission is to:

- Advance **scientific knowledge** through world-leading foundational research in quantum physics and materials science.
- Deliver **policy solutions** for government related to disruptive innovations in quantum technologies and nanomaterials to strategic government partners.
- Mobilize the scientific, government and industry research community to support **business innovation** through research collaboration, intellectual property (IP) generation, workshops, roadmaps, technology projects and symposia, in order to provide social, economic and environmental solutions for Canada.

5-year strategic priorities (2019-24)

1. **Support scientific world leadership by select emerging physical science research fields:** SDT aims to be a world leader in the emerging field of ultrafast quantum photonics and in next generation designer nanomaterials chemistry.
2. **Sustain a culture of entrepreneurial research excellence at the bench level:** the research center intends to have a research culture that nurtures entrepreneurial creativity and produces both world leading science and disruptive technology ideas.
3. **Build sustainable funding to support research excellence:** SDT plans to have strong partnerships with government organizations, universities and industries whose missions intrinsically require world leading science and disruptive technology.

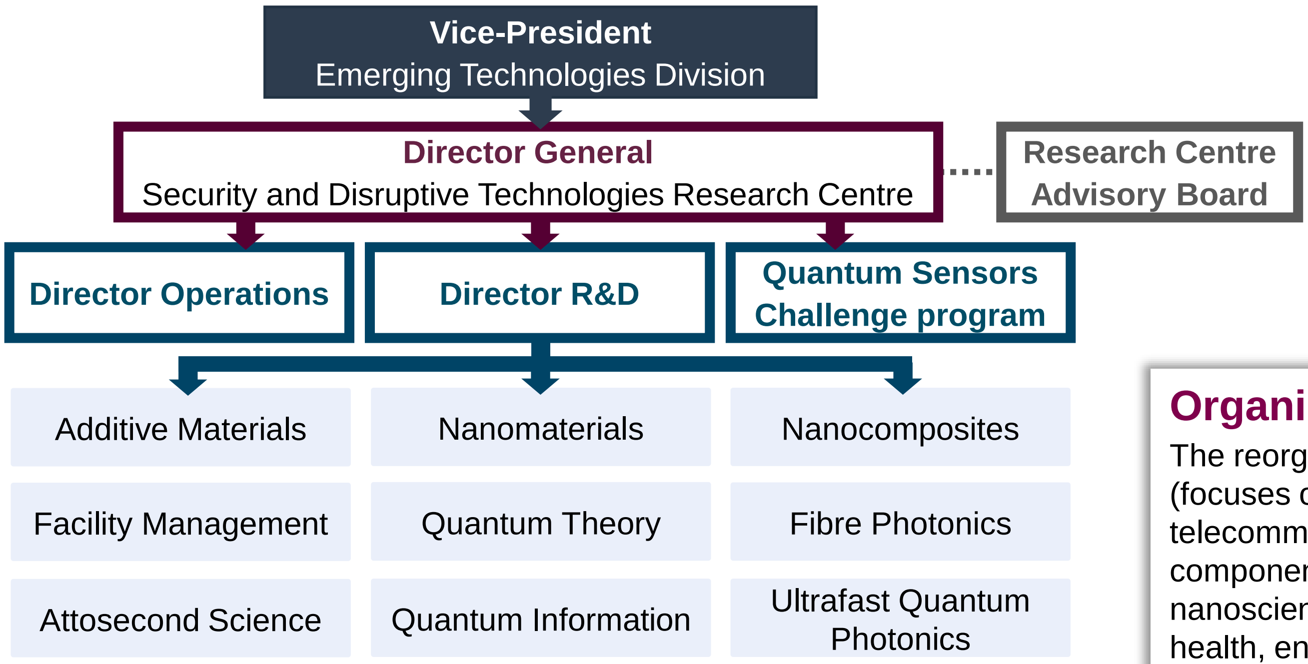
During the evaluation, strategic planning for 2024-2029 was underway; thus, the new vision and priorities are not reflected here.

Source(s): document review

Organizational structure

SDT is within the NRC's Emerging Technologies division. The DG of the research centre receives strategic advice from an independent Research Centre Advisory Board (RCAB). Eight (8) research teams and one (1) facility management team are led by the director of R&D and supported by the director of operations.

Figure 1. SDT organizational structure (2022-23)



Organizational change

The reorganization of SDT to include AEP (focuses on the application of photonics to telecommunications and sensor components), and NANO (develops nanoscience platforms for applications in health, environment and future technologies) occurred during the evaluation period. The impact and synergies of the teams and facilities were not a focus of the evaluation.

Source(s): data review

Human resources

As of March 31, 2023, SDT had a total of 109 staff with the largest proportion being research officers (40%).

- **44** research officers
- **15** technical officers
- **13** research council officers (researchers)
- **26** students
- **6** admin and corporate (incl. 1 research council officer)
- **5** management

SDT improved its representation of women and racialized persons over the evaluation period; however, the percentages remain below the labour market availability

Employment equity group	2017-18 labour market availability[2]	2022-23 labour market availability[2]
Women	65%	80%
Racialized persons	70%	97%
Indigenous peoples	*	*
Persons with disabilities	*	*

[2] Labour market availability is derived from the 2016 Census and the 2017 Canadian Survey on Disability. A result of 100% means that the percentage of staff in the equity group equals the labour market availability.

* Figures representing 5 staff or fewer are redacted due to self-identification confidentiality rules.

Gender-based Analysis Plus (GBA Plus)

GBA Plus is an analytical process, used by the Government of Canada, which provides a rigorous method for the assessment of systemic inequalities, and a means to assess how diverse groups of women, men, and gender diverse people may experience policies, programs and initiatives.

When it comes to SDT research impacts on diverse groups of people, key informants indicated that the research and technologies developed by the research centre are generally at a low technology readiness level (TRL) and have universal applications, not targeting any specific group.

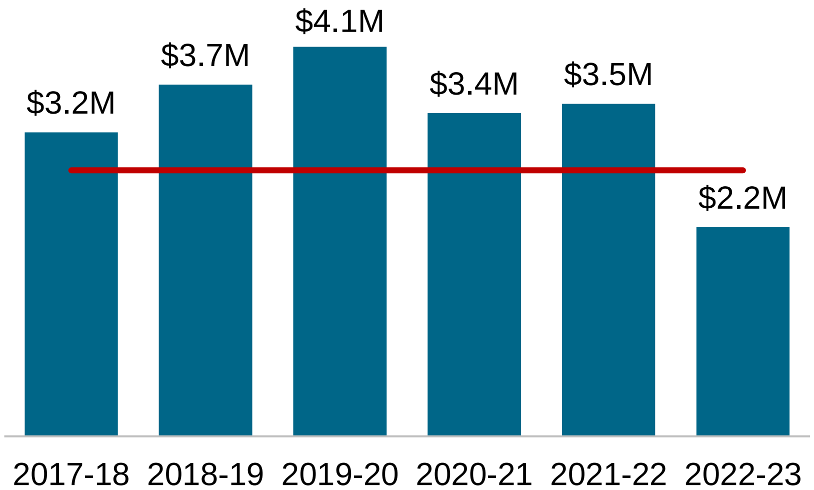
Source(s): data review

Financial resources

Average annual budget: $13.3 million

Average annual revenues: $3.4 million

Figure 2. With the exception of 2022-2023, revenues exceeded the target over the evaluation period



Although not counted as revenue, SDT leveraged funds from supplementary sources, starting in 2019-20. The main source was a vote transfer from the Department of National Defence (parent agency)/Defence Research and Development Canada (DND/DRDC) in the amount of $5.8 million over 3 years to support a partnership in quantum technologies.

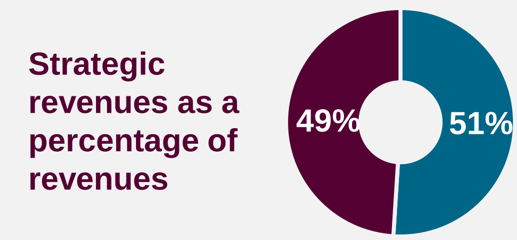
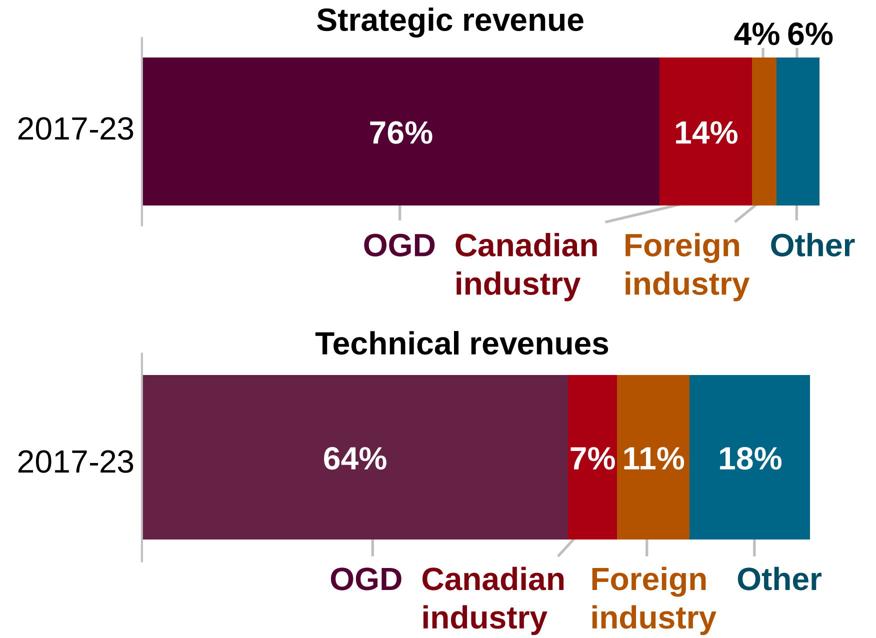


Figure 3. Largest percentage of both strategic research and technical service revenues were from OGDs



Note: there was no revenue expected or earned from QSP projects.

