TRIUMF's Role in the Canadian University Research System

Introduction

The Canadian research enterprise is largely driven by the research programs of the Canadian universities. In many fields, especially nuclear and particle physics, the quest to unlock deeper secrets exceeds the resources of a single institution. A national laboratory, working closely with the university community and drawing together the strengths and capabilities of many institutions, is required. In the context of the Canadian nuclear physics community, this requirement led to the founding of TRIUMF in 1968. Initially launched by three universities as a local facility for intermediate-energy nuclear physics, the laboratory has now grown to be a truly nationwide effort, engaging Canada from sea to sea with seven member universities and six associate members. It has also expanded from nuclear physics to include particle physics, molecular and materials science, and life science. TRIUMF with its user community leads Canada in addressing a wide range of the important science and technology questions that transcend the capabilities of individual institutions.

TRIUMF's contribution[1] to the Canadian academic community is, in its fields of expertise, crucial in allowing Canadian researchers to make world-leading advances in science. TRIUMF possesses a unique combination of resources, including engineering staff, detector expertise, specialized machine shop equipment, particle beams, and clean rooms. University-based researchers are drawn to work with TRIUMF because these resources and capabilities simply are not available at their home institutions. Scientists at TRIUMF become the key points of contact. This fosters collaborative partnerships among Canadian researchers and between Canadian researchers and their international colleagues.

In deciding which projects to undertake TRIUMF has a policy of only supporting projects that have been independently peer reviewed by the scientific community. TRIUMF is part of that scientific community. In the field of subatomic physics, TRIUMF scientists participate along with the university-based physicists in developing the NSERC Long-Range Plans for subatomic physics. These community-based plans discuss the long-term objectives of the field are used when developing TRIUMF's own priorities. The university community has always been involved in the decision-making process at TRIUMF and recently, a new committee, the Policy and Planning Advisory Committee, has been established to foster increased university input into TRIUMF policy and planning decisions.

[1] In this section, only TRIUMF's contribution to Canadian research capabilities is discussed. The contribution to training highly qualified personnel will be discussed in another section of the Five-Year Plan report.

TRIUMF adds significant value to the Canadian academic community in a number of areas including molecular and materials science, subatomic physics, and the life sciences. However, its largest impact is in subatomic physics. To quantify this impact, consider the NSERC grants awarded to subatomic physics in fiscal year 2006—2007 (similar results hold for other years[2]). During that year, the total NSERC budget for subatomic physics was $22.4 million. Of this amounts, approved proposals with at least one TRIUMF-supported signatory accounted for $12.1 million dollars while those without a TRIUMF signatory but which used TRIUMF facilities in some manner accounted for another $4.6 million. Taken together, 74% of the NSERC budget for subatomic physics involves TRIUMF. If theory grants are excluded, TRIUMF's involvement with experimental subatomic physics is 86% ($16.4 out of $19.3 million). Included in this figure are projects like TIGRESS and ATLAS but also projects like the Sudbury Neutrino Observatory (SNO) where TRIUMF supports two scientists and supplies some infrastructure. TRIUMF is involved in a large fraction of the Canadian experimental subatomic-physics program.

The CFI program has had a dramatic impact on the Canadian university research program. Although TRIUMF cannot apply directly for CFI funds[3], TRIUMF's capabilities have been expanded because a number of universities have elected to compete for—and win—support for projects that are then based at TRIUMF. Over the five-year period under discussion, CFI awards totaling more than $30 million were used by universities to expand the capabilities and competencies at TRIUMF. Examples are the ATLAS Tier-1 Computing Centre, the M-20 beamline, the Laboratory for Advanced Detector Development, and projects led by researchers at St Mary's University. These CFI proposals were successful in part because of the support from TRIUMF.

TRIUMF is well recognized as a key element of the national research portfolio in subatomic physics.[4] The molecular, materials, and life sciences programs at TRIUMF exploit the unique beams and expertise at TRIUMF to provide specialized tools to the university research community. These specialized tools allow crucial insights that would not otherwise be possible. In materials science, the unique facilities are the muon beams, radioactive ion beams, and the associated instrumentation.[5] Many of the techniques used at muon facilities worldwide were developed at TRIUMF. Working with TRIUMF, the university user community pioneered this area of condensed-matter research. As a result, TRIUMF remains one of two leading centers worldwide. Members of the university community use the TRIUMF facility, bringing key samples to TRIUMF, to supplement techniques available at their home institutions or at other laboratories.

