DRAFT – FOR DISCUSSION

The Subatomic Physics (GSC 19) Report for the 1998 NSERC Reallocations Exercise

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1 A Vision of Subatomic Physics Research for Canada

One of most important questions in basic science is that of the origin and nature of the universe. Subatomic physics addresses this by examining the universes most fundamental constituents – elementary particles and nuclei – and seeking an understanding of the interactions between them. Despite considerable advances, there still remain questions that elude consistent or satisfactory answers. These include such basic issues as the origin of mass, the abundance of matter over anti-matter in the universe and the details of nuclear "burning" in stars that allow them to generate enormous amounts of energy and to synthesize the heavy elements out of primordial hydrogen and helium.

To address the fundamental questions in subatomic physics today and in the future, Canadian researchers must successfully compete in the international arena through collaborative experimental projects that often span a decade or more at facilities in Canada and abroad. Critical mass and multiyear funding commitments for each research team are essential to the success of the Canadian effort. Perhaps more than any other NSERC-funded discipline, subatomic physics must engage in a continuous process of long term planning. The consensus that emerged from the most recent community-based planning exercise in 1995 was to focus the research programme through the year 2000 and beyond on three high priority initiatives, together with a number of key smaller projects in nuclear and particle physics to maintain an appropriate balance. Two of the top three priorities are based on new facilities under construction in Canada; the third makes use of national laboratory infrastructure to assist in constructing both accelerator and detector components for participation in the world's largest international collaborative effort in particle physics at the high energy frontier.

These three highest priorities are:

- **SNO:** The Sudbury Neutrino Observatory (SNO), to begin data taking in 1998 in a deep underground site at INCO's Creighton mine, is a unique experiment that capitalizes on Canada's large inventory of heavy water to act as the detection medium for neutrinos. These weakly-interacting fundamental particles are generated copiously in radioactive processes taking place in stars. Data from SNO will shed light on fundamental properties of neutrinos, which have far-reaching consequences for the fate of the universe, and on our understanding of energy generation in the sun.

- **ISAC:** The Isotope Separator and Accelerator (ISAC) facility under construction at TRIUMF in Vancouver will provide beams of a wide range of radioactive nuclei in unprecedented quantities. ISAC is ideally suited to carry out a broad range of measurements of important nuclear reactions at astrophysical energies. Such a "radioactive beams facility" has been identified in several countries as a high priority, but Canada's ISAC will be the first and most intense source of many beams for experiments beginning in 1999-2000. Coupled to a high resolution experimental facility, ISAC's science programme will be a world leader and is attracting a significant number of foreign researchers to Canada.

- **ATLAS:** The Large Hadron Collider (LHC) project, under construction at CERN in Geneva, will generate the highest energy colliding beams ever produced by mankind beginning in 2005. ATLAS is one of two large, complementary detectors under construction for the LHC that have as their main goal the discovery of the "Higgs boson", which provides the mechanism to generate the masses of elementary particles. The versatility of the ATLAS detector will allow many other topics to be addressed, with great discovery potential.

While the Canadian subatomic physics community focusses its efforts in the short- to medium-term future on these three large, high priority projects, sufficient resources must also be provided to support a number of smaller, strategically chosen projects where Canadians will have significant scientific impact. The experimental programme is complemented by a very active and renowned community of theoretical physicists who continue to develop the theoretical foundations of the field, to shape the plans of future experiments and to help interpret experimental data. This scientific diversity is necessary for Canada to continue to excel in the field of subatomic physics.

Subatomic physics in Canada is at a turning point. Faced with a collision course of the capital funding requirements for all three of its highest priority initiatives in 1997, the GSC proposed a five-year spending plan (1997 - 2001) that has been approved by NSERC Council. A necessary feature of the spending plan is the short term sacrifice of operating support to existing programme elements in order to maximize the funds available for urgent capital investments. A more appropriate balance between operating and capital expenditures must be restored in the intermediate term for the health of the discipline in Canada, while the longer term future will be considered in a new long range planning exercise to commence late in 1998.

An essential component of support for Canadian subatomic physics research is the existence of at least one strong national laboratory, to provide a home base for research and world class technical infrastructure to facilitate accelerator and detector construction for national and international projects. Following a multiyear process in which support to two federally funded accelerator laboratories – SAL in Saskatoon (supported in part by NSERC) and TASCC at Chalk River (supported by AECL) – was phased out due to funding pressures, the TRIUMF laboratory in Vancouver (funded through NRC) has emerged with an expanded mandate as Canada's national facility for subatomic physics research. While building ISAC for primarily nuclear physics investigations, TRIUMF provides infrastructure support to all areas of subatomic physics in Canada, and plays a crucial role in the construction of both accelerator and detector components for the CERN LHC and ATLAS physics programs.