Source(s): data review

Facilities

SDT operates out of research facilities in 2 locations in Ottawa, Ontario:

100 Sussex Drive

- fibre photonics
- Joint Attosecond Lab (JASLab)
- advanced materials labs
- ultrafast quantum photonics facility

1200 Montreal Road

- advanced materials labs
- nanomaterial production
- quantum information facility

M-50: quantum information labs

M-23A: plasma reactor, nanomaterial fabrication

M-12: chemistry labs, sensors, electronic materials

Source(s): document review

Quantum Sensors Challenge program and JCEP

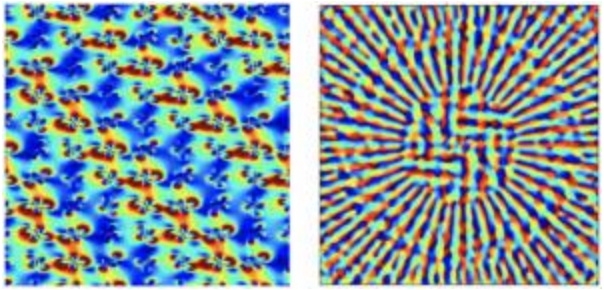
The Internet of Things: Quantum Sensors Challenge program (QSP) was approved in May 2021. It is hosted and managed by SDT and administered by the National Program Office (NPO). The goal of the program is to enable the development of revolutionary sensors that harness the extreme sensitivity of quantum, through collaborative research and development.

The program's objectives are to keep Canada at the forefront of science in quantum sensors; enable transition and commercialization; and play a role in a national approach to quantum technologies.

The QSP aims to advance scientific and technical knowledge by providing grant and contribution funding under three main themes:

- **Quantum photonics for sensing applications**
- **Semiconductor-based quantum sensing systems**
- **Quantum sensing for next generation metrology and standards**

The NRC-University of Ottawa Joint Centre for Extreme Photonics (JCEP) is a joint undertaking between the NRC and the University of Ottawa. Launched in Ottawa on January 31, 2020, JCEP was established to amplify the research efforts of both the NRC and the University of Ottawa in the area of photonics and is an innovation hub for extreme and quantum photonics research.



JCEP Project from Dr. Vampa and Dr. Ramunno: Snapshot of a large-scale simulation of a plasmonic metasurface (left, only a small section is shown) designed to create a high order orbital angular momentum state at the third harmonic (right).

Source: JCEP Projects (extremephotonics.com)

QSP project selection and annual reviews include **GBA Plus considerations**. At project close out, Challenge programs examine how differences in gender, race and identify affected the outcomes of their projects.

Client and collaborator profile

SDT works with a range of clients and collaborators from numerous sectors and NRC research centres and programs.

SDT collaborates with academia, industry, OGDs, foreign governments, other NRC research centres, other NRC Challenge programs and NRC Ideation Fund Initiatives. Examples of client and collaborators include:

Academia

- Canadian universities (e.g., Ottawa, Toronto, Polytechnique Montréal, McGill)
- International universities (e.g., Max Planck, Imperial College, Ludwig Maximillian)

Industry

- small and medium sized enterprises (e.g., Logistik Unicorp, Fibos, Collins Aerospace, Raymor, Tekna Systems, e2ip, SBQuantum, evolutionQ Inc., Xanadu Quantum Technologies)

OGDs

- DND/DRDC, Communications and Security Establishment, the Canadian Space Agency, Natural Resources Canada, Health Canada

Foreign governments

- Defence Science and Technology Organisation (Australia), Korea Institute of Science and Technology, National Institute of Standards and Technology (United States)

NRC research centres, collaboration centers and Challenge programs

- other NRC research centres: Aerospace, Automotive and Surface Transportation, Digital Technologies
- collaboration centres: JCEP, NRC–University of Toronto Collaboration Centre for Green Energy Materials
- Challenge programs: High-throughput and Secure Networks, Materials for Clean Fuels, Aging in Place

NRC Ideation Fund Initiatives

- New Beginnings: collaborations with grant and contribution recipients ($2,500 and under)

Source(s): document review, key informant qualitative research

Scientific excellence

The extent to which the Security and Disruptive Technologies Research Centre (SDT) is leading in scientific excellence varies across the research centre. Some activities, particularly in quantum science and technology, were world-leading; while others, in advance materials, played a supportive role. SDT has been recognized for scientific leadership and has advanced scientific knowledge, exceeding publication targets and publishing in prestigious journals. SDT's field-weighted citation impact (FWCI) was positive but lagged behind those of the NRC overall and Canada. SDT exceeded intellectual property (IP) targets, particularly in the advanced materials area.

Scientific leadership

SDT has been recognized for scientific leadership through its national and international awards, and invitations to committees and conference presentations.

SDT received international scientific recognition

SDT has been recognized for scientific leadership through awards and conference participation, particularly in quantum science and technology.

Between 2017-18 and 2021-22, the research centre received 15 awards and recognitions (13 national and 2 international) and 2 NRC Intellectual Property Achievement Awards.

Dr. Paul Corkum shared the 2022 Wolf Prize in Physics

Dr. Chantel Paquet received the Women in Flexible and Hybrid Electronics Science, Technology, Engineering and Mathematics Award (at the Canadian Printed and Flexible Electronics Symposium 2022)

SDT demonstrated conference and committee leadership

SDT staff presented at 46 national or international conferences. They participated in 32 committees (13 Canadian, 19 international), including at least 15 as leads and organizers, and 3 as experts:

- ambassador to Korea Institute of Science and Technology
- expert for technical committee, TC229 nanotechnologies for the International Standards Organization
- steering committee and project lead for the Versailles Project on Advanced Materials and Standards

Source(s): document and data review, key informant qualitative research, PRC

Scientific leadership

The extent to which SDT is leading in scientific excellence varies. Some activities, particularly in quantum science and technology, were world-leading; while others, in advanced materials, played a supportive role.

Quantum science and technology demonstrated world leadership

The Peer Review Committee (PRC) noted that SDT demonstrated scientific excellence and leadership in Canada through its involvement in the National Quantum Strategy (NQS). They recognized SDT as world-leading or having strengths in attosecond science, ultrafast processing for photonics and germanium spin qubits.

Clients and collaborators also indicated that SDT is a national and international leader in its niche areas. Their views were supported with examples of leadership in quantum dot technology, quantum communication, and attosecond science.

SDT's foundational research in quantum theory and computation allowed the research centre to be recognised as a world leader in simulation of new ultrafast techniques and quantum communication and information applications, and increased SDT's reputation as a sought-after collaborator.

Quantum key distribution project

This SDT project put Canada at the forefront of quantum communications by establishing the longest intra-city free-space quantum communication link in the world.

Advanced materials research was supportive and maintained authority

The work on volumetric 3D printing was identified by the PRC as leading work in the advanced materials science group, whereas other elements of this section were felt to be more supportive rather than innovative. For volumetric 3D printing, the PRC indicated that SDT had established a valued presence in a relatively short time. They also noted that SDT's carbon nanotube researchers have maintained authority in the field. SDT advanced the purification process for single-walled carbon nanotubes (SWCNT), and supported innovation through Challenge programs and Small Teams initiatives.

Volumetric 3D printing is a new type of light-based 3D printing, whereby light is projected into a rotating vial of photocurable resin. This allows for printing of the entire volume at once.

Source(s): document and data review, key informant qualitative research, PRC

Advancing knowledge

SDT contributed to the advancement of knowledge in quantum science and technology, and advanced materials.

Demonstrated scientific excellence and advanced scientific knowledge

Clients and collaborators indicated that involvement with SDT resulted in publications, new partnerships, discoveries or achievements, and innovation capabilities within academia.

SDT quantum science and technology has allowed partners to explore low-TRL and experimental hypotheses, leading to new experimental ideas, further research, and publications. Key informants cited advancements in areas such as quantum dots, attosecond science, quantum sensing, and the development of single photon quantum sources.

JCEP is a collaboration that advances scientific knowledge. It maintains strong collaboration with the University of Ottawa and attracts highly-qualified personnel (HQPs), including post-doctoral fellow (PDFs), and students. The NRC Principal Research Officer and Co-Director of JCEP has an excellent reputation and has developed additional relationships.

