



**NRC·CNRC**

# Evaluation of TRIUMF

Final Evaluation Report  
March 14, 2019

Office of Audit and Evaluation



National Research  
Council Canada

Conseil national de  
recherches Canada

Canada 

© (2019) Her Majesty the Queen in Right of Canada,  
as represented by the National Research Council of Canada.

Cat. No. NR16-272/1-2019E-PDF  
ISBN 978-0-660-30449-6

Également disponible en français

**Prepared by:**

Office of Audit and Evaluation  
National Research Council Canada

**Date of Approval:**

March 24, 2019

## Executive summary

TRIUMF is a particle accelerator laboratory conducting research in nuclear and particle physics, nuclear medicine as well as materials and accelerator science. These research areas require large-scale, expensive facilities for experimentation. As such, TRIUMF maintains unique scientific infrastructure which is accessed by members of the Canadian and international scientific communities. In addition, TRIUMF collaborates on international projects, which allows Canadian researchers access to international facilities.

TRIUMF receives operational funding from the federal government through a contribution agreement with the National Research Council (NRC). Therefore the NRC conducts an evaluation of TRIUMF every 5 years in compliance with requirements of the Financial Administration Act (Sec 42.1) and as per the NRC's approved Departmental Evaluation Plan. This evaluation focused on the five-year period of 2013-14 to 2017-18. Because the NRC's contribution is only one source of funding and there are no distinct outcomes associated solely with it, this evaluation considers the full slate of TRIUMF activities and outcomes.

The evaluation's data collection approach incorporated both qualitative and quantitative methods including:

- a review of documents
- a review of administrative and performance data
- interviews with TRIUMF staff, clients, partners and other key stakeholders
- a survey of TRIUMF users
- an international peer review

A bibliometric analysis (commissioned by TRIUMF) and an economic impact assessment (commissioned by the NRC) were also completed by external consultants with the objective of informing the evaluation. These were included as key documents consulted as part of the document review.

### Evaluation findings

TRIUMF addresses the needs of a growing research community, in particular by providing necessary equipment and facilities, which are not available elsewhere in Canada. Because of the considerable funding it receives from the federal government, the relevance of TRIUMF was also assessed through an examination of its alignment with federal government priorities. In the area of science, technology and innovation, the evaluation found significant alignment. The International Peer Review Committee (IPRC) suggested a need for more advocacy of TRIUMF within the Canadian government to facilitate its continued success.

TRIUMF has been important to Canada's position on the global stage in TRIUMF-related fields. This is in part due to the facilities it provides to researchers, which enables their important research, as well as the international collaborations TRIUMF has facilitated. TRIUMF has also contributed to Canada's positive reputation through its own scientific achievements, including its

contributions to important work such as the discovery of the Higgs Boson at CERN and elucidation of neutrino properties by the T2K experiment in Japan. TRIUMF also contributes to the scientific community by fostering the training of HQP and attracting HQP to Canada. Lastly, TRIUMF, through its regular activities, and through TRIUMF Innovations has generated important benefits for Canada.

TRIUMF has made a number of changes to increase efficiencies and are planning many others. For instance, they have addressed the issues identified in the previous evaluation and introduced a number of new mechanism to increase efficiencies. They are also currently undergoing a transformation of their governance structure which will streamline their Board of Management and broaden its scope to include, in addition to members with knowledge of TRIUMF's research, experts in resource and facility management. Lastly, TRIUMF's strategic plan for 2020-2025 demonstrates its vision for the next phase of the laboratory and was found by the IPRC to be ambitious, yet achievable in its approach.

The evaluation also found areas with potential for improvement and thus, recommends that:

1. The NRC should work with TRIUMF and TRIUMF Innovations to diversify commercialization activities (and to expand royalties and patents), to spread and reduce the risk associated with a too-narrow portfolio.
2. The NRC should work with TRIUMF to identify ways to expand their outreach to regions outside of British Columbia, in an effort to increase both TRIUMF's impact and its base of support. Methods to broaden TRIUMF's reach could include virtual means.
3. In order to facilitate understanding and buy-in by TRIUMF staff of planned organizational changes, the NRC should work with TRIUMF to develop and implement a plan for communicating the changes and their expected benefits.
4. The NRC should work with TRIUMF to identify metrics to monitor the implementation and impact of the organizational changes, to ensure outcomes are as expected, and to allow TRIUMF management to make slight changes as needed to achieve outcomes.

## Acronyms

AAPS	Advanced Applied Physics Solutions, Inc.
ACOT	Advisory Committee on TRIUMF
ACT	Agency Committee on TRIUMF
ARC	Average of Relative Citations
ARIEL	Advanced Rare Isotope Laboratory
ARIF	Average of Relative Impact Factors
BC	British Columbia
BOM	Board of Management
CFI	Canada Foundation for Innovation
CIHR	Canadian Institutes of Health Research
COO	Chief Operating Officer
FRIB	Facility for Rare Isotope Beams
FTE	Full Time Equivalent
GDP	Gross Domestic Product
HAL	Hickling, Arthur, and Low
HQP	Highly Qualified Personnel
IAMI	Institute for Accelerator-based Medical Isotopes
IPRC	International Peer Review Committee
ISAC	Isotope Separator and Accelerator facility
ISOL	Isotope separation on-line
KPI	Key Performance Indicator
LSPEC	Life sciences project evaluation committee
MMS-EEC	Molecular & materials science experiments evaluation committee
MMS-bNMR	Molecular and material science – beta nuclear magnetic resonance
MMS-MuSR	Molecular and material science – muon spin rotation
NACRI	National Advisory Council on Research and Innovation
NRC	National Research Council
NRCan	Natural Resources Canada
NSCL	National Superconducting Cyclotron Laboratory
NSERC	Natural Sciences and Engineering Research Council
PDF	Post-Doctoral Fellow
PMO	Project management office
PPAC	Policy and Planning Advisory Committee
QMS	Quality Management System
R&D	Research and Development
RIB	Rare Isotope Beam
SAP	Subatomic physics
SAP-EEC	Subatomic physics experiment evaluation committee
SAP-RIB	Subatomic physics – rare isotope beams
S&T	Science and Technology
SSHRC	Social Sciences and Humanities Research Council
UBC	University of British Columbia
WED	Western Economic Diversification

# Table of Contents

1	About TRIUMF .....	1
2	About the Evaluation .....	4
3	TRIUMF addresses the needs of Canadian scientists and is aligned with federal government priorities .....	5
3.1	TRIUMF serves the needs of a growing Canadian subatomic research community..	5
3.2	University researchers and students need the large scale facilities at TRIUMF .....	6
3.3	Research needs could not be met in Canada in the absence of TRIUMF .....	7
3.4	TRIUMF aligns with federal government priorities in the area of science, technology and innovation .....	8
3.5	The NRC’s oversight role of TRIUMF is appropriate .....	10
4	TRIUMF has made important contributions to science and has generated social and economic benefits for Canada.....	10
4.1	TRIUMF supports Canada’s performance and reputation in TRIUMF-related fields.	11
4.2	TRIUMF contributes to important research and discoveries.....	12
4.3	TRIUMF facilitates collaboration within Canada and internationally .....	16
4.4	TRIUMF fosters the training of HQP .....	19
4.5	TRIUMF attracts HQP to Canada .....	20
4.6	TRIUMF activities have resulted in economic and social benefits to Canada.....	21
5	TRIUMF is committed to efficient and economic operations .....	27
5.1	TRIUMF is improving its efficiency through new mechanisms and governance .....	27
5.2	TRIUMF has managed resources soundly.....	29
5.3	TRIUMF has proposed a feasible strategic plan for years 2020-2025.....	31
5.4	Canada’s current approach to funding does create challenges for TRIUMF as it does for other facilities .....	32
6	Conclusion .....	33
7	Management Response .....	35
	Appendix A – Evaluation questions .....	38
	Appendix B – Evaluation methodology .....	39
	Appendix C – International Peer Review Committee membership.....	43

## 1 About TRIUMF

TRIUMF is a particle accelerator laboratory conducting research in nuclear and particle physics, nuclear medicine as well as materials and accelerator science. These research areas require large-scale, expensive facilities for experimentation. As such, TRIUMF maintains unique scientific infrastructure which is accessed by members of the Canadian and international scientific communities. In addition, TRIUMF collaborates on international projects, which allows Canadian researchers access to international facilities.

TRIUMF, originally known as the Tri-University Meson Facility, began as a university research facility for nuclear physics but has evolved into a national laboratory with a broader range of activities. TRIUMF was established in 1968 through an agreement between the federal government of Canada, Simon Fraser University, the University of British Columbia (UBC), and the University of Victoria. This consortium has since grown to include 20 Canadian universities, of which 14 are full TRIUMF members and 6 are associate members.<sup>1</sup> Currently, full members share the legal and financial liability for TRIUMF and have voting privileges on the Board of Management. Each full member university shares an equal interest in all assets except for the land and buildings, which are owned by UBC as the laboratory is located on UBC land. Section 5 of this report discusses a current exercise being undertaken by TRIUMF that will transform its governance and the roles and responsibilities of full members.

TRIUMF receives operational funding from the federal government through a contribution agreement with the National Research Council (NRC). The NRC's role is to administer the contribution agreement. The NRC is also a non-voting member of TRIUMF's Board of Management and Audit Committee. Additional oversight of TRIUMF operations is conducted by the NRC-established Advisory Committee on TRIUMF (ACOT) and by the Agency Committee on TRIUMF (ACT). The NRC dedicates approximately one Full Time Equivalent (FTE) position to TRIUMF-related activities.

### **TRIUMF's Objectives**

TRIUMF's ultimate objective is to improve quality of life and economic growth in Canada. It aims to achieve this outcome by leading in science, leveraging university research, connecting Canada to the world and by creating social and economic growth.

---

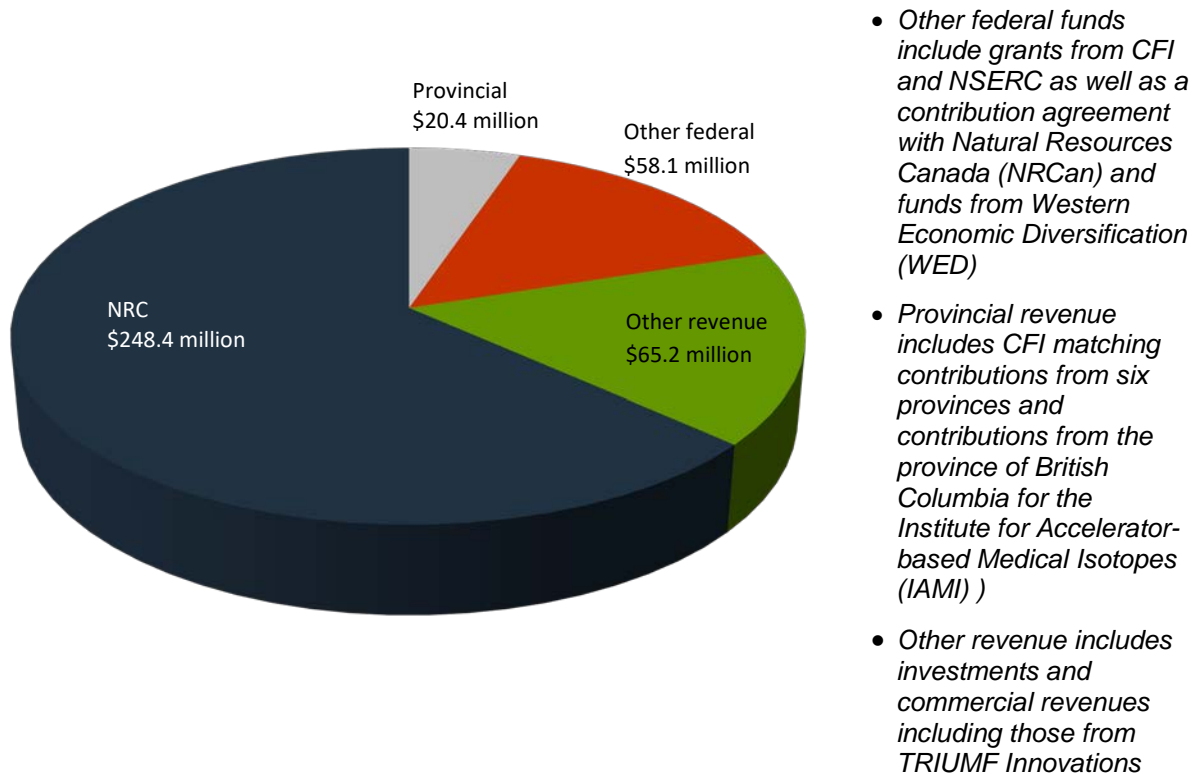
<sup>1</sup> TRIUMF member universities include: University of Alberta, University of British Columbia, University of Calgary, Carleton University, University of Guelph, University of Manitoba, Université de Montréal, Queen's University, University of Regina, Simon Fraser University, University of Toronto, University of Victoria, McMaster University, and York University. Associate members are: McGill University, University of Northern British Columbia, Saint Mary's University, Université de Sherbrooke, Western University, University of Winnipeg.



