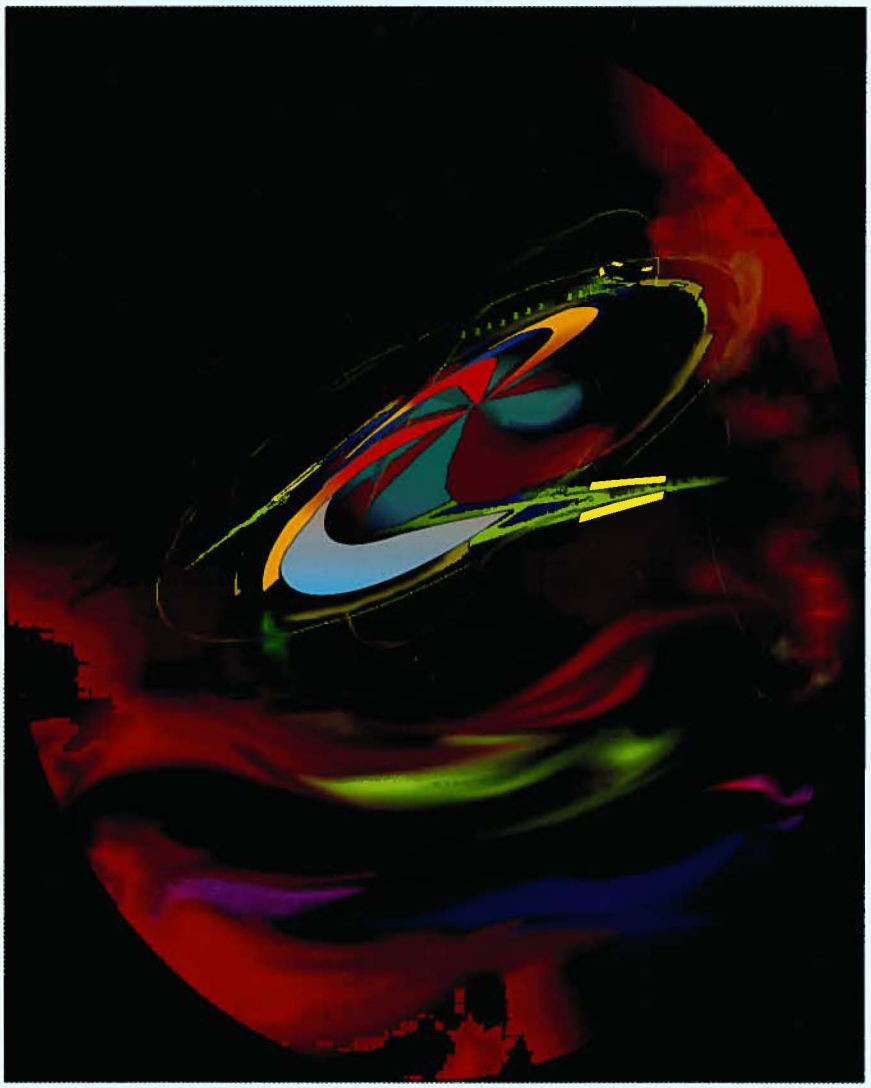
TRIUMF

1996 - 97



Annual Financial & Administrative Report

including summaries of

- ✔ *Pure Research Activities*
- ✔ *Practical Applications of Research*

TRIUMF is Canada's national meson research facility, managed as a joint venture by a consortium of Canadian universities. It is operated under a contribution from the Government of Canada through the National Research Council of Canada.

Consortium Members
University of Alberta
University of Victoria
Simon Fraser University
University of British Columbia

Associate Members
University of Manitoba
Université de Montréal
University of Regina
University of Toronto

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Annual Financial & Administrative Report

1996–97

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Plus ça change . . .

TRIUMF is a basic research facility in subatomic physics. Many of us believe that we receive our funding largely because of support from a small number of politicians and bureaucrats with vision, who believe that Canada of the future will be disadvantaged without today's core of curiosity-driven research, which provides hands-on access to new frontiers of knowledge, and a constant supply of very bright young people. It is our responsibility to ensure that our money is spent on the most interesting and pressing problems in our science, and the brightest young people.

Because we exist as a laboratory, many peripheral but important activities can easily be accommodated. Such things as medical treatment and diagnostics, and the many aspects of technology transfer, are often used to justify our drain on the public purse. It would be difficult, but not impossible, to sew together a patchwork quilt of financial support, piece by piece, to cover these individual activities. How much better the enlightened approach of National Research Council which permits these activities as pieces of our basic program. However, we should not lose sight of our real mission in a maze of public relations. We are primarily here to do excellent basic science.

The work of that experimental giant, Ernest Rutherford, in the early part of this century, created for us the science of subatomic physics. The following extract is taken from the book entitled "Rutherford, Reflections of the Cambridge Days". It is written by Mark Oliphant, the "I" in the extract, and reveals that times may change but perceptions do not!

"For seven years, until his death, Rutherford was Chairman of the Advisory Council of the Department of Scientific and Industrial Research. I often met him at the railway station in Cambridge after a trip to London, and drove him to Newnham Cottage, sometimes in the evening following a meeting of that Council. He always had something to say about the work of the day. On one occasion, if I remember rightly in 1931, he was very quiet when he got into the car, and when I asked whether the day had gone well, he said that he was worried because members of Council had again attacked him for not relating the work of the Cavendish more closely to the industrial needs of the nation. Moreover, he had been accused of producing research workers who were of little or no use when faced with 'real' problems. On a later such occasion, in about 1935, when he thought that any misgivings should have been laid to rest through Chadwick's discovery of the neutron and Cockcroft and Walton's demonstration of transformations produced by artificially accelerated particles, he said: 'They have been at me again, implying that I am misusing gifted young men in the Cavendish to transform them into scientists chasing useless knowledge.'

"Rutherford's spirits soon recovered. He realized, more than most, the importance of the application of scientific knowledge if Britain was to prosper, but he remained convinced that one of the best training grounds for physicists was the sort of fundamental science pursued in the Cavendish. His faith was demonstrated dramatically after his death, when the needs of war found almost all the men whom he had trained leading such practical developments as radar, atomic energy, and operational research."

Alan Astbury

Astrophysics with ISAC

In 1995 the Government of Canada promised the required funding for TRIUMF's ISAC project, and we began work on the construction of this major addition to our experimental facilities, to be completed by the end of this century.

ISAC is an acronym for "Isotope Separator and ACcelerator". It will allow researchers the opportunity to produce large yields of rare, short-lived, radioactive isotopes. Of course, in any such process of synthesis, many different isotopes may be formed simultaneously, but ISAC will separate these from each other in a magnetic separator, and channel only atoms or ions of a single, desired isotope to the experiment area in the form of an accelerated beam.

TRIUMF scientists envisage many distinct uses for these beams of rare isotopes, and two of particular importance are mentioned here. They will send some of them directly from the separator to experiments in "TRINAT" — the TRIUMF Neutral Atom Trap. TRIUMF's 1995–96 annual report mentioned some of the experiments destined for this "low energy" area. Ions of other radioactive isotopes will be accelerated to higher energies in the ISAC accelerator. While accelerator technology in recent decades has allowed us to study interactions involving almost any stable nuclei, developments being pursued at facilities like ISAC allow us to study the interactions of unstable nuclei — many with unusual nuclear composition and shapes — at the limits of particle stability.

Astrophysicists are extremely interested in the kinds of products formed when such beams of radioactive nuclei interact with selected targets, e.g. helium or hydrogen nuclei (used in the form of gases). They will be able to study the rates of production in the cosmos of various elements from simpler components. Such production is currently happening inside stars, and the products are released during an explosion of the star i.e., in supernovae. In this annual report we outline some of these experiments to be performed in ISAC which have a direct bearing on our understanding of astrophysical phenomena.

