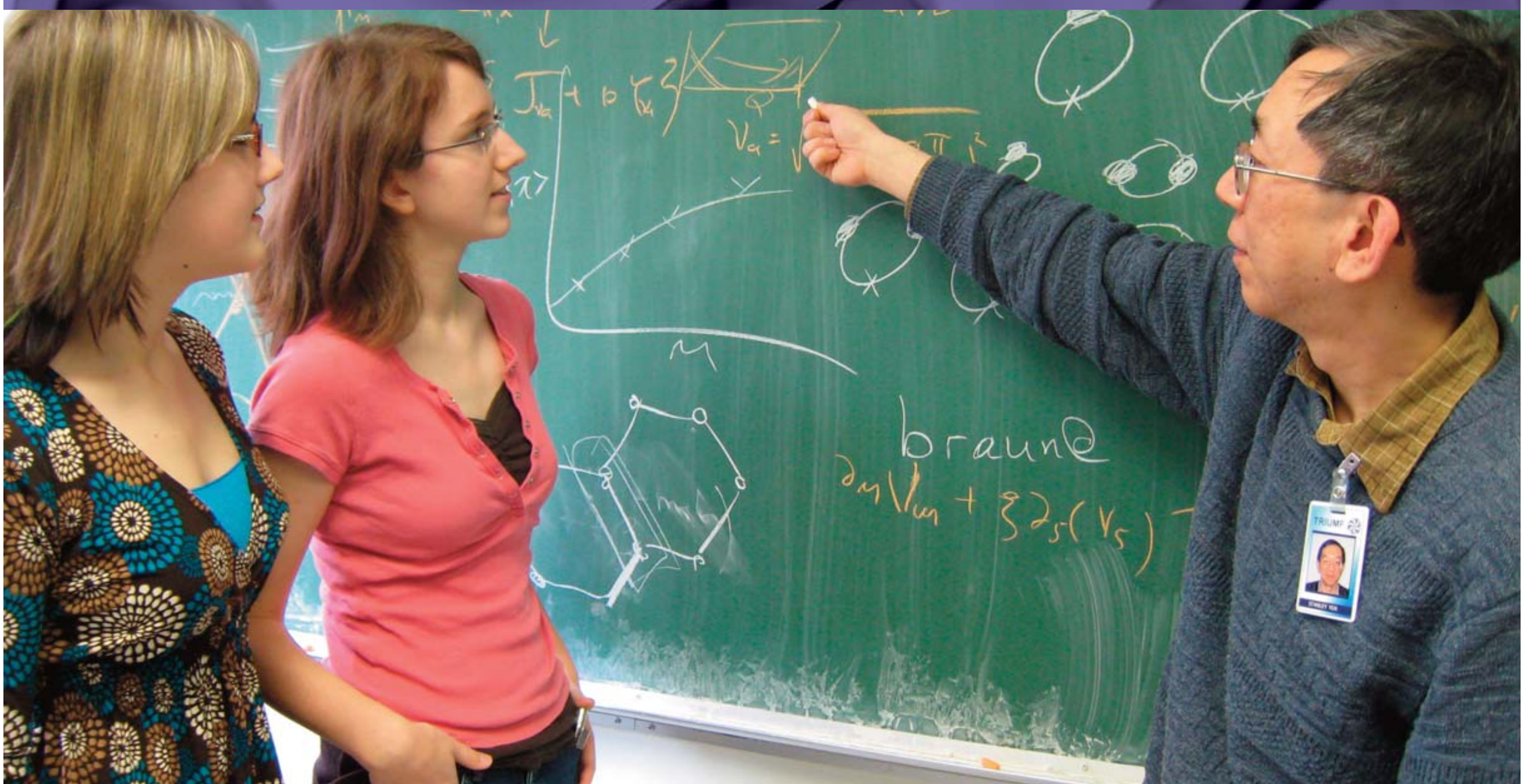
3

Partnerships

From Global Excellence to Local Impact



CHAPTER 3 | PARTNERSHIPS: FROM GLOBAL EXCELLENCE TO LOCAL IMPACT

COMPLETE TABLE OF CONTENTS

OWNED AND OPERATED BY A CONSORTIUM OF UNIVERSITIES, TRIUMF'S VERY EXISTENCE DEPENDS ON PARTNERSHIPS DRIVEN BY COMMON COMMITMENTS AND SHARED RESOURCES. THIS SECTION DISCUSSES THE NATURE OF TRIUMF'S COLLABORATIONS AND CONNECTIONS WITH CANADIAN UNIVERSITIES AND RESEARCH INSTITUTIONS, INTERNATIONAL UNIVERSITIES AND LABORATORIES, AS WELL AS INDUSTRY. THE WHOLE IS GREATER THAN THE SUM OF ITS PARTS: **TRIUMF'S ACCOMPLISHMENTS ARE ONLY POSSIBLE THROUGH THE HEALTHY STEWARDSHIP OF THESE RELATIONSHIPS**.

3.1 INTRODUCTION

Several efforts have been made to diagram the Canadian science, technology, and innovation environment. One feature is immediately apparent: no single performer, patron, or benefactor of basic research has value without the seemingly complex web of interconnections to other institutions and organizations. TRIUMF is no different. The laboratory maintains a unique collection of accelerators and detectors; it employs hundreds of highly talented scientists, technicians, and engineers; and it maintains a system of controls, checks, and balances in order to conduct its research and development activities on time and on budget. But the full value of TRIUMF is realized through its set of partnerships and agreements, which are driven by common commitments and shared resources, those which are (1) “upstream”—some TRIUMF activities require resources and/or guidance from outside the laboratory to achieve its goals and (2) “downstream”—sometimes TRIUMF provides the ingredients or resources for its partners to generate successes.

“Best 10 Research Facilities in Canada:
#8 – TRIUMF, a Vancouver-based lab specializing in particle and nuclear physics.”

Backbone.com, “Backbone 200: The best of everything in Canadian tech,” 25 Feb 2013.

3.2 PARTNERSHIP STRATEGY

TRIUMF was founded to provide the centralized resources, tools, and expertise for scientific research that no single Canadian institution could afford to build or maintain. Through international partnerships, TRIUMF endeavours to connect Canada to the global science and technology community. Additionally, as a bridge between the academic sector and the private sector, TRIUMF is resolved to drive Canada's innovation engine through collaborative and joint projects. Partnerships do not just happen. TRIUMF actively sought, and continues to seek, two-way partnerships that benefit both the lab and the larger community.

3.2.1 CANADIAN UNIVERSITIES AND RESEARCH INSTITUTIONS

At its core, TRIUMF is a partnership among leading Canadian research universities. It is owned and operated as a joint venture by a consortium of 18 Canadian universities, from Halifax to Victoria, in an inherently close relationship that keeps TRIUMF relevant and connected to Canada's science, technology, and innovation ecosystem. As such, it is globally unique, although through its practical exercise of governance, TRIUMF shares many characteristics and best practices with other publicly supported laboratories around the world.