**Resources and Expenditures**

Over the evaluation period (2013-14 to 2017-2018), TRIUMF secured \$392 million, of which 63% was from the contribution agreement with the NRC. The remainder of the funds were from a variety of other sources. (Figure 1.1)

**Figure 1.1: TRIUMF’s income between 2013-14 and 2017-18 totaled \$392 million**



Source: TRIUMF Data

Funding from the NRC is used for the core operations of TRIUMF, including staffing, maintenance and repairs, basic infrastructure and upgrades and utilities. Funding from other sources is used for research and related activities as well as other operational/function costs.

**Human Resources**

Over the evaluation period, TRIUMF’s total full-time equivalent resources (FTEs) increased from 495 to 535. (Figure 1.2) On average, the NRC funded 74% of all TRIUMF FTEs.

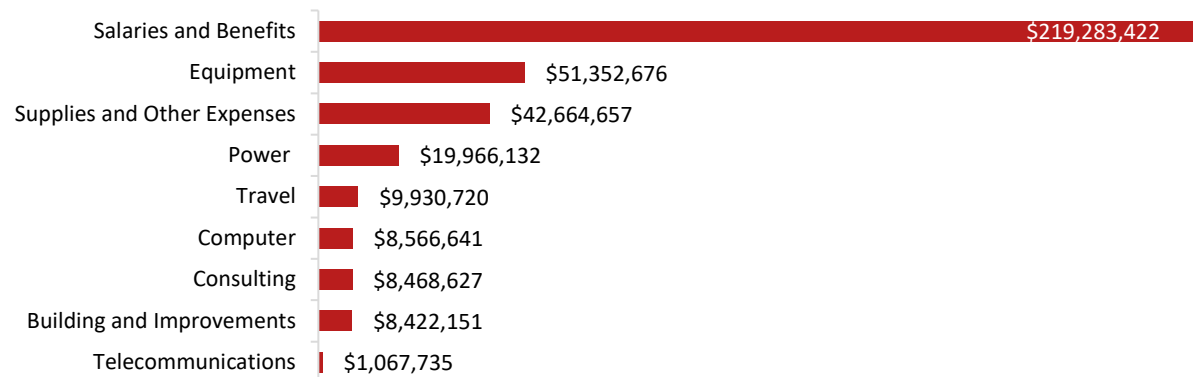
**Table 1.2: TRIUMF increased their FTEs by 40 between 2013-14 and 2017-18**

	2013-14	2014-15	2015-16	2016-17	2017-18
	#	#	#	#	#
Administrative staff	37	39	44	49	46
Facility and site services	26	27	29	30	33
Board-appointed research scientists	46	45	43	49	47
Faculty joint appointments <sup>2</sup>	6	7	11	11	11
Staff scientists	33	35	36	38	43
Engineers	83	78	80	91	93
Information systems and technologists	21	19	22	18	21
Technicians/Technologists	161	165	163	162	158
Postdocs & research associates	50	45	42	43	49
Graduate students	32	30	35	31	34
<b>TOTAL</b>	<b>495</b>	<b>490</b>	<b>505</b>	<b>522</b>	<b>535</b>

Source: TRIUMF Data

Over the evaluation period, TRIUMF incurred \$370 million in expenses. The largest cost incurred by TRIUMF was for salaries and benefits, which represents 60% of total expenses during the evaluation period. Other considerable costs are associated with equipment, supplies and with power to operate the facility. (Figure 1.3)

**Figure 1.3: TRIUMF’s expenses between 2013-14 and 2017-18 totaled \$370 million**



Source: TRIUMF Data

### **TRIUMF Innovations**

TRIUMF Innovations connects TRIUMF to the business world. The first iteration of TRIUMF’s “business arm” was established in 2008 in an effort to increase the socio-economic impact achieved by the lab. Originally launched with funding support from the Networks of Centres of Excellence for Commercialization and Research program, the initially called Advanced Applied

<sup>2</sup> As of 2017-18, distribution of the 11 Faculty Joint Appointments is as follows: Carleton University (x2), Simon Fraser University (x2), University of Alberta, University of Guelph, McGill University, University of Toronto, University of Victoria, University of Winnipeg and IMPU Tokyo.

Physics Solutions, Inc. (AAPS) was re-launched as TRIUMF Innovations in 2017 with a new structure, new governance and an expanded mandate. Legally separate from TRIUMF, TRIUMF Innovations provides market opportunities for applied physics-based technologies that emerge through TRIUMF; streamlines access to TRIUMF's expertise and infrastructure; and facilitates industry partnerships, licensing and business development for TRIUMF researchers and technologies.

## 2 About the Evaluation

As noted earlier, TRIUMF receives operational funding from the federal government which is administered by the NRC. Therefore the NRC conducts an evaluation of TRIUMF every 5 years in compliance with requirements of the Financial Administration Act (Sec 42.1) and as per the NRC's approved Departmental Evaluation Plan. This evaluation focused on the five-year period of 2013-14 to 2017-18. Because the NRC's contribution is only one source of funding and there are no distinct outcomes associated solely with it, this evaluation considers the full slate of TRIUMF activities and outcomes.

The evaluation explores the relevance and performance of TRIUMF. The questions addressed through the evaluation were developed following consultations with NRC's Vice-President (VP) of Emerging Technologies (as well as key staff members of the VP's office), TRIUMF management, other federal funding organizations and a review of key documents. (See Appendix A for the evaluation questions.)

In order to generate the most useful, valid and relevant evaluation findings possible, mixed methods to collecting data were used. The data collection approach incorporated both qualitative and quantitative methods including:

- a review of documents
- a review of administrative and performance data
- interviews with TRIUMF staff, clients, partners and other key stakeholders
- a survey of TRIUMF users
- an international peer review

A bibliometric analysis (commissioned by TRIUMF) and an economic impact assessment (commissioned by the NRC) were also completed by external consultants with the objective of informing the evaluation. These were included as key documents consulted as part of the document review. (See Appendix B for a detailed description of the methodology used for the evaluation.)

The following sections present the findings of the evaluation by broad theme: relevance/need (section 3), performance (section 4), and efficiency (section 5). The conclusion is discussed in section 6 and the management response is in section 7 of the report.

### 3 TRIUMF addresses the needs of Canadian scientists and is aligned with federal government priorities

The evaluation explored the relevance of TRIUMF through an examination of whether Canadian scientists needed access to a facility like TRIUMF and whether their needs could be met in its absence. The evaluation found that TRIUMF addresses the needs of a growing research community, in particular by providing necessary equipment and facilities, which are not available elsewhere in Canada. Because of the considerable funding it receives from the federal government, the relevance of TRIUMF was also assessed through its alignment with federal priorities in the area of science, technology and innovation, for which the evaluation found significant alignment.

#### 3.1 TRIUMF serves the needs of a growing Canadian subatomic research community

The need for TRIUMF is demonstrated in part through the existence of a growing Canadian community of researchers in TRIUMF-related fields. The most recent profile completed by NSERC (2015) describes a subatomic research community spread across 31 universities and facilities such as TRIUMF and SNOLAB.<sup>3</sup> This community is also experienced. NSERC's research shows the average number of years since researchers in this community completed their PhD is 25 years. Along with the implied excellence that experience fosters, this finding could also suggest an aging population. Instead, the data indicates growth and renewal. For instance, between 2010 and 2015, 13% of researchers stopped being active (e.g., retired or resigned). Despite this, the population of 224 researchers in 2010 grew to 233 in 2015.<sup>4</sup> Students in subatomic research are also part of the community and, in fact, represent double the number of researchers in the community.

Growth of the community was also mentioned by interview participants. Many noted that the expanding community affects demand for facilities and that this poses a risk for TRIUMF's continued capacity to meet needs. The oversubscription of some of TRIUMF's facilities supports this finding. Data collected by TRIUMF shows that the requests for time in the TRIUMF facilities significantly surpassed the time available. (Table 3.1).

**Table 3.1: TRIUMF facilities are consistently oversubscribed or at capacity**

Facility		2013	2014	2015	2016	2017
SAP-RIB	# of shifts requested over the # of shifts available.	2.7	2.1	2.1	2.6	2.2
MMS-MuSR		2.5	1.4	1.5	1.7	1.5
MMS-bNMR		1.5	1.0	2.3	1.5	1.4
Machine shop	Time utilized	115%	133%	116%	120%	99%
Design office		89%	99%	98%	121%	115%
Detector facility		110%	110%	110%	110%	116%

Source: TRIUMF Data

<sup>3</sup> SNOLAB is an underground science laboratory specializing in neutrino and dark matter physics located near Sudbury Ontario Canada. <https://www.snolab.ca/>

<sup>4</sup> Canadian Subatomic Physics Long Range Plan 2017-2021, <http://www.subatomicphysics.ca/#toc>

Oversubscription of TRIUMF facilities limits access for individual researchers. While the survey of TRIUMF users found that most researchers are currently satisfied with the access they have been granted to date, many interview participants were concerned that the increasingly competitive desire for access will affect this satisfaction. The completion of the Advanced Rare Isotope Laboratory (ARIEL), slated for 2023, is expected to help mitigate this issue by increasing TRIUMF's capacity.<sup>5</sup> The IPRC also noted the importance of the ARIEL project, saying

*“The oversubscription of beam time limits the Canadian and world nuclear physics program and probably limits the, albeit healthy, international participation. This points to the need for the planned upgrade of the ability to deliver beam to researchers. Such improvement is a key goal of the 2020-2025 strategic plan”.* – IPRC Report

### **3.2 University researchers and students need the large scale facilities at TRIUMF**

TRIUMF provides researchers and students with the capabilities of a large facility, which are required for their research and which are not available within their own institutions. Researchers also benefit from the support found at TRIUMF. For instance, it was mentioned by interview participants that universities leverage the expertise found at TRIUMF (e.g., engineering resources) that they would not have access to otherwise. The International Peer Review Committee (IPRC) noted that TRIUMF enables Canadian universities to participate in the global research community at a much higher level than would be possible without TRIUMF or an equivalent.

Universities recognize the benefits of working with TRIUMF and many seek to benefit through TRIUMF membership: since the last evaluation in 2013, 6 universities have joined TRIUMF as full members (3) or associate members (3).<sup>6</sup> Beyond having an influence on the strategic direction of TRIUMF, member universities also benefit from access to the TRIUMF network of expertise and support. Membership can also provide opportunities for joint or reciprocal faculty appointments.<sup>7</sup> Data collected by TRIUMF shows that the number of Canadian researchers and students using TRIUMF has increased 60% between 2013 and 2016.<sup>8</sup> Also, results of the survey of users suggest that use is meeting research needs:

---

<sup>5</sup> ARIEL is TRIUMF's flagship multidisciplinary research facility. Once completed, the facility will broaden Canada's research capabilities in particle physics, nuclear physics, nuclear medicine, and materials science and is expected to increase TRIUMF's annual productivity for rare-isotope science to 2-3 times its current level.

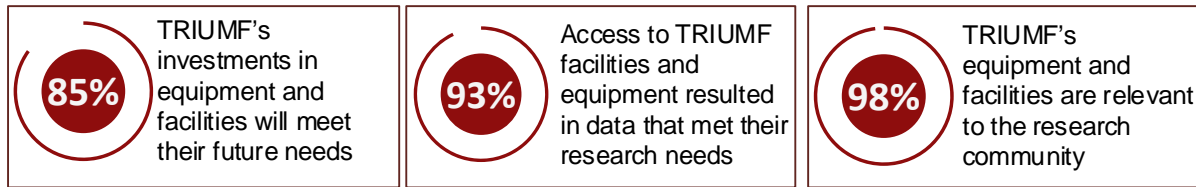
<https://www.triumf.ca/ariel>

<sup>6</sup> TRIUMF website

<sup>7</sup> Ibid.

<sup>8</sup> Numbers from 2017 were omitted because a change to the tracking system, implemented in 2017, does not allow for comparison of years prior.

Most TRIUMF users agree that:



Source: Survey of TRIUMF Users

Overall, evidence collected for the evaluation shows that researchers and students need TRIUMF to facilitate their work and that their use of TRIUMF is increasing.

