TRIUMF

Financial and Administrative Annual Report 1983–1984

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Director's Report

Erich Vogt
Director

The description of a year's activities, in a project such as TRIUMF, can be given in terms of completed facilities, science accomplishments and financial statements. But no description is complete without reference to the people associated with the activities. Perhaps a brief account here will supplement the picture provided by this annual report.

TRIUMF itself employed about three hundred and sixty persons in 1983. According to the Joint Venture agreement under which TRIUMF operates, each of these is appointed through one of the four TRIUMF universities. All of TRIUMF's employees have some direct association with the operation of the facility. About half are members of the technical staff coping every day with the extraordinary and complex challenges provided by the TRIUMF facility. The range of technical skills in this group – from mechanical design to electronics and software – must certainly constitute a unique resource for Canada. About a quarter of the total staff work in a variety of professional and supervisory roles – ranging from engineering to accounting. A somewhat smaller fraction are research engineers and scientists primarily responsible for developing and maintaining the various major research facilities and the TRIUMF cyclotron. The remainder are loyal and overworked clerks and secretaries. TRIUMF's accomplishments have, in large measure, been due to the exceptional skill and dedication of all of its staff. Any visitor or participating scientist cannot help but be impressed by the generally fine morale throughout the project.

Most of the experiments at TRIUMF are carried out in the "user mode" – by groups of scientists from various institutions, provinces and countries, combining for an experiment in which TRIUMF's beams and facilities are used. In the last year about fifty experiments were completed or received significant beam time. Typically, during the 36 weeks of the year in which TRIUMF operates around the clock, about half a dozen experiments are collecting data simultaneously. A two or three week data taking run is about the average.

The mixture of scientists participating in the experiments is both national and international. Counting only scientists with Ph.D.'s and only those who spent at least several weeks at the main site the number of participants last year was about 200. Of these, about two thirds are from Canada. The Canadian participants came from every region of the country and represent most of Canada's major universities. TRIUMF has evolved into Canada's national meson facility. The eighty or so participants from abroad came from all the continents (except Antarctica!) but especially from Europe and the United States. The ideas and technology which they bring here are essential for keeping our national meson facility at the highest international level of excellence in science. In addition to the participating users, about fifty graduate students are engaged in thesis work at TRIUMF during the year.

Perhaps this brief annual report will convey to our Joint Venturers, to the National Research Council of Canada (from which our principal support derives) and to Canadians everywhere some indication of the very high level of science now emerging from TRIUMF.

TRIUMF is Canada's national meson facility, situated on the University of British Columbia campus and managed as a Joint Venture by the universities of Alberta, British Columbia, Victoria and Simon Fraser. The laboratory is operated under a contribution from the National Research Council of Canada.

Facilities

Reliable beam production remained TRIUMF's highest priority during 1983–84. Even with 3 planned shutdowns and a major event like a water leak in the resonator cooling system, this year's beam production still exceeded last year's record by more than 6%. The Cyclotron Division also achieved a new record for polarized beam production and completed 2 major construction projects.

As for buildings and facilities, TRIUMF's phase II building program continued, adding the new M15 experimental building and a third-ion-source service annex to our site plan. After many years of "rest", TRIUMF's neutron beam facility in the Proton Hall has been recommissioned. And new detector facilities on-site included a scintillation counter lab and a wire chamber workshop.

Cyclotron

The resilience of the TRIUMF project received its severest test in mid-summer 1983 at the beginning of a long cycle of high-intensity operation. A water leak occurred inside the cyclotron vacuum tank, in the system that feeds cooling water to the resonators. The recovery from this trauma was magnificent, due to extraordinary effort by the cyclotron maintenance and operations staff and by the remote handling group.

A minute leak in the 18 metre diameter tank had to be located. A problem resonator had to be removed with remote handling manipulators and leak checked, and then the bellows connecting it to the cooling system had to be extracted and replaced. The complete recovery, from initial vacuum loss to resumed operation at high intensity, took only 2 weeks – a small fraction of the time expected for such a major event.

Another highlight during 1983 was the extraction of more than 600 nanoamperes of polarized beam at 500 MeV, which doubled the record previously achieved. This level of polarized current could be maintained over a period of a few weeks (which is vital to the success of the charge symmetry experiment – see Pure Research, pages 8 and 9).

The Cyclotron Division also completed 2 major projects by the end of the 1983 spring shutdown: the vault improvement program and an upgrade of the thermal neutron facility. The vault improvement program was aimed at making the front end of the beam lines adequate for long-term, high-intensity cyclotron operation and the thermal neutron facility upgrade now makes it possible to extract proton beam currents above the previous limit of 150 microamperes. The progress toward high proton beam intensities is driven by the Experimental and Biomedical Programs' needs for higher fluxes of pions and muons.

New facilities

The new M15 experimental hall was completed in November 1983 and the design of the M15 surface muon beam line has received a great deal of engineering effort. Much of the mechanical design of the beam line, magnet elements and support structures was completed and many of the beam line components delivered. During March 1984, the front end of the channel was installed and aligned immediately behind the 1AT1 pion production target in the Meson Hall. This brings the number of secondary channels "fed" by this target station to 3.

In the Proton Hall experimental area, the neutron beam facility was recommissioned in 1983 for

The M15 experimental building, completed in November 1983.

The third ion source, currently under construction.

the charge symmetry breaking experiment. (See Pure Research, pages 8 and 9.) The experiment uses a major new target system constructed at TRIUMF – a large frozen spin target. The target took 2 years to complete and features a 55 cubic centimetre volume frozen spin polarized target with a refrigerator capable of cooling the target down to nearly 50 millikelvin. The target was installed in the neutron beam facility during July 1983 and operated for 3 experimental runs in September, October and November.

The neutron facility produces polarized neutron beams in the energy range of 180 to 520 MeV, accepting proton beam intensities of up to 1 microampere. The facility can precisely maintain the position and incident direction of the proton beam onto a liquid deuterium target, by using a microprocessor which sends information gathered from secondary emission split plate monitors to a controls computer. The controls computer then calculates corrections and automatically updates the values of the bending magnet and 3 steering magnets to ensure proper horizontal and vertical alignment of the proton beam. This capability ensures that the properties of the neutron beam do not vary during the course of an experiment. (Neutrons cannot be focused or steered like a proton beam as neutrons have no electric charge to respond to electromagnetic forces.)

Scintillation and wire chamber labs

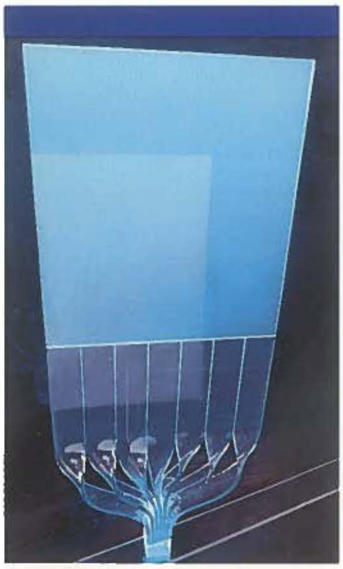
To integrate the development and construction of detectors at the TRIUMF site, the scintillation counter group was moved during 1983 from the Physics Department of UBC to a new lab area at TRIUMF. Also, in April 1984, to bring our wire chamber designers much closer to the experimental facilities, the wire chamber facility moved from the University of Alberta in Edmonton to the TRIUMF site. Both labs take up part of what previously was the old workshop area.

These moves have improved direct contact between the detector manufacturers and users.