Universities are either full members or associate members of the TRIUMF consortium. Full members share equally in the liability of the laboratory (including both operations and decommissioning) and enjoy two positions on the governing Board of Management. Associate members have one position on the Board and do not vote, although they listen and contribute to the overall strategic direction of the laboratory and the deployment of its resources. For a university to join the consortium, it must already have a campus-based research program that intersects with and connects with TRIUMF activities. Full members are expected to have three or more distinct research activities that will be strengthened and benefit from full participation in TRIUMF. Membership in TRIUMF works both ways. TRIUMF expands the on-campus footprint of particle and nuclear physics in Canada and some universities will expand their research to better fit with and work with TRIUMF.

The TRIUMF consortium presently comprises eleven full members and seven associate members. This represents substantial expansion over the past five years; in 2008, the consortium was seven full members and six associate members.

Staff researchers at TRIUMF often get involved in Canadian universities, ranging from seasonal instructors and adjunct appointments for supervising students to full investiture as grant-tenured faculty in an academic department. Managed by the Board of Management's Personnel Committee, staff researchers can be designated Board Appointed Employees, which grants them eligibility for competitively peer-reviewed NSERC research funds.

TRIUMF does not itself grant degrees but all graduate students at TRIUMF are associated with a university and work either with a TRIUMF staff researcher or a visiting university researcher as their supervisor. In many instances, students at TRIUMF have co-supervisors from both TRIUMF and a university.

Since 2009, TRIUMF has also expanded its training programs to include select opportunities for non-science graduate students. Working with faculty at nearby Emily Carr University of Art + Design, TRIUMF has participated in offering training opportunities for arts students. And, at the present time, we are exploring similar arrangements with several business schools.

For universities, the process of membership begins with informal conversations with TRIUMF to assess the benefits of joining. These benefits include:

- Enhancing the university's reputation;
- Leveraging TRIUMF resources and opportunities to augment "campus" research efforts, including boosting international access and reputation;
- Enhanced student and faculty research or training opportunities (including recruitment); and
- Stewardship role for the types of resources and capabilities that TRIUMF provides.

Universities support and drive the TRIUMF agenda in another way: by securing and steering other grants and funds to the laboratory. For instance, TRIUMF is not directly eligible for awards from the Canada Foundation for Innovation (CFI). Canadian universities and colleges are eligible and can apply for funds to co-develop and place leading-edge infrastructure at TRIUMF. This practice is very effective from several considerations: **(1)** By requiring a university and its community to support the application, infrastructure placed at TRIUMF through CFI will automatically connect a university-based user community with the laboratory; **(2)** Universities have the opportunity to co-locate their relevant infrastructure with other tools and facilities at TRIUMF to obtain the best leveraging; and **(3)** TRIUMF's multi-university structure facilitates the cooperation and coordination of university proposals to CFI in its primary research areas. For instance, the University of Victoria led a national consortium of 13 Canadian institutions to secure nearly $18M from CFI for the superconducting electron accelerator (e-linac), which forms the heart of ARIEL at TRIUMF.

In addition to academic institutions, TRIUMF partners with the two other major subatomic-physics institutes in Canada: SNOLAB and the Perimeter Institute of Theoretical Physics. More details are given below.

> "With the coming of the new regional Cancer Centre to Prince George, additional research into generation, transport, and novel application of medical isotopes in smaller-scale urban and rural communities is in the works. 'We are delighted to strengthen our connections with TRIUMF and look forward to a new level of research excellence with national and international impact,' said UNBC vice president of research Gail Fondahl. UNBC has been involved in TRIUMF since the university began operations nearly 20 years ago."
>
> Prince George Citizen, "UNBC Joins TRIUMF," 06 Jan 2011.

3.2.2 INTERNATIONAL ORGANIZATIONS

TRIUMF's purposeful international outlook began in the 1980s with Director Erich W. Vogt. Today, TRIUMF attracts experts from around the world, stimulating a give-and-take sharing of knowledge and innovation.

Over recent years, the laboratory has redefined its strategy for international engagement to focus the attention of TRIUMF leadership, to guide communications efforts for promoting and enhancing TRIUMF, and to develop an approach for implementing the third element of the lab's vision statement: "Connect Canada to the World." Actively following this vision keeps Canada right at the forefront of breakthroughs and technologies that can be quickly deployed for Canada's benefit. Moreover, Canadians can experience the excitement of scientific discoveries that happen on home soil or are driven by researchers in their own backyard.

When considering international opportunities and/or invitations TRIUMF uses five evaluation criteria:

- Does it enable Canadian university scientists and students to work at the best facilities and with the top scientists in the world?
- Does it afford access to scientific or technological facilities not already available in Canada?
- Will a significant benefit accrue to TRIUMF and Canada either in technology or infrastructure?
- Does government policy encourage such a collaboration? and
- Does TRIUMF have a critical mass in the activity and will the activity significantly advance the TRIUMF mission?

The application of these criteria allow TRIUMF to focus on delivering value to Canada for each international engagement by seeking those opportunities that address Canadian objectives and add to the country's global reputation for integrity and excellence. For example, TRIUMF's work with the VECC laboratory in Kolkata, India, not only directly advances the ARIEL project, but it also engages a partner designated both provincially and federally as one of high priority. In a related example, TRIUMF is monitoring development of discussions in Japan with the help of Canadian diplomatic channels regarding the International Linear Collider. If Japan makes a forward move, TRIUMF would provide scientific, technical, and engineering leadership for many aspects of Canadian involvement.

Canada has an unwritten policy for engaging in foreign megaprojects in subatomic physics that TRIUMF supports and implements. For substantive involvement that returns the best value on investment, the research team will seek to become involved in the accelerator or core infrastructure (e.g., the LHC at CERN), to become involved in the scientific apparatus or detector (e.g., the ATLAS detector), and to compete for leading roles in the physics analysis and results (e.g., leadership in the analysis working groups and participation in the ATLAS Collaboration Board). TRIUMF underpins this triple involvement to ensure triple impact: participation in the core infrastructure broadens the chance for Canadian industry to participate and provides unique learning experiences for students; participation in the detector again can engage Canadian industry and gives Canadian researchers recognized "ownership" of part of the science project; in turn, these contributions give Canadians stature in the collaboration and encourage talented scientists and students to be on the front lines of the research.