In advanced materials science, clients and collaborators benefited from the technologies and materials developed by SDT in areas such as boron nitride nanotubes (BNNT), carbon nanotubes, printable electronics, and molecular inks (MINK).

Key projects demonstrated knowledge advancements

Quantum science and technology projects

- A quantum dot project demonstrated a "plug-and-play" single photon source, which could impact quantum information technologies and secure communications.
- A project linking solids and gases provided the opportunity for a large field of potential applications (e.g., new approaches to imaging electric fields in semiconductor circuits), and literature on the topic continues to cite this research.
- A project that explored the speed limit where magnetic domains can be reversibly switched and achieved the production and characterization of the THz pulses is being applied to semiconductors to enhance the speed of computers to operate faster.

Advanced materials projects

- A project developed the ink formulations and conditions for the fabrication of in-mold electronics for surfaces with integrated electronic devices (e.g., lights, touch sensors). SDT continues to work with private industry to enhance the functionality (e.g., sensors, antennas) and the human-to-machine experience in sectors such as automotive and aerospace.

Source(s): document and data review, key informant qualitative research

Advancing knowledge

The Quantum Sensors Challenge program advanced research and collaboration, but caused internal resource challenges

External key informants had positive views on the Quantum Sensors Challenge program (QSP), indicating that it advanced high-risk, high-reward research, and allowed for collaboration between the research centre and partners.

Some NRC staff, however, indicated that staff time shifted to QSP projects, leaving less time for revenue-generating projects (which contribute to SDT's budget).

The SDT budget generally includes an amount to be received through revenues. If SDT does not meet its revenue target, it is required to seek out supplementary funds or reduce its spending to balance its budget.

In 2022-23, to support knowledge advancement, SDT strategically leveraged funding from DND/DRDC, for a partnership in quantum technologies, and sought co-investment and in-kind contributions from other collaborators. It is expected that the DND/DRDC funding will continue to the end of 2025-26.

Although **GBA Plus considerations** are built into the QSP project selection process, due to the early stages of projects, it remains to be seen how projects might advance outcomes for specific groups.

Factors that contributed to advancements in scientific knowledge:

- SDT's high-quality researchers
- engagement and ability to connect academia, government and industry
- a management approach that provides flexibility to researchers and long-term investment in science
- access to advanced facilities

Factors that hindered advancements in scientific knowledge:

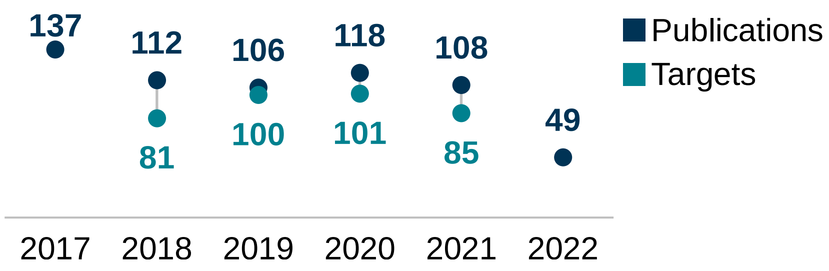
- the need for SDT to generate revenues while simultaneously focusing on scientific excellence, and Challenge and Cluster Support projects
- increased paperwork in applications for NRC funding for students and industrial collaborators
- NRC reporting requirements for external clients and collaborators
- 2-year delay in the installation of the NRC's high-performance computing cluster within SDT

Source(s): document and data review, key informant qualitative research

Advancing knowledge: publications

SDT produced a total of 630 publications over the evaluation period, exceeding its targets and publishing often in prestigious journals.

Figure 4. Between 2017 and 2021 (calendar years) SDT publications decreased, however it consistently exceeded its targets



Note: no target was available for 2017. For 2022, only a partial count of publications was available at the time of the analysis. The publication target for SDT was lowered in 2021 because of the effects from COVID-19.

SDT indicated that the decrease in publications, over the evaluation period, was due to researcher retirements, effects from the pandemic, and revenue-generation efforts.

COVID-19 contributed to lower levels of publications as experimental work slowed, pre-pandemic data was used in prior publications, and the numbers of students fluctuated. Other impacts included project delays (due to limited access to the labs) and delays in procurement and hiring.

SDT published in prestigious journals

- 20% of the research centre's publications were in Nature Index journals, well above the NRC's 8% figure
- SDT published most often in the journal, Physical Review A (5% of total publications, 31 articles total)
- Publications in Nature Photonics (n=7) and Science (n=5) were highly cited (average number of citations 24.1 and 56.8 respectively)

A large proportion of Canadian publications were in 2 notable areas:

- 39% in the area of attosecond science (quantum science and technology)
- 59% in the area of boron nitride nanotubes (advanced materials science)

Tracking the number of new granted patents citing NRC publications provides a means of identifying the degree to which NRC research is linked to potential business innovation and economic impacts. **SDT publications are cited in patents at a higher rate** (per 1,000 publications) than the NRC (30.2 vs. 25.8).

Source(s): document and data review, key informant qualitative research

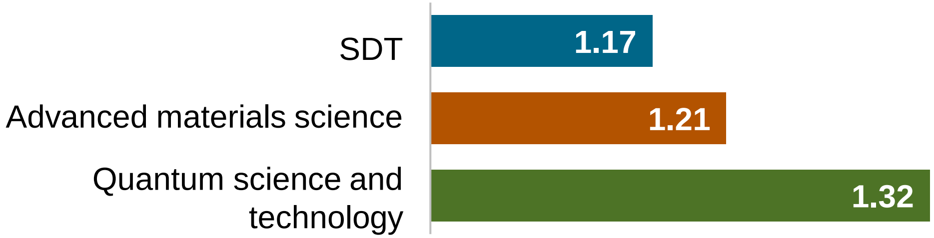
Advancing knowledge: citations

SDT's field-weighted citation impact (FWCI) was in a positive position, but was below the NRC and Canadian averages.

Figure 5. SDT's FWCI was in a positive position for the calendar years 2017-22, but was below the averages of NRC and Canada

The **FWCI** is a normalized citation metric that indicates how the number of citations received by a research centre's publications compares with the average number of citations received by all other similar publications. An FWCI of 1.00 means that the publication performs just as expected for the global average; more than 1.00 means that the publication is more cited than expected according to the global average.

Figure 6. SDT's advanced materials science and quantum science and technology are above the overall SDT FWCI



Separate FWCIs[3] were based on manual categorization of SDT's publications. The overall SDT FWCI (at 1.17) is below the FWCI for advanced materials science (at 1.21) and the FWCI quantum science and technology (at 1.32).

The number of publications in this analysis was about half (303) of the research centre's total publications (630). This means that only half of SDT's publications could be manually categorized to its 2 major areas of research, as there is no subject classification precise enough to automatically classify the publications.

[3] The field-weighted citation impact (FWCI) for advanced materials was computed on a very low number of publications (n=62) and should be treated with caution. This result may be due to SDT's advanced materials higher focus on patenting and lower focus on publishing.

It is noted that over the evaluation period, SDT produced 20 publications and conference presentations that were not included in the FWCI as they do not count as publications in Scopus.

Source(s): document and data review

Intellectual property

Involvement with SDT led to new discoveries and innovations for clients and collaborators. As well, SDT's patent applications increased significantly over the evaluation period, surpassing its target.

Patent applications far exceeded goal

Clients and collaborators indicated that involvement with SDT resulted in increased research and development in their organizations, and advanced or accelerated technology development.

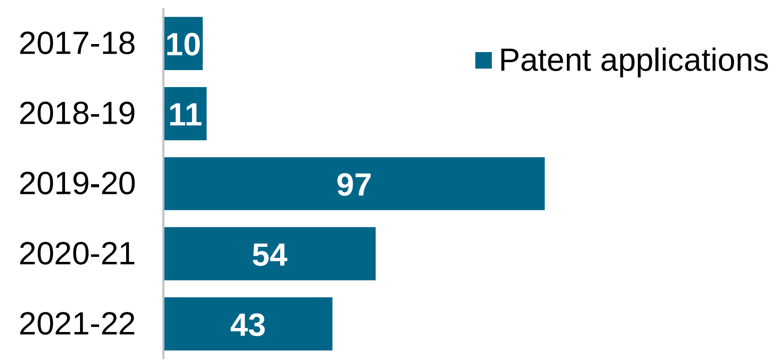
SDT's count of patent applications filed, over the 5-year evaluation period, was 215, far exceeding SDT's Strategic Plan 2019-24 target of 10 to 14, annually. The large number of patent applications in 2019-20 was due to single patent applications being filed in multiple jurisdictions across the globe.

The PRC noted that SDT lacks direction with respect to its patenting and felt that the focus on revenue generation could be a barrier for strategic investment and high-risk/high-return research, especially in the advanced materials area.

Examples of licences or co-ownership in the advanced materials science area include:

- MINK patents for fine line printing and in mold electronics
- a non-exclusive license ($2.75 million) to access to conjugated building block (with a large multi-national)
- patents for fiber Bragg grating technology
- BNNT synthesis via a plasma reactor

Figure 7. SDT patent applications[4] increased significantly in 2019-20



[4] "Patent applications" indicates the volume and geographic reach of the NRC's patenting activities. It is the sum of patent applications filed with the Canadian Intellectual Property Office, various foreign national intellectual property offices, and under the Patent Cooperation Treaty, and Provisional Applications filed with the United States Patent and Trademark Office.