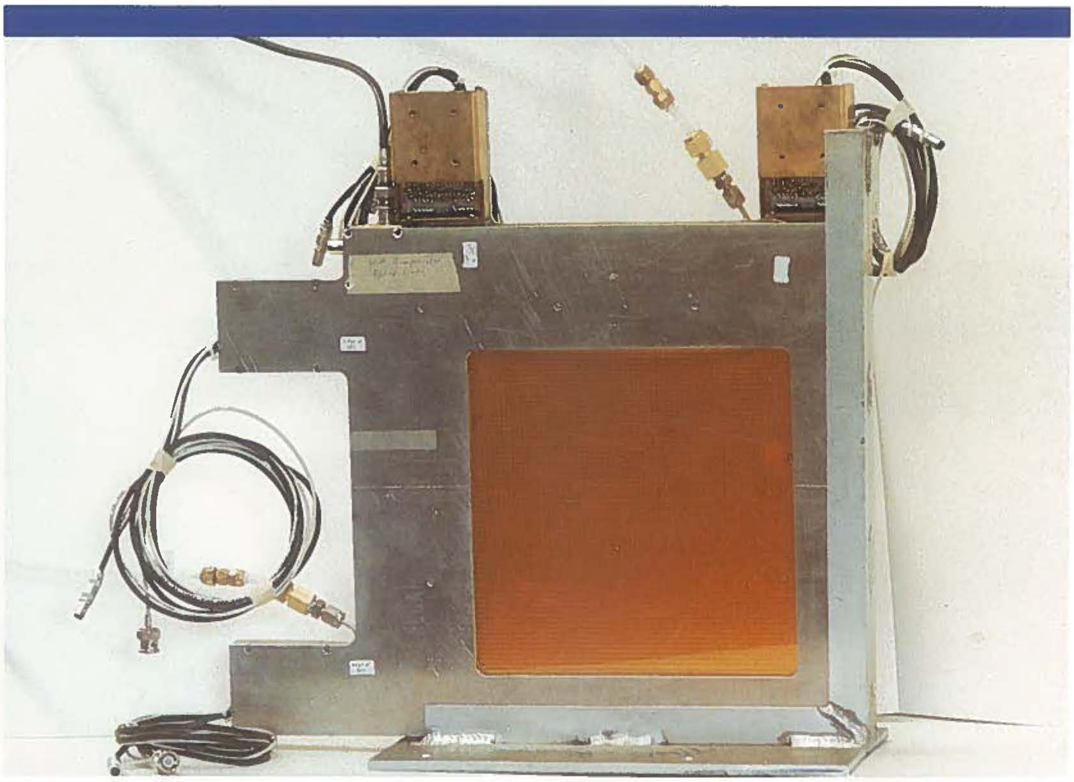
Building program

Projects completed in TRIUMF's Phase II building program included a service annex extension to house a third ion source for the cyclotron and the new M15 experimental hall (adjacent to the Meson Hall experimental building.)

Detailed construction drawings and specifications for a Meson Hall extension were prepared by March 1984 and were released for public tender. The 80-foot extension on the east side of the Meson Hall will add approximately 8500 square feet of floor space and provide much-needed space in this area. The project is similar in scope to the Proton Hall extension completed in 1981/82.



Scintillation counters...



...and wire chambers are now constructed at the TRIUMF site.

Applied Program

The TRIUMF Applied Program made great progress throughout the year and continued its high public profile. The pion therapy program treated many more patients. TRIUMF's positron emission tomograph (PET), which was dedicated by HRH Queen Elizabeth II in March 1983, was being used regularly for brain scans of patients by the fall of 1983. The new isotope-producing 42 MeV cyclotron, operated by Atomic Energy of Canada Limited (AECL), began full operation late in 1983. Now, both the AECL and the PET groups can conduct isotope production runs on a regular basis.

Pion therapy

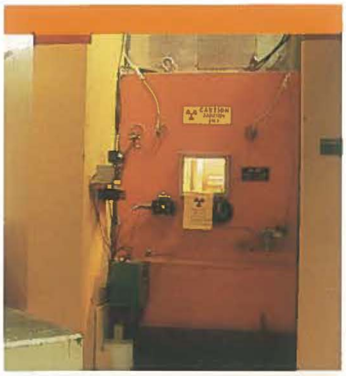
Activities in the Batho Biomedical Facility provided for rapid expansion of the TRIUMF pion radiotherapy program. The Facility is being transformed into a routine radiotherapy treatment centre equipped with reception, waiting area and examination rooms. A total of 90 days of high intensity beam were available for treatment during 1983 and 24 patients were treated, bringing the total number of patients with deep-seated tumours treated since May 1982, to 39 patients.

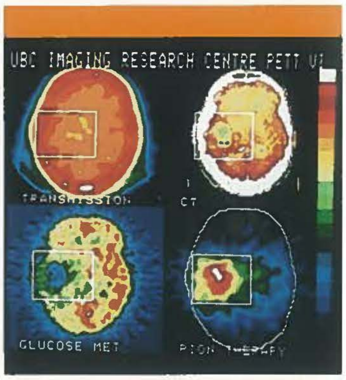
After clinical follow-up studies on 1982's patients, the treatment regime has now been improved. The pelvic tumour dose has been increased from 10 to 12 daily fractions of 2.5 Gy each and, for brain tumours, it was decided to increase the primary pion dose gradually to eliminate whole brain photon irradiation. This escalation of pion dose has increased the brain tumour treatment time to an average of 45 minutes, which is still well-tolerated by patients. Patient immobilization with reasonable comfort has been developed using thermal-plastic shells for brain tumours and polyurethane molds for pelvic tumours.

Positron emission tomography

Performance of the TRIUMF/UBC positron emission tomograph, located in the UBC Imaging Research Centre, has been highly satisfactory throughout its first year of operation. Its performance characteristics have been shown to be quite stable and machine failures have been fewer than expected.

The development of PET scanning agents continued throughout 1983–84. Two significant innovations in the production of FDG (2-deoxy-2-fluoro-D-glucose) were introduced to simplify and accelerate the synthetic procedure. By the end of 1983, the chemistry for the production of water labelled with oxygen-15 (used for measuring cerebral blood flow) was essentially complete. And the synthesis of oxygen gas labelled with oxygen-15 and of carbon monoxide labelled with oxygen-15 or carbon-11 was also well-advanced. These agents will allow the measurement of regional cerebral oxygen metabolism, of particular importance in studies of stroke. Also in late 1983, the development of dopa and dopa analogues were instituted. These agents are expected to allow imaging





Pion therapy demonstration.

(Top) 500 MeV isotope production facility.

(Bottom) UBC Imaging Research Centre scans show the results of a recent pion therapy treatment.

of the metabolic activity of neurons associated with movement disorders and some psychiatric conditions.

Medically, patients suffering from Parkinson's disease and Huntington's disease were scanned with FDG, and the first medical research publication from the program resulted from this work. In psychiatric disease, studies of schizophrenia were begun and subjects suffering from Alzheimer's disease (senile dementia) were also scanned. In November 1983, studies of patients suffering from stroke were initiated, with techniques being developed to scan subjects within a few hours of the event. By year's end, 30 subjects had been examined – patients suffering from the aforementioned diseases and normal volunteers for comparison.

TRIM

The TRIUMF Radioisotopes for Medicine group has long concerned itself with the supply and clinical applications of iodine-123-labelled fatty acids, as these substances are important worldwide for imaging the diseased human myocardium (the middle muscular layer of the heart wall). In 1983, TRIM discovered that omega-labelled iodine-123 fatty acids can be prepared from *macrocyclic lactones.* Scores of these lactones are readily-available from the perfume industry. With lactones supplied by this industry, new fatty acid analogues are being prepared for testing in animals. It is hoped that, with this research, new analogues will emerge providing superior diagnostic characteristics.

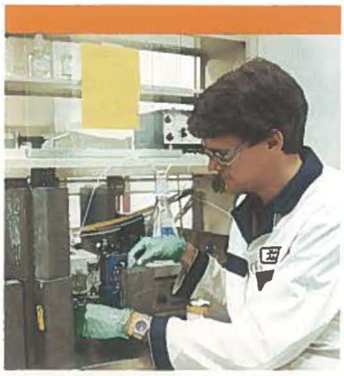
Radioisotope production with the "baby" cyclotron

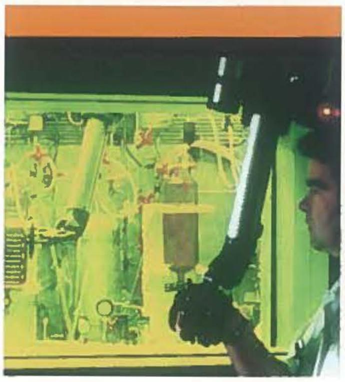
Atomic Energy of Canada Limited's (AECL) 42 MeV "baby" cyclotron was finally commissioned in 1983. Much of the year was spent on testing and start-up of the new facility and during October and November the cyclotron was operating, but almost exclusively for product development and evaluation. Of the total of 248 target irradiations in 1983, 27 were used for PET patient scans. All patient scans were run on schedule without failure.