VOYAGE OF DISCOVERY SIGHTS WHAT COULD BE THE HIGGS

04 July 2012

Early this morning, the ATLAS and CMS particle-physics experiments at the LHC accelerator at CERN presented their latest results in the hunt for the Higgs boson with thousands of viewers from around the world at a global press conference in Geneva, Switzerland. Both experiments observe a new particle in the mass region around 125-126 GeV consistent with the Higgs. Across Canada, hundreds have played critical roles in this breakthrough and are now celebrating.

More than a 150 Canadian scientists and students are involved in the global ATLAS experiment at CERN. TRIUMF has been a focal point for much of the Canadian involvement that has ranged from assisting with the construction of the LHC accelerator to building key elements of the ATLAS detector and hosting one of the ten global Tier-1 Data Centres that stores and processes the physics data for the team of thousands.

"The discovery of a particle consistent with the Higgs boson opens the way to more detailed studies, requiring larger statistics, which will pin down the new particle's properties, and is likely to shed light on other mysteries of our universe," said CERN Director-General Rolf Heuer.

TRIUMF's approach to international engagement can be roughly organized into three categories with broad overlaps.

Scientific/Intellectual. Most international collaborations start with individual researchers identifying common work of mutual interest and benefit. Once their one-on-one experiences prove successful, the relationship is usually formalized through a laboratory-to-laboratory Memorandum of Understanding (MOU). Although the MOU is not legally binding, it provides a framework of specific scope and extent that will greatly assist with student and staff exchange. At this stage, collaboration typically involves exchange and sharing of just personnel and equipment.

Diplomatic. When scientific collaboration is working well, TRIUMF seeks to brief the Canadian embassy in the foreign country about the activities and highlight the role of both partners. TRIUMF would then also connect with the foreign consulate in Vancouver to brief the host nation. The objective is to have embassies and diplomatic staff support the future of the partnership and guide future initiatives; at times, international visitors would be encouraged to visit the foreign effort in Vancouver or the Canadian effort in the foreign country. This type of promotion is especially key to stimulating the next phase of interaction.

Business. Once regular scientific and diplomatic relations are established, the goal is to connect Canadian suppliers or industrial partners with counterparts and customers in the foreign country. TRIUMF will make introductions and provide informal recommendations as appropriate. At times, TRIUMF will take the "first customer" role to validate and endorse a Canadian supplier developing a new product. (See Section 4.4 for further examples.)

TRIUMF does not have a formal list of priority countries and scientific collaborations are openly encouraged between individuals and small groups. Institutionally, the lab does pursue a more focused strategy with partners in China, Germany, India, Israel, Italy, Japan, the U.K., and the U.S. The laboratory also seeks institutional relationships with the major laboratories in subatomic physics, the most significant of these being CERN as a true multi-national laboratory.

Through this strategy, TRIUMF aims to achieve the following objectives:

- Work with the best in the highest-priority fields, no matter where they are;
- Attract international talent and investment to TRIUMF and Canada;
- Work with countries that the public (government) prioritize as important;
- Open new international markets for Canadian companies;
- Enhance TRIUMF's image as a conduit for international science and collaboration; and
- Generate global interest in and support for TRIUMF and its programs.

A list of TRIUMF's international collaborations and partnerships is included in Section 5.10. About 50 active international entities are involved in a collection of 600 inter-institutional agreements.

From a public policy perspective, international networking and collaboration are crucial to competitiveness.

- As science becomes more complex and sophisticated, the combined talents and resources of multiple nations are required to make true progress. These partnerships have to be designed to be of mutual advantage to work in the long term.

- In a globalized world, exploiting scientific breakthroughs to economic or social benefit depends on swift action and complete understanding of the science. To do this, Canada needs to be at the table and alongside the pioneers, otherwise we will read about the science in the newspaper and be obliged to buy the new technology from an overseas company a few months later.
- For Canadians to be globally competitive, they have to train with and compete with the best. International access and exposure is critical to developing our best talent.
- Canada cannot borrow from other countries forever; there is a *quid pro quo* principle in play. Other countries sharing access to their facilities with Canada expect that over the course of a decade, Canada will develop and share access to leading-edge facilities on its own soil with them. To the point, other countries will expect Canada to build and maintain leading-edge facilities with a global-access policy.
- Major science initiatives attract, retain, and develop the best talent. If Canada wants to compete globally, it needs some crown jewels on home soil to bring talent to or through Canada.

As a final comment, TRIUMF is modifying its international engagement strategies to reflect the modern theme of "brain circulation" as opposed to the conventional theme of "brain gain." As human talent becomes increasingly mobile, what matters most is not where people are located in the long term, but what level of access and familiarity they have with working with the best and the brightest.

> "On November 7, 2011, KEK hosted the third KEK-TRIUMF Scientific Symposium with the theme, 'From Collaboration to Partnership: Accelerator-Based Science at KEK and TRIUMF.' This symposium was attended by about 70 researchers from Canada and Japan. Commemorating the 80th anniversary of diplomatic relations between Japan and Canada, and in keeping with the theme of Innovation, the Canadian Embassy in Tokyo hosted the inaugural Canada-Japan Particle Accelerator Science Symposium in 2009."
>
> KEK website, "From Collaboration to Partnership:
> KEK –TRIUMF Scientific Symposium held at KEK," 17 Nov 2011.

3.2.3 CANADIAN INDUSTRY

One of the three primary outcomes of basic research, in addition to knowledge and highly trained personnel, is economic growth, which is driven either (a) by the direct application of scientific breakthroughs to develop new products and services or (b) by the demands that scientific research places on technology causing it to "stretch," thereby improving performance or generating new applications and markets. The third element of TRIUMF's mission mandates attention to these types of opportunities by "transferring knowledge" and "commercializing research" for the benefit of all Canadians.

TRIUMF's approach to working with industry is collaborative as opposed to transactional. The laboratory is committed to fostering innovation and building long-term, mutually beneficial relationships with partners. Moving a technology out the door is no longer sufficient; in some instances, that might be just the beginning of a valuable long-term relationship. And that relationship holds greater value than any one new product.

> **Because the pathway from laboratory bench to commercial product is complex, involving numerous and sometimes difficult steps, the process can derail at any point and products may not always reach, or find success in, the marketplace.**
>
> U.S. Government Accountability Office report on U.S. DOE Technology Transfer (GAO-09-548), 2009.

As a national laboratory, TRIUMF must bring together the talents and resources of Canada to advance the country's innovation objectives. With a solid connection to Canada's world-class university-research system and long-time experience in delivering complex programs and projects on time and on budget, TRIUMF provides a unique platform for innovation, collaboration, and commercialization. Although breakthroughs and inventions are not individually predictable, a firm commitment to innovation from the leadership and staff of a laboratory makes a critical difference.