During an explosive event such as a supernova, clearly the temperature is quite high. In such a hot environment, nuclei can fuse with protons faster than in a normal stellar environment. Under these circumstances it is believed that short-lived radioactive nuclei can, before they decay, capture protons. If, in fact, this *does* happen, it could explain how the synthesis of heavy elements can take place rapidly along

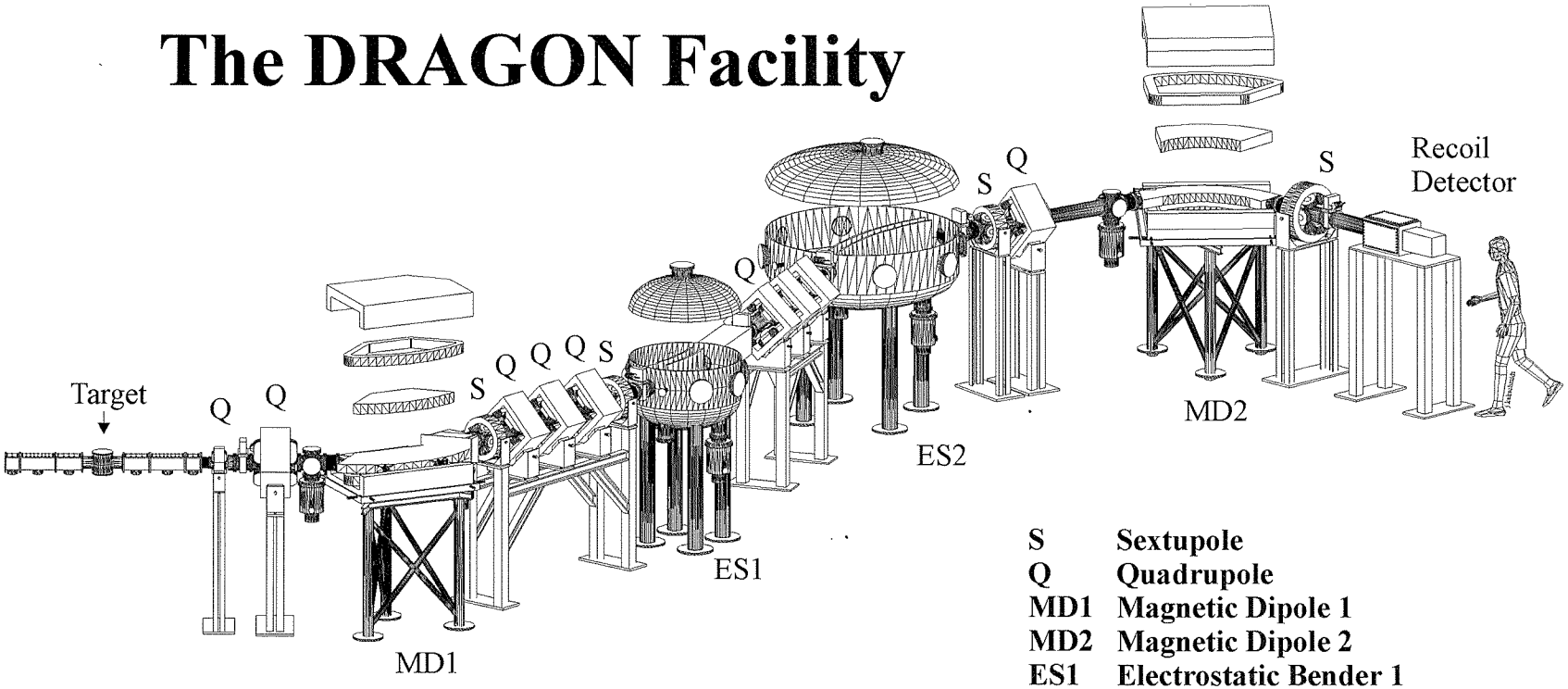
Why are some isotopes radioactive?

The nucleus of an atom of any element has a fixed number of protons, e.g. 2 for helium, 11 for sodium. But each nucleus can also contain a variable number of neutrons—between 1 and 6 for helium, or from 8 to 24 for sodium (each combination is called a different *isotope* of that element). Most elements have a few stable isotopes and several unstable ones, the latter having either a very high or a very low proportion of neutrons to protons. An unstable nucleus breaks down — "decays" — by ejecting charged or neutral particles (electrons, positrons, neutrons, alpha particles, etc.), while sometimes also radiating gamma rays. This process might continue through a series of intermediate, unstable nuclei of the same element or of other "nearby" elements. It will end with the formation of a stable nucleus.

For most of the lighter elements, the stable isotopes have roughly equal numbers of protons and neutrons. For the elements closer to the "heavy" end of the periodic table, the stable isotopes may have up to about 60% more neutrons than protons, e.g. uranium-238 has 92 protons and 146 neutrons.

Some of these unstable, intermediate isotopes may have extremely short half lives — a few seconds, or even fractions of a second. We must obtain data on these sequences if we are to understand the rates of formation of heavy atoms. These are the kinds of processes that we will examine in the ISAC facility.

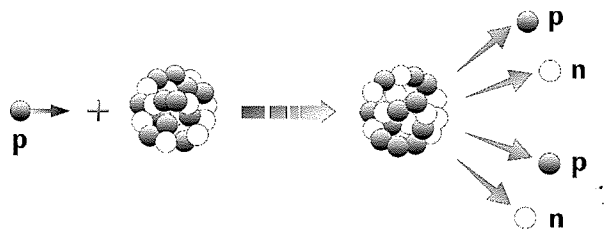
The DRAGON Facility



S	**Sextupole**
Q	**Quadrupole**
MD1	**Magnetic Dipole 1**
MD2	**Magnetic Dipole 2**
ES1	**Electrostatic Bender 1**
ES2	**Electrostatic Bender 2**

The "DRAGON" (**D**etector for **R**ecoils **A**nd **G**ammas **O**f **N**uclear reactions) facility in the ISAC complex will be installed in the high-energy area. The target at the far left will contain hydrogen or helium gas, and will be bombarded with a beam of the newly created, accelerated, radioactive isotopes. Some of these radioactive ions will interact with the target atoms. Unchanged isotopes plus any reaction products will move forward into the DRAGON detector. Here the magnetic dipoles and electrostatic benders will separate the particular product of interest from the much larger number of ions still present from the original beam.

paths different from those previous envisaged. We can test such a theory of rapid proton capture only by creating a radioactive beam such as can be produced at ISAC, and using it to bombard a hydrogen gas target (or a helium gas target, for alpha capture). Our goal would be to measure the rate of such capture reactions on various radioactive species. For us to perform this study, the special capability offered by ISAC is essential: it can produce the kind of beam required, with the energy range needed (low energy is more important than high energy), and provide the actual beam intensity needed to do the study.



$p + {}^{24}Mg \rightarrow {}^{21}Na + 2p + 2n$

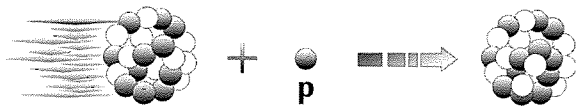
Step 1: A proton from TRIUMF's cyclotron strikes a target of magnesium-24 (in magnesium oxide) to form an ion of sodium-21, as four nucleons are ejected. This isotope will be separated from any other interaction products, and will be accelerated in ISAC's linear accelerators.

The other key essential is a new facility to measure the products resulting from the interaction of the radioactive beam with the gas target. This new facility will be called the DRAGON (Detector of Recoils And Gammas Of Nuclear reactions). We are presently designing this unique, multimillion-dollar facility and it should be ready to take the accelerated ISAC beam by the year 2000. After commissioning the facility, we will select the first experiment reactions from one of the following:

$^{21}Na + H$

$^{18}F + H$

$^{19}Ne + H$



$^{21}Na + p \rightarrow {}^{22}Mg$

Step 2: An accelerated ion of sodium-21 (half-life: 22 seconds) strikes a proton, in a target of hydrogen gas. It absorbs the proton to form magnesium-22. This, as well as other interaction products plus unchanged sodium ions, will continue moving forward to be separated and detected in the "DRAGON".

These are not necessarily the most important but are indeed of great interest, and we shall be able to produce the radioactive beams mentioned. We have created and seen such beams at the TISOL facility (predecessor to ISAC) and expect to produce them at ISAC.

In a second experiment of great astrophysics interest, we will study the capture of an alpha particle by a lithium-8 radioactive beam—the capture being followed by the emission of a neutron. This reaction may help us to understand the importance of the so- called "Inhomogeneous Big Bang Theory". Many believe this theory provides an alternative pathway for the production of elements heavier than lithium (which is element #3 in the periodic table). The standard Big Bang model does not deal with such production as well as could be expected.

Scientists in Japan will provide an unusual detector, a "neutron detection wall", to enable us to perform this experiment.

These kinds of experiments — many are presently being considered — will ensure that TRIUMF with ISAC will remain an exciting, innovative research centre, and will have a long, bright future on the stage of international science.

Models and Predictions

The goal of physics is to provide a description of the physical phenomena that we observe in the universe around us. Ultimately we seek a description couched in the language of mathematics. This is the domain of theoretical physics. It involves the development, exploration and testing of our mathematical descriptions of physical systems.

Rarely are these descriptions complete. Usually we have only incomplete knowledge of the input into the equations that provide the framework for our theories, and only rarely can the equations be solved exactly. The art of theoretical physics is to abstract general results from incomplete empirical knowledge, to devise simple, effective models of complex systems, and to deal with approximations and numerical computations.

At research facilities like TRIUMF, theoretical physicists work with their experimental colleagues on a variety of common problems. The TRIUMF Theory Group, numbering about a dozen staff, research associates and visitors, is pursuing a wide-ranging program in subatomic physics. This program can be divided into three broad topics: phenomenology of *electroweak* interactions, hadron physics and nuclear physics.