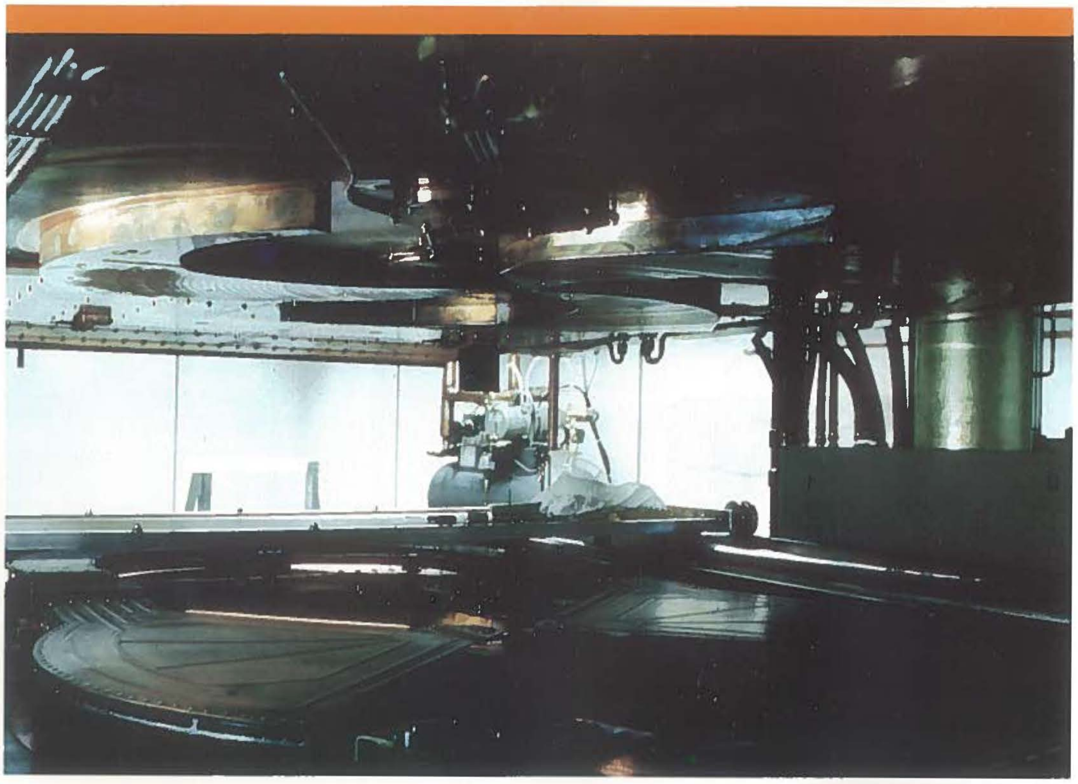
Using the 42 MeV facility, AECL developed procedures to produce thallium-201, gallium-67, and cobalt-57; commercial shipments of these isotopes started in January 1984. Indium-111, used to label monoclonal antibodies for tumour imaging, was also available commercially in the first quarter of 1984.

In October, AECL demonstrated that commercial quantities of high-purity iodine-123 could be produced using the baby cyclotron and xenon-124 target gas. As a result, commercial shipments began in January 1984.

AECL also irradiated targets with the 500 MeV isotope production facility, coupled to the TRIUMF cyclotron. In 1983, this facility performed without failures and was able to deliver 74 irradiated targets to AECL (compared with 42 delivered in 1982). The majority of targets were used to produce xenon-127, but targets used to produce cadminium-109, copper-67, germanium-68 and strontium-83 were also delivered.







(Top) The development of PET scanning agents.

(Bottom) AECL hot cell.

The 42 MeV "baby" cyclotron.

Pure Research

TRIUMF has facilities for experiments requiring intense beams of pions, muons, protons or neutrons. Each year the Pure Research section describes research at TRIUMF using one of these particle beams. This year our report will focus on experiments requiring neutron beams.

The neutron

All atoms consist of a heavy central core, called a nucleus, surrounded by a cloud of very light particles called electrons. In turn, the nucleus is made up of two types of particles – positively-charged protons and uncharged neutrons. The "orbiting" electrons are negatively-charged and held in orbits by their attraction to the positively-charged protons.

Neutrons are slightly heavier than the combined mass of a proton and an electron. They are stable when combined with protons to form a nucleus – but a free neutron outside of the nucleus is unstable. The free neutron radioactively decays into a proton, an electron and a massless neutrino, after about 15 minutes. This is a tremendously long time, by nuclear physics standards, and so the decay of the neutrons is not a problem in the preparation of a beam of neutrons for use as a sub-atomic probe.

Neutron facility

One of the first facilities installed at TRIUMF, in the Proton Hall, was a liquid deuterium target which formed the basis of a neutron production facility. Deuterium is a heavy isotope of hydrogen. Its nucleus is composed of a single neutron and a single proton very loosely bound together. If a high speed proton strikes this nucleus, there is a good chance that it will hit the neutron. Like in billiards, the neutron will be knocked out moving at about the same speed as the incoming proton. And, depending on just how the incoming proton strikes the neutron, the neutron will be knocked straight forward or off to one side at an angle. If the neutron is observed coming out of the target at a small angle then it is most likely to have been produced by a process known as "charge exchange". In this process the incoming proton transfers its positive charge to the neutron, in the deuterium nucleus, as it passes and becomes a neutron.

If the proton beam bombarding the deuterium target is polarized, then the outgoing neutrons are also polarized. This procedure is used to generate polarized neutron beams.

Neutrons are uncharged and cannot, therefore, be directed and focused like a proton beam. Instead, a hole must be left in a heavy metal shield through which the neutrons are allowed to pass. These neutrons form a beam. The heavy metal shield with the hole is called a collimator and the hole's direction and size determine the direction and size of the neutron beam. While a neutron beam does not "feel" a magnetic field the direction of its polarization is changed after passing through the magnetic field. By passing a neutron beam through one or more magnets a neutron beam with a pre-determined polarization direction can be prepared for experiments.

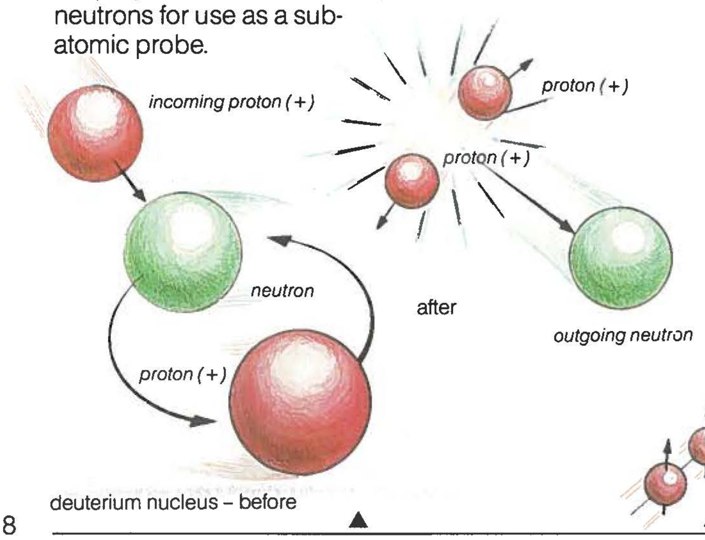
Early neutron experiments

The first neutron experiments at TRIUMF were carried out by the BASQUE Group, an international collaboration including physicists from the Universities of Victoria and British Columbia. The group was interested in measuring the force between free neutrons and protons – that is, neutrons and protons freely moving outside of a nucleus. This force is known as the "strong" force and is responsible for binding protons and neutrons together to form all of the stable nuclei found in nature.

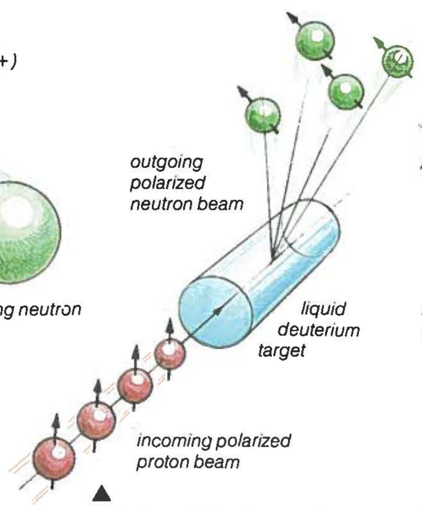
The group directed a beam of polarized neutrons onto a target chamber filled with liquid hydrogen (the hydrogen atom is a proton orbited by a single electron). Neutrons in the beam collided with the protons in the target, knocking them out of the container. Both the neutron and the proton, with which it collided, were detected in sensitive instruments surrounding the target.