Source(s): document and data review, key informant qualitative research, PRC

Economic and social impacts

Security and Disruptive Technologies Research Centre (SDT) has expanded its connections with industry and moved products up the technology readiness level (TRL) ladder to commercialize them. These efforts had cascading impacts on businesses as they hired new staff and increased revenue, but the scale of these impacts was not quantifiable.

SDT made a significant contribution to the development of the National Quantum Strategy (NQS) and supported government priorities, mainly through Challenge programs. Beyond this, SDT's impact on government policy priorities is not well quantified. Connections to Government of Canada central themes such as sustainable development (e.g., green economy and move to net zero emissions) and Indigenous engagement are not evident in SDT's work.

Contributing to business innovation

SDT has made strides to further connect with industry since the last evaluation. For advanced materials, in particular, patenting and technology transfer have been the focus in order to support businesses to commercialize in innovative areas. Work with SDT has enabled industry clients to hire new staff, attract talent, increase revenues, and develop scalable processes.

Compared with the previous evaluation, connections with industry partners expanded during this evaluation. However, the number of projects decreased partially due to larger projects with multiple clients.

2013-17 evaluation		2018-22 evaluation
65	Industry clients	76
110	Projects	91

Key informants believed that SDT has contributed significantly to innovation capabilities within Canadian industry

The Research Centre Advisory Board (RCAB) 2021 annual report noted that the NRC has an important role to play in talent development and job creation. SDT has advanced these goals for its clients who reported that their work with SDT has resulted in their ability to hire new staff, attract talent, and increase revenues. These effects, however, could not be quantified.

Access to facilities for low-TRL research has allowed clients to develop projects and improve technologies and processes.

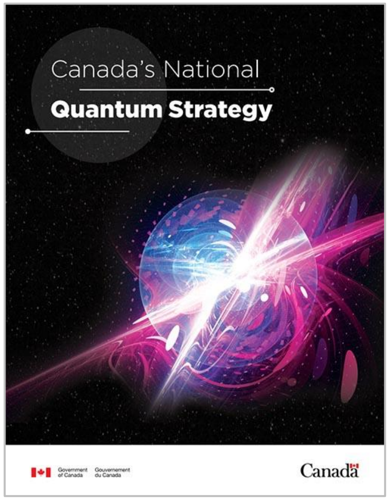
Project outcomes include business innovation, development of IP, product commercialization, and new hires

Work on single-walled carbon nanotube (SWCNT) synthesis via plasma reactor and SWCNT purification resulted in commercial products. In the boron nitride nanotube (BNNT) commercialization area, new IP was developed related to a scalable purification process. The industry partner hired new talent, established an international reputation, and developed multiple BNNT products for sale. The PRC commented that SDT is setting some megatrends with its BNNT work.

Source(s): document and data review, key informant qualitative research

Contributing to government policy solutions

SDT made a significant contribution to the development of NQS and implementation of the corresponding QSP.



Source: Canada's National Quantum Strategy

SDT provided science-based policy solutions to government

The Peer Review Committee (PRC) indicated that SDT made a significant contribution to the Canadian NQS and the development of the QSP. They felt that SDT has built a national ecosystem in quantum, which aligns national and international strategies in an effective manner.

SDT leadership team worked with Innovation, Science and Economic Development Canada throughout the development of the NQS (published in January 2023), which also included the involvement of academia, industry, not-for-profit organizations, other government departments, and provincial and international representatives.

SDT management attended meetings, provided feedback and advice on the strategy, assisted in finalizing text of the strategy's pillars (research, talent and commercialization), and identified areas for further investment. The NQS included top-up funding for QSP and new funding for the Applied Quantum Computing Challenge program.

The DG of SDT is the co-chair of the interdepartmental DG Quantum Coordination Committee and the lead of the NRC's Quantum Strategy, which will become a pillar of the upcoming NRC 5-year strategy (2024-29). The SDT DG also attends the interdepartmental Assistant Deputy Minister Quantum Coordination Committee meetings to support the implementation of the NQS.

To strengthen Canada's leadership role, the federal government announced $360 million in 2021 for the NQS, which included close to $25 million for **expansion of the QSP**. The NQS aims to:

- make Canada a leader in the development, deployment and use of quantum computing hardware and software
- ensure the privacy and cyber-security of Canadians in a quantum-enabled world
- enable the Government of Canada and key industries to be developers and adopters of new quantum sensing technologies

Source(s): document and data review, key informant qualitative research, PRC

Contributing to government policy solutions

SDT supported government priorities, contributed to science-based policy solutions, and has the potential to contribute to future policy initiatives; however, these contributions were not well quantified. Government of Canada central themes such as sustainable development and Indigenous engagement are not evident in SDT's work.

Supports several government priorities and has the potential to contribute to future government policy direction

The advanced materials team supported several government priorities through Challenge programs such as Aging in Place and Artificial Intelligence for Design. There were, however, 2 advanced materials projects notable for their policy contribution potential:

- In the SWCNT project, the resulting material has been used for the NRC's Aging in Place Challenge program.
- A project with Natural Resources Canada on pipeline sensors resulted in a patent application being filed and may provide future policy innovation through regulation in the oil and gas sector. It has potential to support an environmentally sustainable oil distribution network through a reliable leak detection system.

Revenue from OGDs made up about 77% of SDT's total from 2017-18 to 2022-23, and about half of OGD clients interviewed indicated that, due to SDT's involvement, there has been a significant impact to innovation capabilities within Canadian government organizations.

In the absence of meaningful performance indicators on impacts related to government policy solutions, it was difficult to quantify SDT's full contribution to the policy landscape.

The PRC noted that the Government of Canada's central themes such as sustainable development and Indigenous engagement were absent. The PRC expected to see more connectivity with these priorities and felt this was an area where SDT could improve.

Source: Aging in Place Challenge program - National Research Council Canada

The **Aging in Place Challenge program** aims to support older Canadians' desire to age within their own homes and communities through technology and innovation.

Source(s): document and data review, key informant qualitative research, PRC

Research focus

An updated overarching vision is required for the research centre (in alignment with the 2024-29 strategic planning exercise that was underway during the evaluation). This vision would help prioritize research areas, provide future direction, and define SDT's role within the Canadian ecosystem.

In quantum science and technology, SDT's research focus aligned strategically with the NQS, supported the needs of current clients, and was on trend with some market predictions. SDT's advanced materials research also aligned with some market trends; however, its activities supported the needs of clients and other Challenge programs with less overall strategic orientation.

SDT is positioned to move forward in its niche areas, filling a complementary role, addressing gaps, and acting as connector for other organizations.

Strategic alignment

An updated overarching vision for the research centre is required (in alignment with the 2024-29 strategic planning exercise that was underway during the evaluation). With the exception of alignment with the NQS, the process of choosing among trends and establishing priorities was unclear.

Despite the research centre having a vision and mission outlined in the 2019-24 Strategic Plan, the PRC believed that an overarching vision was required for SDT, as they could not see how the process of choosing priority areas was organised and established. It is noted that the NRC 2024-29 strategic planning exercise was underway during the evaluation.

In quantum science and technology, SDT's research focus was aligned strategically with the NQS. The PRC noted the absence of a comparable national advanced materials strategy, and felt that this contributed to a lack of focus and coherence in this area. In advanced materials, activities aligned with needs of current clients and other Challenge programs, with less focus on an overall strategic orientation, mainly due to revenue expectations and the need to support OGDs.

SDT research areas

Quantum science and technology

- **Quantum photonics:** quantum light-matter interactions; ultra-fast spectroscopy; precision clock comparison; single/few-photon sources/detectors
- **Quantum electronics:** photon to spin conversion; alternative 2D systems; atom-scale electronics; quantum dots and wires
- **Quantum sensing:** frequency combs; photonics-based sensor; mid-IR lasers and IR imaging; nano-optomechanical devices
- **Quantum information:** millimeter wave generation; single photon sources; form factor reduction for data centre; design for drugs, photonics and materials

Advanced materials

- **Nanocomposites:** structural polymer-based composites, adhesives; conductive polymer-based composites; ceramics
- **Additive materials:** MINKs, thermo forming – in-mold electronics; self-assembling 3D printable materials; volumetric printing – photopolymers; R2R printed electronics
- **Nanomaterials:** electronic-grade SWCT; pilot scale nanomaterial plasma synthesis (BNNT, CNT, high entropy alloys); colloidal quantum dot synthesis sensors: embedded sensors – composites; printable near IR and gas sensors (CNT/QD); printed antennas – frequency selective surfaces

Source(s): document review, key informant qualitative research, PRC

Alignment with user needs

SDT's research focus was aligned with needs of clients and collaborators (academia, industry, and OGDs) and areas where there is potential for innovation. SDT is positioned to keep pace with the rapidly evolving field in its respective niche areas.