Within the realm of particle physics the description of nature on the submicroscopic scale has evolved into the so-called Standard Model. This is a set of rules which specifies the basic constituents of our Universe and the forces that act between them. The Standard Model has been amazingly successful in its description of *electromagnetic* and *weak* forces. Nonetheless it has aspects that many theoreticians find unpalatable. Currently the main effort in *electroweak* phenomenology is to make increasingly precise tests of the Standard Model and to propose and investigate extensions. At present, the idea of supersymmetry has the "most favoured candidate" status for physics beyond the Standard Model, and some work on this topic is being pursued in the Theory Group.

In the Standard Model, we use a theory called Quantum Chromodynamics (QCD) to describe hadrons, the particles which experience *strong* interactions. The constituents of hadrons are quarks, which interact through the mediation of *strong* force carriers called gluons. Although the basic equations of QCD are relatively simple, solving them is not. In fact, the description of hadron phenomena in QCD is enormously difficult and continues to be a goal of active research.

Research into hadron physics is a large part of the Theory Group program. One method that is being used is called chiral perturbation theory. In this approach one does not deal with the quarks and gluons of QCD directly. Rather, one tries to capture an essential property of QCD called chiral symmetry in an effective theory that can be used in place of QCD to describe hadron physics at low energies which are relevant for TRIUMF. This chiral perturbation theory approach has found many applications in the past decade — for example, in predicting how pions scatter at very low energies, which we have studied in a number of experiments at TRIUMF. An application of chiral perturbation theory which is under active investigation is the capture of muons by protons. This process has also been the subject of experiments at TRIUMF.

Forces and Force-Carriers

The universal gravitational force was identified by Isaac Newton more than 300 years ago, and in the 19th century, the theory of electromagnetism was developed. In this century, two other basic forces were discovered — the strong and the weak force, which are effective only in the interaction of subatomic particles at very small distances. These four basic forces can account for all physical phenomena with which we are familiar from the cosmic to the subatomic scale, including the array of forces that we might notice daily due to winds, tides, motors, muscles, gravity, chemical explosions, and so on.

With the advent of quantum theory it has become customary for physicists to describe forces in terms of "force carriers" — the gluon, carrier of the strong force; the W and Z particles, carriers of the weak force; the photon, carrying electromagnetism; and the graviton, believed to carry gravity.

More recently, physicists have "unified" the mathematics of the electromagnetic and the weak forces, and they often refer to this hybrid as the "electroweak" force. One of the goals of present research is to seek a "grand unification" of the strong and electroweak forces. More ambitious schemes to provide common mathematical descriptions of all four basic forces are also being pursued.

(Continued on page 9)

Positron Emission Tomography

The PET group has developed several new tracers which will enable us to study different aspects of brain function, both in health and disease. These are molecules to which we have attached radioactive atoms produced in our cyclotrons. When introduced into an animal or human body, tracers accumulate in specific areas or organs, and the radiation emanating from them can provide an image of the functional characteristics of the organ. The new compounds include markers for systems in the brain — the dopamine system, which is involved in movement, and the serotonin system, which is involved in mood disorders such as depression. Such new developments were made possible by the availability of the TRIUMF-designed and -built cyclotron, the TR13. This production cyclotron provides intense proton beams up to 13 MeV in energy, and is now commercially available.

The PET group continues its close relationship with the Neurodegenerative Disorder Centre on the UBC campus, and has begun collaborations with the Department of Psychiatry in studying schizophrenia and mood disorders.

The Chemistry group is also supporting studies at the local hospitals using tracers that can monitor tissue suspected of being cancerous.These trials may lead to wider use of the isotopes that are available only from accelerators.

Proton Therapy for Cancer

Up to the end of March 1997, we had used our proton therapy facility to treat 25 patients with ocular melanoma. About half of the patients resided in British Columbia, with the others coming from Alberta, Saskatchewan and Manitoba. Their ages ranged from 36 to 88, and the median height of their tumours was 6 mm, with a diameter of 13 mm. Early clinical follow-up is showing that the tumours are shrinking as expected, based on experience at other proton therapy centres. (The severity of complications increases with tumour volume.)

We made no significant changes to the treatment procedures or the control system hardware or software during the year, but one small change that we did introduce was to use a blinking rather than continuous light for the patient to stare at during treatment. This improved eye fixation. We carried out some tests on the use of wedges, and are now using these where appropriate. (To correct for the curvature of the eye, aluminum wedges, accurately positioned just in front of the eye, can be inserted in the path of the proton beam, and in some cases they can improve the "dose distribution" to the tumour.) The TRIUMF personnel involved are meeting regularly with those from the B.C. Cancer Agency to determine the course of future developments at the facility. In the short term, we expect that we will treat only ocular melanoma patients, but the patient numbers may increase if we receive referrals from Eastern Canada.

TRIUMF Radioisotopes for Medicine (TRIM)

The TRIM effort in 1996–7 was in three projects.

The first was production of xenon-122 in sodium iodide targets for a group at the Center for Functional Imaging at Berkeley. The radioxenon has a 20-hour half life and decays to 3.6-minute iodine which they will use for labelling newly developed agents for myocardial perfusion studies. Our part of the project will be to build a high-level production facility for ^{122}Xe and the work during this past year has been just the first step.

The second project is an ongoing collaboration with the Ottawa Heart Institute to support a clinical test, with about 250 severely impaired heart patients, of the ability of a combined diagnosis using 18-FDG and rubidium-82 to direct a program of treatments. This year, staff from OHI visited TRIUMF and learned how to make rubidium-82 strontium generators with material produced in our beam line 2C. They have subsequently developed the protocol for manufacturing generators for human use and obtained the appropriate approvals. Also within the past year, Dave Morris of TRIUMF Electronics Services has designed, built and commissioned a stand-alone heart infusion unit to work with the Rb-Sr generators at OHI.

The third project, in collaboration with the Institute for Nuclear Research, Moscow, has been the measurement of ^{103}Pd production cross sections from natural silver. It is hoped that this reaction can be used to provide the cancer research community with a potent new agent for development of radiotherapeutic complexes.

Proton Irradiation Facility

The proton irradiation facility on beam line 1B was financed in part with a grant from the Space Systems and Technology Section of Defence Research Establishment Ottawa (DREO) and the Canadian Space Agency. Personnel from DREO were involved in the initial commissioning early in 1996.

Basically, this facility allows us to bombard equipment or small devices with protons of a specific energy from our main cyclotron. Current interest is focused on determining how various electronic devices, intended for use in artificial satellites, will withstand radiation in space. In addition to the high-energy measurements on this beam line, the proton therapy line (which we call 2C) can be used to extend the measurements from 115 MeV down to about 20 MeV. The capability of the TRIUMF beams to cover the entire energy range of interest for studies of proton effects in space has now been demonstrated.

A number of electronic devices including SRAMs, 486 chips and a neutron detector were characterized at proton energies of 500, 350 and 200 MeV on beam line 1B, and down to 20 MeV on line 2C. For the electronic devices the main interest was in determining "single event effect" rates due to the high-energy protons. During a run in March 1997, we carried out some tests of proton fluence detectors for space applications. These detectors included some based on measuring single-event rates in well characterized devices, and bubble detectors.

The proton flux is measured at high rates by an ion chamber (which actually measures dose), and at low rates with a small plastic scintillator telescope which measures the rate directly. The flexibility of the system was demonstrated in providing useful beams varying in intensity from 100 to 10^8 protons per square cm per second, at various energies.