In several experiments (taking four years in all) the group measured the probability of the neutron being deflected through any angle and, simultaneously, the polarization of the knocked-out proton. As the force between protons and neutrons depends on the relative directions of their spins, (like the force between bar magnets brought close together), the measurements were carried out for several orientations of the neutron beam polarization.

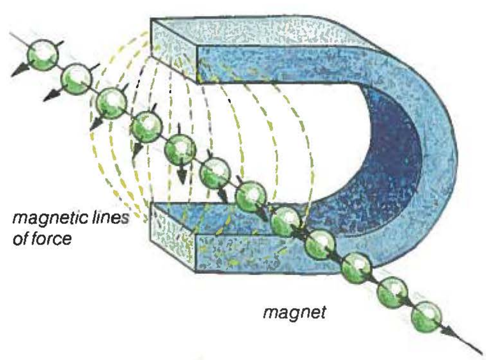
The results of the experiments allowed the different pieces of the neutron-proton "strong" force to be determined for the first time over the range of energies of interest to TRIUMF. An accurate knowledge of the "strong" force between neutrons and protons is of fundamental importance to nuclear physicists trying to calculate the properties of neutrons and protons bound together as nuclei.



In a collision between a deuterium nucleus and a high speed proton the neutron is very likely to be struck and knocked out of the nucleus.



Protons and neutrons "spin" about an axis like small spheres. If the axes of rotation of all protons in a beam are lined up, the beam is said to be polarized in that direction – similarly for neutron beams. Polarized protons striking a deuterium target produce a polarized neutron beam.



The neutron's spin direction (its axis of rotation) is precessed (turned) by the magnetic field but its direction of motion is unchanged. By passing the neutron beam through two magnets arranged at right angles it is possible to orient the polarization in any direction.

Recent neutron experiments

The early TRIUMF neutron experiments accurately determined the major pieces of the "strong" force. A group of Canadian physicists, headed by Dr. W.T.H. van Oers (University of Manitoba) proposed to investigate a symmetry of nature which is known to be approximately true; namely, what would happen if all the neutrons turned into protons and all the protons into neutrons? This symmetry is known as charge symmetry. A novel and sensitive test of this question is being investigated at TRIUMF using the neutron facility and a recently constructed "frozen spin" proton target.

Charge symmetry is already known to be violated in that two nearby protons, (both having positive charges), will repel each other but two neutrons will not. The electrostatic force destroys the symmetry between protons and neutrons in this case but physicists believe that this electromagnetic process is fully understood. It is the small charge symmetry breaking part of the "strong" force that is being measured in this new experiment at TRIUMF. The cause of this "breaking" of the symmetry will give us a better understanding of the origin of the "strong" force.

The "frozen spin" target being used in the experiment contains hydrogen atoms. At a temperature just above absolute zero, a magnetic field and a small amount of microwave power are used to align, and then "freeze", the spins of all these protons into the same direction, forming a polarized proton target. The magnetic field can then be turned down, without losing this polarization, so that protons knocked out of the target by neutrons are not deflected appreciably as they leave. The experiment is being carried out in two phases: first, polarized neutrons are directed onto an unpolarized proton target and, in a second experiment, unpolarized neutrons are directed onto a polarized proton target. A precise measurement is then made of the difference in the angle, (at which the number of neutrons scattering to the left and right are equal) between the two experiments. (In general, when using polarized beams, the number scattering to the left is not the same as that to the right. An idea familiar to ping-pong experts able to put a spin on the ball.)

As shown in the figure, the two experiments are related to each other by changing neutrons for protons and vice versa in our special "mirror". Although in the laboratory the neutrons are moving and the protons stationary, we could make a beam of protons and collide it with a neutron beam of the same speed. Then the view in our "mirror" would be exact.

The angular difference is expected to be half of a degree but it must be accurately measured to four-hundredths of a degree.

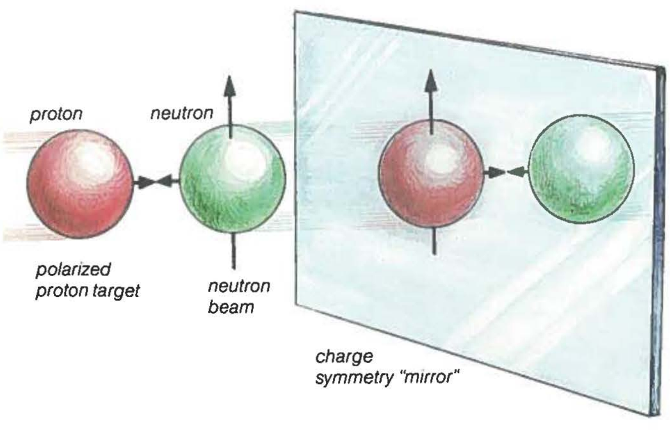
Radiative capture

In the experiments of the BASQUE Group no new particles were created in the neutron-proton collisions. To fully understand how neutrons and protons combine to form nuclei we need additional information that can only be gained by studying collisions in which new particles are created and carry off some of the energy. One such reaction occurs when a neutron is captured by a proton, to form deuterium, and the surplus energy is given off in the form of a gamma-ray. This process is called "radiative capture" and is being studied in the neutron facility for several neutron beam energies by a collaboration of physicists from the universities of Alberta, Oregon State, Saskatchewan and Western Cape (South Africa).

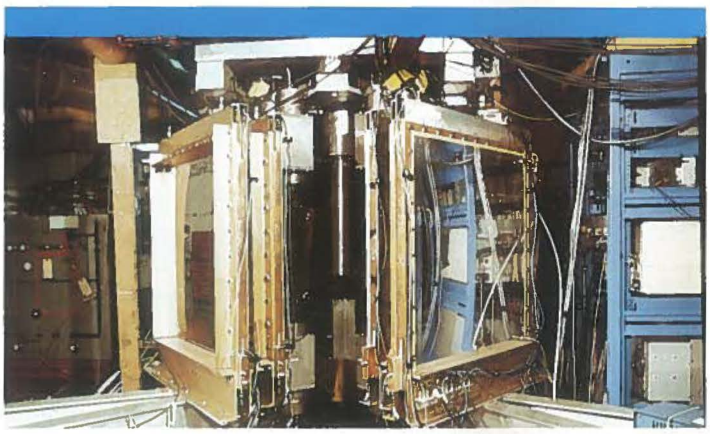
Thermal Neutron Facility

The beam stop of TRIUMF's high intensity proton beam line is a metal can about 25 cm long and 15 cm in diameter, filled with lead and surrounded by heavy concrete shielding. This beam stop is known as the thermal neutron facility (TNF). Protons stop in the lead and produce neutrons by colliding with the neutron-rich lead nuclei. The neturons are slowed (moderated) to thermal velocities in a bath of heavy water immediately below the lead target. They are known as thermal neutrons. Thermal neutrons have velocities comparable to those of the molecules in air and an energy of approximately 0.1 eV. Fluxes of up to 10^{12} neutrons per square centimetre are produced in the TNF.

There are two main users of the secondary thermal neutron beams. Novatrack Analysts Ltd., is a commercial company specializing in neutron activation analysis techniques, applied to mineral and environmental sampling. This technique is being used by researchers at Simon Fraser University where iodine concentrations in kelp are being investigated. Also from this university, Dr. A.S. Arrott is producing and utilizing a beam of thermal neutrons for neutron diffraction studies with a view to providing more suitable crystals for monochromating thermal neutron beams and developing the field of precision measurements of static magnetic induction waves in ferromagnetic materials.



▲ In our special "mirror" all protons are changed into neutrons and vice versa. The polarized proton or neutron is shown with an arrow representing the direction in which all the neutron spins are aligned. An unpolarized beam has particles whose spins are randomly oriented. No direction is preferred over any other and hence no arrow is drawn.



The "frozen spin" target surrounded by the 1 metre square proton detectors. The central (white) column houses the target assembly.