The TRIUMF Life Sciences program is built on TRIUMF's unique ability to use its accelerator technology to produce isotopes, radiopharmaceuticals, and radiotracers for the

[2] Appendix B in the full Five-Year Plan report will contain this information.

[3] CFI funding is only available to university researchers; TRIUMF cannot apply directly for a CFI award. However, university teams may apply for CFI awards with projects to be based at TRIUMF.

[4] A subsequent draft of this chapter will include descriptions of and quotations from the Institute of Particle Physics and the Canadian Institute of Nuclear Physics.

[5] These comments will be expanded in other sections of the full Five-Year Plan report.

diagnosis and treatment of disease. The centerpiece of this program is a joint TRIUMF-university venture—the TRIUMF/UBC PET Centre—that studies the origins, progression and treatment of Parkinson's disease and other neurological diseases such as Alzheimer's. The PET Centre, established in 1980, also dedicates substantial resources to basic research in psychiatry, the genetic causes of neurodegeneration, and diabetes. It is one of only a few centres in the world capable of this broad, successful multi-disciplined research program. The PET Center depends critically upon TRIUMF and its production of the isotopes. In 2005, the British Columbia Cancer Agency, the Vancouver Hospital and Health Sciences Centre, and the TRIUMF/UBC PET Centre opened a Centre of Excellence for Functional Cancer Imaging. This Centre of Excellence, with the first publicly funded PET/CT scanner in British Columbia, will improve cancer diagnosis and treatment for patients, build research programs for the discovery, development, and application of new radiotracers and promote collaboration with the national and international network of functional imaging programs.

Examples of TRIUMF's Relationship with University Partners

TRIUMF has a wide range of resources including high quality beams of protons, muons, and radioactive isotopes; detectors to be used in conjunction with these beams; facilities for making detectors; and detector components. Because TRIUMF is driven by a large user community, it can maintain specialized equipment and resources that are utilised sequentially by different groups. In addition to the physical plant there are the human resources that include research scientists, engineers, and people with technical expertise in various relevant areas.[6] Salary support (in whole or in part) for about fifteen scientists resident at Canadian universities is provided by TRIUMF. This strengthens the scientific and intellectual ties between TRIUMF and the Canadian universities. As an active research center, TRIUMF maintains an atmosphere that promotes intellectual activity through seminars, visitor programs, and workshops. Tying it all together is a management structure geared to maximizing the science impact for Canada.[7]

TRIUMF's role, in the academic context, is to work with the Canadian research community to enhance Canada's scientific productivity. TRIUMF's core contribution to the research enterprise is its supply of resources that can be applied coherently to a diverse set of endeavours. TRIUMF's collaborations span medical techniques, accelerator research, chemistry, molecular and materials science, nuclear physics, and particle physics experiments at foreign laboratories. Flexibility in interacting with this diverse community is one of TRIUMF's strengths.

This section describes three of the most prevalent approaches, the first of which describes the approach typically used for TRIUMF nuclear physics experiments, the second for large international experiments performed at foreign laboratories, and the third for experiments in molecular and material science performed at TRIUMF.

[6] The specifics of TRIUMF's human capital will be detailed elsewhere in the Five-Year Plan report.

[7] TRIUMF's management and administration will be described elsewhere in the Five-Year Plan report.

1. For collaborations undertaking subatomic research at TRIUMF the laboratory provides particle beams of the desired species, intensity, and energy. Typically these collaborations include a TRIUMF scientist and a specialized apparatus that is already commissioned and operational. In instances where new equipment is being used it is typical that TRIUMF personnel are heavily involved in the specification, design, procurement, and commissioning of the new equipment. The actual equipment for individual experiments and most of the detector facilities are funded from outside resources, either Canadian or foreign.
2. For experiments at foreign laboratories, TRIUMF normally contributes in the areas of design, fabrication, and installation of portions of the experimental apparatus. In several instances there has also been a contribution of systems, such as a set of magnets or power supplies, for the accelerator being custom built for the experiment. In large collaborations TRIUMF scientists often assume senior roles in the management of the collaboration.
3. For experiments in molecular and materials science, university based teams provide the samples to be studied, while TRIUMF provides the beam, detection equipment and data acquisition program. Typically, the focus is on a specific scientific problem (for example high temperature superconductivity or novel magnetic materials) requiring multidisciplinary investigation. TRIUMF acts as a user facility providing valuable and frequently unique services, but it is often one of several resources used by the group of experimenters.