Theoretical Program *— continued from page 7*

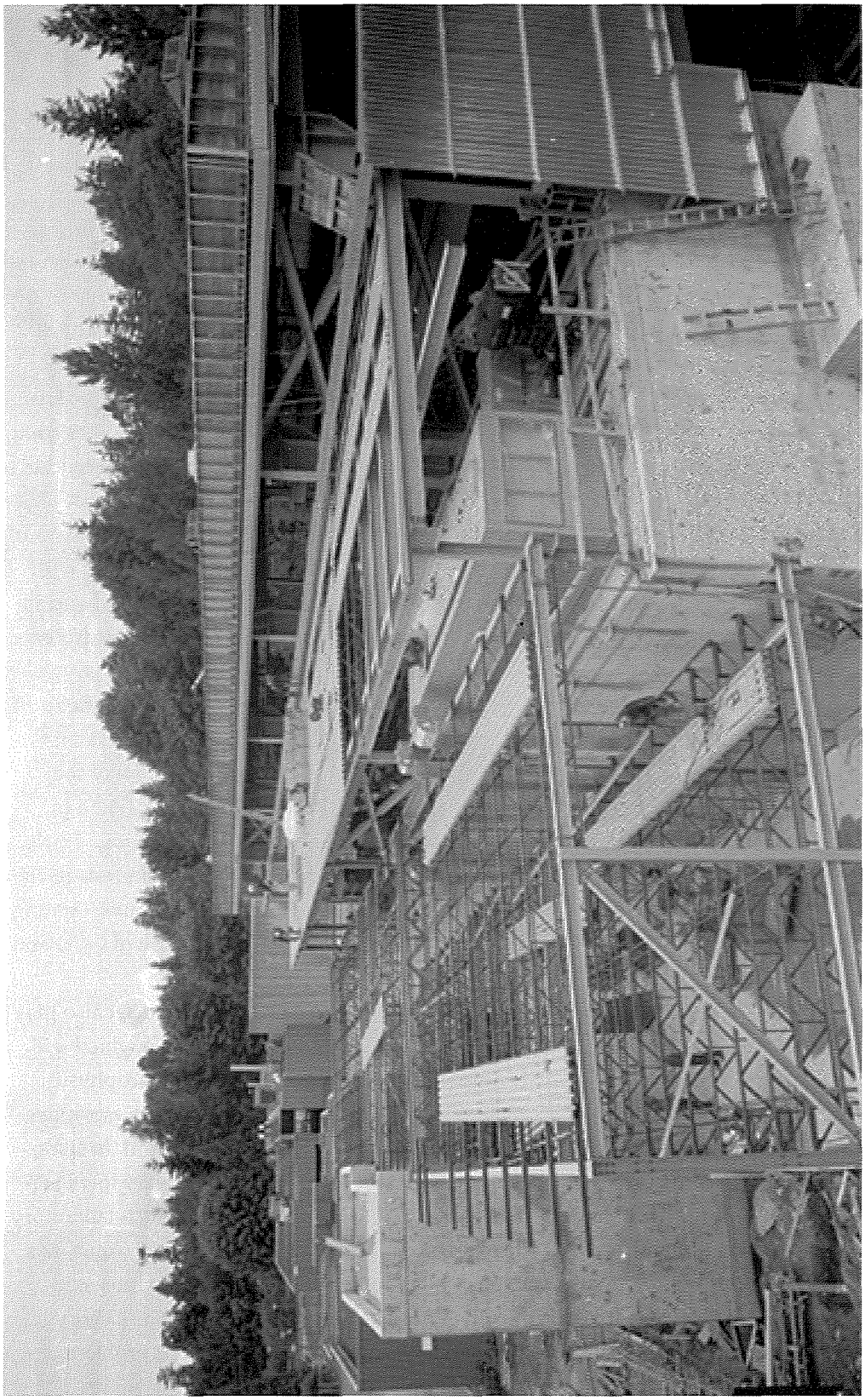
Another approach to the study of hadron physics being pursued in the Theory Group is that of numerical simulation of QCD, using the methods of lattice field theory. Recent work done here in this area deals with improving the accuracy of the lattice QCD algorithms and thereby gaining in computational efficiency. Applications of these methods are focused mainly in the area of heavy-quark physics, an area of particle physics phenomenology that we expect will gain importance in the future with the startup of accelerator facilities designed specifically to produce large numbers of the heavy, *b* (bottom) quarks — the so-called "B-factories".

Although nuclear physics has been studied since almost the beginning of this century it continues to be a very active research area. One of the frontiers of this work deals with the question of how the structure of neutrons and protons, which are made up of quarks and gluons, manifests itself in the properties of nuclei. TRIUMF is investigating this topic, which lies at the intersection of QCD and nuclear physics.

The properties and reactions of nuclei also play a role in other disciplines. An example which will be important in TRIUMF's future is astrophysics. Measuring nuclear reactions relevant to astrophysics is a cornerstone of the ISAC program. In stars, however, nuclear reactions occur at very low energies — much lower than those for which laboratory measurements are feasible. Some theory, then, has to be applied to extrapolate laboratory measurements to the astrophysical domain. The Theory Group is working on this and related problems.

ISAC

Under Construction



The new ISAC building, funded by the Province of British Columbia, is a large addition to the TRIUMF site, with 4900 square metres of floor space. This photo was taken in the spring of1997, as the wall and roof supports were being installed. The present office building can be seen in the background, to the left.

Construction of the new ISAC (Isotope Separator and Accelerator) facility at TRIUMF was well under way in March 1997. This facility is a major component of the TRIUMF five-year plan, which began in April 1995. Funds for constructing the building were provided by the Province of British Columbia, and funds for the technical systems inside the building by the Government of Canada. ISAC is being built to the north of the existing TRIUMF accelerator building and will be using a 500 MeV proton beam from the main TRIUMF cyclotron to produce exotic, short-lived isotopes for research in nuclear physics, nuclear astrophysics, nuclear medicine and materials science.

When the facility is completed, the isotopes will be formed as a proton beam impinges on a target optimized to enhance the yield of a requested isotope. In general, each target would produce several isotopes with different masses. An ion source will then quickly ionize the isotopes, form them into a beam, and a magnetic mass-analyser will separate them from each other. The chosen isotope will be transported to a system of accelerators, accelerated, and then sent to experimental research stations. The isotopes will be available at energies up to 60 keV per nucleon for all atomic masses, and variable from 0.15 to 1.5 MeV per nucleon for atomic masses from 6 to 30.

By April 1996 we had cleared the building site, previously used as a parking lot and a location of temporary office trailers, and had given our engineering consultants the authorization to proceed with detailed drawings of the ISAC buildings. We awarded the first major construction contract in August, and excavation began in September 1996. In spite of an unusually wet winter, we have not changed the scheduled completion date for constructing the $10 M building: November 1997. TRIUMF allocated $350 K from its royalty earnings to permit the addition of an upper floor which will eventually be used for offices. The ISAC building includes a proton beam line tunnel (from the main cyclotron building), a target service facility, several office areas, a target vault with a 20-ton rolling crane and hot cells, a mass separator pit, mezzanines, an experimental/accelerator hall with an overhead 35-ton rolling crane, and "counting rooms" (from which experimenters monitor the progress of their experiments). Construction required 6100 cubic metres of concrete, and the overall floor space is approximately 4900 square metres.

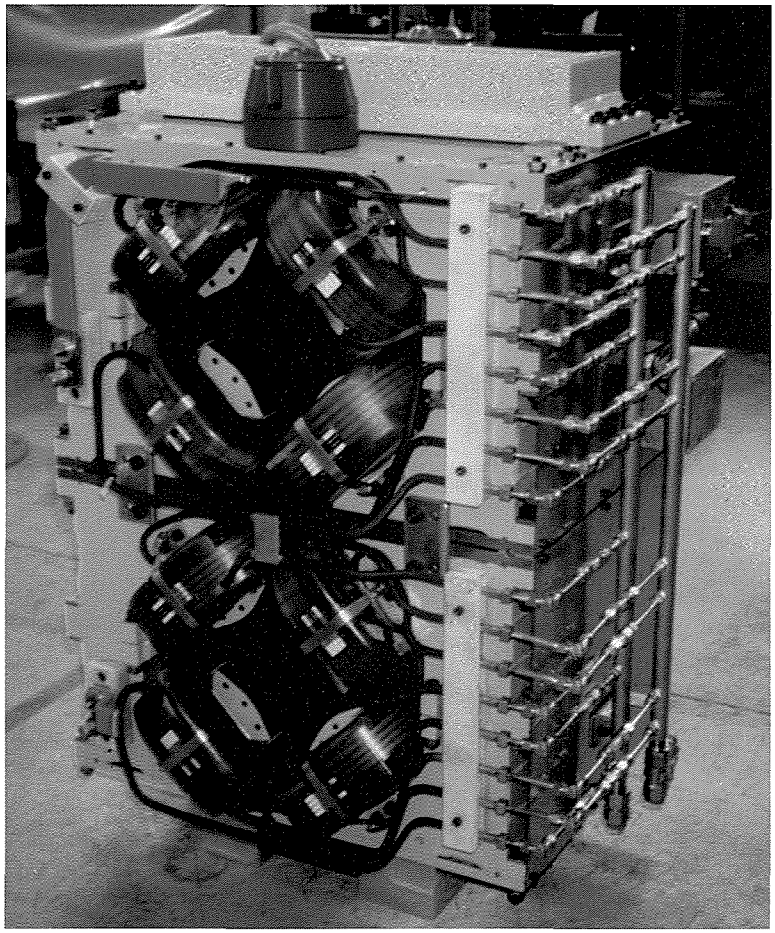
Concurrently with the building construction, we were working on the technical systems. We had to modify the cyclotron to permit the extraction for ISAC of an additional beam to the north (beam line 2A). Most of the budget for this year was, in fact, allocated to ordering the components for this new beam line. The ISAC facility includes several novel devices which needed to be tested as prototypes. We have built an ion source "test stand" to allow characterization of the ISAC ion source parameters, and to evaluate a proposed control system. We commissioned this test stand in August 1996 and used it to define the first ion source to be used in ISAC. To take full advantage of the limited number of short-lived isotopes, it is necessary to use a linear accelerator that operates continuously. (Most operating linear accelerators are pulsed.) A 1-m-long prototype radio-frequency quadrupole (RFQ) accelerator was built and tested successfully at full power in November 1996. Results from these tests allowed us, early in 1997, to begin the detail design of the final 8-m-long RFQ accelerator. We plan to have the ISAC facility ready in January 1999 for the first scheduled experiment with the TRIUMF neutral atom trap (TRINAT) using the new ISAC ion source.