Research aligned with current client needs

Academics reported that SDT had research interests and priorities similar to their own. Industry clients reported that SDT's research focus was well-aligned with their needs and OGD clients reported that SDT's research focus complemented theirs.

Positioned for the future in its niche areas

Clients and collaborators indicated that SDT's quantum science and technology is well-positioned to keep pace with the rapidly evolving ecosystem in its niche areas despite its smaller size compared to other international research institutes, such as JILA (Colorado, USA).

For advanced materials, clients and collaborators noted that SDT has the researchers and access to facilities to maintain its position in relation to other government labs (e.g., the U.S. and Japan). However, the PRC indicated that the state of the advanced materials facilities may inhibit SDT's ability to attract and retain HQP.

Aligned some research to innovation potential

Some SDT projects were in areas that are expected to grow considerably in the future such as:

- improved computer speed to solve complex problems, including:
  - a collaboration with an industry partner in quantum computing to determine when computing will break modern cryptography
  - supporting Communications Security Establishment in understanding requirements for quantum computing that could threaten modern cryptography
  - the purification of nanotubes for new microchips in computers
- enhanced security and rapid data communications (e.g., Quantum Key Distribution Link project)
- detection, monitoring, and drug delivery:
  - collaboration with an industry partner in the purification of nanotubes for biomedical sensors
  - collaboration with another industry partner on MINK for an in-mold human machine interface

SDT focused on its niche areas and did not pursue other areas (e.g., gravimetric research) where there is innovation potential as they lacked the internal expertise.

Source(s): document review, key informant qualitative research, PRC

Alignment with market trends

The NQS and associated QSP considered the overall trends for quantum technology, where market growth is expected to expand substantially to at least 2045. SDT's low-TRL and quantum research focus was aligned with market trends and leading quantum technology nations. SDT's concentration on carbon nanotubes and printed electronics was aligned with market trends.

Quantum is aligned with market trends

Quantum technology is expected to grow substantially in the future. Through to 2024, military and automotive applications should dominate the quantum market, which is expected to remain steady, while agricultural applications are projected to grow fastest. With the exception of agricultural applications, SDT is focused on many of these quantum technologies.

The global race to convert quantum science into quantum technology reaches across various sectors such as health, defense, and the environment. Within Canada, the NQS supports the entire innovation continuum from basic research and scaling up, to adoption, to advancing commercialization. SDT's current and planned quantum programming taps into some of these opportunities. In particular, the PRC viewed positively the work on gate-defined quantum dots in semiconductors. They cautioned that specific aspirations on transduction need wider engagement given its importance to quantum information processing.

SDT's focus on low TRL research is in line with the emerging nature of the quantum field. Collaborations between academics, with less participation from industry, may limit market penetration.

Carbon nanotube research aligns with one of the fastest growing materials

There is rising demand for lightweight and environmentally sustainable composite materials in various sectors. SDT is working with the fastest growing material (carbon nanotube, with an expected compound annual growth rate of 21.5%). SDT is not involved in other expanding advanced materials areas (e.g., graphene, lithium-ion batteries). Mainstream adoption of carbon nanotubes will be at a slow pace. High cost, lack of scalable manufacturing processes, and rapid improvements in silicon-based integrated circuits have prevented adoption. SDT is involved in nanocomposites, where new materials such as carbon-reinforced polymer composites are poised for rapid growth.

Printed electronics and conductive inks are gaining huge popularity

In 2020, silver-based conductive inks accounted for the largest share of the global market. Asia-Pacific dominated this market. SDT worked with Japan and South Korea in this area.

Source(s): document and data review, key informant qualitative research, PRC

Complementary role

SDT's niche research areas complemented the research and technological applications of other organizations. JCEP provided SDT with the opportunity to contribute to joint research projects in quantum science.

Specialized in niche areas and filled gaps for other organizations

Most key informants reported that there are many organizations conducting research in quantum science and technology, however SDT specialized in small niches and filled gaps for other organizations. SDT was seen as the federal hub of expertise in the quantum field and often approached by OGDs for quantum knowledge, facilities, and complementary collaborative work.

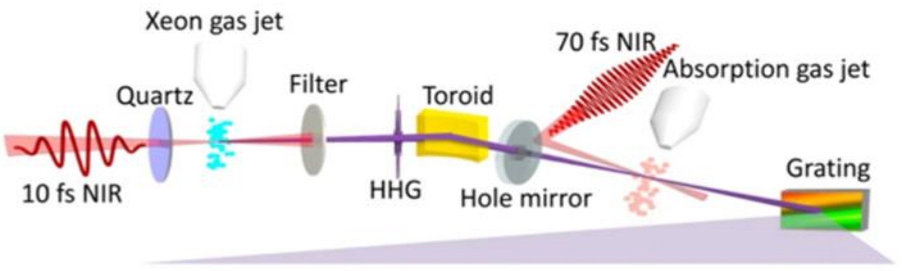
In terms of advanced materials science, SDT's research focus was unique, which was attractive to collaborators. OGDs and industry partners often expanded on SDT's discoveries as they were complementary to their research areas and applications.

Industry partners reported that there was no other organization within Canada that has a similar research focus as SDT. This filled a critical gap, which led to improvements in their research. The 2019 Research Centre Advisory Board (RCAB) report noted that the accomplishments of SDT were unique.

JCEP promoted collaboration in quantum science

Through the NRC–University of Ottawa Joint Centre for Extreme Photonics (JCEP), the NRC contributed to the advancement of quantum science through their support of joint research projects with co-leads from the SDT and the University of Ottawa.

In addition, NRC provided access to facilities; support to NRC researchers, University of Ottawa staff, visiting scientists, PDFs and students; operational funding; and business development in terms of IP and licensing.



JCEP Project from Dr. Staudte (NRC) and Dr. Stolow (University of Ottawa): Use of attosecond transient absorption techniques and 3D Photoelectron Imaging to study molecular structure and dynamics in the valence electron region, and use core-level electrons to probe dynamics.

Source: JCEP Projects (extremephotonics.com)

Source(s): document and data review, key informant qualitative research

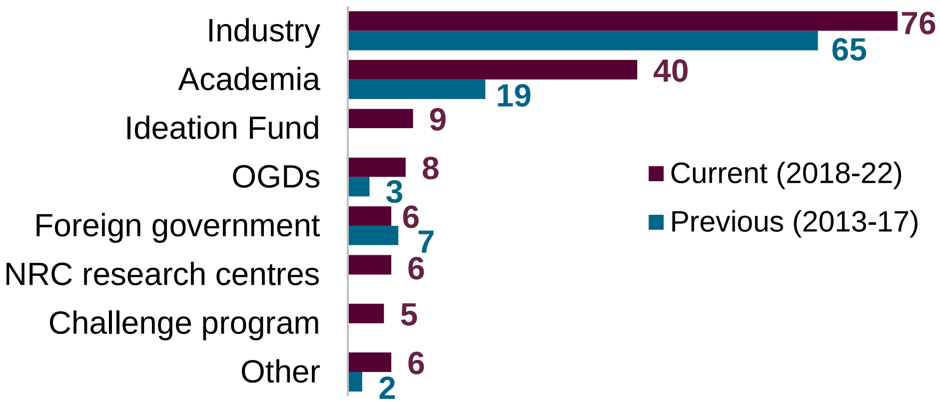
Engagement

Security and Disruptive Technologies Research Centre (SDT) significantly increased the number of clients and collaborators since the last evaluation, due, in part, to the launch of the Quantum Sensors Challenge program (QSP). The research centre engaged with academia, industry and other government department (OGD) clients and collaborators in numerous ways, and its reputation and expertise are attractive to them. Although engagement is effective to some degree, SDT lacks a well-articulated engagement strategy and could improve its mix of clients and collaborators. QSP is the exception to this and has made SDT a major integrator and quantum player in Canada.

Client and collaborator engagement

SDT significantly increased the number clients and collaborators since the previous evaluation. The launch of new programs such as the QSP contributed to this increase. Almost half of SDT projects and almost 75% of project revenues were from OGDs with a large portion from the DND/DRDC.

Figure 8. There was an increase in the number of clients and collaborators[5] compared to the previous evaluation (156 vs. 96)



[5] Includes Quantum Sensors Challenge program (QSP) collaborators.

SDT engages heavily with OGDs

SDT had 151 projects with external clients and collaborators:

- 43% with OGDs
- 25% with industry
- 27% with academia
- 5% with other or multiple clients and collaborators

Project revenues were quite stable, at an average of $3.4 million/year.

From 2017-22, OGDs accounted for a large amount (72%) of SDT project revenues[6] (in millions)

SDT client	2017-18 to 2021-22
OGDs	$12.2
Industry	$4.3
Academia	$0.5
Total	**$17.0**

[6] There was no revenue expected or earned from the QSP projects.

DND/DRDC remain a key partner

DND/DRDC accounted for 51% of total project revenue versus 53% during the previous evaluation. In terms of leveraged funds (not counted in revenue), SDT received $5.8 milion from DND/DRDC.

The percentage and number of projects with DND/DRDC (31%, 47 projects) has increased significantly since the previous evaluation (15%, 29 projects).