In Table YY, contributions that TRIUMF brings to collaborations are listed vertically and several major collaborations are listed horizontally. This table is by no means a complete list of all collaborations but is included to provide insight into the diversity of our collaborative model.

Collaboration Or Facility	Major Detector Contribution	Major Accelerator Contribution	Beam or Isotopes	TRIUMF Scientist	Canadian Intellectual Leadership
HERMES					
BaBar					
ATLAS					
T2K					
TIGRESS					
G0, Qweak					
μSR Facility					
Accelerator R&D					
Medical Technology					

TABLE YY: The diverse nature of the collaborations in which TRIUMF is involved. Vertically the representative collaborations are listed, while horizontally the typical contributions of TRIUMF are listed. Areas coloured blue indicate that in these experiments this aspect the contribution is strong.

Contributions to Canadian Academic Leadership

From the extensive work described in this five-year plan it is clear that Canadians have, through TRIUMF, played a leading role in a wide variety of internationally recognized scientific endeavors. Many of these would not have been possible without TRIUMF. In the first instance, the primary community is the research community at the universities within the TRIUMF consortium. In the second instance, it is other members of the Canadian research community. A typical participant in TRIUMF from the Canadian research community uses not just one of the physical resources but rather accesses a number of different physical resources and also obtains technical support and collaborates with on-staff scientists. In fact, TRIUMF often provides a project engineer who coordinates the project and resources.

TIGRESS

TIGRESS is a state-of-the-art gamma-ray escape suppressed spectrometer for use at the ISAC facility.[8] A preliminary CFI grant through the University of Guelph for $0.6 million was used for initial prototyping. Subsequently a collaboration headed by Carl Svensson, consisting of eight university-based and two TRIUMF-based physicists, applied for NSERC funding in the autumn of 2002. NSERC awarded the collaboration eight million dollars over six years. This award is the largest single NSERC grant for nuclear physics ever awarded. A follow up CFI grant through St. Mary's University added an additional third of a million dollars for electronics. Presently 8 of the 12 modules of the full spectrometer are on site and three experiments have been performed.

This collaboration—university-based and led—has had substantial TRIUMF contributions. First and foremost, the project depended on the existence of the ISAC beams at TRIUMF. As part of providing the beam for this experiment, TRIUMF built a dedicated beam line. Secondly, TRIUMF provided specialized dedicated laboratory services and personnel—engineering support, design office and machine shop time, and installation technicians. While these services may be routinely available at laboratories, the size of the TIGRESS project meant that these contributions were substantial. Finally, two TRIUMF research scientists, Greg Hackman and Gordon Ball, oversaw the day-to-day management of the project and did a lot of the hands-on work that was necessary to make the spectrometer a reality. Thus, Canada's ability to design, build, and operate the TIGRESS experiment depended upon TRIUMF.

TIGRESS with its the auxiliary detectors provides a world-leading detector system to exploit the beams that only ISAC can supply. This unique combination of detectors and beams was only possible because TRIUMF, NSERC, CFI, the Canadian university research community, and their foreign collaborators worked together for a common good.

[8] The TIGRESS spectrometer is described in more detail elsewhere in the full Five-Year Plan report.

ATLAS

The ATLAS collaboration comprises (as of October 2007) about 2,000 scientific authors from 167 institutions in 37 countries. In terms of people, Canada represents 4% of the collaboration. The Canadian involvement started in 1991 with R&D involvement from the University of Victoria and the University of Montreal. TRIUMF joined the team in 1994 and led the Canadian contribution to the LHC accelerator itself. TRIUMF has subsequently been a major player in the experiment and presently hosts one (and the only one in Canada) of the 10 ATLAS Tier-1 computing centres that process the data from the experiment. With the support of NSERC, Canadians made major contributions to the construction of ATLAS—and this effort had a very significant TRIUMF component. Canadians were prominent in the construction of ATLAS primarily in the end-cap calorimeters, but more recently have significant involvements in the luminosity monitor (LUCID), the diamond beam-conditions monitor, and the trigger. Without TRIUMF's specialized capabilities, these contributions—and hence any involvement—would not have been possible.