This Reallocations Exercise presents a unique opportunity to optimize the NSERC support to subatomic physics in the context of new emerging areas of research to be pursued both in Canada and abroad. The period 1999-2003 will see first data extracted from the SNO detector in Sudbury, initial experiments performed at ISAC in Vancouver, and the construction and installation of detector components for ATLAS in Geneva. Proposals for timely reallocation of NSERC funding to enhance the scientific impact of each of these key Canadian research projects are described in section 4.

2 Importance to Canada

Canada has a long history of outstanding contributions to fundamental science and must continue to support fields such as subatomic physics if it is to maintain a strong intellectual capital base. The severe competition for funding in subatomic physics, together with rigorous, international peer review, guarantees that projects supported by the GSC are at the very highest level of scientific excellence and impact. The research performed at world-class Canadian laboratories such as TRIUMF, SAL and Chalk River Laboratories (CRL/TASCC) has had an enormous impact on our understanding of the behaviour of nuclear systems and the properties of the weak and strong interactions that govern the behaviour of matter at very short distance scales. Canada also has a significant impact abroad, where of the five experiments in the particle physics programme currently taking data, Canadians have acted as spokespersons or deputy spokespersons for three and as coordinators for the physics analyses of the other two. These are reflected in the words of the international assessors of the subatomic physics programme undertaken by the joint CAP/NSERC Review of Physics[1] in 1997: *'Canadians can be justly proud of their scientific results in subatomic physics and of the leadership roles they are playing in several international endeavors. The record of accomplishment by Canadians, the strong established base, and the potential for important new discoveries make the field an attractive one for further investment.'*

By providing high quality facilities in Canada where foreign scientists come and do research and by making significant contributions abroad, the subatomic physics community has enhanced Canada's reputation as a centre for intellectual and technological innovation. Subatomic physics projects regularly push the limits in such areas as electronics, computing, and superconducting magnet design, with advances made for research applications in cooperation with industry. Companies that have developed new products in this manner go on to sell them directly or to apply the new technology in other fields. Many recent examples are associated with Canada's contribution to the CERN LHC accelerator, for which an agreement is in place to provide $19M in high-tech components through the year 2000.

One of the key considerations when assessing the importance to Canada of a discipline is the people trained in it who go on to form the intellectual base from which future innovation is born. Subatomic physics provides students with a broad education that includes not only the science itself but also state-of-the-art electronics, instrumentation, computing, and other information technologies. The problem-solving skills that are provided by training in subatomic physics can be readily applied to address issues in other fields. While 25% of recent graduates have found academic positions in Canada or abroad[2], the majority are employed primarily in industrial positions ranging from the high-tech to financial sectors. A unique aspect of training in subatomic physics is that by working in large international collaborations under externally set deadlines and operating budgets, students gain experience in project coordination and management that prepares them to compete effectively in a business environment where internationalization is becoming the norm rather than the exception.

While subatomic physics research is unquestionably basic science, there have also been numerous technical spin-offs that have benefitted Canada. For example, Canada has become a world leader in the field of positron emission tomography (PET), a medical imaging technique that relies on short lived radiopharmaceuticals and fast gamma ray detectors. This technique has opened up a new window on *in vivo* studies of the physiology and metabolism of the human brain, which cannot be accessed in any other way. In cooperation with EBCO technologies of Vancouver, TRIUMF has developed cyclotrons specifically for radiopharmaceutical production that are now sold to an international market. TRIUMF is also building an accelerator-based system for the detection of explosives and contraband at airports and other risk centres, with high potential for commercialization. There are numerous other examples of similar technological impact spawned by the Canadian subatomic physics programme.

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[1] Summary of Assessors Report on the Canadian Subatomic Physics Program, J. Deutsch et al., 28 July 1997.

[2] Report of the NSERC/CAP Review of Physics: Subatomic Physics, May 1997, available at http://cepheid.physics.utoronto.ca/Review/

3 The Canadian Subatomic Physics Programme

The Canadian subatomic physics programme is focussed on several key questions concerning the Standard Model of elementary particle interactions and its implications for the world in which we live. In this model, the fundamental constituents of matter consist of six quarks (the lightest pair give rise to atomic nuclei) and six leptons (the lightest of these are the electron and its associated neutrino). The unified electroweak and strong interactions are described in terms of the exchange of force carriers: the photon and intermediate vector bosons for the electroweak force, and the gluon for the strong force. This model forms the basis for most theoretical and experimental work in subatomic physics.

Although it is consistent with experimental data, the Standard Model contains almost two dozen parameters whose values are not predicted by the theory. There remain key questions about the fundamental properties of quarks and leptons, the mechanism that gives rise to mass, and the observed preponderance of matter over anti-matter in the universe. Canadian researchers have made significant contributions to our current understanding of the Standard Model, its predictions, its limitations and searching for what lies beyond. Against this background, the Canadian subatomic physics community has made three complementary projects its highest priorities: SNO, ISAC and ATLAS. These will form the core of the Canadian subatomic physics programme through the period of the 1998 Reallocation exercise and beyond, and are balanced with a number of smaller projects based both in Canada and abroad.