TRIUMF has been encouraging Canadian industry to become involved in constructing ISAC. Major contractors for this project are listed below.

Alnor Services Ltd.
EBA Engineering Ltd.
Keen Engineering Ltd.
Lex Engineering Ltd.
Norelco
Schneider Canada Ltd.
Swagger Construction Ltd.
Yale Electrical Sales Inc.
Chernoff Thompson Architects
Electric Power Equipm't (1980) Ltd.
Lafarge Canada Inc.
L E C Quantity Surveying Inc.
Richmond Elevators Ltd.
Southwest Contracting
Transwest Roofing (1994) Ltd.
Yolles Consulting Engineers Inc.
Cummins Diesel
Entec Systems Inc.
Lam Metal Contracting Ltd.
Lockerbie & Hole Contracting Ltd.
Ricketts-Sewell Electric Ltd.
Supreme Steel Ltd.
UMA Projects

CERN Collaboration

The Canadian government's present five-year funding plan for TRIUMF requires our laboratory to make, on behalf of Canada, "in-kind" contributions of accelerator expertise and components to the Large Hadron Collider (LHC) project at CERN. These contributions will amount to $30 million. CERN is the main European laboratory for subatomic physics, located near Geneva and run by a consortium of 19 nations. As of April 1996, following a number of meetings between personnel from TRIUMF and CERN, 24 tasks were identified for initial TRIUMF involvement. We estimate these tasks will cost about $10 million and involve about 40 person-years of TRIUMF effort. The tasks cover the full range of accelerator expertise available at TRIUMF, and were selected so that most of the equipment procurement is compatible with the capabilities of Canadian industry.



A pair of quadrupole (focusing) magnets for the CERN complex of accelerators, assembled in Canada under the CERN-TRIUMF Cooperation Agreement. The unit is about 1 metre high.

Many of these initial tasks are connected to the PS Conversion project, which involves upgrades to the PS complex of accelerators (page 13) to provide the high-brilliance beams needed for the LHC. We anticipate completion of this work by 1999. To meet this schedule TRIUMF had to provide some equipment before the January 1997 shutdown, and must provide other equipment for the shutdown in January 1998. Shown are the first magnets designed by TRIUMF, which were assembled by a British Columbia company.

At its September 1996 meeting, the CERN Council finalized and approved a new version of the Cooperation Agreement between CERN and TRIUMF for this work. This agreement sets out the protocols for scientific and technical cooperation between Canada and CERN, with TRIUMF representing Canada.

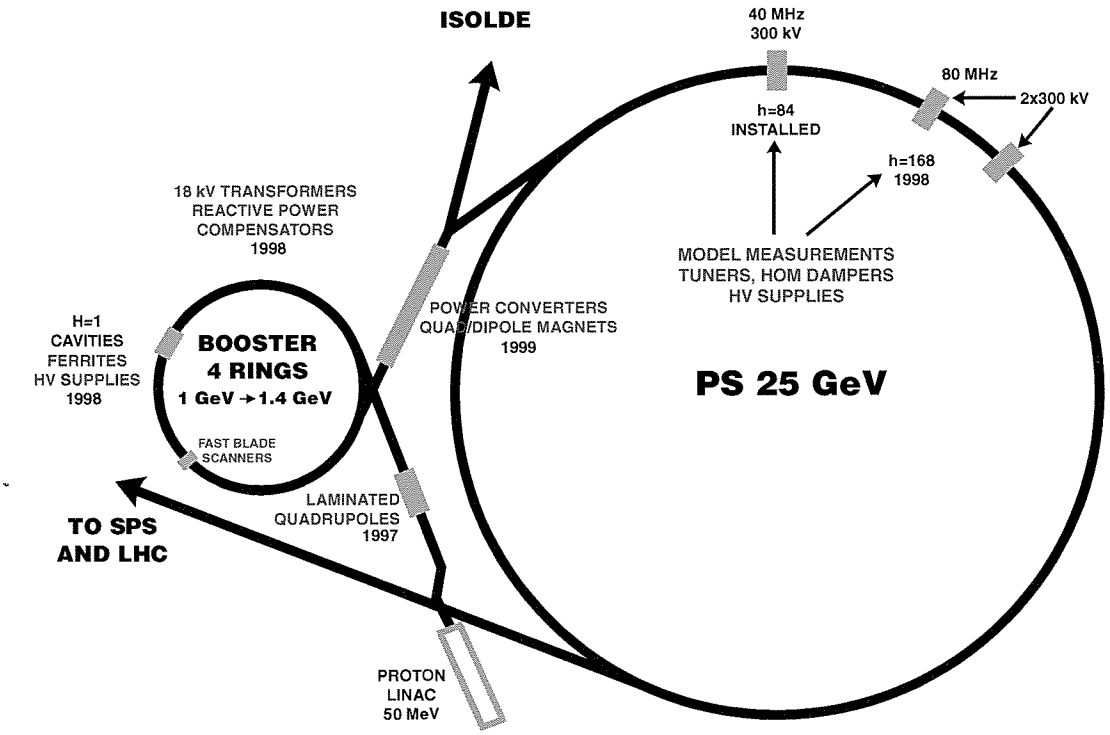
At a collaboration meeting held during the European Particle Accelerator Conference in June 1996, participants reviewed the technical work. TRIUMF and CERN authors at this conference presented a number of papers on the

collaborative work, several being joint presentations. The next collaboration meeting was planned for the Particle Accelerator Conference in Vancouver in May 1997.

Here are some highlights of the work completed in 1996–97:

- 40 MHz radio frequency cavity commissioned at CERN (TRIUMF was involved in design)
- First measurements on 80 MHz radio frequency cavity model at TRIUMF
- Prototype high-frequency calibrator modules sent to CERN for SPS diagnostics
- Delivery to CERN of 9 kV and 24 kV power supplies manufactured by Inverpower Controls (Ontario)
- $4M in contracts awarded for transfer line power supplies, five large transformers and a 20 MW reactive power compensator (Inverpower Controls, Ferranti-Packard, GEC-Alsthom Canada)
- Designs completed and contracts awarded for fabricating a number of transfer line quadrupole and dipole magnets
- Expressions of interest indicate that the prototype twin-aperture quadrupole magnet for the beam-cleaning insertions in LHC can be built in Canada
- Significant design effort on a 66 kV resonant, charging power supply for LHC injection
- Collaboration on beam dynamics problems — impedances/stability and cleaning insertion design optimization

Part of the CERN complex of accelerators. The dates indicate the anticipated year of delivery for equipment being contributed by Canada, via TRIUMF.



TRIUMF's Technology Transfer

The mandate of Technology Transfer Division (TTD) is the pursuit of all financially and technically viable opportunities for commercializing the technologies evolving from research at TRIUMF. The provincial government provides funding of about $115,000 *per annum* for the Division.

However, the contribution agreement between the National Research Council (NRC) and TRIUMF places a new emphasis on enhancing the impact of TRIUMF on the economies of Western Canada. In particular, we are giving higher priority to small and medium-sized businesses in our commercial activities. NRC has commissioned both Western Economic Diversification (WED) and the Industrial Research Assistance Program (IRAP) to provide assistance in this effort.

The objectives of the TTD are twofold: to transfer TRIUMF technology to the Canadian economy, in particular the Western Canadian economy; and to generate income for the applied technology program at TRIUMF.

The crucial first step to commercializing new or innovative technologies from a research laboratory is to generate disclosures of such innovations. To this end, we have documented 25 potentially commercial disclosures this past year, and TRIUMF has funded six of these.

Also, in keeping with the mandate and objectives listed above, TRIUMF does have a number of technologies that are currently attracting the most interest from industry. They are:

- isotope production
- medical imaging using advanced positron emission tomography
- radio frequency drying of agricultural products and lumber
- producing cyclotrons
- proton therapy for eye melanomas
- novel imaging techniques for detecting concealed contraband
- 3-D imaging
- neutron imaging
- environmental protection using cryogenics to eliminate smoke stack emissions
- monitoring levels of ionizing radiation

In keeping with the focus on Western Canadian small- to medium-sized businesses, the TTD has, with the help of WED, organized a show for suppliers from industry in each of the Western provinces this past year. The purpose of these shows was to acquaint industry representatives with TRIUMF's activities, to introduce the ISAC project, to present procurement opportunities, and to establish contacts.