It is noted that the previous evaluation recommended that SDT expand its client base beyond the DND/DRDC.

Source(s): document and data review

Strategic and effective engagement

SDT engaged clients and collaborators in numerous ways, and its reputation and expertise are attractive to them. SDT acted as a connector between industry and academia; strong partnerships often led to further collaborations.

SDT engaged clients and collaborators in ways such as:

- business development outreach activities
- marketing campaigns
- direct sales contacts
- engaging both researchers and the business development teams in discussions
- providing workshops to attract new clients and collaborators
- leveraging existing relationships
- responding to inquiries from outside the NRC

GBA Plus considerations are being embedded into client and collaborator engagement processes. This is not consistent or formalized. GBA Plus considerations are included in the QSP grant application process where at least 50% of research teams need to be composed of underrepresented groups. Currently there is no formal process for assessing GBA Plus with other SDT clients and collaborators.

Clients and collaborators satisfied

SDT clients and collaborators reported that the reputation of the NRC and the excellence of SDT's researchers encouraged engagement. SDT is well connected with academia and industry, has relevant expertise and facilities, and a research focus that meets their needs. Collaborating was relatively easy (once agreements were in place) compared to academia or foreign organizations.

Most clients and collaborators reported strong partnerships with SDT, with some indicating that initial work led to further collaboration. Some noted that the research centre acted as a connector between industry and academia. Most were satisfied with collaboration(s) and were likely to work with SDT again.

NRC staff in other research centres indicated that SDT has collaborated well; however, the PRC noted the absence of a strong functional connection with the NRC's Metrology Research Centre, which they viewed as essential.

To enhance collaboration, some suggested that SDT have more interaction (e.g., regular meetings, joint proposal writing) and improve awareness of their services and communication with them. In terms of barriers, the NRC's bureaucracy and rules (e.g., hiring practices, non-optimized processes), IP constraints, and SDT's focus on low TRL projects (for industry partners) were obstacles to engagement.

Source(s): document and data review, key informant qualitative research, PRC

Strategic and effective engagement

SDT does not have a well-articulated engagement strategy. The successful engagement strategy of the QSP, however, has made SDT a major quantum player in Canada. A similar approach is not present for advanced materials, which could guide where SDT should engage. SDT's mix of stakeholders could be improved.

SDT lacked an engagement strategy—QSP is the exception

Despite a number of successful engagement activities, SDT does not have a well-articulated engagement strategy. SDT has limited information on targets and does not have a documented approach to engagement, making it challenging to determine if goals were met. Given the organizational change underway, strategic engagement planning could become more complex and important.

The PRC indicated that the QSP is the exception to this. Here, there is a successful engagement strategy that has made SDT a major quantum player in Canada. QSP grant and contribution funding, totalling close to $12 million (for 2021-22 and 2022-23), fostered engagement. The PRC also commented that SDT's involvement in the NQS facilitated the integration of all Canadian quantum stakeholders and made SDT a major player in the Canadian ecosystem.

As noted by the PRC, a national-level strategy is not present for advanced materials. Although advanced materials do not have an articulated engagement strategy, the team engages externally through other Challenge programs (e.g., Aging in Place, Artificial Intelligence for Design, and Materials for Clean Fuels).

Engagement mix could be improved

The previous evaluation found that SDT relied heavily on DND/DRDC and needed to increase its industry engagement. SDT continues to rely heavily on DND/DRDC for projects and revenues, but has increased industry engagement.

Only about half of NRC staff interviewed indicated that SDT has a good balance of stakeholder groups, noting that international relationships could be improved. The RCAB recommended that SDT broaden its relationship with international organizations (e.g., South Korea) outside of key NRC partners. They also mentioned that SDT should work to connect small and medium sized enterprises (SME) with larger companies.

The PRC noted that the need for SDT to generate revenue seems to pull them in opportunistic directions dictated by others and possibly abandon areas where major industry dominates (e.g., aerospace and automotive); however, SDT engages externally through Challenge programs and other research centres such as Aerospace, Automotive and Surface Transportation and Energy, Mining and Environment. The PRC also noted that, for advanced materials, SDT established strong engagement with specific SMEs, but has not sufficiently engaged universities.

Source(s): document and data review, key informant qualitative research, PRC

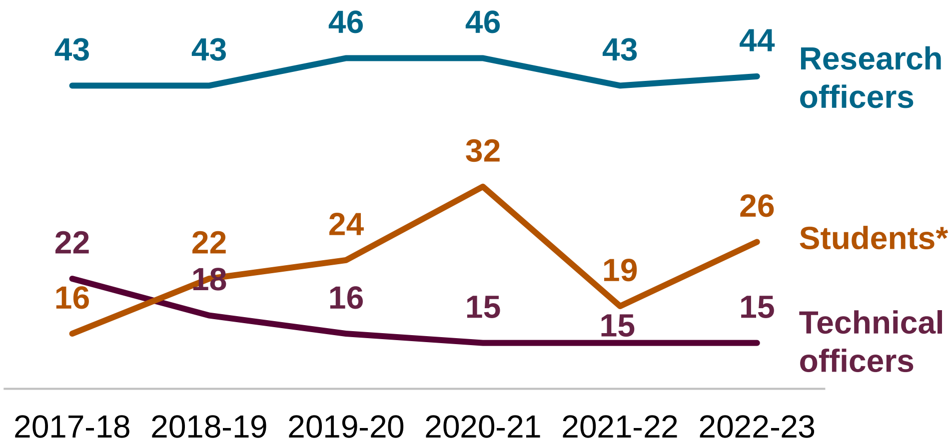
Capacities, competencies, and facilities

Security and Disruptive Technologies Research Centre (SDT) has the financial capacity and human resource competencies needed to meet its objectives. With regard to facilities, SDT has excellent quantum facilities. To be prepared to move forward, planning for quantum facilities needs to happen now. To this end, the quantum photonics equipment procurement is part of the first wave of the NRC facilities renewal project. The advanced materials facilities are in need of substantial improvement as the physical state of labs could damage morale and inhibit the research centre's ability to attract and retain highly-qualified personnel (HQP).

Capacities

SDT human resource capacity varied over the evaluation period for groups other than research officers (that remained relatively stable). SDT appears to be well-positioned for succession planning.

Figure 9. From 2017-2023, the number of research officers remained relatively stable, technical officers declined, and students varied

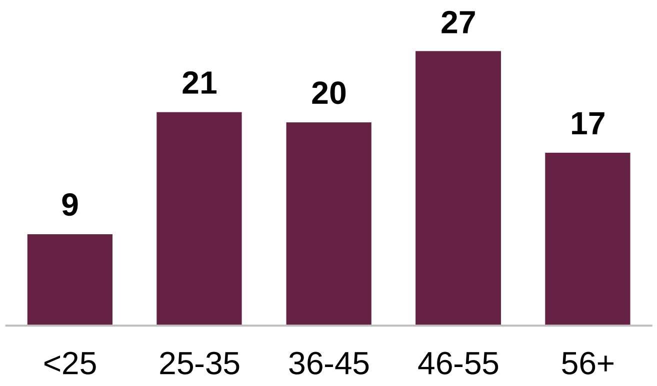


***** While SDT normally has at least 20 students, additional funding, provided by the government during COVID-19, allowed for a greater number of students.

Succession planning is important

The distribution of staff between the ages of 25 to 55 years was relatively similar, with the average age of all SDT staff at 46 years. The PRC noted that the staff age profile looks attractive as there is no significant dip in 30-50 years range.

Figure 10. In 2022, almost half of SDT staff (47%) were over 45 years of age



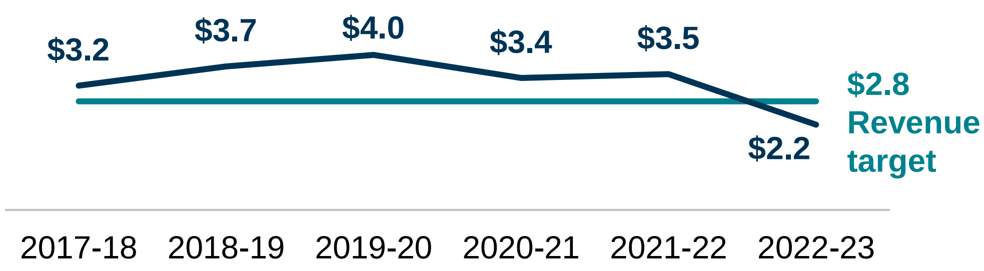
Source(s): document and data review, key informant qualitative research

Capacities

The research centre exceeded its revenue target annually for 4 of the 5 years in the evaluation period. SDT leadership has been proactive in leveraging additional funds (e.g., through QSP and DRDC) so that the budget has grown over the evaluation period. SDT is projected to receive additional funding through to 2027-28 from these supplementary sources.

On average, SDT exceeded its revenue target

Figure 11. With the exception of 2022-23, SDT consistently exceeded its revenue target over the evaluation period



SDT noted that DRDC cancelled a $300,000 project late in 2022-23 which contributed to the shortfall in revenue.