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H. Blok, *Novatrak Analysts Limited*

G.T. Ewan, B.C. Robertson, *Queen's University*

X. Aslanoglou, G. Huber, G.J. Lolos, S.I.H. Naqvi, Z. Papandreou, *University of Regina*

S. Ahmad, Y.M. Shin, E.J. Ansaldo, *University of Saskatchewan*

J.T. Sample, *Research Secretariat of B.C.*

M. Krell, *Université de Sherbrooke*

T.E. Drake, *University of Toronto*

R.T. Morrison, *Vancouver General Hospital*

W.P. Alford, *University of Western Ontario*

Overseas

A.W. Thomas, *University of Adelaide*

D.V. Bugg, R. Gibson, *Queen Mary College, London*

N.M. Stewart, *Bedford College, London*

A.S. Clough, *University of Surrey*

A.N. James, *University of Liverpool*

C. Amsler, *CERN*

R. Engfer, R. Kiefl, *Universitat Zurich*

J. Domingo, E.L. Mathie, *SIN*

L. Antonuk, *Université de Neuchatel*

R. Grynszpan, *CNRS Vitry*

R. van Dantzig, *IKO Amsterdam*

J. Niskanen, *University of Helsinki*

D. Horvath, *Central Research Institute for Physics, Budapest*

M. Furic, *Inst. R. Boskovic*

C. Cernigoi, R. Rui, *Universit di Trieste and INFN*

A. Bracco, *Universit di Milano*

J. Alster, D. Ashery, *Tel-Aviv University*

B. Olaniyi, *University of Ife*

K. Nagamine, T. Yamazaki, *University of Tokyo*

K. Sakamoto, *Japanese Federal Government*

I.R. Afnan, *Flinders University of South Africa*

C. Wiedner, *MPI Fur Kernphysik*

United States

D. Ashery, *Argonne National Laboratory*

K.W. Jones, *Brookhaven National Laboratory*

F.P. Brady, *University of California, Davis*

S. Kaplan, B.M.K. Nefkens, J.R. Richardson, *University of California, Los Angeles*

M.B. Epstein, D.J. Margaziotis, *California State University*

J.J. Kraushaar, T. Masterson, *University of Colorado*

H.S. Plendl, *Florida State University*

E.R. Siciliano, *University of Georgia*

B. Blankleider, H.O. Meyer, M.E. Rickey, P. Schwandt, T. Ward, *Indiana University*

Y.K. Lee, *Johns Hopkins University*

P. Tandy, *Kent State University*

C. Clawson, K.M. Crowe, G. Gidal, R.H. Pehl, V. Perez-Mendez, S. Rosenblum, H. Steiner, M.W. Strovink, R. Tripp, *Lawrence Berkeley Laboratory*

J.W. Blue, *Lewis Research Center, NASA*

L.E. Agnew, H.L. Anderson, J. Clark, J.S. Fraser, C.Y. Huang, R.J. Macek, *Los Alamos National Laboratory*

R.P. Redwine, *Massachusetts Institute of Technology*

F.D. Becchetti, *University of Michigan*

H.B. Willard, *National Science Foundation*

B. Bassalleck, B. Dieterle, *University of New Mexico*

J.K. Chen, *State University of N.Y. Geneseo*

R.A. Segel, K.K. Seth, *Northwestern University*

F.E. Bertrand, D.J. Horen, T.P. Sjoreen, *Oak Ridge National Laboratory*

B.C. Clark, *Ohio State University*

D.K. McDaniels, J. Lisantti, J. Tinsley, *University of Oregon*

K.S. Krane, R. Landau, A.W. Stetz, L.W. Swenson, *Oregon State University*

R.F. Carlson, *University of Redlands*

G.S. Mutchler, *Rice University*

R. Dubois, *Stanford Linear Accelerator Center*

R. Bryan, *Texas A&M University*

V.G. Lind, R.E. McAdams, O.H. Otteson, *Utah State University*

M. Blecher, K. Gotow, D. Jenkins, *Virginia Polytechnic Institute and State University*

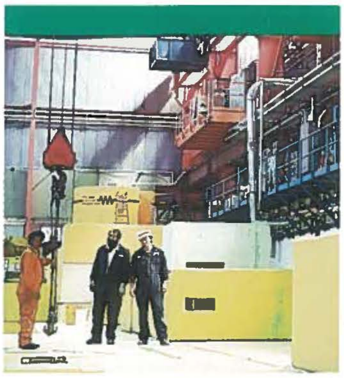
J.P. Geraci, I. Halpern, E.M. Henley, *University of Washington*

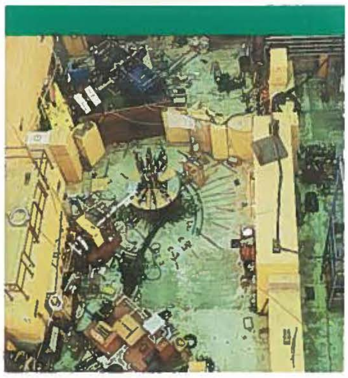
A.S. Rupaal, *Western Washington University*

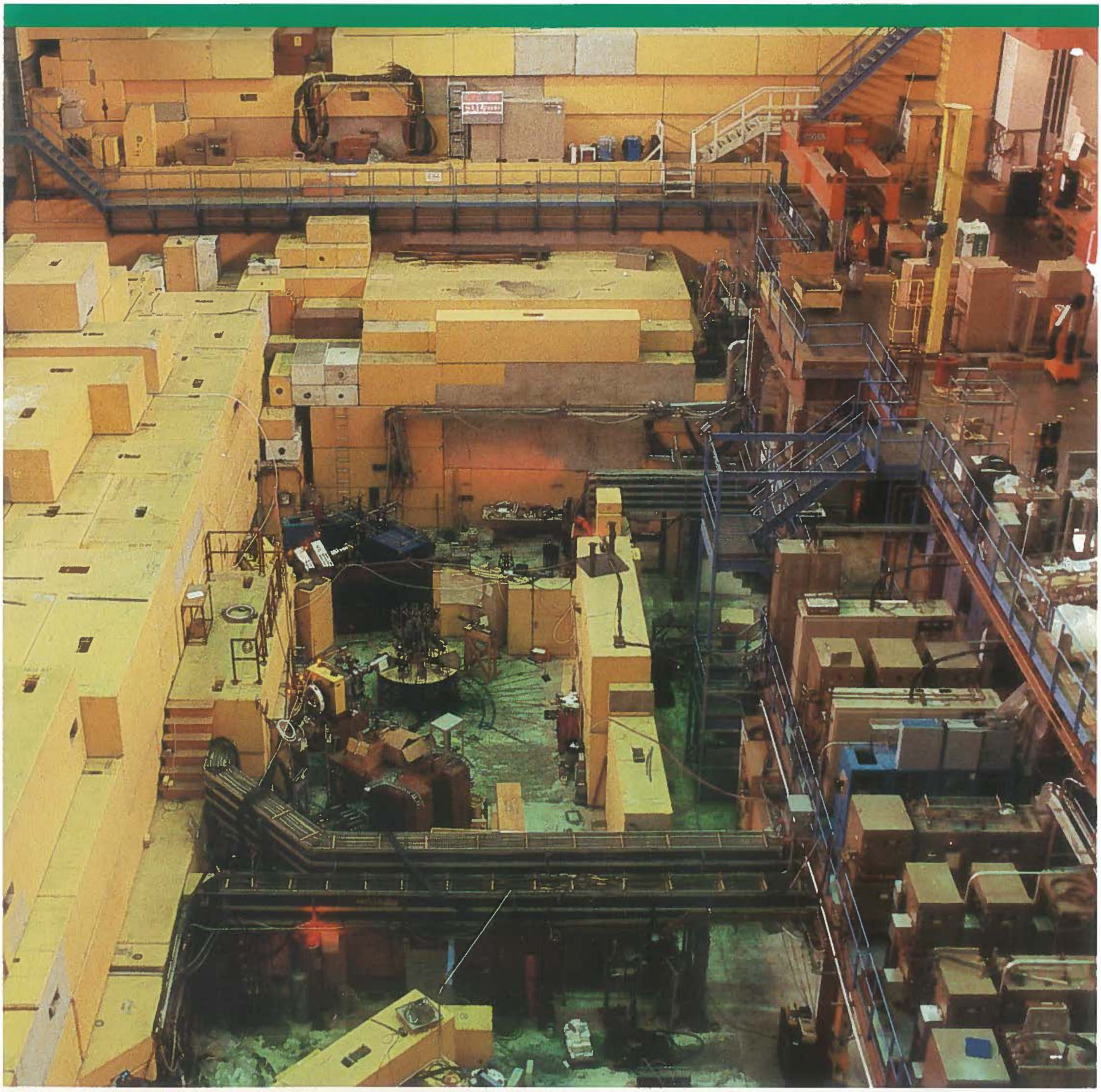
W.C. Sperry, *Central Washington University*