The Jenkins report, "Innovation Canada: A Call to Action," identified four complementary inputs to innovation when R&D is a key driver: ideas and knowledge; talented, educated, and entrepreneurial people; networks, collaborations, and linkages; and capital and financing. Through its partnerships with Canadian universities, TRIUMF develops and accesses the ideas and knowledge. Through industrial partners and AAPS, Inc. TRIUMF accesses and develop the talented personnel. Through its collaborations domestically and overseas with researchers, laboratories, and business, TRIUMF develops the networks and linkages. Access to capital and financing is almost always a bottleneck, but the creation of AAPS, Inc. is a powerful step forward: AAPS has its own limited capital as well as access to the broader community of business investors.

The Board of Management has developed a policy statement to control the amount of "contract research" that TRIUMF undertakes. With limited resources and a basic-research mandate, the laboratory uses the following considerations for evaluating involvement in externally proposed projects for innovation and industrial partnerships. This policy is a combination of what the laboratory is prepared to do and what it is not:

- TRIUMF does not generically undertake "work for others" (i.e., work for hire). Exceptions are not prohibited.
- TRIUMF does have a mandate to drive and develop new technology.
- Any project with a private-sector partner should be formalized and agreed to using the TRIUMF project management framework if it is above threshold for resource usage.
- A project with a private-sector partner should advance the TRIUMF research program. Licensing the technology would be a natural follow-up, and intellectual property is not generally given away.

In this context and beyond the conventional model of simply patenting an invention and launching a start-up company to sell the product, TRIUMF's partnerships drive business development and commercialization through three primary channels:

- TRIUMF's expertise is in demand by companies who are looking to enhance their revenue-generating activities. By making this expertise available on a selected basis, either through licenses or by contracting out employees, TRIUMF not only helps these companies, it increases its own expertise and capabilities. (Example: Nordion, Inc.)

MDS NORDION & TRIUMF TO COLLABORATE ON URANIUM-FREE ISOTOPE PRODUCTION

28 April 2009

TRIUMF and MDS Nordion, a leading global provider of medical isotopes and radiopharmaceuticals used in molecular medicine, announced on Tuesday, April 28, 2009, that they have signed an agreement to study the feasibility of producing a viable and reliable supply of photo-fission-produced molybdenum-99 (Mo-99) used globally for diagnostic medical imaging. MDS Nordion and TRIUMF will also provide their respective expertise and resources to collaboratively develop a commercialization plan, which will include an operations plan, business model, and time lines.

Medical isotopes produced using photo-fission employ the use of a linear accelerator rather than nuclear reactors. As such, the need to ship and handle highly enriched uranium is eliminated in favour of naturally occurring uranium. The photo-fission technology is based on superconducting radiofrequency cavities to achieve the high levels of beam power required to produce the isotope.

"With the superior level of the science at TRIUMF, combined with Nordion's market and technical expertise, we seek to provide a flexible, reliable and responsive medical isotope solution to potentially strengthen the global supply chain," said MDS Nordion President Steve West.

- TRIUMF trains people in specialized areas of expertise, and these people, in turn, take their expertise to existing companies or to start new companies. (Example: D-Pace, Inc.)
- TRIUMF, as a laboratory doing leading-edge research, frequently requires equipment that is not available off-the-shelf but must be developed in conjunction with commercial suppliers. The expertise developed by these suppliers, with TRIUMF's help, then aids the supplier to generate additional business and, in some cases, significantly increases their bottom line. TRIUMF may also help the company develop access to new markets. (Example: PAVAC Industries, Inc.)

Fueled by the Centres of Excellence for Commercialization and Research (CECR) program of the federal Networks of Centres of Excellence virtual agency, TRIUMF has added a fourth mechanism for industrial interactions with the formation of Advanced Applied Physics Solutions, Inc. This non-profit company, AAPS Inc., has a primary mission to develop the most commercially viable technologies arising from TRIUMF and to exploit new ideas that arise through interactions with TRIUMF's university owners and corporate partners. In this way, AAPS expands TRIUMF's capability and capacity for commercial impact.

When promising inventions and innovations arise at TRIUMF, AAPS will assemble a collaborative team to evaluate and develop the commercialization potential, and then launch a new spin-off company using the intellectual property. Not only has AAPS supplied direct expertise on projects where TRIUMF is developing new technology for industrial use (such as the production of the medical isotope technetium-99m using existing commercial cyclotrons), but AAPS has also challenged TRIUMF's leadership and its staff to recognize and bring forward potentially relevant technologies for commercialization (such as geotomography using cosmic rays).

AAPS enhances a distinct class of TRIUMF-industry interactions by providing expertise in contract management, IP control and technology licensing, product development, business planning, market analysis, fund-raising, and corporate governance. AAPS operates in the sphere of commercializing technologies by connecting TRIUMF intellectual property with either real-world investors (e.g., creating a start-up such as IKOMED) or real-world industrial partners (e.g., ACSI, Inc., for the high-resolution magnetic separator device). TRIUMF scientific and engineering staff need the expertise and guidance of AAPS to navigate, survive, and ultimately succeed "out there."

TRIUMF's industrial partnership and business-development activities are organized around four main business lines. In each of the areas, TRIUMF has specialized expertise and equipment that attract industrial partners.

- Irradiation Services. TRIUMF's accelerators provide beams of particles that can be used to probe materials to reveal their structure or bombard systems to examine their performance in elevated radiation environments. The space industry and segments of the high-performance electronics sector are steady customers.
- Isotope Production and Chemistry. TRIUMF's research program in nuclear medicine has developed core competencies in the production of isotopes using a variety of cyclotron and target technologies. TRIUMF also has expertise in the purification, processing, and chemical synthesis that attaches the isotopes to biologically relevant molecules for medical imaging or treatment. These capabilities are regularly in demand by the private sector.
- Technical Consulting. TRIUMF's capabilities in physics, engineering, and design are often tapped in the form of short-term technical consulting arrangements. TRIUMF staff might contribute to trouble-shooting a private company's product line or provide advice in developing needed high-tech infrastructure. TRIUMF's contributions to the success of AAPS, Inc. projects fall into this category.
- Professional Training. Last but extremely important, TRIUMF provides training experiences for highly skilled workers ranging from apprentices and journeymen in the technical trades to professional development of scientists and engineers through courses, workshops, and conferences.

With each industrial partnership, TRIUMF develops Canadian business in several ways. TRIUMF might provide direct technical assistance to the company on a product line or a platform for product development. Or it might be involved with a vendor to enhance an existing product to meet an application needed for TRIUMF's research program. Finally, TRIUMF might also collaborate with a company to investigate and develop a new technology, market, or service offering. One example of an industrial partnership is with Nordion, Inc, a relationship that won a NSERC Synergy award in 2004.