SDT leveraged additional financial capacity

SDT received net appropriations (budget) of between $11.5 and 14.7 million annually over the evaluation period. SDT leadership also sought out supplementary funding for 2019-20 to 2027-28:

- NPO-QSP ($4.0 million)
- NQS ($4.8 million)
- DND/DRDC ($5.8 million, partnership in quantum technologies)
- Small Teams and New Beginnings (close to $1.3 million)

Leveraged sources of funding continue to 2027-28

Looking at the interplay between SDT appropriations and the supplementary funding sources reveals the following:

- Assuming that the research centre's overall appropriations remain the same, it is projected that these supplementary funding sources will contribute 9% ($1.7-1.9 million) to the total budget in each year from 2022-23 to 2024-25. This situation could continue to at least 2027-28, with the exception of the DND/DRDC funding that only continues to the end of 2025-26.

The PRC indicated that a lack of an overall vision for SDT could translate to a lack of direction on long-term investments in buildings, infrastructure and people. It is noted that strategic planning was underway during the evaluation, and that major capital funding for the NRC is centrally managed through the Office of Facilities and Renewal Management.

Source(s): document and data review

Capacities

SDTs participation in the QSP has underscored challenges relating to funding and priority setting.

SDT staff struggle to balance participation on traditional projects and new Challenge programs

SDT staff struggled to equally participate in QSP projects as they felt that SDT did not receive sufficient operational funds to fully participate. However, as a result of changes to NRC timecoding practices, it is not possible to determine the amount of researcher time dedicated to QSP projects.

As SDT has taken on new challenges, the PRC had concerns regarding maintaining scientific leadership if staff are overstretched. They cautioned the research centre not to lose strategic focus by going for quick (revenue-generating) wins. Moving forward, SDT will need to prioritize programs based on available resources.

Some SDT staff voiced concerns about splitting their time between revenue and non-revenue generating projects (such as QSP), suggesting a preoccupation with revenue generation at the expense of scientific leadership. Additional funding to be received from supplementary funding sources may alleviate some of these concerns for the next few years.

SDT is taking action to mitigate operational challenges

The 2022-23 SDT Operational Plan identified several risks to the research centre’s ability to achieve its objectives and identified mitigations that include:

- Challenges in reaching revenue targets due to researchers being overcommitted in other areas such as Challenge programs or changing priorities of funding partners. To mitigate these, the research centre has reviewed its revenue process and determined its baseline staffing level to meet revenue targets. In addition, they considered financial impacts when prioritizing activities and increase revenue predictability with longer term project agreements.
- Challenges in maintaining financial sustainability of the research centre in the absence of QSP funding. To mitigate, SDT will explore other funding paths and programs for equipment, labour and operations and diversify its client base.

Source(s): document and data review, key informant qualitative research, PRC

Competencies

SDT has the competencies needed to meets its objectives, having recently hired a number of top-level researchers and attracted PDFs. The PRC noted early career researchers' abilities were impressive and that attrition has been managed.

SDT currently has the competencies it needs

SDT staff reported that SDT has the next generation of lead scientists. Recently the research centre hired a number of top-level researchers and has had the ability to attract post doctoral fellows (PDFs) comparable to that of academia. The National Program Office (NPO) funding for QSP, has allowed for greater academic collaboration by bringing on PDFs and graduate students, providing additional critical mass in research.

SDT had 15 adjunct professors. The PRC supported SDT's encouragement of adjunct academic affiliations, as it enables SDT researchers to recruit students funded by NSERC grants.

The PRC was impressed with the abilities of SDT's early career researchers and noted that the research centre has managed to maintain capability despite attrition. However, SDT is facing stiff competition against other organizations making researcher retention difficult.

SDT is proactive in attracting and retaining talent

In the 2022-23 Operational Plan, SDT identified career development strategies:

- group leader rotation or acting management and leadership opportunities
- use of the NRC mentorship program
- providing opportunities for high-potential employees
- encouraging participation in committees, conferences, and editorial boards

SDT is trying to balance recruitment with the fact that NRC research centres are in a budget reduction exercise. The PRC applauded SDT's focus on acquiring fixed term post doctoral research associates as a welcome mechanism for revitalizing and enhancing capability in core research areas. The SDT mentoring approach was seen as essential to bring researchers to the level of group leader.

In order to reallocate resources to real property and major capital, in 2021-22, the NRC introduced a **10% reduction over 3 years for all NRC research centres** and corporate branch budgets.

Source(s): document and data review, key informant qualitative research, PRC

Competencies

SDT recognizes its current equity, diversity and inclusion (EDI) shortcomings and is making advances by increasing its representation of women. EDI is considered during hiring, promoting, career development and succession planning.

SDT has increased its representation of racialized persons and women, but has not met full labour market availability

Over the evaluation period, SDT increased its representation of racialized persons (from 70% of labor market availability to 97%) and women (from 65% of labor market availability to 80%). SDT has been led by a woman at the DG level since 2019. The PRC noted an excellent gender balance while touring the SDT facilities.

Statistics on the number of Indigenous peoples and persons with disabilities were not available as numbers were too low.

SDT management is taking action regarding EDI

SDT management reported that SDT has been actively considering EDI when hiring and promoting. Due to a variety of structural factors, women and people from diverse ethnic, geographic and socioeconomic backgrounds are underrepresented in the physics and quantum talent pool.[7]

[7] Wall, Katherine (2019), *Persistence and representation of women in STEM programs*, Statistics Canada

The PRC recognized the efforts of SDT leadership to promote EDI and hard work to bring balance to the team by offering project management opportunities to build skills.

SDT leadership commissioned a study of EDI

In response to the findings of an SDT study on EDI, SDT's 2022-23 operational plan included mitigation strategies to improve EDI.

Examples of mitigation strategies:

- ✓ promoting self-identification
- ✓ learning from best practices at the NRC and other organizations
- ✓ training at all levels on unconscious bias
- ✓ encouraging participation of women in STEM events

Strategies with longer-term impact include:

- ✓ succession planning with an emphasis on EDI recruitment
- ✓ placing emphasis on EDI for group leader renewal

"I want to be the place where women feel they can come and thrive, and feel comfortable."

—DG of SDT, June 2023

Source(s): document and data review, key informant qualitative research, PRC

Competencies

QSP is implementing strategies that address systemic barriers and biases.

Gender-based Analysis Plus in the Quantum Sensors Challenge program

A report, commissioned by the NRC, applied gender-based analysis plus (GBA Plus) to Challenge program processes, including QSP. Based on this report, Challenge programs, such as QSP, are implementing strategies to address systemic barriers and biases that disadvantage women, gender-diverse, black, Indigenous and people of colour in applying for and participating in research. Examples of these strategies include:

- ensuring that advisory panels include academics and industry practitioners from diverse backgrounds
- practicing inclusive meeting design and facilitation techniques for consultation events
- targeting grants and contribution funds to incentivize the hiring and professional development of diverse researchers

The implementation of QSP has shown a positive effect of considering GBA Plus in research activities, particularly in the project selection and review processes. QSP's project selection and annual project review processes provide evidence that GBA Plus factors are being included. Primary Investigators (PIs) are:

- soliciting applications from underrepresented groups by advertising widely and writing inclusive ads
- setting up evaluation criteria grids in advance to avoid unconscious bias
- de-emphasising the importance of grades or a continuous career path
- considering possible implicit bias in reference letters
- actively engaging in EDI, GBA Plus, sexual harassment, and misconduct training

As an example, in one QSP project plan:

- all team members would take unconscious bias training
- recruitment processes for PIs would be advertised to the entire research team or to the entire department (for senior researchers)
- senior members would support and integrate team members from underrepresented groups (e.g., rotating presentations to ensure equal opportunity)
- the team would include all members in social activities and organize some social activities that foster cultural diversity

Source(s): document and data review, key informant qualitative research

Facilities

Quantum facilities are excellent but future planning for these facilities should be ongoing. The SDT photonics facilities have been scheduled for a $13.5 million renewal in the first wave of the NRC's facilities renewal project, which will likely begin in 2023-24. Some advanced materials facilities are in need of substantial improvement.

Quantum facilities are excellent but some upgrades are needed

The NRC Facility Review (2017 to 2021), concluded:

- The ultrafast quantum and quantum information facilities have adequate labs that are impactful in their fields.
- The fibre photonics facility has technology that is sufficient but aging. Some companies have acquired technological capabilities beyond what the fibre photonics facility can do, reducing its competitive advantage.

SDT staff felt that the research centre has adequate quantum facilities, but noted that usefulness of 100 Sussex may be limited due to age, configuration and size.

The PRC found that the quantum facilities were excellent, but noted that facility planning needs to occur now in order to accomplish future integration into systems. To this end, the SDT photonics facilities have been scheduled for a $13.5 million renewal in the first wave of the NRC's facilities renewal project with equipment procurement beginning in 2023-24.

SDT has a number of specialized scientific computing tools, which are necessary for its quantum research. The PRC noted some deficiencies in support for these tools. The NRC's high-performance computing within SDT requires specialized scientific computing support (separate from IT) and infrastructure upgrades.