### 3.3 Research needs could not be met in Canada in the absence of TRIUMF

In Canada, there are a number of small facilities and institutes that support the activities of the subatomic physics community. TRIUMF and SNOLAB are the only two major facilities in Canada at which large experiments can be conducted. These facilities serve different needs and are considered complementary. For instance, SNOLAB is the leading underground (2 km below the surface) facility, providing ideal conditions for nuclear and particle physics rare-event experiments.<sup>9</sup> TRIUMF provides specialized infrastructure to researchers in nuclear physics, nuclear astrophysics and particle physics. For example, the accelerator at TRIUMF includes a primary beam driver and methods to select a secondary beam to synthesize and deliver short-lived isotopes.<sup>10</sup> Further, TRIUMF's Isotope Separator and Accelerator facility (ISAC) is the only isotope separation on-line (ISOL) facility in North America and one of the leading Rare Isotope Beam (RIB) infrastructures in the world. Also, once completed, ARIEL will be a flagship program in Canada, offering novel production features and access to new isotopes.<sup>11</sup> In addition, TRIUMF remains the only laboratory in North America using muons for condensed matter physics and is world-unique in  $\beta$ -detected Nuclear Magnetic Resonance ( $\beta$ -NMR).<sup>12</sup> The IPRC agree that TRIUMF is home to capabilities that enable unique research. Without TRIUMF, they noted, the Canadian research community would have to rely on facilities outside the country and thus, the community would not be as strong.

Results of the survey of TRIUMF users supports these findings, with survey respondents noting that research needs would be more difficult to meet without access to TRIUMF:

- In the absence of TRIUMF, 54% of users said it is unlikely they could obtain access to facilities and equipment to meet their research needs. Of those that say they could (35%), most (88%) said this would be outside of Canada.

<sup>9</sup> <http://www.subatomicphysics.ca/>

<sup>10</sup> Canadian Subatomic Physics Long Range Plan 2017-2021, <http://www.subatomicphysics.ca/#toc>

<sup>11</sup> Report of the Advisory Committee on TRIUMF 41<sup>st</sup> meeting, National Research Council (2017)

<sup>12</sup> Report of the Advisory Committee on TRIUMF – Thirty-Fifth Meeting, National Research Council (2014)

### 3.4 TRIUMF aligns with federal government priorities in the area of science, technology and innovation

In addition to addressing needs in the science community, TRIUMF also plays a role in supporting the government's Science & Technology (S&T) priorities. The government's priorities in these areas were originally detailed in the 2007 document: Mobilizing Science and Technology to Canada's Advantage. This strategic document was developed by Industry Canada to focus Canada's efforts to increase the country's productivity and competitiveness. The next iteration of this plan, developed in 2014, builds on its predecessor, focusing on 3 pillars: people, knowledge and innovation.<sup>13</sup>

The previous evaluation found considerable alignment between TRIUMF's activities and the 2007 strategy, particularly around people and knowledge. The evaluation also found that TRIUMF did conduct activities aligned with what at the time was called the "entrepreneurial" pillar. Referred to as "Innovation" in the 2014 strategy, TRIUMF increased its alignment to this pillar through the work of TRIUMF Innovations. The table 3.2 below demonstrates alignment between TRIUMF activities and each of the three pillars of the 2014 S&T strategy.

**Table 3.2 –TRIUMF activities align with the pillars of the 2014 Canadian Government S&T strategy**

Pillar	Demonstration of Alignment
People	This pillar aims to strengthen the skills and capacity for Canada to remain a leader in research and innovation. This includes promoting science to youth and supporting researchers making groundbreaking discoveries. It also highlights the importance of international connections, at the personal and institutional levels. As indicated throughout this report, TRIUMF conducts many activities related to the training of HQP and attracting youth to science (including a co-op program and public outreach). TRIUMF also fosters discovery and is key to Canadian researchers participating in international collaborative projects.
Knowledge	The 2014 strategy emphasizes support for research and scientific capacity in educational institutions. As previously discussed, TRIUMF aligns with this priority by providing the large scale equipment and facilities required by university researchers and students which are not available within universities.
Innovation	Part of the intention of this pillar is to close the innovation gap that hinders the transfer of research to market. For TRIUMF, this is achieved through TRIUMF Innovations.

Source: Federal Science and Technology Strategy 2014

<sup>13</sup> Seizing Canada's Moment: Moving Forward in Science, Technology and Innovation 2014



There is also alignment between TRIUMF and the government's broader Innovation and Skills Plan, introduced in Budget 2017.<sup>14</sup> The plan aims to grow the economy by focusing on "people and skills", "investment, scale-up and clean growth", "program simplification", and "research, technology and commercialization."<sup>15</sup> The latter is in particular alignment with TRIUMF.

The direction and commitment of the government show no signs of shifting. Science, technology and innovation continue to be priorities. Budget 2018 committed funds for activities that align with TRIUMF's vision of making Canada a leader in science, discovery and innovation, improving lives and building a better world. This includes:

- More than \$1.7 billion over five years to support the next generation of Canadian researchers
- More than \$1.3 billion over five years for investments in laboratories, equipment and infrastructure
- Funds to CFI including \$160 million for increased support to Canada's national important research facilities

For TRIUMF in particular, the funds it is allocated every 5 years through contribution agreements with the NRC represent a significant investment by the federal government, toward achieving objectives of their science and technology-related objectives. The NRC also benefits from TRIUMF and its activities as the facility contributes to the achievement of the NRC Core Responsibility "Science and Innovation", in particular through the two departmental results: "Scientific and technological knowledge advances" and "Innovative businesses grow".<sup>16</sup>

Support from the federal government is important to research facilities. For instance, interview participants noted that federal support is crucial to the existence of a facility like TRIUMF in part because it allows for financial stability and facilitates connections with federal departments (e.g., Health Canada). While it does not have a mission from the federal government, interview participants noted that TRIUMF considers itself a national laboratory and works in the interest of the country (e.g., Isotope crisis), but also maintains flexibility to operate based on its own vision. Considering TRIUMF's important role in Canadian subatomic physics research, some interview participants as well as the IPRC noted that there should be more advocacy for TRIUMF.

The IPRC suggested identifying and cultivating an advocate for TRIUMF within the Canadian government who is invested in the success of the laboratory, championing for its needs and well-being. Some interview participants suggested that the NRC take on this role. The role of the NRC with regard to TRIUMF is to ensure the effective stewardship of the federal funding provided to TRIUMF through the contribution agreement. Advocacy is not part of this role.

In the 2017 Fundamental Science Review, the need for strengthened stewardship of the federal research ecosystem in general was recognized. As such, the establishment of the National

---

<sup>14</sup> Budget 2017. [https://www.budget.gc.ca/2017/docs/themes/Innovation\\_en.pdf](https://www.budget.gc.ca/2017/docs/themes/Innovation_en.pdf), accessed on January 30, 2019

<sup>15</sup> Innovation, Science and Economic Development Canada: [https://www.ic.gc.ca/eic/site/062.nsf/eng/h\\_00083.html](https://www.ic.gc.ca/eic/site/062.nsf/eng/h_00083.html) accessed on January 30, 2019.

<sup>16</sup> National Research Council Canada, 2018-19 Departmental Plan



Advisory Council on Research and Innovation (NACRI) was recommended. This council would provide broad oversight and advice and foster coordination of research funding.<sup>17</sup> It is unclear at this time whether NACRI, while fulfilling its mandate, will provide the level of advocacy sought after for TRIUMF.

### **3.5 The NRC's oversight role of TRIUMF is appropriate**

As mentioned above, the NRC's role in relation to TRIUMF is to administer federal funding provided via a contribution agreement with TRIUMF. The NRC provides guidance, oversight and accountability for TRIUMF, but does not play a role in management of TRIUMF operations, nor in advocating for TRIUMF. The evaluation examined the appropriateness of the NRC role through key informant interviews.

Most respondents agree that federal involvement, like that provided by the NRC, is crucial to the existence of a facility like TRIUMF. Federal involvement gives it a stature that a provincial or private lab would not have, provides necessary funding (which creates stability), and enables connections to other federal departments. Interviewees also suggested that federal involvement facilitates collaborations across Canada.

There is some lack of awareness of the role of the NRC, particularly amongst TRIUMF's university partners. However, other key informants who were able to comment on NRC's oversight role of TRIUMF, agree that it is appropriate and that there is currently no better fit. Key informants noted that the NRC is well placed to provide oversight because of their expertise in managing a large science organization.

## **4 TRIUMF has made important contributions to science and has generated social and economic benefits for Canada**

Several aspects of TRIUMF's performance were explored through the evaluation. This includes its role in Canada's achievements in TRIUMF-related fields, its own contributions to the fields, its support to researchers and universities as well as the economic and social benefits it has generated for Canada. The evaluation found that TRIUMF has been important to Canada's position on the global stage. This is in part due to the facilities it provides to researchers, which enables their important research, as well as the international collaborations TRIUMF has facilitated. TRIUMF has also contributed to Canada's positive reputation through its own scientific achievements, including its contributions to important work such as the discovery of the Higgs Boson at CERN and elucidation of neutrino properties by the T2K experiment in Japan. TRIUMF also contributes to the scientific community by fostering the training of HQP and attracting HQP to TRIUMF, and to Canada. Lastly, TRIUMF, through its regular activities, and through TRIUMF Innovations has generated important benefits for Canada.

---

<sup>17</sup> Investing in Canada's Future. Strengthening the Foundations of Canadian Research. Canada's Fundamental Science Review (2017).

#### 4.1 TRIUMF supports Canada’s performance and reputation in TRIUMF-related fields

Over the years, work conducted by Canadian researchers has contributed to a positive international reputation for Canada. All interview participants noted that Canada was well perceived around the world for its role in TRIUMF-related fields. This notion is also supported by the results of the survey of TRIUMF users. Survey respondents noted that Canada’s international reputation in TRIUMF-related fields was mostly “world class” or “above average”. (Table 4.1)

**Table 4.1: Most survey respondents perceive Canada’s international reputation as world class or above average in TRIUMF-related fields**

	World class	Above average	Average	Below average
<b>Particle Physics (n=103)</b>	40%	47%	14%	0%
<b>Nuclear Physics (n=136)</b>	57%	38%	4%	0%
<b>Nuclear Medicine (n=84)</b>	54%	42%	5%	0%
<b>Accelerator Physics (n=104)</b>	44%	47%	7%	2%
<b>Materials Science (n=81)</b>	51%	38%	11%	0%

Source: Survey of TRIUMF Users

‘Don’t know’ responses were excluded from the analysis

Through its outreach work and collaborative projects as well as by providing researchers with the required facilities in which to conduct their research, TRIUMF has also contributed to Canada’s international reputation. Most survey respondents noted that TRIUMF contributed “extremely” or “considerably” in establishing Canada’s reputation. (Table 4.2)

**Table 4.2: Most survey respondents perceive that TRIUMF contributed extremely, or considerably to Canada’s reputation in TRIUMF-related fields**

	Extremely	Considerably	Moderately	Slightly	Not at all
<b>Particle Physics (n=112)</b>	44%	44%	8%	4%	0%
<b>Nuclear Physics (n=143)</b>	71%	26%	2%	1%	0%
<b>Nuclear Medicine (n=90)</b>	51%	41%	4%	3%	0%
<b>Accelerator Physics (n=105)</b>	56%	37%	7%	0%	0%
<b>Materials Science (n=89)</b>	40%	40%	12%	7%	0%

Source: Survey of TRIUMF Users

Note: ‘Don’t know’ responses were excluded from the analysis.

Publications are another indication of Canada’s reputation and performance in TRIUMF-related fields. The bibliometric study which covers the period between 2001 and 2016 found that Canada is performing relatively well. Canada is among the 20 most-published and -cited countries in each TRIUMF-related field; publications are highly-cited and are published in impactful journals. (Table 4.3)

**Table 4.3: Canada ranks well in scientific output and impact (2001 – 2016)**

Field	Scientific Output	Scientific Output Ranking*	Scientific Impact (ARC)	Research Quality (ARIF)	CDI (Citation Impact Index) Ranking*
Particle physics	14,298	12 <sup>th</sup>	1.8	1.3	2 <sup>nd</sup>
Nuclear physics	5,707	13 <sup>th</sup>	2.0	1.3	5 <sup>th</sup>
Accelerator physics	2,943	13 <sup>th</sup>	2.7	1.3	4 <sup>th</sup>
Materials science <sup>18</sup>	888	8 <sup>th</sup>	1.0	1.1	12 <sup>th</sup>
Nuclear medicine	6,168	8 <sup>th</sup>	1.5	1.3	3 <sup>rd</sup>

Source: Science-Metrix Bibliometric analysis (2018)

\* Ranking is based on the Top 20 most-published and -cited countries in each field

## 4.2 TRIUMF contributes to important research and discoveries

The IPRC found that there are world-class efforts from TRIUMF in all areas in which they perform research. They noted that some are unique or highly unusual, and others position Canada to play a significant role in important international collaborations. Examples identified by the IPRC of TRIUMF's contribution to science excellence in each research area are provided in the text box below:

### **Particle physics**

TRIUMF has leadership roles in the ATLAS collaboration at CERN. This experiment is widely recognized as world class and has produced a large number of scientific publications. ATLAS discovered the Higgs boson, referenced in the Englert & Higgs Nobel prize of 2013. TRIUMF scientists contributed to the Higgs discovery and continue to study its properties. The laboratory is making significant contributions to the upgrades of the ATLAS detector to enable precision measurements of Higgs properties at higher luminosities. These upgrades are done in partnership with researchers at Canadian universities with TRIUMF providing key infrastructure and expertise.