The business partnership between TRIUMF and Nordion Inc. is a well-known and successful example of technology transfer involving isotope-production technologies, and it certainly is the lab's largest model of success. The mixing of the laboratory's academic culture (TRIUMF is, after all, owned by universities), and the business culture has taken time and effort to develop, but it is by all measures a smooth and profitable partnership. During a period when federal and provincial governments are seeking to enhance Canada's competitiveness with the best economies in the world, it is certainly the time to develop new success stories.

> "Norsat International Inc. ("Norsat") (TSX: NII and OTC BB: NSATF), a leading provider of broadband communications solutions, announced today that one of its Ka-Band BUCs was recently used in an antimatter study called the ALPHA (Antihydrogen Laser Physics Apparatus) experiment at the CERN Laboratory located near Geneva, Switzerland."
>
> Business Wire, "Norsat Ka-Band BUC Unit Used in CERN Laboratory in Antimatter Research," 22 Dec 2010.

3.3 SELECTED EXAMPLES

3.3.1 ARIEL

The ARIEL project, from its inception, through the funding application, to the project execution, is a prime example of how TRIUMF works with its partners in Canadian universities, various international laboratories, and Canadian industry to the benefit of Canadian science, students, and the economy.

The CFI (Canada Foundation for Innovation) proposal for the ARIEL project was enabled through a broad consortium of TRIUMF member universities under the leadership of University of Victoria with Dean Karlen, joint TRIUMF/UVic appointment, as principal investigator. The UVic group is also making major contributions to the e-linac front end, including the development of diagnostics elements to characterize the high-intensity electron beam. The technical development of the e-linac is ideally suited for the education of graduate students in accelerator science; as such, TRIUMF has initiated Canada's only graduate program in accelerator science with graduate lectures at UVic and UBC. Several graduate students from Canadian universities are carrying out their Ph.D. projects in this program and working directly on the e-linac.

The electron gun and the injector cryomodule (ICM) of the e-linac have been developed in close cooperation with the VECC laboratory in Kolkata, India, under the auspices of a cooperative MOU signed in 2008. Using substantial investments by VECC, two electron sources and ICMs are being constructed: one for the ARIEL e-linac and one for the corresponding ANURIB project in India. The VECC MOU also enabled the implementation of a test stand that expedited validation of the front-end design including beam parameters and beam optics that fed into the final choices for the Electron Hall and ARIEL building.

NORDION, TRIUMF, AND THE UNIVERSITY OF BRITISH COLUMBIA ANNOUNCE PARTNERSHIP TO DEVELOP NEW DIAGNOSTIC IMAGING AGENTS

May 4, 2009

Nordion, TRIUMF, and the University of British Columbia announced that they have entered into a three-year research and development partnership to pursue the development of new diagnostic imaging agents—medical isotope products using technology based on radiometals and chelates.

Radiometals are a class of medical isotopes that has been the backbone of nuclear medicine for decades and are currently used in 80% of nuclear medicine procedures. Scientists will combine select radiometals with newly developed chelates—substances that bind to radiometals and protect them as they are carried through the body—with the goal to provide new agents for the diagnoses and treatment of cancer and heart disease.

"This strategic partnership with TRIUMF and UBC is expected to accelerate innovation, which could provide the opportunity to commercialize new molecular medicine products," said Nordion President Steve West. "Our combined capabilities and technical expertise will create a dynamic setting in which to develop new tools for physicians to detect disease earlier and more precisely, and to offer breakthrough treatments for patients."

International collaborations also facilitated other technical developments for the e-linac, including a cooperation with the Helmholtz-Centre Berlin, Germany, on the klystron providing RF power to the ICM; DESY Hamburg, Germany, on physical and chemical processing of the accelerating cavities; MPIK Heidelberg on the ARIEL electron beam ion-source (EBIS) charge breeder; and the U.S. Fermi National Accelerator Laboratory for the e-linac's cryogenic system. In each case, TRIUMF was able to tap into established international expertise and experience to more effectively advance its objectives.

ARIEL is also an excellent example of TRIUMF's cooperation with Canadian industry and efforts to bring high-technology solutions developed for Canadian science to the global market.

The chief technical element of the e-linac is the superconducting radio-frequency (SRF) cavity that performs the acceleration of the beam of electrons. Only four companies in the world had the ability to fabricate these components and none of them were in Canada. Recognizing the emergence of SRF as the technology of choice for modern accelerators, TRIUMF elected to develop and transfer its expertise to a local company, PAVAC Industries in Richmond, BC. PAVAC started as an electron-beam welding company, a vendor to provide one of the key assembly services required to make an SRF cavity. TRIUMF worked with PAVAC to master the entire fabrication and assembly process. Through the VECC MOU, TRIUMF made introductions to their Indian counterparts for PAVAC and the company promptly sold several multi-million dollar e-beam welder products to India. Furthermore, PAVAC has now been selected as the vendor of choice for the five SRF cavities needed for ARIEL and will also be contracted by India to make the SRF cavities for their ANURIB project.

The technology used for these cavities is also the technology of choice for the prospective international linear collider (ILC), which Japan has recently indicated an interest in hosting. The ILC would need on the order of 16,000 cavities for this next-generation particle-physics accelerator, and PAVAC is now well positioned to secure substantial contracts for this project, enabling a visible Canadian contribution to this world project. PAVAC's work with TRIUMF has also generated SRF contracts for the company in China, Japan, Korea, and the U.S.

The construction of the high-resolution mass separator, a set of precision magnets, for the ARIEL front-end will be carried out in cooperation with local industry with the aim to commercialize this technology. TRIUMF, AAPS, and ACSI—a leader in the production of the TR-series of medical cyclotrons based on a TRIUMF design—have teamed up to develop these very demanding precision magnets. They are of interest to numerous other laboratories in the world for projects that are either under construction or in the planning stage. This mass-separator project is part of a broader effort led by Saint Mary's University with the support of CFI via the "CANREB" initiative that also engages funding from the provinces of Nova Scotia, Manitoba, and British Columbia.

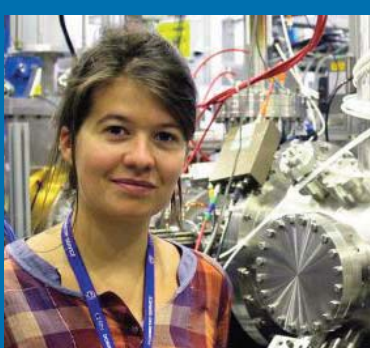
3.3.2 CYCLOTRON-PRODUCED TECHNETIUM MEDICAL ISOTOPES

Technetium-99m (Tc-99m) is the most widely-used radionuclide in diagnostic nuclear-medicine studies around the world. This radioisotope is used in 20 to 40 million diagnostic procedures worldwide annually, for purposes ranging from detecting bone metastases to detecting coronary artery disease. The conventional approach for the parent isotope molybdenum-99 or Mo-99 production involves the fission of weapons-grade uranium in a small number of aging reactors around the world. Alternative, safe, non-reactor and non-uranium based production methods of Tc-99m are known.