3.1 SNO

The Sudbury Neutrino Observatory, under construction since 1990 in a deep underground site at the Creighton nickel mine, is due to begin data taking in 1998. SNO is an international project with almost a third of its $76M construction and $3M annual operating costs being funded by the U.S. and U.K. A team of 18 Canadian researchers[3] together with their graduate students, postdoctoral research associates, and international collaborators, will use SNO to detect the neutrinos produced in nuclear reactions in the core of the sun to attain an unparalleled glimpse into the fundamental processes taking place there. Previous measurements imply that the sun is only producing about half of the expected number of these weakly interacting particles. However, fundamental properties of the neutrino which have hitherto escaped detection, such as a finite mass, could be responsible for the discrepancy in the number of solar neutrinos detected on earth.

Because of its unique heavy water detection medium (a loan from AECL valued at $300M), SNO will be able to distinguish between neutrinos of different types and energies, providing an unprecedented opportunity to solve this solar neutrino "problem" and a chance to make fundamental discoveries about the properties of neutrinos themselves. Results from SNO, with its unique detection capabilities, are eagerly awaited by the international scientific community.

3.2 Nuclear Physics and ISAC

Canada has a very strong nuclear and intermediate energy physics program, that has traditionally been based at Canadian laboratories – SAL, TASCC and TRIUMF – carried out by approximately

[3] By convention, we count only full-time-equivalent, NSERC grant-eligible researchers when quantifying the size of the research groups in this report.

60 NSERC funded researchers. The Saskatchewan Accelerator Laboratory (SAL) in Saskatoon developed a unique and highly successful physics programme based on tagged photon beams produced with its 300 MeV continuous wave electron accelerator. Researchers at SAL carry out precision measurements of the electromagnetic structure and properties of nucleons and light nuclei, testing models of the strong interaction with impressive accuracy. Scientists at the Tandem Accelerator and SuperConducting Cyclotron (TASCC) facility at CRL developed a world class scientific programme based on the wide range of heavy ion beams available at TASCC. Their achievements include several discoveries that relate to the behaviour of nuclei spinning at very high angular momentum, precision tests of the Standard Model using nuclear beta decay, and development of techniques to perform precision mass measurements of unstable nuclei. At the TRIUMF 500 MeV cyclotron, researchers have made key contributions to our understanding of the weak and strong interactions, including some very important tests of the Standard Model with particle decays. TRIUMF is widely recognized for its development of a very high intensity polarized ion source that is unique in the world and for precision experiments using these beams. At a precursor to the ISAC facility, Canadian scientists attracted world recognition for their determination of the reaction rate for carbon burning in so-called 'Red Giant' stars, which has important implications for stellar evolution.

Nuclear physics in Canada is undergoing a dramatic transition. In 1995, TRIUMF embarked on a new five-year programme with an expanded mandate to build the ISAC facility, maintain an excellent research programme with the existing cyclotron, serve as a national infrastructure base for subatomic physics, coordinate a contribution to the CERN LHC accelerator construction, and foster technology transfer to industry. In 1996, responding to severe financial pressures and acting on advice from a community-based planning process, the GSC terminated its annual \$3M operating support of SAL as of 1998[4]. Citing financial pressures, AECL withdrew its \$7M annual operating support of TASCC and closed the laboratory in 1997. While a number of the researchers who formerly based their programs at TASCC and SAL are now travelling to foreign facilities such as Jefferson Laboratory (U.S.) and Lawrence Berkeley National Laboratory (U.S.) to continue the work begun in Canada, a significant fraction are now shifting their research to ISAC and TRIUMF.

The TRIUMF ISAC project will make a major contribution to our understanding of nuclear phenomena of importance to astrophysics and cosmology. Due to deliver accelerated radioactive beams to experiments by the year 2000, this facility will open up a completely new area of subatomic physics research by delivering hitherto unavailable radioactive nuclei to a variety of target and detection facilities for study. ISAC's nuclear astrophysics programme will focus on measurements of key nuclear reaction rates under conditions comparable to those taking place in the core of the sun, which can be input to detailed solar models to improve our understanding of its behaviour. Precision tests of the Standard Model are also planned, making use of a newly commissioned laser atom trapping facility, which will take advantage of ISAC's ability to generate specific radioactive beams tailored for sensitive experimental tests.