Some advanced materials facilities are in need of substantial improvement

The NRC Facility Review (2017 to 2021), concluded:

- The nanomaterial production facility has leading-edge technology and specialized systems for material synthesis, which has provided SDT with a competitive advantage particularly with respect to the single-walled carbon nanotube (SWCNT) purification process.
- The nanomaterials facility is lacking sufficient human resources to properly support industry partners, making industry collaboration challenging.

The PRC noted that the current physical state of advanced materials labs (particularly the M-23 and M-12 facility) could damage morale and inhibit SDT's ability to attract and retain HQP. In the M-12 facility, the PRC was concerned about the condition of the “ancient and stained” wooden chemistry benches, in particular.

Source(s): document and data review, key informant qualitative research, PRC

Recommendations and Management response and action plan

Supporting rationale and recommendations

Advanced materials: direction-setting and leadership

Security and Disruptive Technologies Research Centre's (SDT) advanced materials research is aligned with needs of clients and other Challenge programs with less overall strategic orientation. A strategic direction would help prioritize research areas, provide future direction, and define SDT's role within the advanced materials ecosystem. In addition, on the advanced materials side, SDT does not have a well-articulated engagement strategy, which is needed in the strategic direction to guide where SDT should engage.

Recommendation 1

SDT should clearly set out a strategic direction for the advanced materials area that will allow leadership to prioritize areas of greatest potential impact. This could include development of an NRC-wide advanced materials strategy.

Advanced materials: facilities

SDT's advanced materials facilities are in need of substantial improvement. The PRC noted the poor physical condition of wooden chemistry benches (in the M-12 facility), adding that the state of the advanced materials labs (including the M-23 facility) could damage morale and inhibit SDT's ability to attract and retain HQP.

Recommendation 2

SDT should identify priorities, develop strategies and implement actions to address physical condition issues identified by the PRC and ensure advanced materials facilities support attraction and retention of HQP.

Quantum science and technology: support for new directions

SDT researchers are stretched as Challenge program projects continue. Leveraged funds have contributed to short-term sustainability of SDT; however, the PRC noted that SDT researchers could be overstretched by the new programs and the focus on revenue generation. This could impact the research centre's ability to maintain scientific leadership.

Recommendation 3

When exploring new quantum directions (e.g., quantum networking), SDT should match available competencies, capabilities and facilities to its quantum agenda by mapping SDT's existing strengths, examining gaps, and generating a concrete plan to address the gaps.

Management Response and Action Plan

Recommendation 1

SDT should clearly set out a strategic direction for the advanced materials area that will allow leadership to prioritize areas of greatest potential impact. This could include development of an NRC-wide advanced materials strategy.

Risk-level: low

Management response	Measure of achievements	Proposed person(s) responsible	Expected date(s) of completion
Response: accepted **Action:** SDT will finalize an advanced materials strategy that takes into consideration AEP, NANO and other NRC research centres' work in advanced materials.	Advanced materials strategy for the SDT developed.	SDT DG	June 2025

Management Response and Action Plan

Recommendation 2

SDT should identify priorities, develop strategies and implement actions to address physical condition issues identified by the PRC and ensure advanced materials facilities support attraction and retention of HQP.

Risk-level: moderate

Management response	Measure of achievements	Proposed person(s) responsible	Expected date(s) of completion
Response: accepted **Action:** SDT will identify priorities and develop strategies for advanced materials facilities, as part of the 2024-25 SDT Operational Plan. SDT will also continue working with the Real Property Planning and Management (RPPM) branch to identify a suitable space for relocation of facilities in M-23. In addition, physical condition issues will be addressed for M-12.	1. 2024-25 Operational Plan. 2. Minor upgrades (e.g., new counter) to M-12 laboratory completed.	1. SDT DG 2. SDT DG	1. June 2024 2. June 2025

Management Response and Action Plan

Recommendation 3

When exploring new quantum directions (e.g., quantum networking), SDT should match available competencies, capabilities and facilities to its quantum agenda by mapping SDT's existing strengths, examining gaps, and generating a concrete plan to address the gaps.

Risk-level: low

Management response	Measure of achievements	Proposed person(s) responsible	Expected date(s) of completion
Response: accepted **Action:** SDT will develop an internal resourcing plan (outlining strengths and gaps) based on identified new directions and consultations with stakeholders.	Internal resourcing plan developed.	SDT DG	June 2026

Appendices

Appendix A: methodology

Bibliometric study

The NRC's Intelligence and Analytics team conducted a bibliometric assessment. The SDT publication dataset was compiled by searching the Scopus database for all NRC-affiliated publications for the period 2017 to 2022. The research centre's publications were identified based on references to SDT in the metadata or authorship. The list was validated by the research centre.

Data review

The research centre's administrative and performance data for 2017-18 to 2021-22 were reviewed to provide information on scientific excellence, contributions to business innovation and government policy solutions, client engagement and capacities. These included financial, human resource, project, client and intellectual property data.

Online questionnaire

A web-based questionnaire was distributed to SDT's clients and collaborators (n=127). The questionnaire assessed the engagement practices and impacts of SDT on clients and collaborators. Despite conducting follow-up calls, the questionnaire had a low responses rate (n=22, 18% response rate). At a 95% confidence level, this response rate generates a 20% margin of error. Given the low response rate the findings from the questionnaire were used only in conjunction with other qualitative lines of evidence.

Document review

Both internal and external documents were reviewed and analyzed to provide context and to complement other lines of evidence in assessing relevance, engagement and performance of the research centre.

Key informant interviews

Interviews were conducted with 15 internal staff and 20 external stakeholders to collect perceptions and expert knowledge related to the relevance, engagement and performance of SDT. The findings generated from the interviews provided contextual information and were used in conjunction with the other lines of evidence. The evaluation did not have a strong focus on collaborations with other research centres and other NRC Challenge programs (due to the concurrent evaluation of the Collaborative Science, Technology, and Innovation Programs), but included this information where available.

Peer Review Committee

An international peer review committee (PRC) was convened in Ottawa from June 12 to 15, 2023 to assess SDT's performance during the evaluation period. The PRC was made up of 8 individuals with expertise in quantum science and technology and advanced materials science. The PRC, led by the chair, wrote the PRC report, including recommendations, which were considered in the development of this evaluation report.

Appendix B: limitations and mitigation strategies

Although the evaluation encountered some challenges, methodological limitations were mitigated, where possible, through the use of multiple lines of evidence and the triangulation of data. This approach was taken in order to establish the reliability and validity of the findings and to ensure that conclusions and recommendations were based on objective and documented evidence. Details on limitations and their associated mitigation strategies are described below.

Use of publications to measure scientific excellence

The use of field-weighted citation impact (FWCI) scores as a measure of scientific excellence introduces a limitation as only publications included in Scopus are considered, and citations accrue over time (i.e., recent articles will usually have a lower number of citations than articles that are at least 2 years old). As a result, scientific excellence of more recent publications is likely underestimated.

Mitigation: To mitigate this limitation, other lines of evidence were used to assess scientific excellence and the advancement of knowledge for the research centre.

Low response rate for online questionnaire

The low response rate to the online questionnaire (18%) could have introduced a sampling bias thereby reducing population representativeness[8]. Therefore the online questionnaire findings are not generalizable to the target population.

Mitigation: To mitigate this limitation, where applicable, results were used to complement other lines of qualitative data.

[8] Fincham, J. (2008), *Response Rate and Responsiveness for Surveys, Standards and the Journal,* [Response Rates and Responsiveness for Surveys, Standards, and the Journal]

Lack of gender balance on the Peer Review Committee

Despite best efforts, the PRC lacked a gender balance. The evaluation team invited 6 female experts to join the committee, however only one was available and accepted.

Mitigation: Unfortunately, the lack of a gender balance on the PRC could not be mitigated.

Inability of 2 PRC members to attend in-person

There were 2 PRC members who were unable to attend the PRC meeting in Ottawa. They participated virtually, however, they could not attend the in-person activities (e.g., facility tours, meetings with early career researchers). This created challenges integrating their perspectives into the PRC deliberations.

Mitigation: The inability of 2 PRC members to attend in-person could not be mitigated, however they did participate virtually where possible.

Appendix C: Peer Review Committee members

Sir Peter Knight (committee Chair)

Emeritus Professor Faculty of Natural, Sciences, Department of Physics

Imperial College London

Dr. Mohammad Arjmand

Canada Research Chair in Advanced Materials and Polymer Engineering, Assistant Professor

University of British Columbia

Dr. Rainer Blatt

Emeritus Research and Director Quantum Optics and Spectroscopy, Institut für Experimentalphysik,

Universität Innsbruck

Dr. Steven Cundiff

Director, Harrison M. Randall Collegiate Professor of Physics, Professor of Electrical Engineering and Computer Science

University of Michigan

Dr. Vladimir Falko

Director of National Graphene Institute,

Professor of Theoretical Physics, University of Manchester

Dr. Aaron Franklin

Professor of Electrical and Computer Engineering

Duke University

Dr. Mark Ritter

Chair, Physical Science Council,

IBM Research

Dr. Clara Santato

Canada Research Chair in Sustainable Organic Electronics

Professor of Engineering Physics, Polytechnique Montreal