Based on evidence presented in a 1971 report from the University of Miami School of Medicine, Dr. François Bénard (BC Cancer Agency, UBC) with Thomas J. Ruth of TRIUMF spearheaded a joint proposal to produce and validate using Tc-99m from medical cyclotrons in 2009. The proposal engaged TRIUMF, the BC Cancer Agency, UBC, Lawson Health Research Institute (London, Ont.), the University of Sherbrook, Advanced Cyclotron Systems Inc. (ACSI), and was funded by NSERC/CIHR.

The effort was successful and established the feasibility of producing Tc-99m using particle accelerators already installed at major hospitals around the country. This research led to a second and third round of funding, this time from Natural Resources Canada (NRCan). The second round collaborators were TRIUMF, the BC Cancer Agency, Lawson Health Research Institute, the Centre for Probe Development and Commercialization (CPDC) (Hamilton, Ont.), UBC, and Advanced Applied Physics Solutions Inc. (AAPS). For the third round of funding, the collaborators were the same with AAPS taking a facilitating role for the development of the BC market. With a total investment of over $13M across these three efforts, the consortium has now successfully developed, and is in the process of commercializing, the competitive cyclotron-based production of Tc-99m.

The initial development work was funded by NSERC/CIHR, who support academic research, but as the project progressed to a more commercial focus the funding shifted to NRCan who were interested in alleviating shortages of Tc-99m (notably when Canada's NRU reactor ceases isotope production in 2016). The mix of collaborators is also relevant: it includes two research institutes (TRIUMF and Lawson), a provincial health-care agency (BC Cancer), a private company (ACSI), three universities (UBC, Alberta, and Sherbrooke) and two Centre of Excellence for Commercialization and Research (CECR) award recipients (AAPS and CPDC). While this may seem complicated, it reflects the collaborative nature of research with the different stake holders each playing an important role and the roles changing as the project progresses. The end result of all this collaboration will be a commercial product that saves lives, secures isotopes for Canadian patients, and generates economic benefit to the country.



TRIUMF STUDENT AWARDED CERN FELLOWSHIP

18 July 2013

UBC physics doctoral graduate and former TRIUMF researcher, Chloé Malbrunot was recently awarded a Senior Research Fellowship at CERN, effective this October in Geneva. As a member of the ASACUSA (Atomic Spectroscopy And Collisions Using Slow Anti-protons) Collaboration, Dr. Malbrunot studies the properties of antihydrogen and anti-matter.

Dr. Malbrunot was on hand from the early stages of TRIUMF's PIENU experiment through to its recent completion, which measured rare pion decays. Dr. Malbrunot credits this experience within the team to her successful application for the CERN fellowship this year:

"I learned a lot from the scientists, technicians, and different experts within the collaborative environment at TRIUMF, and am thankful to those from whom I learned for their contribution to this fellowship!"

As a Senior Research Fellow at CERN, Malbrunot will continue developing the spectroscopy apparatus needed to do precise studies of the properties of antihydrogen. The lack of precise and wide-ranging details about antihydrogen stands as a great challenge within physics today.

> So far, the cost of using the process on a commercial scale is not known, though Bénard expects it would be cheaper than using a reactor. Bénard says another benefit of using medical cyclotrons instead of nuclear reactors is that a cyclotron produces no radioactive waste.
>
> Vancouver Sun, "Team of BC scientists makes breakthrough in producing isotope for medical imaging," 09 Jun 2013.

3.3.3 CERN

Over the past five decades, experimental particle physics has coalesced into an increasingly collaborative global enterprise. The founders of TRIUMF had the foresight to appreciate that university physics departments with a small cyclotron or Van de Graaff generator in the basement could not hope to explore the energy frontier alone: they needed a joint venture. Those original efforts, which created TRIUMF and built the world's largest cyclotron, allowed Canadian universities to develop, own, and operate a facility big enough to nurture the engineering and technological skills required to remain relevant in a field that was rapidly transforming from regional to global.

CERN, born out of post-war Europe's need for collaboration not only among universities but also nations, has been a natural inspiration from the start. With improvements in communication shrinking the world, and the growth of high-energy physics collaborations from tens to thousands of participants, CERN has increasingly become not just a model but a home to experiments assembled in labs and universities around the globe.

TRIUMF has helped Canadian university researchers to design and build experiments destined for CERN since the early 1980s, when scientists from TRIUMF, UBC, and UVic participated in the ASTERIX experiment. More formal involvement began in the early 1990s when TRIUMF, Victoria, and the Université de Montréal collaborated on the silicon-strip microvertex detector of the OPAL detector at the Large Electron Positron Collider (LEP).

It was in the 1995–2000 Five-Year Plan that TRIUMF was given the mandate to act as Canada's main conduit for interactions with CERN and to develop and construct components for the Large Hadron Collider (LHC). Although Canada was not a member of CERN, universities across Canada wanted to be part of the world's only viable energy-frontier project. A mechanism for Canadian participation in the LHC through in-kind contributions made by TRIUMF provided the means. The agreement between TRIUMF and CERN involved a $30M contribution made up of $19M in equipment and $11M in TRIUMF labour. Initially, TRIUMF was asked to work on the conversion of the Proton Synchrotron (PS) and its Booster, to upgrade them for use in the LHC injector system. The LHC required proton beams with twice the brightness, more strictly controlled emittance, and different bunch spacing for LHC operation, a task well matched to TRIUMF's in-house expertise. The Canadian contribution included high-voltage power supplies for the PS Booster, all the magnets and power supplies for the upgraded transfer line between Booster and PS, new transformers for the Booster main magnet supply, and various related projects. Specialized beam instrumentation and electronics for the upgrade were developed at TRIUMF; in addition, the beam-dynamics group assisted in beam simulation studies towards higher

JAPANESE APPROVE FUNDING FOR UCN PROJECT AT TRIUMF

03 June 2009

The Japan Society for the Promotion of Science (JSPS) recently announced that it has approved the grant application to fund a new international user facility for Ultra-Cold Neutrons at TRIUMF. The project is a collaborative effort among over a dozen Japanese, Canadian, and U.S. institutions led by Professor Jeff Martin at the University of Winnipeg.

Ultra Cold Neutrons (UCN) are free neutrons that move very slowly (typically less than 30km/h), due to their low energies, allowing scientists to study their properties like never before. When completed, the UCN source at TRIUMF will provide the highest density of UCN in the world. It will enable a new generation of experiments on the fundamental interactions of neutrons to be conducted with higher precision than ever before.