TRIUMF scientists are core members of the T2K<sup>19</sup> collaboration that has observed, and is now characterizing, neutrino oscillations. TRIUMF scientists have been key to the observation of the  $\nu_{\mu} \rightarrow \nu_e$  flavor transformation and to exclusion of the CP conserving phase at 95% CL in 2017. The T2K collaboration was awarded the Breakthrough Prize in Fundamental Physics in 2016.

TRIUMF is making significant contributions in precision tests of fundamental interactions. The ALPHA<sup>20</sup> program has established the formation, trapping, and precision spectroscopy of anti-matter and is one of the highlights of the research program. The next steps, ALPHA-2 and

<sup>18</sup> For this bibliometric study, "materials science" refers only to subtopics on which TRIUMF concentrates, such as heavy fermion materials and other exotic materials as well as their properties. The data used for the study was limited to publications that align with TRIUMF's focus, therefore results must not be extrapolated to the larger definition of materials science.

<sup>19</sup> T2K is a neutrino experiment based in Japan and designed to investigate how neutrinos change from one flavour to another as they travel ([neutrino oscillations](http://t2k-experiment.org/))  
<http://t2k-experiment.org/>

<sup>20</sup> ALPHA is an international collaboration based at CERN, which studies antihydrogen atoms. By comparison of hydrogen and antihydrogen, the experiment hopes to understand fundamental symmetries between matter and antimatter. TRIUMF website.

ALPHA-g, will look for evidence of CPT violation and will test the limits of Einstein's equivalence principle. The ALPHA-Canada team was awarded the Polanyi Prize in 2013.

### **Nuclear physics**

The strength of TRIUMF in nuclear physics derives from the accelerator complex. The 520-MeV cyclotron provides a superb base for a high power ISOL rare isotope beam facility. Within North America, it is complementary to the fragmentation dominated Facility for Rare Isotope Beams (FRIB) facility. Worldwide, and within its energy reach, the TRIUMF ISOL is arguably the best in the world.

The accelerator is complemented by a suite of approximately 10 top-class instruments that enable a broad front approach to understanding the origin of the heavy elements as well as exploring nuclear structure. The excellence of the instruments is demonstrated by the replication of several at other facilities, including FRIB/National Superconducting Cyclotron Laboratory (NSCL).

The exploration of the origin of the heavy elements is fundamental to the understanding of our existence and is explored on a broad front. One particular area of achievement of TRIUMF science is in the exploration of the migration of the "Magic Numbers" of neutron-rich nuclei. Some initial measurements in an experiment at TRIUMF hinted at an issue, and an *ab initio* calculation by the theory group reproduced the measurements. Other key measurements with several nuclei followed at TRIUMF and elsewhere, and the TRIUMF theory group continued to enlighten this fundamental feature of nuclear physics.

### **Nuclear medicine**

The division's objectives and research topics are broad, covering synthesis and isolation of rare isotopes for cancer therapy (e.g., Ac-225), production of isotopes which are currently absolutely essential for nuclear medicine (Tc-99m), technologies for labeling molecular probes, commercialization of these radionuclide and radiopharmaceuticals, and strong collaborations with groups, for instance at BC Cancer Center, UBC and others. Development of target technologies, studies of biochemical processes with  $\beta$ -NMR technology, and contributions to proton therapy complement the focus on molecular imaging. Securing of finances to enable the creation of the IAMI center will bundle this expertise into a strong core facility. Given the small staffing level in this division, the quantity and quality of output is remarkable as mirrored by revenues as well as the publication output.

### **Accelerator physics**

The 520-MeV cyclotron, which has four extraction beam lines, is unique and has excellent capabilities in accelerating high-intensity proton beams of more than 100 microamperes per beamline. Its performance has been further improved in the last 5 years by a new power supply for the main magnet and improved infrastructure like the H<sup>-</sup> ion source.

It is well known that the high-power target technology of TRIUMF leads the world, and forms the technological basis of providing various secondary particles such as rare isotopes and muons. Implementation of rastering the proton beam on ISAC target has improved the RIB yield and has increased target life. Recently new techniques have been developed in the target material, which reduced production time and increased the extraction efficiency.

Fundamental studies on superconducting radio frequency (SRF) technologies have advanced significantly. For example, the group succeeded in measuring the field of the first flux entry in Nb and new coatings using  $\mu$ SR. Easy access to the beamlines for materials science and

collaboration in TRIUMF enabled these advancements. TRIUMF also invented and realized the world's first balloon single spoke resonator for reduced multipacting. A new method of fabricating the bulk-Nb resonator based on machining and tungsten inert gas (TIG) welding will have great impact in the mass production of SRF cavities with reduced cost.

### **Materials science**

The unique  $\mu$ SR and  $\beta$ -NMR facilities are world-class enablers of breakthrough science. For example, for  $\mu$ SR there are few facilities worldwide. One that is relatively comparable is at the Paul Scherrer Institute (PSI) in Switzerland; another at the Japan Proton Accelerator Research Complex (J-PARC) in Japan differs technically in that it is based on a pulsed beam, while the beam at TRIUMF is continuous.

Confidence in the future performance is supported by recent successes such as the understanding of the structure and function of an important new catalyst for ammonia synthesis. This impacts agriculture due to the ability to efficiently supply fertilizer, especially in developing countries. The new catalyst provides an easier production pathway that is energy-efficient due to enabling lower temperature synthesis of a critical catalyst needed to literally help feed the world.

Another area of focus is within the realm of quantum materials, especially explorations of a new class of materials whose properties are topologically protected. The topic encompasses topological insulators, magnetic skyrmions, topological superconductors, Majorana fermions that are their own antiparticles, and Weyl semimetals, with their fascinating low-energy excitations. An additional beauty of these studies is that they bring together disparate realms of physics. For example, massless chiral Weyl fermions play an important role in quantum field theory and the standard model. Weyl published his theoretical work in 1929, following Dirac's work, but it was not until quite recently that the condensed matter and materials physics community has been able to contribute to this field.

A study of bibliometrics also provides evidence of TRIUMF's contribution to science. Despite its relatively small size compared to other international labs, TRIUMF is competitive in terms of publication output and impact:<sup>21</sup> (see table 4.4)

- In particle physics, TRIUMF participated in 15% of all Canadian publications and was among the most central actors in the network of Canada institutions, collaborating with all but three between 2009 and 2016.
- In nuclear physics, TRIUMF was the only Canadian institution ranking in the top 50 institutions for outputs. It scored above the world level and above the Canadian average for impact, however it was not among the most impactful organizations in Canada, likely due to the high proportion of publications that are conference proceedings, which are less cited than articles.
- In accelerator physics, TRIUMF's share of conference proceedings, 41%, was among the highest of the Canadian institutions. When comparing its citation profile with the top

---

<sup>21</sup> Science-Metrix, Bibliometric analysis on TRIUMF's research performance 2001-2016. Analytical report (2018)

publishing institutions in the world, TRIUMF's impact score makes it comparable to other national labs or high-producing universities.

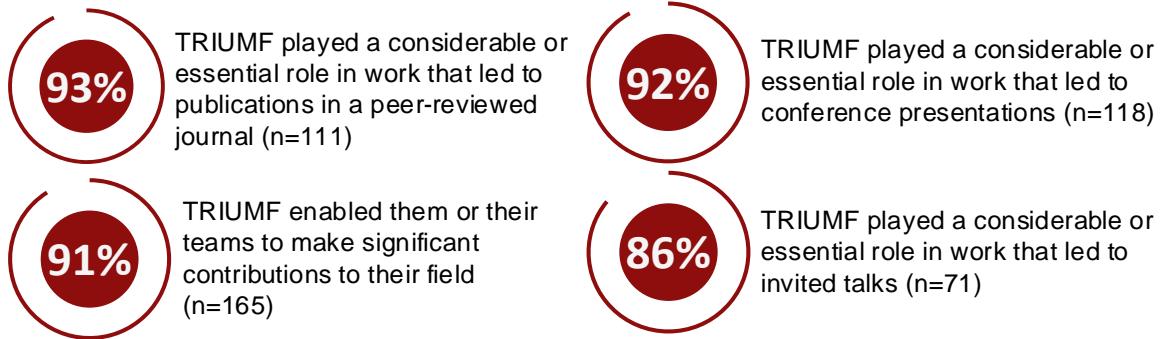
- In materials science, TRIUMF was the largest Canadian producer in its area of expertise; it participated in more than 55% of all Canadian publications in that area. Despite a lower ARC score compared to the other fields, TRIUMF's overall impact in this field was on par with the world level.
- In nuclear medicine, TRIUMF was among the institutions with the highest international collaboration rates. TRIUMF participated in some highly-cited publications, among the top 1% most-cited worldwide.

**Table 4.4: Despite its relatively small size compared to other international labs, TRIUMF publications are impactful (2001-2016)**

Field	Scientific Output	Scientific Impact (ARC)	Research Quality (ARIF)
Particle physics	2,210	2.5	1.4
Nuclear physics	1,753	2.3	1.3
Accelerator physics	840	3.4	1.3
Materials science <sup>22</sup>	480	0.8	1.0
Nuclear medicine	332	1.9	1.3

Source: Science-Metrix Bibliometric analysis (2018)

TRIUMF also enables excellence among its users. Findings from the survey of TRIUMF users showed that TRIUMF is important to the advancement of science because:



Source: Survey of TRIUMF users

### 4.3 TRIUMF facilitates collaboration within Canada and internationally

TRIUMF has played a role in international collaborations that have resulted in significant discoveries. TRIUMF’s participation in such important projects is in part due to the infrastructure and the unique capabilities they offer. As a result, they are able to collaborate on a wide range of projects, in Canada and globally. For example, they are involved in 86% of Canada’s experimental subatomic research.<sup>23</sup> As another indication of their considerable involvement and support, over the last five years, they were involved in projects which received 77% (on average) of NSERC – SAP awarded funding.

The amount of CFI funding granted to TRIUMF-related projects is also an indication of TRIUMF’s importance to physics in Canada. CFI provides funding to institutions for infrastructure to accommodate researchers’ experiments. Not eligible on their own, TRIUMF partners with institutions to compete for this funding in order to build required infrastructure. For

<sup>22</sup> For this bibliometric study, “materials science” refers only to subtopics on which TRIUMF concentrates, such as heavy fermion materials and other exotic materials as well as their properties. The data used for the study was limited to publications that align with TRIUMF’s focus, therefore results must not be extrapolated to the larger definition of materials science.

<sup>23</sup> State of TRIUMF (2017). TRIUMF

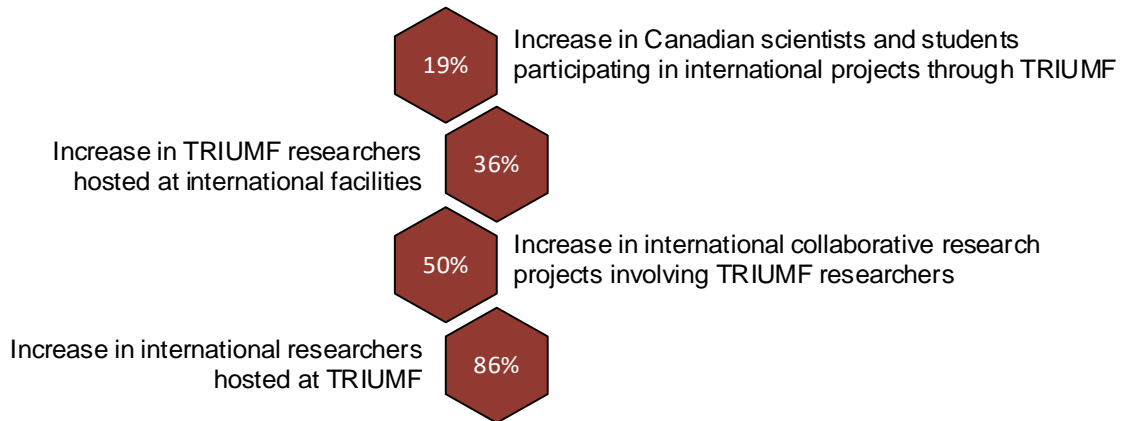


institutions, partnering with TRIUMF is important as TRIUMF has the expertise and the physical space for infrastructure, and institutions can also leverage existing infrastructure found at TRIUMF. During the evaluation period, there were two CFI funding competitions, for which 15% and 12% of the total funding was awarded to TRIUMF-related projects. This represents an investment of approximately \$81 million across seven projects.