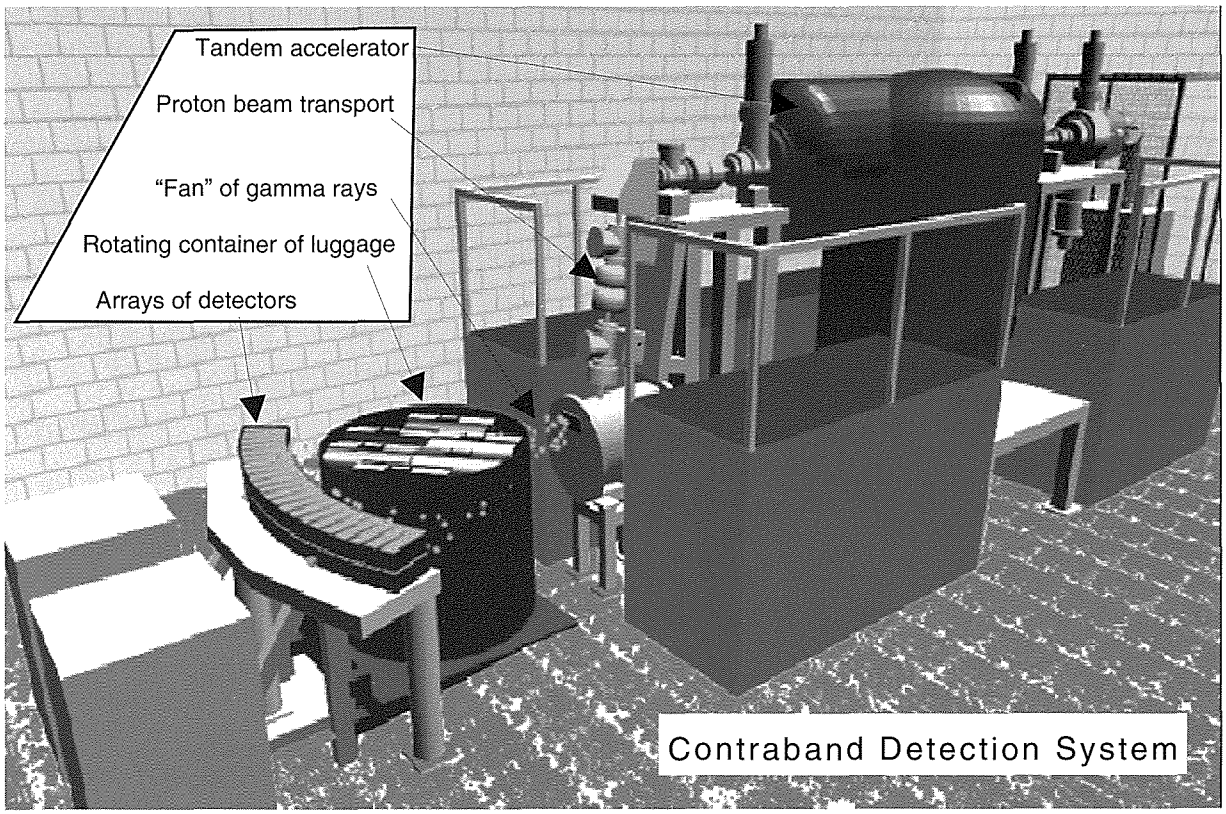
Our contract administrator is also ensuring that we make a conscious effort to attract bids from as many eligible Western Canadian companies as is reasonably possible, especially for the ISAC project. Copies of the invitations to bid, or to request information, are sent to Vancouver's WED representative for dissemination to WED representatives, and to company representatives across Western Canada.

As can be seen, a broad spectrum of technologies evolves at TRIUMF, each with its own window of opportunity for commercialization. Any technology advance not properly exploited can become stale, and may be surpassed either technically or economically in the marketplace. Our goal at TRIUMF must be the timely identification of the technologies followed by appropriate commercialization that optimizes the opportunity.

TRIUMF's strength lies in the unique aspects of the facilities, combined with the scientific excellence of the staff and the research conducted here. Patent protection can be important in identifying a novel technology, but at this level of scientific discovery we cannot rely on it as a long-term shield from competitive alternatives.

The TTD has established a network of contacts with many commercialization offices throughout North America, and constantly utilizes those contacts in its own activities.

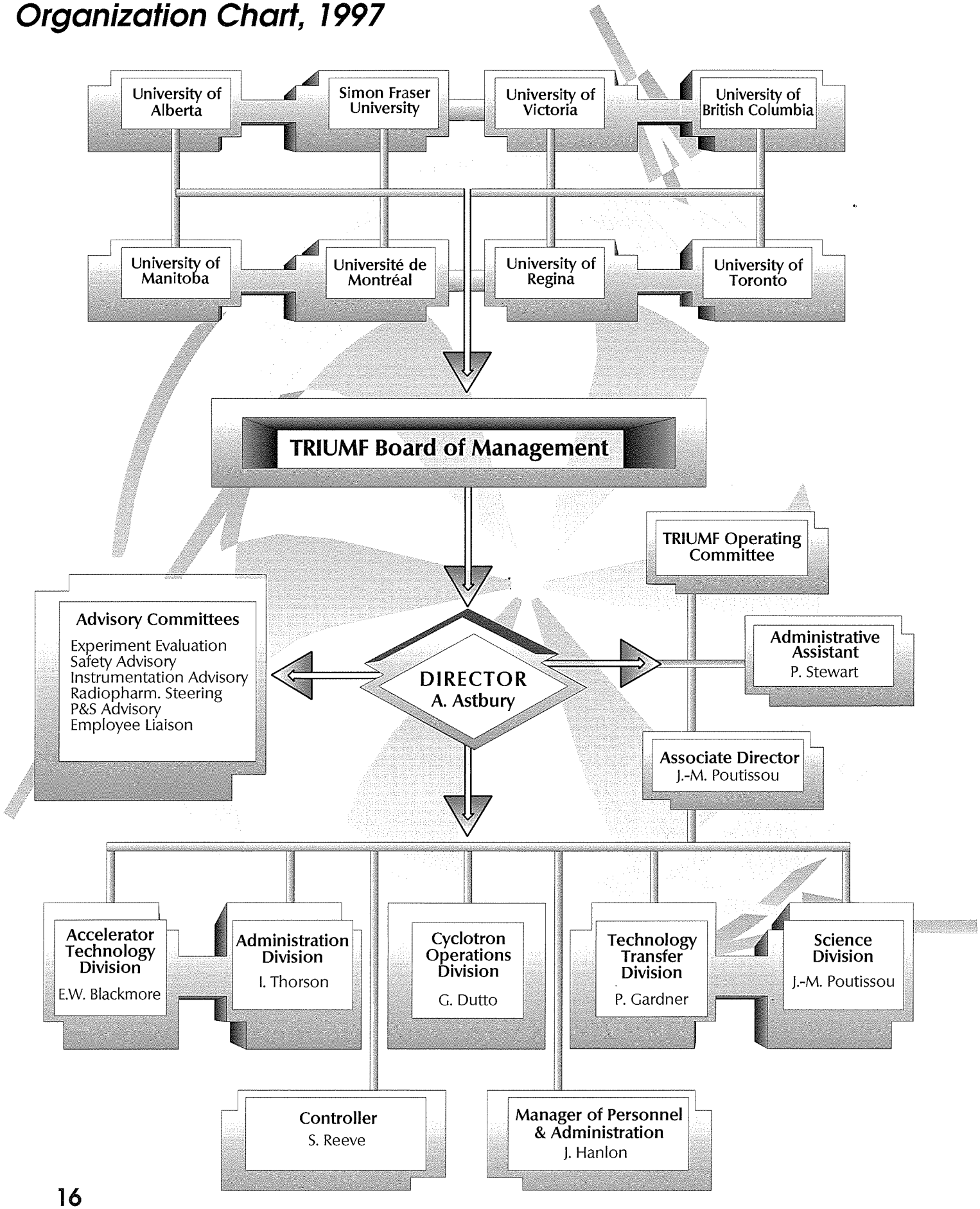
New technology such as that emanating from TRIUMF leads, by its very nature, to high-risk ventures. Although projects may appear to have promising potential, from experience we can predict that not all of them will actually fulfill expectations. The TTD always takes a conservative approach in projecting current opportunities into future commercial activities.