As a result of this funding announcement, the Japanese component of the project has already begun to move forward with activities for explicitly siting the project at TRIUMF. These developments will take place over the next two years, with efforts in Canada having started as soon as Canadian funding was later secured.

currents in the Booster. By 2000 TRIUMF had completed all of the tasks included in the PS conversion. By the end of that year, the nominal LHC beam with the required protons/bunch in an emittance below the allowed limit—and with 25 ns bunch spacing—was produced in the PS.

In 1998, TRIUMF had initiated prototype developments on two large projects for the LHC itself. The first involved development of a resonant charging power supply for the LHC injection kickers as an in-house project and the second, working with industry, the fabrication of a prototype twin-aperture quadrupole magnet for the focusing elements of the beam-cleaning insertions of the LHC. In 2002, TRIUMF and CERN signed an extension to Canada's agreement that involved substantial Canadian industrial partnerships in the design and fabrication of components. The largest and most important item in this extended contribution was a series of 52 twin-aperture warm quadrupoles for LHC beam cleaning. These magnets had to be assembled with much higher precision than is common for normal quadrupole magnets due to the small aperture required to get the necessary high field gradient. Series production began at ALSTOM Canada in Tracy, Quebec in 1999. This work required ALSTOM Canada to meet much higher assembly tolerances than their previous experience in fabricating generators for the power industry and to set up improved quality assurance procedures for this type of work.

Funding at a level of $11.5M for the completion of this ambitious project, which also included the production of the components for four LHC injection kicker systems, was part of TRIUMF's Five-Year Plan 2000–2005. The power supplies, pulse-forming networks and switch tanks for the kickers were completed and shipped to CERN where they were installed between 2005 and 2006.

All of the Canadian contributions to the LHC were selected based on the technical expertise that existed or could be developed at TRIUMF as well as the availability of Canadian industry to supply a high fraction of the components. Approximately 90% of the total contribution was spent in Canada. There were a number of spin-offs from this activity. The companies I.E. Power, Inverpower, and Digital Predictive Systems in Ontario were awarded $3.7M in contracts for high current power supply design and fabrication for the PS conversion project, and the expertise gained in developing high-precision pulse mode power supplies subsequently allowed them to compete favourably in the international market.

They went on to receive contracts in excess of $10M from Brookhaven, Los Alamos, SLAC, Argonne, and the Canadian Light Source. Likewise, ALSTOM took the quality assurance procedures they created during magnet construction and used them elsewhere in the plant. The company and its subcontractor for the coil fabrication were asked to bid on other magnet projects.

Today, these major in-kind contributions to the CERN accelerator complex have made it possible for TRIUMF and the Canadian university community to participate in the ATLAS experiment at the LHC, as well as several other parts of the CERN program. The University of Calgary became a member of TRIUMF through its participation in the ALPHA antihydrogen experiment at CERN. McGill University, which has recently joined TRIUMF, has collaborated for years on nuclear physics experiments both at TRIUMF's ISAC and at CERN's ISOLDE.

The results from experiments conducted at CERN are revolutionizing our understanding of matter, energy, space, and time. LHC operations are currently supported by CERN member states to the benefit of all participating countries. This model—requiring member states to commit to sustaining the laboratory on a long-term basis, while allowing countries like Canada to participate in specific projects by means of in-kind contributions—is being stretched and will likely give way to a more equitable, "pay-to-play" model within the next 5-10 years.

Over 300 Canadian researchers, graduate students and technical staff are currently involved in the CERN program. Of the nearly 100 graduate students working at CERN with Canadian universities, a third have scholarships and a quarter were recruited from outside of Canada. TRIUMF's involvement in CERN puts Canadian universities and industries on the world stage.

3.3.4 ULTRA-COLD NEUTRONS

TRIUMF is in the process of installing a new beam line and spallation target in its Meson Hall. This new infrastructure will form the basis for the Ultra-Cold Neutron (UCN) facility that seeks to discover an electric dipole moment (EDM) of the neutron. The project is only possible through the close collaboration of TRIUMF with a number of university partners in Canada and in Japan as well as in Canadian industry.

The project is funded in its initial stage through a CFI grant along with matching funds contributed by the two major Japanese laboratories: KEK near Tsukuba and RCNP in Osaka. In addition, the Manitoba company Acsion Industries is contributing its nuclear-engineering expertise for the design of the neutron moderator.

On the Canadian side, the collaboration includes researchers from University of Winnipeg, University of Manitoba, University of British Columbia, University of Northern British Columbia, Simon Fraser University, and TRIUMF. TRIUMF is responsible for the implementation of the beam line and spallation target, and the Canadian collaboration is expanding its involvement with various aspects of the source and EDM experiment itself. The Japanese collaborators provide beam line magnets, the UCN source itself, as well as a first version of the EDM experiment, and contribute to the procurement of the liquid helium recovery and liquefaction plant, the first stage of which is currently being installed.

The design of the kicker magnet, which will kick bunches of the proton beam away from BL1A into the new beam line, was carried out with strong input from CERN, which had recently completed the design of a similar magnet for the hadron therapy facility, MedAustron, in Austria.

Japan will invest around $2M in this project in addition to $2M of in-kind contribution for the experiment itself. In addition, the project will benefit from a soon-to-be-launched KEK office at TRIUMF, a first of its kind outside Japan that will provide support for Japanese researchers at TRIUMF, not just the UCN project, but also users of the ISAC and materials-science facilities.

3.3.5 COMBINED STRENGTH IN SUBATOMIC PHYSICS: PERIMETER INSTITUTE, SNOLAB, AND TRIUMF

In Canada, there are three institutions with a common interest in subatomic physics: The Perimeter Institute for Theoretical Physics (PI) in Waterloo; SNOLAB, with laboratory space situated two kilometers below the surface in the Vale Creighton Mine located near Sudbury; and TRIUMF in Vancouver. Each institution has a distinct niche in the Canadian scientific ecosystem. The PI's raison d'être is theoretical studies of fundamental physics; SNOLAB is dedicated to low-background experiments primarily relating to neutrinos or dark matter, and TRIUMF is a more broadly-based facility with both theoretical and experimental physics capabilities and technical, computing, and engineering facilities. There are multiple points of contact between TRIUMF and the theorists at PI in terms of defining research avenues, evaluating and interpreting physics results, and synthesizing the larger picture. To support these interactions, TRIUMF and PI have signed a formal MOU that outlines a framework of regular personnel exchanges, joint meetings (especially the theory/ATLAS experimentalist joint meetings), and coordination of student opportunities. TRIUMF and PI also participate in a national award recognizing the top high-school physics teachers in each province.