C.F. Perdrisat, M. Eckhause, R.T. Siegel, *College of William and Mary*

T.C. Sharma, A. Rosenthal, *TEVALAC Project*



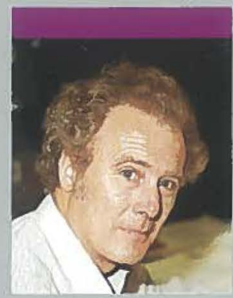




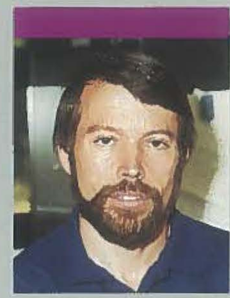
TRIUMF Organization

E.W. Vogt

P. Adams



J.L. Beveridge



E.W. Blackmore

C.W. Bordeaux

M.K. Craddock

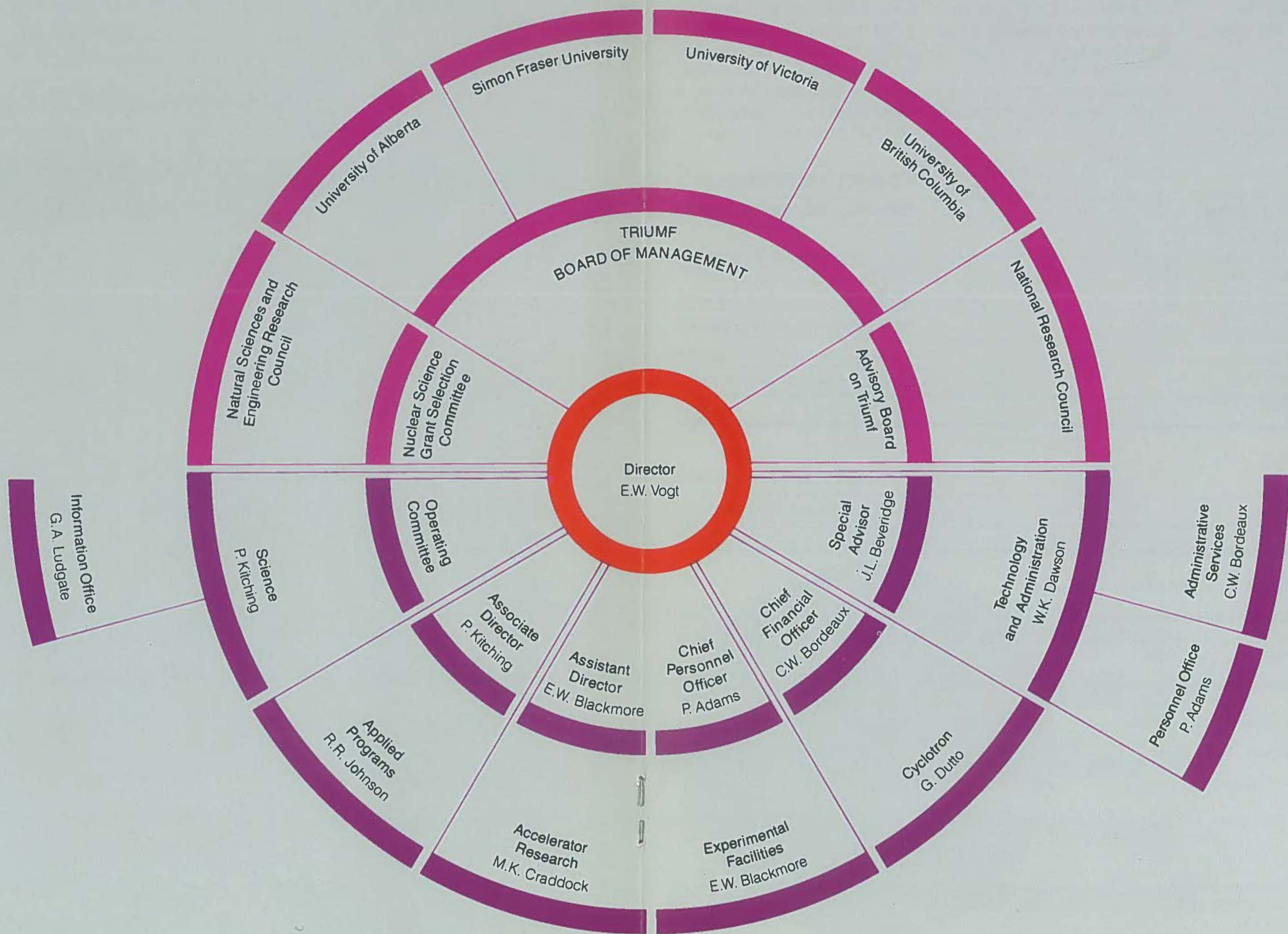
W.K. Dawson

G. Dutto

R.R. Johnson

P. Kitching

G.A. Ludgate



Financial Review

In accordance with the terms of the Joint Venture Agreement of 3 November 1981, the handling of cash receipts, banking and cheque issuing was transferred from the University of British Columbia to TRIUMF. The firm of MacGillivray & Co. Chartered Accountants, was commissioned to monitor the changeover process. The transfer has been completed satisfactorily.

The firm of Coopers & Lybrand Ltd., Chartered Accountants, was consulted regarding the redesign of Management Information Systems partially necessitated by the above-described transfer of duties. Revised Management Information Systems are expected to be operational by fiscal year 85/86.

Although the overall activities at TRIUMF increased, the total receipts show only an increase of 1.4%. The reasons for this low percentage are:

1. Construction of new buildings has slowed down considerably, resulting in a decline of funds received from the Province of British Columbia of 56.2%.

Through the Universities Council of British Columbia, the Province of British Columbia approved a building program to keep pace with expansion as reflected in the TRIUMF Five-Year Plan (next page). The total approved amount to date is $7,475,500.

2. Construction of facilities for Atomic Energy of Canada Ltd. (AECL) is completed. Therefore, funds received from AECL are 38.9% lower than in the prior year.

3. Affiliated Institutions show a drop in receipts of 12%. This does not mean a decrease in participation in experiments at TRIUMF (see Figure #1 below) but is an indication that more financial transactions were handled by the institutes themselves.

The contribution from the National Research Council (NRC) increased by 11.2%. NRC funds all TRIUMF's operations, maintenance, development and capital expansion. NRC funding represented 81% of the total funds received.

The principal financial support for experiments performed under the aegis of TRIUMF (and the only such agency whose grants are administered through TRIUMF) is provided by the Natural Sciences and Engineering Research Council (NSERC). The funding decreased by 7.4%. With more experimental facilities becoming available each year, there is a continued need to expand the financial support to experimenters.

Activities by Affiliated Institutions increased from 39 institutes being actively involved in experiments at TRIUMF to 51.

Expenditures in the Statement of Combined Funding and Expenditures are within budget.

In line with the 5-year plan projections, a general increase in activities led to hiring additional staff which is reflected in increased salary expenditures within approved limits.

A successful year was experienced in that all major obligations were met and expenses were at acceptable levels. The forecast for next year, fiscal 1985, is a continued real growth from NRC and NSERC, a continuation of the building construction programs funded by the Province of British Columbia, and the usual support from all institutions using the TRIUMF facilities.

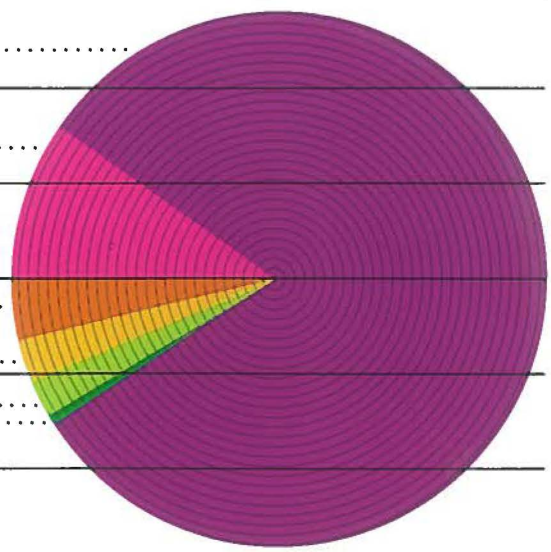
Figure 1 % Changes in receipts over previous year:

NRC	+ 11.2%
NSERC	− 7.4%
AECL	− 38.9%
Province of B.C.	− 56.2%
Affiliated Institutions	− 12.0%
Investment Income	+ 24.1%
Total Receipts	+ 1.4%

Figure 2 Source of Funds

(Millions of dollars)

National Research Council	$23.24	80.95%
Natural Sciences and Engineering Research Council	2.84	9.89%
Atomic Energy of Canada Limited	1.08	3.76%
Province of British Columbia	.74	2.58%
Affiliated Institutions	.68	2.37%
Miscellaneous	.13	.45%
	$28.71	100.00%



Five Year Plan

TRIUMF's Five Year Plan is submitted to the NRC Advisory Board on TRIUMF each fall. It is a rolling plan intended to forecast TRIUMF's future intentions and the associated financial requirements. Within the plan three broad areas of expenditure are identified, namely: the basic support and operation of the existing facility, the development of new facilities which enhance TRIUMF's capabilities, and the support of experiments to be performed at TRIUMF. Forecasts of requirements in each of these areas are centred about the development of major facilities and are based on a model to guide the extension of the Five Year Plan. This model identifies additional financial requirements associated with the general increase in TRIUMF's scope and capabilities implied by the completion of major facilities.