Drawing much attention in the past year was the contraband detection system (CDS) being developed by TRIUMF and its industrial partner, the Northrop-Grumman Corp. It uses beams of gamma rays, instead of the X-rays usually used in airports, to examine luggage (as in the figure) or goods in large shipping containers, and can identify plastic explosives or illicit drugs from their absorption of gamma rays.

The CDS requires a small tandem accelerator to accelerate the protons used to create gamma rays of a specific frequency; suitable arrays of detectors; and computer software to interpret the data from the detectors and to create a 3-D image of any suspicious material. TRIUMF has expertise in all three of these areas. Early in 1997 the prototype model was sent to the USA for testing.

Organization Chart, 1997



TRIUMF Users' Group

1997 TRIUMF Users' Executive Committee (TUEC)

Chairman:	M. Hasinoff
Chairman Elect:	L. Buchmann
Members:	J. D'Auria, S. Kreitzman, E.L. Mathie, S. Yen
Past Chairman:	G. Roy
Liaison Officer:	M. La Brooy

In March 1997, the TRIUMF Users' Group had:

711 members from
236 institutions in
37 countries.

— *From the Users' Group Charter* —

The TRIUMF Users' Group is an organization of scientists and engineers with special interest in the use of the TRIUMF facility. Its purpose is:

(a) to provide a formal means for exchange of information relating to the development and use of the facility;

(b) to advise members of the entire TRIUMF organization of projects and facilities available;

(c) to provide an entity responsive to the representations of its members for offering advice and counsel to the TRIUMF management on operating policy and facilities.

Membership of the TRIUMF Users' Group is open to all scientists and engineers interested in the TRIUMF programme.

Government Committees Reporting on TRIUMF

NRC Advisory Committee on TRIUMF (ACOT), March 1997

Dr. D. Stairs	McGill University *(Chairman)*
Dr. N. Sherman	NRC *(Secretary)*
Dr. P.-G. Hansen	Michigan State U.
Dr. J.C. Hardy	AECL
Dr. J.G. Martel	NRC
Dr. D. Perkins	Oxford U.
Dr. B. Peters	
Dr. V. Soergel	Max Plancke Inst., Munich
Dr. M. Stott	Queen's U.
Dr. R. Taylor	SLAC
Ex officio	
Dr. R. Carnegie	Carleton U.
Dr. C.H. Jones	Simon Fraser U.
Dr. S. Page	U. of Manitoba

Agency Committee on TRIUMF (ACT) March 1997

Dr. A.J. Carty	President	NRC *(Chairman)*
Dr. T. Brzustowski	President	NSERC
Mr. K. Lynch	Dep. Minister	Industry Canada
Mr. J. McLure	Dep. Minister	Western Economic Diversification
Dr. N. Sherman		NRC *(Secretary)*

Financial Review

The ISAC building is nearing completion and the ISAC technical facilities are starting to take shape for an estimated commissioning date of early 1999. The CERN project continues to give TRIUMF and Canada a very high profile in the world scientific community, and TRIUMF management and staff are still putting the same full effort into the science and technology transfer activities as we did before the CERN and ISAC projects came on line. How can the TRIUMF Financial and Administration group best serve these activities?

We live in an era where "More for less" are the words we must all live by, and external reporting requirements to governments, tax departments, funding and other agencies, are taking more and more of our time and resources. In this era, new and innovative technologies, implemented with care and attention to what the users need and want, can make a big difference: An old-style financial and information system merely pays the bills and meets the annual audit and reporting requirements; the new ones do all that *and* provide the users of the system with a full range of self-defined financial information and assistance at any time they need or want it.

The scientific staff in an organization such as TRIUMF grabs on to new technology, ideas and innovations as fast as they come into the marketplace. Any group managing the financial and information system for TRIUMF must also seize the appropriate new technologies if it truly wishes to provide useful and timely information to its users and maintain an ongoing partnership with the staff and senior management.

However, new technologies, including the new information technologies, are seldom inexpensive. They are often time-consuming and are difficult to implement and maintain. Unless chosen and implemented with care, the new information technologies can make obtaining and using information and systems *more* difficult and confusing, rather than easier and clearer. There is always the risk of overwhelming the users with information they neither need, want or will use.

The TRIUMF Financial and Administration group is working hard to find and implement those information-based technologies that will take us past the year 2000 in partnership with our very creative and innovative colleagues. The TRIUMF Business Office is fortunate to have these creative and technological sophisticated scientists, engineers and technicians as our drivers and role models for the 21st century.

It is an exciting time for all of us!

Shirley Reeve, C.G.A.
Controller

	1996–97		1995–96	
SOURCE OF FUNDS	*$ million*	*%*	*$ million*	*%*
National Research Council	31.000	69.1	33.318	75.3
NSERC	2.818	6.3	3.438	7.8
MDS NORDION Inc.	1.806	4.0	1.675	3.8
Province of British Columbia	4.724	10.5	1.144	2.6
Affiliated Institutions	3.053	6.8	3.449	7.8
Commercial Revenue	1.216	2.7	1.003	2.3
Investment & Other Income	0.259	0.6	0.240	0.4
	44.876	100.0	44.267	100.0

Coopers &Lybrand

chartered accountants

Coopers & Lybrand Building
1111 West Hastings Street
Vancouver, British Columbia
Canada V6E 3R2

telephone : (604) 661-5700
fax : (604) 661-5756

Auditors' Report to the Board of Management of TRIUMF

The accompanying condensed financial statements have been prepared from the statement of financial position of TRIUMF as at March 31, 1997 and the statements of funding, income/net recoveries and expenditures and changes in fund balances for the year then ended. We have audited those financial statements and reported thereon without reservation on May 30, 1997.

In our opinion, the accompanying condensed financial statements are fairly stated in all material respects in relation to the financial statements from which they have been derived.

Coopers & Lybrand

Vancouver, B.C.
May 30, 1997

Chartered Accountants

NOTE: The excerpts from the Auditor's Report in the following pages are prepared by the TRIUMF Information Office, which takes responsibility for any inadvertent errors or deviations. Copies of the entire Auditor's Report to the TRIUMF Board of Management are available from the TRIUMF Business Office. [Editor]

TRIUMF

Statement of Combined Funding/Income and Expenditures and Changes in Fund Balances

For the Year Ended March 31, 1997

Funding/income	1997	1996
National Research Council Fund	$ 31,000,000	$ 33,318,000
Natural Sciences & Engineering Research Council Fund	2,817,745	3,437,900
MDS NORDION Inc. Fund	1,806,320	1,674,713
Affiliated Institutions Fund	3,053,027	3,448,749
Provincial Government Building Fund	4,724,087	1,144,000
Commercial Revenue Fund	1,215,717	1,003,448
General Fund	259,315	240,469
	44,876,211	44,267,279
Expenditures		
Buildings	4,291,881	54,694
Communications	220,497	219,657
Computer	1,207,552	1,554,936
Equipment	5,080,855	2,337,781
Power	1,752,411	2,007,527
Salaries and benefits	24,331,310	28,228,997
Supplies and other expenses	7,904,869	7,748,475
	44,789,375	42,152,067
Excess of funding/income over expenditures before the undernoted	86,836	2,115,212
Adjustment for change in Capital Fund		
Capital expenditures during the year	351,212	578,694
Amortization of capital assets	(577,049)	(542,161)
	(225,837)	36,533
Excess (deficiency) of funding/income over expenditures for the year	(139,001)	2,151,745
Fund balances — beginning of year	5,611,153	3,459,408
Fund balances — end of year	5,472,152	5,611,153

TRIUMF

Statement of Financial Position

As at March 31, 1997

	1997 $	1996 $
Assets		
Cash & temporary investments	5,764,940	4,816,676
Funding receivable (note 4)	2,331,648	2,123,157
Capital assets (note 5)	1,451,439	1,677,276
Total assets	9,548,027	8,617,109
Liabilities		
Accounts Payable	3,227,406	2,445,970
Funds received in advance (note 6)	794,132	704,709
	4,021,538	3,150,679
Due to (from) joint venturers		
The University of British Columbia	12,519	(122,248)
The University of Alberta	(443)	(10,219)
The University of Victoria	(1,799)	(38,326)
Simon Fraser University	44,060	26,070
	54,337	(144,723)
	4,075,875	3,005,956
Fund Balances		
Restricted		
Natural Sciences & Engineering Research Council Fund (note 7)	568,358	377,186
MDS NORDION Inc. Fund	100,000	100,000
Provincial Government Building Fund	740,851	916,407
Affiliated Institutions Fund	(1,466)	43,500
	1,407,743	1,437,093
Other		
Commercial Revenue Fund	1,804,253	1,273,264
General Fund	424,175	197,344
Intramural Accounts Fund	384,542	1,026,176
Capital Fund	1,451,439	1,677,276
	4,064,409	4,174,060
	5,472,152	5,611,153
Total Liabilities and Fund Balances	9,548,027	8,617,109