In addition to collaboration in Canada, TRIUMF has been instrumental in connecting Canadian researchers to the world. The evaluation found that TRIUMF has taken on the role of facilitator when it comes to connecting Canada to the world. For instance, the review of documents confirmed that TRIUMF is considered Canada’s main point of contact for collaboration with international partners such as CERN (Europe) and KEK (Japan).<sup>24</sup> Further, the IPRC remarked that TRIUMF has created a brand for Canada, not just for nuclear and particle physics and accelerator technology, but for Canadian physical, biological and life sciences. They noted that this has been indispensable in connecting Canadian science in TRIUMF-related areas to the world. Interview participants noted that this connection has allowed Canadian researchers to be invited to international facilities and to participate in international experiments. Figure 4.5 below provides an indication of increases in collaborations due to TRIUMF during the evaluation period.

95% agree that TRIUMF is a hub for international science  
-Survey of TRIUMF Users

**Figure 4.5: Collaborations involving TRIUMF have increased over the evaluation period**



Source: TRIUMF data

<sup>24</sup> Five-Year Plan 2015-2020: Realizing the Vision. 2013. TRIUMF



According to the IPRC, examples of how TRIUMF is connecting Canadian researchers with the world include:

<p><b>Particle Physics</b></p>	<p>Enabling Canadian researchers to participate in the international ATLAS collaboration at CERN. The detector contributions (including upgrades), the Tier-1 data centre, and accelerator contributions are essential to enable Canadian participation, and they all depend on TRIUMF for success.</p> <p>Japan is partnering with the lab on the construction of a world-class next generation Ultracold Neutron source at TRIUMF.</p> <p>The theory group hosts international workshops and conferences that attract scientists from around the world.</p>
<p><b>Nuclear Physics</b></p>	<p>The excellence of the ISOL facility at TRIUMF has attracted a strong cadre of TRIUMF Faculty who participate in collaborations at laboratories from Japan to Finland and elsewhere.</p>
<p><b>Nuclear Medicine</b></p>	<p>There are international collaborations with research groups, e.g., in <math>\beta</math>-NMR, in the production of molecular probes, etc.</p> <p>IAMI will boost international collaborations and demand for access in many respects.</p>
<p><b>Accelerator Physics</b></p>	<p>Recently, SRF cavities and high-power target design have been exported to several accelerator facilities including CERN, the Variable Energy Cyclotron Centre (VECC) in India, and the Rare Isotope Science Project (RISP) in Korea.</p> <p>The beam diagnostics in the Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE) project have also been successfully commissioned. Thus TRIUMF contributes to international projects with critical components and expertise, which helps to enhance the international presence of Canada in the world.</p>
<p><b>Materials Science</b></p>	<p>TRIUMF materials scientists contribute to the characterization of advanced Li-ion battery materials of considerable interest for energy storage needed for alternative energy sources.</p>

Source: IPRC Report 2018

The 2018 bibliometric study also provides insight into TRIUMF connecting Canadian researchers to the world, through international co-authorship. Canada and TRIUMF's co-authorship rate is above the world average in all five scientific areas. The bibliometric report notes that the need for infrastructure is a common driver for collaboration. Therefore countries that have the critical mass (e.g. USA) and / or the infrastructure and facilities (e.g. Japan) do not need to collaborate internationally as much as other countries. TRIUMF benefits from this situation. Because it is an established facility with unique capabilities, TRIUMF attracts collaboration. Beyond the practical reason for collaboration, some interview participants also noted that international collaboration is crucial to the advancement of science and that sharing knowledge and ideas ensures that science moves forward. In that case, TRIUMF and Canadian

researchers are playing an important role in moving science forward through considerable co-authorship. (Table 4.6)

**Table 4.6: TRIUMF’s international co-authorship rate is above the Canadian and global rates**

	TRIUMF	Canada	Global
Nuclear physics	89%	76%	65%
Particle physics	89%	72%	65%
Materials science	80%	78%	65%
Nuclear medicine	50%	48%	39%
Accelerator science	68%	66%	56%

Source: Science-Metrix Bibliometric report (period : 2001-2016) 2018

#### 4.4 TRIUMF fosters the training of HQP

The evaluation found that TRIUMF prioritizes training of HQP, and that it has been successful in this endeavor. For instance, TRIUMF provides numerous training opportunities for students such as a Co-Op work experience program, the Isotopes for Science and Medicine NSERC CREATE program, and other activities such as conferences and seminars for students.

Students affiliated with TRIUMF also benefit from the extensive facilities available at the laboratory. Between 2013-14 and 2017-18 all SAP-RIB time and almost all MMS- $\beta$ -NMR time was allocated to experiments involving Canadian students and postdocs. The need for facilities such as TRIUMF was discussed previously. One would expect that this need is perhaps greatest for Canadian students, whose access to facilities outside the country could be limited due to cost and other challenges. Just under half (43%) of the survey respondents who were students (undergrad, graduate and post-doc fellow), thought themselves unlikely to have access to similar facilities in the absence of TRIUMF. The IPRC agrees that this is an important benefit of TRIUMF to universities, especially for the students and postdocs that are resident at TRIUMF and well-integrated into its science and operations. Examples of the benefits for students at TRIUMF include carrying out cutting-edge research under TRIUMF faculty supervision, such as R&D of high-resolution separator, laser ion source and novel RIB production targets. Because similar large and complex facilities are not available within individual universities in Canada, the ability of Canadian students to access a large-scale facility would be impossible without TRIUMF. In life sciences, the role that TRIUMF plays in training HQPs in handling radioactive materials is important considering the growing relevance of imaging probes for personalized medicine. TRIUMF’s quality, infrastructure and staff expertise are strengths that are more concentrated than elsewhere and make TRIUMF’s growing role in education and research pivotal.

During the evaluation period, 138 students graduated under TRIUMF supervision or used TRIUMF data to complete their thesis.

-TRIUMF Data

Respondents of the user survey also recognized the importance of TRIUMF for training. Almost all respondents agreed that TRIUMF was critical to the training of highly qualified students (96%) and that TRIUMF enabled them or their research teams to develop new skills or expertise

(93%). Further, survey respondents who indicated they had accessed TRIUMF for their training or education (n=61) agreed that:

- access to TRIUMF facilities and equipment significantly contributed to their training and education (94%)
- training and experience at TRIUMF will be valuable to employers (92%)
- their experience with TRIUMF for training and education was positive (95%)

Students at all academic levels benefit from access to TRIUMF. For instance, during the evaluation period, TRIUMF hosted Post-Doctoral Fellows (PDFs), graduate students and undergraduate students. A similar number of PDFs were hosted each year, but the number of graduate and undergraduate students hosted increased (by 65% and 56% respectively). (Table 4.7)

**Table 4.7: The number of students hosted at TRIUMF has increased overall**

	2013	2014	2015	2016	2017
PDFs	57	59	62	56	54
Graduate students	43	42	73	56	71
Undergraduate students	81	86	109	107	126

Source: TRIUMF data

## 4.5 TRIUMF attracts HQP to Canada

TRIUMF not only develops HQP, but the existence of TRIUMF makes Canada an attractive place for them to remain following their training. For instance, discussions between IPRC members and students during the site visit at TRIUMF suggested that migration to Canada, to work with TRIUMF, often leads to the student seeking long term positions in Canada, particularly in universities.

The positive reputation in subatomic physics has made Canada an attractive place for researchers to work. For example, for survey respondents who had to make decisions about whether to remain in, or move to, Canada, or to pursue studies or employment in Canada, the majority indicated that use of TRIUMF contributed considerably or extremely to this decision:

- to remain in Canada (60%)
- to move to Canada (63%)
- to pursue studies in Canada (54%)
- to pursue employment in Canada (59%)

Further, 85% of the survey respondents agreed that having access to TRIUMF contributed to their decision to perform their research in Canada rather than in other countries. The level of agreement with this statement was similar among respondents from Canada and those from foreign institutions or organizations.

When discussing employment migration of highly qualified persons (HQP) to and from Canada, many interview participants discussed the importance of a transitory scientific community. They

stated this is needed to build scientific excellence because new experiences elsewhere build expertise and new ideas (just as collaboration does). The migration of HQP is a characteristic of the scientific community; people tend to move around. While participants could not quantify any trends in migration to or from Canada, many did agree that TRIUMF has an impact on migration. Due to the unique facilities and its participation on international projects, TRIUMF attracts students and world class researchers.

The IPRC agrees that TRIUMF has played a key role in the training of HQP and that there is a history of many choosing to stay in Canada for some or all of their careers. In addition, TRIUMF has contributed to the attraction of global leaders in the various fields to work with and stay within Canada, as evidenced by the composition of the TRIUMF staff and leadership, as well as of the faculty at Canadian universities in the relevant fields. TRIUMF brings together users and HQP from 39 countries, many of whom are leaders in their fields. For example, during the evaluation period, TRIUMF researchers received 29 awards<sup>25</sup> recognizing their excellence, as well as their contributions to the Higgs Boson discovery that led to the Nobel Prize, as well to the elucidation of neutrino properties that led to the Nobel Prize for Art McDonald, and the Breakthrough Prize in Fundamental Physics for the T2K collaboration. Further, TRIUMF researchers serve on elected boards and committees. Each year since 2013, at least 19 Canadian TRIUMF researchers<sup>26</sup> have participated on elected boards or committees. These include committees for other facilities such as Fermilab, Canadian Light Source, SNOLAB and CERN and for associations such as the Canadian Association of Physicists, and the American Physical Society, among others. This suggests that TRIUMF researchers are known and their expertise sought-after for committees.

#### **4.6 TRIUMF activities have resulted in economic and social benefits to Canada**

Benefits generated by TRIUMF are the result of: 1. TRIUMF's various science and technology programs, and 2. the efforts of TRIUMF Innovations.

Through its regular activities, TRIUMF generates benefits through the following work:<sup>27</sup>

- Providing isotopes for medical diagnostic and clinical purposes
- Assisting Canadian companies to develop needed expertise to build and supply specialized technology, first to meet TRIUMF's research and service provision needs and then to meet the needs of laboratories and businesses world-wide
- Training people in specialized areas who take their expertise to work in existing companies, or start new companies of their own, which contribute to the local and national economies
- Providing services such as beams of energetic protons and neutrons for testing products and treating cancer

---

<sup>25</sup> Data reflects Board Appointed Employees (Faculty equivalents) and Emeritus only

<sup>26</sup> Data reflects Board Appointed Employees (Faculty equivalents) only

<sup>27</sup> Socio-Economic Impact of TRIUMF. Hickling, Arthurs, Low. 2018

- Attracting conferences to the Vancouver region

TRIUMF Innovations translates TRIUMF research to the market, therefore TRIUMF also generates benefits through TRIUMF Innovations, including:

- providing market opportunities for applied physics-based technologies that emerge from the TRIUMF network
- streamlining access to TRIUMF's expertise and infrastructure
- connecting TRIUMF researchers and technologies to the world via industry partnerships, licensing, and business development.<sup>28</sup>

In generating some of these benefits, TRIUMF works with a number of industrial partners. Over the evaluation period, the number of relationships with industry partners increased considerably, from 72 in 2013 to 139 in 2017 (93% growth). Further, since the creation of AAPS/TRIUMF Innovations, 5 spin-off companies have been formed. Examples of industrial partnerships and spin-off companies are provided in table 4.8

**Table 4.8: TRIUMF partners and spin-offs**

Nature of relationship	Company	Description of relationship
<b>Production of isotopes for medical applications</b>	Nordion/BWXT <sup>29</sup>	Collaboration resulting in molecular imaging technology developments and commercial isotope production
	BC Cancer	Receives of medical isotopes and collaborates with TRIUMF and UBC in the Proton Treatment Facility treating choroidal melanomas
	ITM Isotopen Technologien Munchen AG	Produces and processes a variety of cyclotron-based isotopes via ongoing relationship with TRIUMF
<b>Equipment supplies and collaborators</b>	Advanced Cyclotron Systems Inc. (ACSI)	Built the first commercialized hybrid cyclotron to produce both PET and SPECT isotopes, including technetium-99
	GE Healthcare	Supplies technology and provided the cyclotrons used in the development of cyclotron-based technology to produce technetium-99

<sup>28</sup> <https://www.triumfinnovations.ca/what-we-do/>

<sup>29</sup> Nordion has recently been acquired by BWX Technologies: <https://www.bwxt.com/news/2018/08/06/BWXT-Completes-Acquisition-of-Sotera-Health%E2%80%99s-Nordion-Medical-Isotope-Business->

Nature of relationship	Company	Description of relationship
	D-Pace	Licenses cyclotron component and ion source technologies, documents TRIUMF's know-how into manufacturing drawings and technical manuals to preserve valuable knowledge for training and future use
<b>Spin-off companies</b>	IKOMED Technologies, Inc.	Develops technology to autonomously and selectively shutter x-ray source to reduce exposure to the patient but preserve high-res imaging
	CRM GeoTomography Technologies	Offers technology to reduce cost and waste of geology exploration, with other applications in defence and security
	Frontier Sonde Inc.	Develops novel technologies based on neutron imaging to advance oil and gas surveying and recovery
	MICROMATTER Technologies Inc.	Produces carbon and accelerator target foils, and XRF calibration standards
	ARTMS Products Inc.	Established by TRIUMF (AAPS), commercializes TRIUMF's solution to the medical isotope supply crisis.