A proposed major new addition to TRIUMF, the Kaon Factory, is dealt with as a separate line item within this plan. The feasibility of this exciting new possibility at TRIUMF is being actively pursued, however the indicated funding requirements have not been approved.

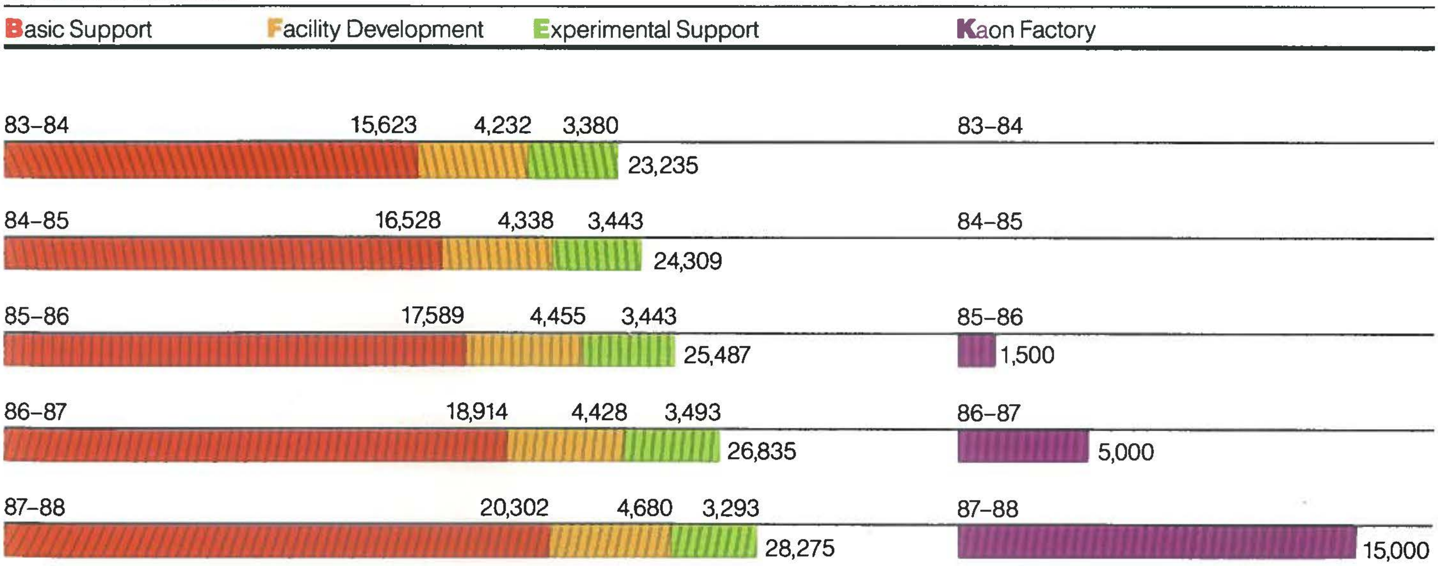
TRIUMF Five-Year Plan

Thousands of 1983 dollars

	1983–84	1984–85	1985–86	1986–87	1987–88
Basic Support	15,623	16,528	17,589	18,914	20,302
Facility Development *(excluding Kaon Factory)*	4,232	4,338	4,455	4,428	4,680
Experimental Support	3,380	3,443	3,443	3,493	3,293
Subtotal	23,235	24,309	25,487	26,835	28,275
Kaon Factory	0	0	1,500	5,000	15,000
Total	23,235	24,309	26,987	31,835	43,275

TRIUMF Five-Year Plan

Thousands of 1983 dollars



Auditors' Report

Board of Management
TRIUMF

We have examined the statement of working capital position of TRIUMF as at March 31, 1984 together with the statement of combined funding and expenditures and the National Research Council statement of funding and expenditures for the year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests and other procedures as we considered necessary in the circumstances.

In our opinion, these statements present fairly the working capital position of TRIUMF as at March 31, 1984 and its funding and expenditures for the year then ended in accordance with the accounting policies set out in Note 2 applied on a basis consistent with that of the preceding year.

MacGillivray & Co

MacGillivray & Co.
CHARTERED ACCOUNTANTS

Vancouver, Canada
June 6, 1984

Financial Statements

TRIUMF Statement of Combined Funding and Expenditures for the year ended March 31, 1984

	1984	1983
Funding		
National Research Council	**$23,235,000**	$20,893,000
Natural Sciences and Engineering Research Council	**2,837,619**	3,064,784
Atomic Energy of Canada Limited	**1,082,286**	1,771,397
Province of British Columbia	**739,333**	1,688,446
Affiliated Institutions	**682,841**	775,669
Investment income	**129,772**	104,556
	28,706,851	28,297,852
Expenditures		
Building construction	**737,625**	1,625,644
Communication	**189,461**	142,569
Computer	**270,545**	180,408
Equipment	**2,548,460**	3,285,896
Facilities in progress	**1,698,310**	1,704,731
Lease payments – Atomic Energy of Canada Limited	**564,185**	758,037
Minor construction	**55,546**	62,865
Power	**1,496,663**	1,086,410
Salaries and benefits	**13,916,630**	12,661,042
Sessional and occasional staff costs	**1,239,448**	1,038,085
Supplies and expenses	**5,855,809**	5,389,460
	28,572,682	27,935,147
Excess of funding over expenditures	**134,169**	362,705
Less funds balance end of year – Note 3	**174,124**	292,819
(Increase) decrease in deficit for the year	**(39,955)**	69,886
(Deficit) surplus beginning of year	**(90,165)**	(160,051)
(Deficit) surplus end of year	**$ (130,120)**	$ (90,165)

TRIUMF Statement of Working Capital Position for the year ended March 31, 1984

		1984	1983
Assets	**Cash on hand**	**$204,646**	$200,000
	Funds recoverable		
	Province of British Columbia	**105,451**	—
	Natural Sciences and Engineering Research Council	**113,275**	105,553
	Atomic Energy of Canada Limited	**24,209**	—
	Affiliated Institutions	**135,138**	126,283
		378,073	231,836
	Due from universities		
	The University of British Columbia	—	149,758
	The University of Alberta	**19,914**	26,623
		19,914	176,381
	Total assets	**602,633**	608,217
Liabilities	**Due to National Research Council**	**1,372**	25,050
	Due to universities		
	The University of Victoria	**9,410**	45,416
	The University of British Columbia	**232,227**	—
	Simon Fraser University	**16,396**	23,992
		258,033	69,408
	Accounts payable – Note 4	**27,974**	104,319
	Funds unexpended		
	Natural Sciences and Engineering Research Council	**378,131**	384,813
	Affiliated Institutions	**67,243**	55,740
	Atomic Energy of Canada Limited	—	59,052
		445,374	499,605
	Total liabilities	**732,753**	698,382
	Working capital (deficit) surplus – TRIUMF	**($130,120)**	($ 90,165)

National Research Council Statement of Funding and Expenditures for the year ended March 31, 1984

	1984	1983
Funding		
Funds unexpended at beginning of year	**$ 25,050**	$ 16,243
Cash contribution	**23,209,950**	20,876,757
Total approved contribution	**23,235,000**	20,893,000
Expenditures		
Administration	**2,779,196**	2,453,547
Cyclotron services	**7,689,045**	6,939,505
General services	**7,084,188**	5,547,011
Commissioned facilities	**1,547,005**	1,225,808
Minor projects	**263,627**	257,996
Major projects	**3,182,942**	3,722,359
Experimental support	**1,063,271**	913,073
Cost centre recovery	**(375,646)**	(191,349)
	23,233,628	20,867,950
Funds unexpended *end of year*	**$ 1,372**	$ 25,050