The Canadian group in ATLAS comprises about 150 people, of whom 41 are university faculty or TRIUMF scientists. The TRIUMF involvement includes five Canadian faculty members who are TRIUMF-University joint appointments, and five TRIUMF resident research scientists. This group is heavily involved in the management of ATLAS Canada (see table ZZ). Four Canada Research Chairs (Brigitte Vachon, Wendy Taylor, Manuella Vincter, and Matt Dobbs) are members of the ATLAS collaboration, as are 5 of the 8 Institute of Particle Physics (IPP) scientists (François Corriveau, Rob McPherson, Steve Robertson, Randy Sobie, Richard Teuscher).

Scientist	**Position in ATLAS Canada**	**Relationship with TRIUMF**
Rob McPherson	Spokesperson/Principle Investigator	TRIUMF resident
Doug Gingrich	Deputy Spokesperson	TRIUMF-University joint appointment
Mike Vetterli	Computing Coordinator	TRIUMF-University joint appointment
Isabel Trigger	Physics Coordinator	TRIUMF Scientist

Table ZZ. Listing of the four principle management positions in ATLAS Canada.

It is difficult to provide meaningful quantitative measures of Canadian involvement in the ATLAS experiment. Presently, Canada's participation in the senior management of the collaboration exceeds what might be expected by its 4% involvement in the overall project. Canadians hold two of the 63 senior ATLAS positions—these leadership positions require approval of the full collaboration. This includes the Collaboration Board Chair, C. Oram, for 2006-2007. Over the past 15 years or so, the Canadian fraction of the leadership has fluctuated but has been consistently high.

βNMR/ βNQR

As implemented at TRIUMF, β-detected nuclear magnetic resonance (βNMR) uses a low energy ISAC radioactive ion beam as a novel depth-resolved local probe of the properties of thin films and heterostuctures. This is an extremely technologically-important field of materials science. The βNMR team consists of three principal investigators from TRIUMF-member universities: A. MacFarlane (UBC, Chemistry), R. Kiefl (UBC, Physics) and K. Chow (Alberta, Physics). The development of this novel technique has been driven by these three researchers, with TRIUMF playing an enabling role.

While the primary isotope of interest, ^{8}Li, is easily produced by the ISAC surface ionization source at TRIUMF, these experiments require a *spin-polarized* beam. This has been achieved through the efforts of TRIUMF scientist P. Levy using an in-flight laser polarization scheme. This complex task is now routine and highly reliable.

βNMR uses low energy beams to study phenomena in thin structures (less than about 200 nm thick and as thin as 2 nm). It thus requires an ultrahigh vacuum sample environment with residual pressures in the range of 10^{-9} Torr. The design challenges imposed by such criteria necessitated a significant investment, largely by TRIUMF, in design and construction of specialized beam lines. In addition, the TRIUMF Centre for Molecular and Materials Science (CMMS) contributed significantly with technical personnel supported by NSERC's MFA program. For example, the system providing the radiofrequency magnetic field essential for many measurements was designed by CMMS leader Syd Kreitzman. Importantly, TRIUMF has also contributed half the salary of a post doctoral fellow position for the development of βNMR. The series of scientists that have occupied this position have contributed significantly to technical advances as well as the scientific productivity of the programme.

The novel technique of zero field beta-detected pure-nuclear *quadrupole* resonance (βNQR) was first demonstrated at TRIUMF [Salman et al., Phys. Rev. B **70**, 104404 (2004)] in a second spectrometer. The βNQR spectrometer has recently been upgraded with (NSERC funded) cryogenic and (TRIUMF funded) deceleration capabilities enabling this totally new technique to be fully exploited in the study of materials. To maximize the use of valuable ISAC beams, the βNMR team (with TRIUMF technical support) implemented a fast electrostatic switch, allowing the near simultaneous operation of the two spectrometers, effectively doubling the available experimental time.

The financial contribution of university researchers to this effort has been largely through NSERC funded personnel in the form of graduate students, post doctoral fellows and undergraduate students as well as NSERC supported CMMS personnel. However, recently infrastructure funding (in excess of $100k since 2005) has been obtained from the NSERC RTI programme to develop spectrometer capabilities.

The βNMR facility provides an excellent example of the enabling role of TRIUMF in research that would be inconceivable in its absence. It also illustrates the potential synergies that exist when university based research operates in concert with the scientific expertise and infrastructural capabilities of a national facility like TRIUMF.