Source: Socio-Economic Impact of TRIUMF. Hickling, Arthurs, Low. 2018

Overall, the activities of TRIUMF have resulted in economic benefits for Canada, and for British Columbia (BC) specifically. The HAL study shows that during the evaluation period, the total gross domestic product (GDP) attributable to TRIUMF was \$609 million.<sup>30 31</sup> BC received 82% of this. In fact, BC saw its GDP increase by \$500.8 million due to TRIUMF, representing a return on investment of 10.2. The short-term return to Canada was 1.5, the long-run return to Canada was 0.48<sup>32</sup>, and the return to government was 0.40 (Table 4.9)

<sup>30</sup> The economic impact of TRIUMF that could be quantified was derived from the following sources: TRIUMF expenditures, the revenue by Canadian businesses that is attributable to their relationship with TRIUMF, and spending by delegates of conferences located in Canada as a result of TRIUMF.

<sup>31</sup> The HAL report describes the benefits that cannot be quantified and were not included in the analysis p. 9-10.

<sup>32</sup> HAL's methodology includes public spending on TRIUMF as a stimulant to economic activity in their short term return. Long-run return considers public spending on TRIUMF as a contribution to the nation's debt, which must be paid back and is therefore not included as a benefit.

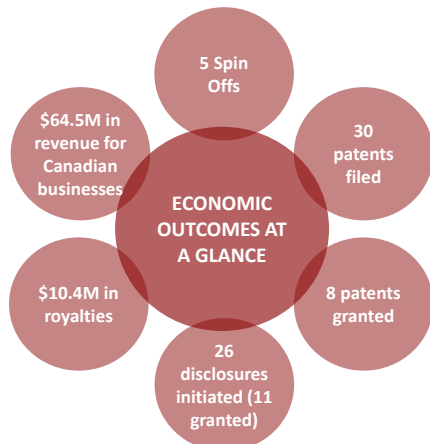


**Table 4.9: TRIUMF represents a positive return on investment, especially for BC**

	Investment in TRIUMF	GDP increase	Return on Investment
Return to British Columbia	\$49.0 million	\$500.8 million	10.2
Short-term return to Canada	\$410.6 million	\$609.2 million	1.5
Long-run return to Canada		\$198.6 million	0.48
Return to government		\$164.9 million in tax revenues	0.40

Source: Socio-Economic Impact of TRIUMF. Hickling, Arthurs, Low. 2018

The HAL economic study indicated that TRIUMF is providing an appropriate return on the government’s investment and that since the last evaluation in 2013, TRIUMF’s economic contributions to Canada have improved with gross outputs increasing by nearly 4% and GDP, employment, labour income and tax revenue increasing on average by approximately 9%.<sup>33 34</sup>



The IPRC recognized the economic benefits generated by TRIUMF. They also suggested that TRIUMF increase benefits by expanding the scope of its activities. For instance, the IPRC noted that, to date, the majority of commercialization activities were related to the life sciences. They suggested TRIUMF explore opportunities for commercialization in other research areas, particularly in accelerator and detector technology.

The IPRC also recognized the progress made in commercialization, but noted a few risks. First, in terms of revenue, 95% of royalty revenue (\$10.4M over the last 5 years) is tied to TRIUMF’s partnership with a single licensee, in which material is produced at cost and royalties are received. This concentration of revenue represents a risk if production issues arise at either the licensee or TRIUMF. Also, the IPRC saw opportunities to widen the scope of opportunities with patents. For instance, of 30 patents filed in the last 5 years, 23 are related to just one company.

**Recommendation 1: The NRC should work with TRIUMF and TRIUMF Innovations to diversify commercialization activities (and to expand royalties and patents), to spread and reduce the risk associated with a too-narrow portfolio.**

<sup>33</sup> Socio-Economic Impact of TRIUMF. Hickling, Arthurs, Low. 2018

<sup>34</sup> The socio-economic study conducted for the previous evaluation in 2013 was also conducted by Hickling, Arthurs and Low, using the same methodology.

The work of TRIUMF has also resulted in social benefits. Results of the socio-economic study and evidence from the interviews suggest that social benefits are mainly due to activities in health innovation and delivery, public outreach, and as previously discussed, training and education:

- Health innovation and delivery
  - Brain Research Program: collaboration with UBC, resulting in production of high quality radioisotopes and incorporation into radiopharmaceuticals
  - Technetium-99m: conducted by CycloMed99, a national consortium led by TRIUMF, that focuses on advancing current technology to ensure continued supply of non-reactor-based Tc-99m
- Education and training of highly qualified personnel
  - Co-operative education: provides valuable hands-on experience to approximately 100 students each year
  - Isotopes for Science and Medicine Program: provides students with distinct skills required for employment in isotope-related fields
- Public outreach
  - Global Physics Photowalk : organized by a number of leading labs, through photos, provides a behind-the scenes look at the labs, increasing their profiles and stimulating interest from the public and young people
  - Regional public engagement: a range of activities to educate public about TRIUMF and foster interest in youth to pursue STEM (science, technology, engineering and mathematics)

The IPRC recognized that TRIUMF has been energetic in its outreach, particularly within BC. They noted that this has the potential to increase the attraction of EDI (equity, diversity, inclusion) candidates to STEM fields.

The social benefits resulting from the activities noted above can be seen in the short and longer-term, and range from participants in public outreach activities gaining new knowledge, to an improvement in health care outcomes. The anticipated social benefits of some of TRIUMF's activities are summarized in table 4.10 below.



**Table 4.10: TRIUMF activities result in a number of social benefits**

Benefit	Activity					
	Brain Research Program	Tc-99m	Co-op	Isotopes for Science and Medicine	Photowalk	Regional Public Engagement
Specialized skills and capabilities	X	X	X	X		
New knowledge	X	X	X	X	X	X
Impacts of cross-disciplinary collaboration	X	X	X	X	X	X
Health care cost reductions		X				
Health care outcome improvements	X	X				
Inspiration of Canadians / youths					X	X

Source: Socio-Economic Impact of TRIUMF. Hickling, Arthurs, Low. 2018

Overall, the IPRC was impressed with the level of benefits resulting from TRIUMF and its activities. Still, results of the evaluation show opportunities for increased impact. Due to location, it is not surprising that the highest level of economic and social benefit has been to BC. Finding ways to expand TRIUMF’s reach to other provinces could further increase benefits. This could possibly be achieved through inexpensive means such as virtual tours and streaming presentations and lectures. Further, as noted by the IPRC,

*“Given that the laboratory now has university members and associate members, plus users and collaborators, from over half of the remaining provinces, it is appropriate that other provinces should be persuaded to increase their support of TRIUMF. One approach to addressing this challenge may be to increase the visibility of TRIUMF and its connection/contributions to other provinces through outreach and targeted communications.” – IPRC Report*

**Recommendation 2: The NRC should work with TRIUMF to identify ways to expand their outreach to regions outside of British Columbia, in an effort to increase both TRIUMF’s impact and its base of support. Methods to broaden TRIUMF’s reach could include virtual means.**

## 5 TRIUMF is committed to efficient and economic operations

The evaluation explored a number of questions relating to the efficiency and economy of TRIUMF. This included following up on changes made by TRIUMF as a result of recommendations from the previous evaluation and how it has managed resources during this evaluation period. The evaluation also considered TRIUMF's strategic plan for the next 5 years as well as external factors that affect efficiency. The evaluation found that TRIUMF has made a number of changes to increase efficiencies, are planning many others, and that they have soundly managed their resources. TRIUMF's strategic plan for 2020-2025 demonstrates its vision for the next phase of the laboratory and was found by the IPRC to be ambitious, yet achievable in its approach.

### 5.1 TRIUMF is improving its efficiency through new mechanisms and governance

The previous evaluation of TRIUMF found that, overall TRIUMF functioned well and was more efficient than some other, comparable facilities. There were some areas that were identified as needing improvement, which resulted in recommendations to be addressed by the NRC and TRIUMF. The first of these recommendations noted that TRIUMF should define and implement an effective performance management system, aligned with its strategic and operational objectives. This would facilitate assessment of performance and provide additional insights to more strategically manage resources and find efficiencies. Since then, TRIUMF has:

- finalized a logic model, implementing key performance indicators (KPIs)
- prepared new mission, vision and values statements
- implemented more formal planning across the various levels of the organization

The previous evaluation also found that any potential strain on TRIUMF's operational budget would impact its ability to appropriately support existing infrastructure, research and other sponsored activities. It was recommended that TRIUMF establish a mechanism to enable them to prioritize and manage the ongoing maintenance of their infrastructure. In response, registries at the organizational and division levels were established to monitor and manage risks, and annual budgets for the divisions are now determined in response.

Over the past 5 years, TRIUMF has made a number of other changes in order to increase its economy and efficiency. This includes the introduction of new mechanisms as well as changes in governance structures. For instance, according to many interview respondents, a key mechanism put in place is the appointment of a chief operating officer (COO) and the establishment of a project management office (PMO). The IPRC noted that this is evidence of an institution dedicated to continuous improvement. Improvements have been evident; interview participants noted that the PMO has helped organize and streamline many activities, including project planning and resource management.

Examples of other mechanisms established to increase efficiency include:

- a restructured quality management system (QMS). The restructuring process includes the appointment of a full time leader and a chief information officer and introduction of a set of QMS audit programs across the laboratory
- new management capacity in the form of two new deputy directors (research and previously mentioned COO)
- a hiring plan that is revised at regular intervals to reflect the ongoing needs of projects
- potential matrix management approach for certain support or core functions

Further, although not directly related to economy and efficiency, the evaluation noted that there has been an increased emphasis on safety at TRIUMF. A few respondents noted that the introduction of safety assessments triggered a cultural change. In addition to safety, this new culture also increasingly considers health, wellness, mentoring, diversity and equity practices, which some recently established committees address.

TRIUMF is also undergoing a significant exercise that will transform its governance structure and is anticipated to further improve efficiency and effectiveness. Currently, TRIUMF is a joint venture of 14 full member universities (i.e., not a separate legal entity). The current Board of Management has 36 members, including full and associate member representatives, private sector representatives, and TRIUMF senior management. In the proposed new structure, TRIUMF would be restructured to have a smaller skill-based board. Directors would be selected from member universities or the general population, in a way that maintains strong member university oversight and engagement. Some interview participants noted that this approach would be strategic and efficient, particularly because the board would include a smaller number of experts who could more effectively steer not only research, but resources and facility management. This new board structure would hold all of the organization to account, not just research.

The IPRC found that TRIUMF leadership is committed to continuing to improve the efficiency and effectiveness of laboratory operations. In particular, they noted the stage-gate process similar to the critical decision process used in the U.S. Department of Energy laboratories as well as the move to matrix management of the engineering function. They perceive this as being important to increase the reliability of operations while delivering on the planned upgrades to facilities. However, as noted by the IPRC, while recent and planned future changes at TRIUMF, such as a move to broadened job descriptions and cross-training of personnel, should result in further efficiencies at TRIUMF, they may lead to problems with morale and lab culture if not handled in a sensitive manner. Proper communication throughout the organization is needed to mitigate any growth pains.