TRIUMF was involved in the original SNO experiment through two TRIUMF scientists and an engineer working on the project. In addition, SNO used TRIUMF's technical facilities in the development and testing of components for their detector. A joint appointment between TRIUMF and Carleton University became the principal investigator of the SNOLAB proposal and its facility development director. Since then, TRIUMF has been involved in a number of SNOLAB experiments: SNO+, HALO, Super-CDMS, and DEAP3600. The partnership is two-way. SNOLAB capitalizes on the accumulated technical expertise, including a TRIUMF engineer residing at Carleton University, and capabilities at TRIUMF, and TRIUMF scientists participate in some of the world's most competitive low-background, underground experiments at SNOLAB. SNO+ has used the expertise of the TRIUMF Design Office and Machine Shop to design and construct the Universal Interface (UI), and TRIUMF is involved in DEAP3600 with a research scientist leading the effort to design and construct the readout electronics and oversee the machining of the light guides in the scintillator shop of TRIUMF's detector facility. A TRIUMF scientist is also involved with the HALO experiment, which studies neutrinos from supernovae.

In addition to the purely technical collaborations, the three institutes have teamed up to run an annual summer school for graduate students, the Tri-Institute Summer School on Elementary Particles (TRISEP). Its location rotates between the three institutes. The first one was held in July 2013 and was well attended. The next one will be at SNOLAB in 2014, followed by PI in 2015, and a return to TRIUMF in 2016.

3.4 SUMMARY

By nature, TRIUMF works with partners in the government, university, and industrial sectors—and these partners extend outside of Canada to international locations. By applying specific criteria that focus on advancing TRIUMF's mission, these partnerships ultimately add value to the investments made by the Canadian taxpayer.

GLOBAL SCIENCE AS GLOBAL ENTERPRISE

The European Centre for Nuclear Research (CERN), based in Geneva, Switzerland, is often cited as one of the most important scientific legacies of the aftermath of World War II and is credited with forging intellectual and cultural connections among a broad, multi-national scientific community—CERN's Large Hadron Collider (LHC) is the largest global science project ever built.

But what actually makes a science project global? Essentially just three ingredients: mutual scientific interest, pooled resources and/or investment, and opportunities for shared impact.

Mutual Scientific Interest

Humans are curious by nature, always asking "Why this?" or "Why that?" and even sometimes "Why me?" The practice of science fulfills our quest to understand the world around us. But not everyone is interested in the same science. Biologists are fascinated by the mechanisms of life, physicists love to reduce observed phenomena to basic principles, and chemists look at the principles that govern our daily experience of the world. Some science questions are global. How old is the universe? How did life evolve? What is inside a proton? These questions excite many minds across the planet and anthropology shows that mankind has been fascinated with these questions for thousands of years. Global science, therefore, is science that many, many people are curious about.

Pooled Resources and Investment

Global science is often called "big science" or even "megascience" (although these days, perhaps we need an upgrade from mega to peta or exa). The manned mission to the Moon was almost global science; one nation, roughly on its own, completed this feat. Global science requires the combined resources and talents of multiple countries to design, build, and operate its major tools. Astronomy is in this category with the growing family of telescopes and telescope arrays populating the Chilean desert. Aspects of particle physics are in this category, too, namely the "energy frontier"– dealing with questions about the origins of mass or whether dark matter is really a particle that springs from modifications to our beloved Standard Model.

CERN's LHC fits exactly in this category; depending on how you do the accounting, the project cost more than $6 billion and took advantage of significant existing infrastructure at CERN. Such an amount actually exceeds many national budgets for total annual investment in basic research. A number of global scientific disciplines now pool resources to assemble the capital investment required to design and construct a megascience facility. This model is being stretched in the present day as annual operating costs (typically 10% of the total capital investment) are themselves becoming large enough to be shared or distributed among multiple countries.

Opportunities for Shared Impact

The third ingredient for global science is perhaps the most critical because it is the glue of the global effort: globally realized and relevant returns. Sure, particle physics is intrinsically interesting and inspires young minds to pursue training in science, technology, engineering, or mathematics. But is that generalized bonus sufficient to justify dozens of countries spending a billion dollars per year to probe the energy frontier?

No. The LHC is not just a globally coordinated extra-large Shakespeare Festival. The pursuit of the science at the LHC actually provides real technological and intellectual value to every participating country. Certain technologies may be invented in the design and construction of the LHC and these technologies are likely to have an impact all around the world. The most direct way to be involved in the development, distribution, and deployment of these technologies is to be directly involved in the project.

This, then, forms the two-way give-and-take relationship of global science. Countries with common scientific interests pool resources to develop the next scientific instrument needed to attack the frontiers of knowledge. The world at large will, ultimately, enjoy the benefit of any discoveries. The participating countries have an extra benefit: not only are they involved in the creation and engineering of new technologies, but they are "at the table" of anything that is developed. Consider the global science project called ITER, the International Thermonuclear Experimental Reactor. This device is the next step on the research and development path of harnessing nuclear fusion for energy. The participating countries are certainly intellectually interested in the detailed properties of confined, high-temperature plasmas, but they are also extremely motivated to have a share of the eventual technology, either to replicate and fuel their own domestic energy needs, or, better yet, to commercialize and sell it to other countries.

Working Together

The LHC is a global science project. There will be future global science projects, and CERN is well positioned to offer the organizing framework. It no longer makes sense to restrict CERN to facilitating ongoing cooperation among just European nations. It is time to consistently and regularly coordinate global science activities.

As CERN picks up the discussion of expanding its membership base to include countries outside Europe, it is a validation of the natural evolution of our global connectedness or our "flattened" world. It is a statement that our mutually shared scientific appetite can be satiated through coordinated investments that bring positive benefits to everyone, and in a world where time-to-market dictates the winner, those benefits go first to the primary participants.

These are the types of considerations that each country will be weighing and judging as they consider a more formal partnership with CERN, perhaps as an associate member. Canada, which has contributed nearly $150M over 15 years to the LHC and the ATLAS detector, is certainly mulling it over. A commitment to an international science venture with CERN is an invaluable opportunity and one that requires careful analysis. If the program shifts too much to CERN, what scientists and students will remain in Canada to reap the benefits of participating in the world's best particle-physics laboratory?

The Government of Canada has identified that future economic growth will come from a knowledge-based economy, one that expands beyond natural resources and added manufacturing value. Formal strategic international partnerships are one vehicle to accelerate (no pun intended) that approach.

There is a distinct advantage for Canada when its scientists connect with the best in the world, and vice versa. Canada contributes unique value to the global enterprise (the cleaning-insertion magnets, which transfer the LHC beam into the final ring, were designed and built in Canada). Working with the best keeps the home team competitive, plugged-in, and up-to-date. These are the downstream, long-term benefits that make it all worthwhile.

Originally published as "The Collider's Scope", *Public Service Review: European Science and Technology*, Issue 12, 05 Oct 2011, pp. 158-159.