Expenditure breakdown by program element:		
Basic Support	**$16,091,550**	$13,978,472
Facility Development	**3,890,657**	3,790,107
Experimental Support	**3,251,421**	3,099,371
	$23,233,628	$20,867,950

Expenditure by object:		
Communications	**$ 167,682**	$ 120,309
Computer	**131,897**	125,442
Equipment	**2,061,105**	2,220,109
Facilities in progress	**1,698,310**	1,704,731
Insurance	**61,019**	45,235
Minor construction	**55,546**	62,865
Power	**1,496,663**	1,086,410
Salaries and benefits	**12,452,212**	10,945,865
Sessional and occasional staff costs	**757,250**	645,247
Supplies and expenses	**4,351,944**	3,911,737
	$23,233,628	$20,867,950

TRIUMF Notes to the Financial Statements for the year ended March 31, 1984

		1984	1983
Note 1:	**Organizational Structure**		
	TRIUMF is a Joint Venture established by The University of Alberta, The University of Victoria, Simon Fraser University and The University of British Columbia, having as its goal the establishment and continuance of a national meson facility for Canada.		
Note 2:	**Accounting Policy**		
	All transactions are recorded on an accrual basis. Expenditures on capital assets and inventories are expensed as incurred.		
Note 3:	**Summary of End-of-Year Funds Balance**		
	Funds Unexpended		
	National Research Council	**$ 1,372**	$ 25,050
	Natural Sciences and Engineering Research Council	**264,856**	279,260
	Atomic Energy of Canada Limited	**–**	59,052
		266,228	363,362
	Funds Overexpended		
	Atomic Energy of Canada Limited	**24,209**	–
	Affiliated Institutions	**67,895**	70,543
		92,104	70,543
	Funds Balance	**$174,124**	$292,819
Note 4:	**Commitments**		
	In addition to the accounts payable reflected on the Statement of Working Capital Position, there are outstanding commitments representing the estimated costs of unfilled purchase orders and contracts placed as at the fiscal year-end.		
	National Research Council	**$1,197,000**	$1,159,000
	Natural Sciences and Engineering Research Council	**131,000**	241,000
	Atomic Energy of Canada Limited	**18,000**	179,000
	Province of British Columbia	**23,000**	249,000
	Affiliated Institutions	**30,000**	31,000
		$1,399,000	$1,859,000
	At March 31, 1984, there were additional outstanding commitments in the amount of $188,000 for expenditures in the 1985–86 and 1986–87 fiscal years.		

Publications

Journal publications:

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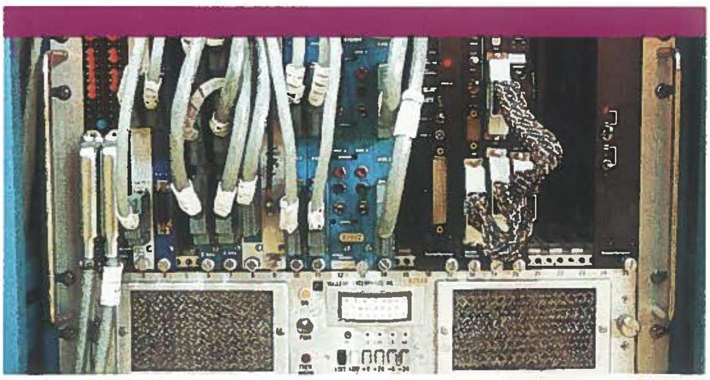

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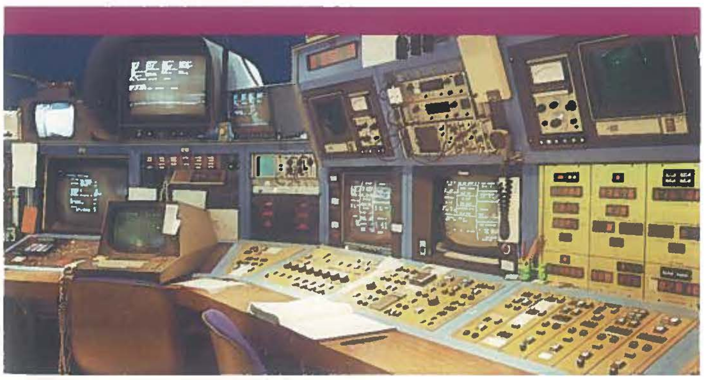

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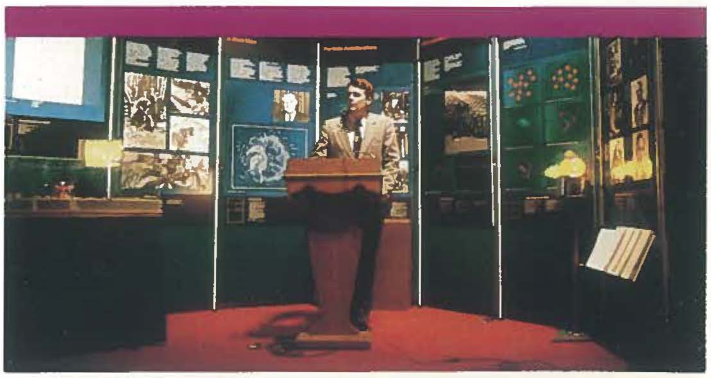

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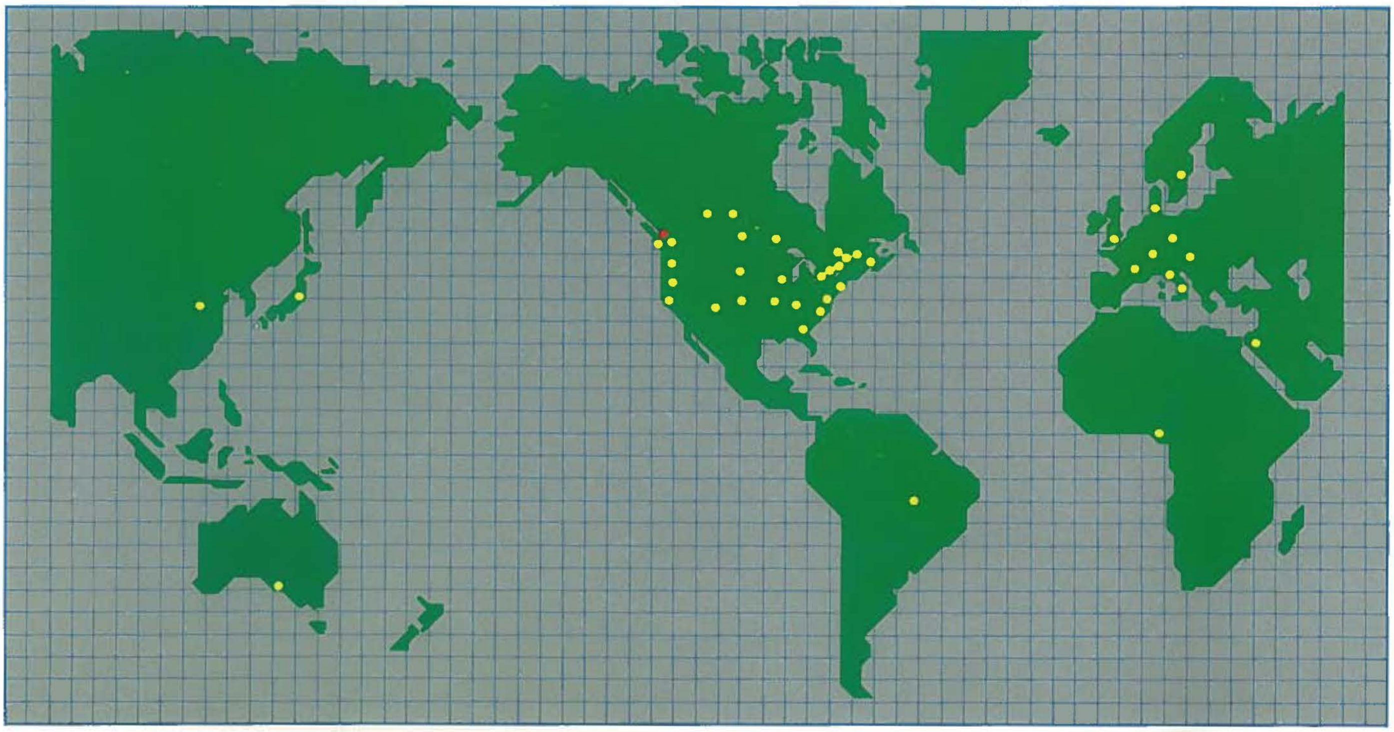

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