Given the considerable changes that have occurred, and will occur in the near future, the IPRC suggested that communication and careful monitoring of the impact of these changes on staff will be important:

*“Throughout a period of rapid change, it is vital to pay attention to the culture and the engagement of the workforce. Communication at every stage, probably even more frequently than might seem necessary, is critical. Metrics must be developed and tracked during implementation of operational and organizational changes to ensure that the anticipated results are being achieved and to determine if unexpected detrimental changes are also occurring. Making structural changes in an organization that will ultimately lead to increased efficiency and effectiveness typically cost money in the short term to implement. Changes must be rolled out at a rate that can be accommodated in the budget and that can be absorbed by the staff and culture.” -- IPRC report*

**Recommendation 3: In order to facilitate understanding and buy-in by TRIUMF staff of planned organizational changes, the NRC should work with TRIUMF to develop and implement a plan for communicating the changes and their expected benefits.**

**Recommendation 4: The NRC should work with TRIUMF to identify metrics to monitor the implementation and impact of the organizational changes, to ensure outcomes are as expected, and to allow TRIUMF management to make slight changes as needed to achieve outcomes.**

## 5.2 TRIUMF has managed resources soundly

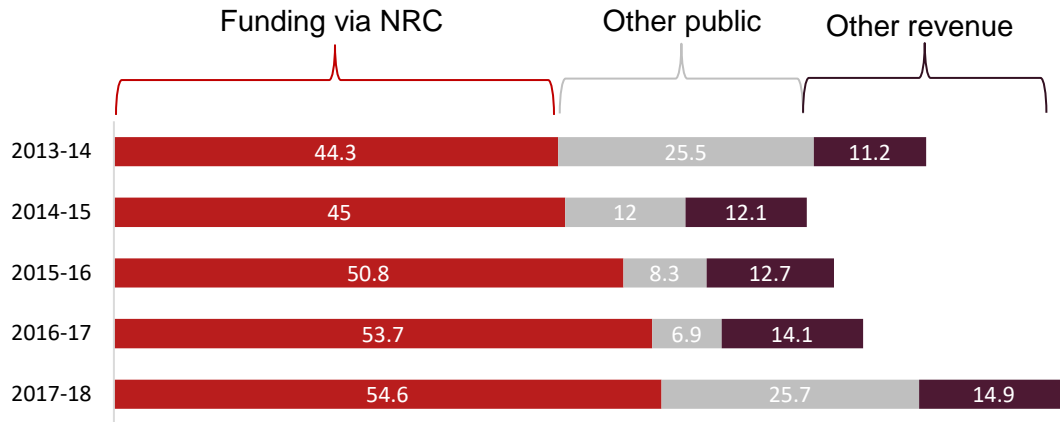
TRIUMF’s total funding has increased over the last 5 years. While there has been a decrease in other major public funding sources, TRIUMF was able to secure increased operational funding from the federal government (administered by the NRC). In a commitment announced in Budget 2015, TRIUMF was allocated an additional \$45 million over 5 years, starting in 2015-16.<sup>35</sup> Over the previous 10 years, the level of NRC-administered funding from the federal government to TRIUMF had been stagnant. The increase was needed to maintain core operations and to advance work on the second stage of the ARIEL project. To date, this represents a funding increase of 23% since 2013-14.

While still representing a small proportion of TRIUMF’s overall income, the biggest growth in TRIUMF’s funding, came from revenues, which grew by 33 percent over the evaluation period. (Figure 5.1) This type of increase is important as it offers TRIUMF more leverage to finance its expenditures from its own sources. Further, these funds are also important to TRIUMF because they support projects and initiatives not easily funded through public funding such as new buildings and commercialization efforts.

---

<sup>35</sup> <https://www.budget.gc.ca/2015/docs/themes/industry-innovation-industrie-eng.html>

**Figure 5.1: Income via NRC and revenues (in million \$) have increased the most during the evaluation period**

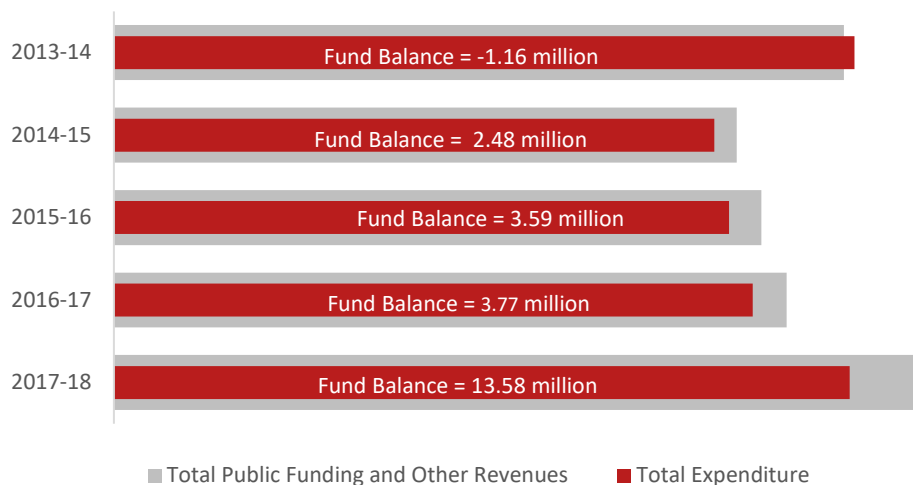


Source: TRIUMF Data

TRIUMF managed its costs well over the last 5 years. Compared to 2013-14, in 2017-18, TRIUMF had slightly higher expenditures in salaries and benefits, but this was offset by a reduction in other expenses, in particular the ARIEL construction.<sup>36</sup> Overall, total expenditure decreased slightly from 5 years ago, while total revenue increased by 18%. (Figure 5.2)

The surpluses of revenue over expenses are committed to planned capital projects, including ARIEL and IAMI. The large 2017/2018 surplus of revenues over expenses resulted from the BC government’s lump-sum contribution to IAMI construction.

**Figure 5.2: TRIUMF’s fund balance has increased each year of the evaluation**



Source: TRIUMF Data

<sup>36</sup> Other expenses include expenditure on building and improvement, computer, consulting, equipment, power, supplies and other expenses, telecommunication and travel

TRIUMF has hired more faculty (joint appointments), staff scientists, and facility and site services workers than administrative staffs in the last 5 years. This may indicate TRIUMF's preference towards maximizing scientific excellence with a lean but appropriate administrative structure.

### **5.3 TRIUMF has proposed a feasible strategic plan for years 2020-2025**

TRIUMF builds their strategic plan on a 5-year cycle, which aligns with the NRC funding. This year's plan, according to TRIUMF, is ambitious but achievable, leverages past investments and builds on an already established brand and global network.<sup>37</sup> The plan is based on 3 key dimensions: science and technology, people and skills, and innovation and collaboration, and includes the following intended outcomes:

- Extension of the frontiers of knowledge and global recognition of Canada's contribution to discovery research
- Increased capacity for world-class, multidisciplinary research and development in Canada
- A new generation of highly skilled Canadians ready to compete in the knowledge and innovation economy
- Greater access to STEM opportunities for all Canadians
- New game-changing technologies that support business-led innovation and improve the lives of Canadians
- A stronger, more competitive Canada in discovery and innovation

As part of the evaluation, the IPRC was asked to review and comment on TRIUMF's strategic plan for 2020-2025. The IPRC found the plan strong and well balanced with clear priorities and measurable outcomes. The IPRC agreed that the plan is aggressive but achievable at the requested budget level. Further, the IPRC agreed that the plan positions TRIUMF to produce ground-breaking results across the breadth of the laboratory's mission space and solidifying its leadership role. Planned projects of particular importance to achieving world-class research and leadership mentioned by the committee were the neutron electric dipole moment experiment at TRIUMF's ultra-cold neutron (UCN) facility, and the completion of ARIEL, which was noted as mandatory for the continued development of Canadian nuclear physics as a world class program. With the complexity of some of the planned projects, the IPRC warned of the importance of strong project management in order to deliver on commitments within the requested budget.

The committee also recognized that, while an explicit 5-year plan is essential, in the context of many of its experiments (particularly in physics) which require longer term planning and investments, TRIUMF should expand their long-range vision and planning to at least twenty years.

---

<sup>37</sup> TRIUMF Strategic Plan 2020-2025

## 5.4 Canada's current approach to funding does create challenges for TRIUMF as it does for other facilities

In Canada, federal funding for scientific research is funneled through 3 granting councils:

- Canadian Institutes of Health Research (CIHR)
- Natural Sciences and Engineering Research Council (NSERC)
- Social Sciences and Humanities Research Council (SSHRC)

The “tri-council” agencies, as they are known, operate at arm’s length to the federal government and typically provide funding for the direct costs of research and research training. These funds are allocated through competitive peer-reviewed processes. The federal government also provides funding for research infrastructure through the Canada Foundation for Innovation (CFI). CFI funding is awarded through a rigorous review process and funding is limited to a maximum of 40% of the total infrastructure costs.

The CFI and the tri-councils work together as much as possible to align and collaborate on peer review and funding processes to deliver funding in an integrated fashion. However, overall, funding for science research is not done using a coordinated approach.

Researchers, as well as labs, are often funded by multiple federal sources. For example, during the evaluation period, TRIUMF activities (in partnership with universities) were funded by NSERC, CFI as well as their core NRC funding. They also receive funds from other sources, including provincial agencies.

The need to coordinate funding is well documented. For example, the latest Canadian Subatomic Physics Long Range Plan (2016) notes that there is a need to coordinate resources, funding and approval processes across the agencies and laboratories that support subatomic physics in Canada. The 2011 Innovation Canada: A Call to Action report reviewed the federal support to research and development and recommended a clear voice for innovation and better coordination with provinces to maximize impact. And most recently, Canada’s Fundamental Science Review (2017) recommended that investments in Big Science be managed in a more coordinated manner. The review resulted in several recommendations that would improve coordination and harmonize funding strategies.

This lack of a national approach was also highlighted by interview participants. A few noted that funding was more coordinated in other countries. For example, a few noted the “top-down”, or direct government ownership model in the USA, and the model in Germany, where all funding is administered through one federally funded, arms-length organization.

Many interview participants noted challenges with Canada’s “ad hoc” approach. For example, uncoordinated funding cycles were said to make project planning and execution difficult. This is often because TRIUMF projects go beyond the timeframe of the funding. This is thought to impact how strategic TRIUMF can be in the projects they undertake. As mentioned earlier, the IPRC suggested a longer strategic vision, up to 20 years was required to fully see projects and strategic direction through to the end.



It should be noted that TRIUMF benefits from a unique position. While other research facilities must secure most of their core funding through the competitive processes of the granting councils and other funders such as CFI, TRIUMF's core operations are funded on a 5-year cycle through its contribution agreement with the NRC. This is because TRIUMF's scope of activity is too wide to be addressed through any individual funder. Despite noting some challenges, discussed below, even the IPRC noted this is superior to the 1-year funding used in the US.

Lastly, uncoordinated funding also impacts administrative effort. For example, the ARIEL facility was funded through CFI and 5 provinces. In all, there were 6 funding applications to prepare and manage in terms of reporting requirements for the grants and contributions.

The IPRC sympathized with this challenge and noted an impact that the funding approach may have on productivity:

*“The need to seek funding for large projects from multiple sources and with explicit restrictions on what the funding may or may not be used for, is a challenge for the projects themselves and for the laboratory. In particular, experience shows that investments in facilities and infrastructure, including staff offices, meeting space, and other reasonable amenities, will increase the productivity of the staff, and hence the return on the funding.” -- IPRC report*

This challenge of funding that restricts the use of funds was also discussed during interviews. In particular, insufficient funding for project planning and feasibility assessments was mentioned as a resulting limitation. The IPRC also mentioned that the lack of funds for important aspects of major projects, such as planning and contingency funds, introduces unnecessary risks.

The challenges encountered by TRIUMF as a result of Canada's funding approach also affect other research organizations. As noted earlier, the issue is widely recognized and steps toward improvement may come, in part from the federal government's implementation of the 2017 Science Review recommendations.

## 6 Conclusion

The evaluation found that TRIUMF continues to be relevant and perform well. The laboratory addresses the needs of a growing research community by providing necessary equipment and facilities, not available elsewhere in Canada. It continues to be a leader, contributing to important research and discoveries and as such, benefiting from a very positive reputation. TRIUMF also plays an important role in connecting Canada to the world through international collaborations. It fosters the training and attraction of HQP to Canada as well as supports government priorities in science and technology and innovation. The benefits TRIUMF has generated for Canada flow from its regular programs and activities, but also to the efforts of TRIUMF innovations, which has increased the laboratory's efforts in commercialization. TRIUMF continues to make changes in order to improve and has proposed an ambitious but feasible plan for the next 5 years of NRC funding. Despite its success and important role in



Canada, the evaluation found that TRIUMF faces challenges as a result of Canada's approach to research funding. This issue is recognized in a number of federal reports on science and innovation calling for actions by the federal government that may reduce these challenges.