Encumbrances and commitments (note 8)

TRIUMF

Statement of Funding and Expenditures

National Research Council Fund

For the Year Ended March 31, 1997

	1997 $	1996 $
Funding		
National Research Council	31,000,000	33,318,000
Contribution from Commercial Revenue Fund	420,000	–
	31,420,000	33,318,000
Expenditures by activity area (schedule)		
Basic lab operations	7,654,282	8,317,190
Base program development	170,675	564,322
Base program support	13,590,916	18,023,647
ISAC-1	7,117,935	5,770,710
CERN collaboration	3,378,105	1,480,032
	31,911,913	34,155,901
Expenditure recoveries	(491,913)	(837,901)
Total expenditures	31,420,000	33,318,000
Excess of funding over expenditures for the year	Nil	Nil
Expenditures by Object		
Buildings	66,672	–
Communications	171,531	174,805
Computer	754,606	1,143,644
Equipment	4,085,736	1,456,714
Power	1,752,411	2,007,527
Salaries and benefits	20,311,529	23,912,943
Supplies and other expenses	4,564,988	4,929,716
Salary expenditure recovered	(287,473)	(307,349)
	31,420,000	33,318,000

1. Nature of operations

TRIUMF is a joint venture established by the University of Alberta, the University of Victoria, Simon Fraser University and the University of British Columbia, and has as its goal the establishment and continuance of a national facility for research in intermediate energy science under a contribution from the National Research Council of Canada. As a registered charity, TRIUMF is not subject to income tax.

Each university owns an undivided 25% interest in all the assets and is responsible for 25% of all liabilities and obligations of TRIUMF, except for the land and buildings occupied by TRIUMF, which are owned by the University of British Columbia.

These financial statements include only the assets, liabilities, funding and expenditures of the activities carried on under the control of TRIUMF and do not include the other assets, liabilities, revenues and expenditures of the individual joint venturers.

Sources of funding include grants and contributions from National Research Council, Natural Sciences and Engineering Research Council and governments, advances and reimbursements from other sources, royalty income, and investment income. TRIUMF has established a number of separate funds to account for various funding sources as follows:

National Research Council Fund (NRC)
Funding of operations, improvements and development, expansion of technical facilities (buildings excluded), and general support for experiments.

Natural Sciences and Engineering Research Council Fund (NSERC)
Funding to grantees for experiments related to TRIUMF activities. These funds are administered by TRIUMF on behalf of the grantees.

MDS NORDION Inc. Fund
Advances and reimbursements for expenditures undertaken at its TRIUMF site.

Provincial Government Building Fund
Funding from the Province of British Columbia for the construction of new facilities and the upgrade of existing facilities.

Affiliated Institutions Fund
Advances and reimbursements for expenditures undertaken on behalf of various institutions from Canada and abroad for scientific projects and experiments carried out at TRIUMF.

Commercial Revenue Fund
Royalties, revenue and expenditures relating to commercial activities and technology transfer.

General Fund
Investment income for discretionary expenditures incurred by TRIUMF.

Intramural Accounts Fund
Net recoveries for internal projects and services. The recoveries of expenditures are charged to the appropriate TRIUMF funding source by Intramural Accounts.

Capital Fund
Expenditures on the acquisition of non-experimental capital assets net of amortization.

2. Changes in accounting policy

During the year ended March 31, 1997, TRIUMF adopted the newly issued accounting recommendation requiring the capitalization of capital assets by not-for-profit organizations. The adoption of this policy has been applied retroactively. Non-experimental computer equipment, trailers and temporary offices and vehicles which were previously expensed in the year of acquisition have now been capitalized and amortized.
As a result of this change, the statement of combined funding/income and expenditures and changes in fund balances has decreased by $225,837 (1996 — increased by $36,533), and the statement of financial position has been increased by non-experimental capital assets purchased at a cost of $2,919,784 (1996 — $2,568,572) less accumulated amortization of $1,468,345 (1996 — $1,120,893), giving rise to the establishment of a Capital Fund of $1,451,439 (1996 – $1,677,276). Capital assets acquired for use in experiments continue to be expensed in the period in which they are acquired.

3. **Significant accounting policies**

Basis of presentation

TRIUMF follows generally accepted accounting principles for not-for-profit organizations as referred to in the CICA Handbook.

Contributions and funding for restricted funds

TRIUMF follows the restricted fund method of accounting for contributions to the National Research Council Fund, the Natural Sciences and Engineering Research Council Fund, the Provincial Government Building Fund and the MDS NORDION Inc. Fund. Contributions and funding for specific programs are recognized as revenue in the period in which they are received.

Royalty Income

TRIUMF records royalty income when notification and verification of sales are received.

Capital assets

Non-experimental capital assets purchased by TRIUMF are recorded at cost. Amortization is provided on a straight-line basis over the estimated useful lives of the assets as follows:

Computer equipment	— 5 years
Trailers and temporary offices	— 20 years
Vehicles	— 10 years

Temporary investments

Temporary investments are recorded at cost.

Statement of changes in financial position

A statement of changes in financial position has not been prepared as management believes such a statement would not provide any additional useful information.

4. **Funding receivable**

	1997 $	1996 $
Natural Sciences and Engineering Research Council Fund	1,225,686	171,895
MDS NORDION Inc. Fund	620,463	197,665
Provincial Government Building Fund	278,585	894,000
Affiliated Institutions Fund	206,914	859,597
	2,331,648	2,123,157

5. **Capital assets**

	Cost $	Accumulated amortization $	1997 Net $	1996 Net $
Computer equipment	2,675,584	1,349,125	1,326,459	1,510,363
Trailers/temporary offices	222,500	108,154	114,346	151,723
Vehicles	21,700	11,066	10,634	15,190
	2,919,784	1,468,345	1,451,439	1,677,276

6. **Funds received in advance**

	1997 $	1996 $
Affiliated Institutions Fund	719,855	694,133
Commercial Revenue Fund	74,277	10,576
	794,132	704,709

7. Natural Sciences and Engineering Research Council Fund balance

	1997 $	1996 $
Funding unexpended	719,681	607,491
Grant accounts overexpended	(151,323)	(230,305)
Fund balance — end of year	568,358	377,186
Number of grants awarded during the year	35	37
Number of grants administered throughout the year	72	72

8. Encumbrances and commitments

In addition to the accounts payable reflected on the statement of financial position, outstanding encumbrances and commitments, representing the estimated costs of unfilled purchase orders and contracts placed at the fiscal year end, comprise:

	1997 $	1996 $
Provincial Government Building Fund	3,948,000	1,037,000
National Research Council Fund	1,736,000	570,000
Natural Sciences and Engineering Research Council Fund	100,000	61,000
MDS NORDION Inc. Fund	45,000	84,000
Affiliated Institutions Fund	57,000	191,000
Commercial Revenue Fund	8,000	4,000
Intramural Accounts Fund	63,000	–
	5,957,000	1,947,000

9. Financial instruments

TRIUMF has various financial instruments including cash and temporary investments, funding receivable and accounts payable. Because of their short-term nature, the carrying values of TRIUMF's financial instruments approximate their fair values.

10. Pension plans

The employees of TRIUMF are members of the pension plan administered by the university that sponsors their employment. TRIUMF records the pension expense as cash contributions are made to the plan based on a prescribed percentage of employee earnings. The pension expense for the year was $1,487,000 (1996 — $1,517,000).

11. Contingent liability

In 1994, an action was commenced against TRIUMF by a former research partner. The plaintiff is claiming that TRIUMF did not provide certain technology transfers as agreed. The outcome of this proceeding and the amount of loss, if any, is not determinable at this time and, accordingly, no provision has been made in the financial statements. Any settlement made relating to this matter will be accounted for in the period of settlement in the Commercial Revenue Fund.

12. Economic dependence

TRIUMF's operations are funded under a contribution from the Government of Canada through the National Research Council of Canada, including support from Western Economic Diversification. TRIUMF is economically dependent upon this funding source for its ongoing viability. On June 14, 1995, the Government of Canada announced a commitment of $166.6 million to fund TRIUMF over the next five years. At the same time, the Government of British Columbia announced its contribution of $9.7 million for conventional construction. Management has no reason to believe that ongoing funding from these governments will not continue into the future after the expiry of the above commitments.

13. Related party transactions

Under the terms of the Joint Venture Agreement, the University of British Columbia provides the land and buildings occupied by TRIUMF at no expense to the joint venture. TRIUMF pays for all other goods and services provided by the University of British Columbia and the other joint venturers on a fee-for-service basis. TRIUMF provides goods and services to the joint venturers on a fee-for-service basis and provides specific equipment, personnel, services and products at no expense to the University of British Columbia.

14. Comparative figures

Certain comparative figures in these financial statements have been restated to conform to the presentation adopted in the current year.