Considering the findings of the evaluation, it is recommended that:

1. The NRC should work with TRIUMF and TRIUMF Innovations to diversify commercialization activities (and to expand royalties and patents), to spread and reduce the risk associated with a too-narrow portfolio.
2. The NRC should work with TRIUMF to identify ways to expand their outreach to regions outside of British Columbia, in an effort to increase both TRIUMF's impact and its base of support. Methods to broaden TRIUMF's reach could include virtual means.
3. In order to facilitate understanding and buy-in by TRIUMF staff of planned organizational changes, the NRC should work with TRIUMF to develop and implement a plan for communicating the changes and their expected benefits.
4. The NRC should work with TRIUMF to identify metrics to monitor the implementation and impact of the organizational changes, to ensure outcomes are as expected, and to allow TRIUMF management to make slight changes as needed to achieve outcomes.

## 7 Management response

Note that the following management response assumes that the NRC and TRIUMF will enter into a 5-year contribution agreement for the period 2020-2025.

Recommendation	Response and Planned Action(s)	Timelines	Proposed Person(s) Responsible	Measure(s) of Achievement
<p>1. The NRC should work with TRIUMF and TRIUMF Innovations to diversify commercialization activities (and to expand royalties and patents), to spread and reduce the risk associated with a too-narrow portfolio.</p>	<p>The NRC agrees with this recommendation.</p> <p>The NRC, through the Advisory Committee on TRIUMF (ACOT), will work with TRIUMF to identify how it can expand commercialization activities and develop metrics to measure progress. ACOT will provide this advice during the site visits conducted at TRIUMF twice per year and will include the advice and the progress against metrics, and recommendations in the ACOT reports submitted to the NRC.</p>	<p>First ACOT report on advice about diversifying activities – December 2020</p>	<p>NRC – Vice-President, ET</p>	<p>Advice and recommendations recorded in ACOT reports twice per year (2020 to 2025)</p>
<p>2. The NRC should work with TRIUMF to identify ways to expand their outreach to regions outside of British Columbia, in an effort to increase both TRIUMF's</p>	<p>The NRC agrees with this recommendation</p> <p>The NRC, through the Advisory Committee on TRIUMF (ACOT), will review TRIUMF's plans for outreach, as outlined in the TRIUMF Implementation Plan 2020-2025 and</p>	<p>First ACOT report on advice about expanding outreach activities – December 2020</p>	<p>NRC – Vice-President, ET</p>	<p>Advice and recommendations recorded in ACOT reports twice per year (2020 to 2025)</p>

Recommendation	Response and Planned Action(s)	Timelines	Proposed Person(s) Responsible	Measure(s) of Achievement
<p>impact and its base of support. Methods to broaden TRIUMF's reach could include virtual means.</p>	<p>identify additional opportunities for expanded outreach as appropriate.</p> <p>ACOT will provide this advice during the site visits conducted at TRIUMF twice per year and will include the advice, and recommendations in the ACOT reports submitted to the NRC.</p>			
<p>3. In order to facilitate understanding and buy-in by TRIUMF staff of planned organizational changes, the NRC should work with TRIUMF to develop and implement a plan for communicating the changes and their expected benefits.</p>	<p>The NRC agrees with this recommendation</p> <p>The NRC, through ACOT, will provide TRIUMF with advice on the development and implementation of a plan for communicating upcoming organizational changes to TRIUMF staff. ACOT will provide this advice during the site visits it conducts at TRIUMF twice per year and will include its advice and recommendations in the ACOT reports submitted to NRC.</p>	<p>First ACOT report which includes advice on the communication plan about the planned organizational changes – May 2019</p>	<p>NRC – Vice-President, ET</p>	<p>Advice and recommendations recorded in ACOT reports twice per year (2019 to 2025)</p>
<p>4. The NRC should work with TRIUMF to identify metrics to monitor the implementation and impact of the organizational changes,</p>	<p>The NRC agrees with this recommendation</p> <p>The NRC will work with TRIUMF to identify metrics to monitor the implementation and impact of organizational changes. These</p>	<p>Metrics developed for inclusion in monitoring activities – April 1, 2020</p>	<p>NRC – Vice-President, ET</p>	<p>Metrics included in reports provided by TRIUMF as part of the CA monitoring process (2020 to 2025)</p>

Recommendation	Response and Planned Action(s)	Timelines	Proposed Person(s) Responsible	Measure(s) of Achievement
<p>to ensure outcomes are as expected, and to allow TRIUMF management to make slight changes as needed to achieve outcomes.</p>	<p>metrics will be included in the reports submitted by TRIUMF to NRC as part of the ongoing monitoring of the contribution agreement (CA).</p>			

## Appendix A – Evaluation questions

1. Is TRIUMF a world-class platform for research excellence?
  - a. Is there a need for TRIUMF?
  - b. To what extent is TRIUMF a leader in scientific excellence in particle and nuclear physics, and related fields, including nuclear medicine and accelerator science?
  - c. To what extent has Canada's participation in TRIUMF connected Canada to the world in TRIUMF-related fields?
2. Is TRIUMF aligned to federal government priorities in the area of science, technology, and innovation, and to the NRC's strategic outcomes?
3. Is the NRC's oversight role of TRIUMF appropriate?
4. To what extent has TRIUMF been a benefit to Canadian universities (i.e., universities have leveraged TRIUMF)?
5. To what extent has TRIUMF contributed to social and economic benefits for Canada?
6. Has TRIUMF been administered and its activities delivered in an economic and efficient manner?
  - a. Has the NRC demonstrated sound stewardship of resources?
  - b. Have any governance issues been dealt with appropriately?
7. Is TRIUMF's proposed 5-year plan appropriate to ensure the continued relevance and success of TRIUMF?
8. Are there external factors that have an impact on the effectiveness of TRIUMF?

## Appendix B – Evaluation methodology

The evaluation was conducted in accordance with the NRC's approved Departmental Evaluation Plan for 2017-2018 and timed in order to comply with requirements of the Financial Administration Act (Sec 42.1). The evaluation focused on the 5-year period of 2013-14 to 2017-18. Because fulfillment of TRIUMF's goals draws upon resources beyond those provided via the Contribution Agreement funding its core operations, the full slate of activities and outcomes of TRIUMF were considered within scope of the evaluation.

The questions addressed through the evaluation were developed following consultations with the NRC's Vice-President, Emerging Technologies (as well as key members of her staff), TRIUMF senior management and staff, other federal funding organizations (CFI, NSERC, ISED) and a review of key documents. They also meet the requirements of the Treasury Board Policy on Results.

In order to generate the most useful, valid and relevant evaluation findings possible, mixed methods to collecting data were used. This allowed for triangulation (i.e., convergence of results across lines of evidence) and complementarity (i.e., developing better understanding by exploring different facets of a complex issue).

The data collection approach incorporated both qualitative and quantitative methods including:

- a review of documents
- a review of administrative and performance data
- interviews with TRIUMF staff, clients, partners and other key stakeholders
- a survey of TRIUMF users
- an international peer review

A discussion of each method used is provided in the following paragraphs.

### **Review of documents**

Reviewed documents informed most evaluation questions, particularly those around relevance, governance and effectiveness. Documents included external reviews of the broader sub-atomic ecosystem as well as internal documents such as strategic plans and presentations.

A bibliometric analysis (commissioned by TRIUMF) and an economic impact assessment (commissioned by the NRC) were also recently completed by external consultants, with the objective of informing the evaluation. These were also key documents consulted as part of the document review.

### **Review of administrative and performance data**

Financial and administrative data contributed to the development of a profile of TRIUMF and also informed questions around efficiencies. Project and performance data were used as indicators of client reach/use, outputs and outcomes. Data was provided by TRIUMF and analyzed by the NRC's evaluation team.

## Interviews

Conducting interviews results in valuable qualitative evidence that provides important context and helps to validate data collected through other methods. Overall, 36 individuals participated in an interview for the evaluation, representing the following stakeholder groups:

- TRIUMF management and staff (n=7)
- NRC management and staff (n=3)
- TRIUMF Innovations (n=1)
- TRIUMF members (n=12)
- Federal funders (n=3)
- Associations (n=6)
- Other labs (n=4)

Interviews were conducted by telephone and lasted between 30 and 60 minutes. Separate interview guides for each stakeholder group were developed. While the guides included some common questions, ensuring the same issues were addressed by all relevant interviewees, they also focused on areas best addressed by each specific group. For example, questions about need were asked to all groups while most questions about delivery and efficiency were only asked to TRIUMF management and staff. Interview participants were sent the guide in advance of the interview, allowing them time to prepare their responses.

Data collected through the interviews were analyzed by question and by theme, allowing common themes as well as nuances between responses to be identified.

## Survey of TRIUMF users

An online survey was conducted to explore the effectiveness, relevance and efficiency of TRIUMF through its users' perspectives. The questionnaire mimicked the survey instrument used for the last evaluation to allow the potential of exploring trends over a longer period of time.

Prior to the survey launch, TRIUMF sent a note to their users to validate the legitimacy of the survey and encourage participation. The NRC evaluation team followed with an invitation email containing the link to the survey.

The survey was sent to all of TRIUMF's non-commercial users (n=653). There were 19 invitations that were returned due to either wrong addresses or closed email accounts. Therefore, the survey was received by 634 people. With 179 surveys completed this represents a response rate of 28%.

Survey respondents were made up of representatives from Canadian (37%) and foreign entities (59%) including universities, government and industry. The remaining 4% did not specify. A further breakdown of respondents is provided below:



% of respondents in the following fields:	Nuclear physics	47%
	Materials science	22%
	Particle physics	17%
	Other	7%
	Nuclear medicine	4%
	Accelerator physics	3%
% of respondents who represent:	Foreign universities	41%
	Canadian universities	36%
	Foreign government organizations	17%
	Other	3%
	Canadian government organizations	1%
	Foreign industry	1%
	No answer	1%
# of respondents who identified as:*	A women	34
	A person of a visible minority	13
	A recent immigrant	11
	A gender-diverse person	3
	An indigenous person	2
	A person with a disability	1
% of respondents with the following current occupation:	Faculty member/staff	50%
	Graduate student	24%
	Postdoctoral fellow	17%
	Other	4%
	Undergraduate student	3%
	Employee of a company	3%
	An elected member of a science committee	3%
	Researcher for a Canadian medical research organization	2%
	An elected board member of a science organization	2%
	No answer	1%

Source: TRIUMF User Survey

\*Question was voluntary and therefore not completed by all respondents

## **International peer review**

An International Peer Review Committee (IPRC) was convened at TRIUMF November 13 to 15 2018 to assess TRIUMF's performance during the evaluation period (2013-14 to 2018-19) and to provide input into the five-year strategic plan proposed by TRIUMF for 2020-2025. The IPRC was made up of 7 individuals in total, 6 with expertise in each of TRIUMF's main research areas and 1 with expertise on commercialization. Potential committee members were identified and validated through a variety of sources including the NRC and TRIUMF and a process to identify any potential biases or conflicts of interests was undertaken.

In advance of the peer review site visit, the committee was provided with the preliminary findings of the evaluation as well as other supporting documents such as TRIUMF's proposed strategic plan for 2020-2025, CV's of key TRIUMF staff and profiles of major projects. The committee was asked to provide their preliminary assessment based on review of these documents. These assessments were discussed during a teleconference meeting held on October 31, 2018. The teleconference meeting also served to identify additional information required by the committee, as well as to identify initial IPRC questions to TRIUMF. The peer review site visit took place over 3 days and included a series of presentations by TRIUMF staff as well as question and answer periods, a tour of the TRIUMF facility, and a student poster session. During the last of day of the site visit, the Peer Review debriefed TRIUMF and the NRC VP, Emerging Technologies on their assessment and began drafting their report.

Following the site visit, the IPRC, led by the Chair, finalized a report, including recommendations. The report was reviewed for factual accuracy by TRIUMF and the NRC VPO. Findings of the IPRC were integrated into this evaluation report.

## Appendix C – International Peer Review Committee membership

	Name	Position	Institution/Organization
Chair	Dr. Julia Phillips	Former Director (retired)	Sandia National Laboratories
Member	Dr. Hugh Montgomery	Former Director (retired)	Thomas Jefferson National Accelerator Facility
Member	Lisa Cechetto	Executive Director	WORLDiscoveries
Member	Dr. Osamu Kamigaito	Accelerator Group Director	RIKEN Nishina Centre
Member	Dr. Patricia McBride	Director, Particle Physics Division	Fermilab
Member	Dr. Roger Alberto	Professor, Department of Chemistry	University of Zurich
Member	Dr. Samuel David Bader	Chief Scientist, Centre for Nanoscale Materials	Argonne National Laboratory