3.3 High Energy Physics and ATLAS

The Canadian high energy physics community of approximately 75 NSERC funded researchers has an impressive track record of making key contributions to multinational collaborative projects addressing some of the most important questions in the field. Most of these projects span over

[4] Interim funding for SAL has been provided by the University of Saskatchewan and the Western Economic Diversification fund, while the laboratory awaits a federal decision on the Canadian Synchrotron Light Source, proposed to be built at the SAL site.

a decade from inception to completion; planning exercises by the community and the GSC have defined timescales for the evolution of support from existing projects to ATLAS and other new initiatives, as described below.

The largest element of the current Canadian high energy physics programme is the OPAL experiment at CERN. Canada has made very important contributions to the OPAL detector beginning in the early 1980's and Canadians have played major roles in the operation of the experiment and analysis of the data – important achievements include very precise measurements of the masses and lifetimes of the weak force carriers and other particles, and sensitive tests that confirm that at this energy scale the quarks and leptons are in fact a complete set of fundamental constituents of matter. Two other major elements of the present programme are concentrated at DESY (Germany), where the structure of the proton is studied in unprecedented detail in electron-proton collisions at high energy. Canada has provided critical components of the accelerator and detection systems and Canadian research groups have played key roles in two of the key experiments (ZEUS and HERMES), with Canadian scientists being deputy spokespersons for both. A Canadian group active at Fermilab in the U.S., currently the world's highest energy accelerator, contributes to the CDF experiment, with several Canadians playing leading roles in the 1995 discovery of the sixth and heaviest quark ("top"). A Canadian group also plays a leading role in the search for the rare symmetry-violating kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$, at Brookhaven National Laboratory in the U.S.; the observation of the very first occurrence of this rare decay in 1997 should shed light on the puzzle regarding the matter-antimatter imbalance in the universe. Another Canadian group is assembling a large tracking detector at TRIUMF, in preparation for the BaBar experiment at the Stanford Linear Accelerator Centre, which will study this important symmetry violation in decays of particles containing "bottom" quarks. From 2000-2005, experiments in this programme actively taking data would include BaBar, ZEUS, CDF and HERMES, with the remainder of the community's effort focussed on preparations for work at the Large Hadron Collider or other new initiatives.

The Large Hadron Collider (LHC), currently under construction at CERN, will be the world's highest energy accelerator by almost an order of magnitude when it is commissioned for experiments beginning in 2005. Canada's contribution to the accelerator construction has opened a window of opportunity for a substantial Canadian participation in the LHC physics program. By identifying the debris from very high energy particle collisions, the ATLAS detector may either discover the Higgs boson, a new particle thought to be responsible for the generation of mass in the Standard Model, or a host of complementary new phenomena. The Canadian ATLAS groups have made key contributions to the design of two important elements of the detector that will measure the energy deposited by strongly interacting particles produced in the collisions, as well as to the development of electronics modules that will extract the signals from these detector elements. Canadians will build parts of these detectors and associated electronics with support from NSERC and TRIUMF.

3.4 Subatomic Theory

The research program in theoretical subatomic physics is rich and diverse. Canadians have made numerous outstanding contributions to the formal aspects of the theory as well as to phenomenological applications, where theory calculations are reconciled with existing data. Canadians have developed new techniques for solving the field equations that govern elementary particle interactions, particularly in a treatment of the notoriously challenging strong force. Applications to the study of the electroweak interaction in nuclei have been particularly successful, complementing the experimental programme.

3.5 Funding of Subatomic Physics

Subatomic physics research requires the use of large, custom-built detectors and international facilities. The size and complexity of the detectors make them quite expensive – for example, the ATLAS detector is estimated to cost $\sim$ \$500M CDN, of which Canada's present commitment is only 2.4%. The GSC budget must provide both the construction capital for the Canadian share of the detectors and the operating support for the participating scientists, including travel to international facilities, cost of user fees, and the ability to adapt to foreign currency fluctuations. For these reasons, the cost per researcher to support subatomic physics is relatively high in comparison to the average over all NSERC disciplines, as detailed in Table 1.

Table 1: NSERC Subatomic Physics Operating Awards 1997-98
(Excluding facility operations)

Category	Total (M\$)	FTE Researchers	k\$/Researcher
Theory	1.7	73	23
Nuclear Physics	2.8	57	49
SNO	1.4	18	77
High Energy Physics	6.5	75	87
TOTAL	12.5	223	56
Other Disciplines	180	7300	25

Table 2: Total Subatomic Physics Investment 1997-98

Source	Application	Total (M\$)
NRC	TRIUMF Operations	31
NSERC	Facility operations (SNO, SAL)	4
NSERC	Operations: Researchers	12.5
NSERC	Equipment	3
Govt. of B.C.	ISAC Construction	5
W.E.D./U. of S.	SAL interim funding	2
Commercial revenues	TRIUMF	1
U.S. DOE	SNO operations	1
Russia INR	TRIUMF experiment 614	0.5
TOTAL		60

NSERC support of subatomic physics has been administered via an envelope system since 1991, placing all expenditures on operating, equipment and infrastructure under the purview of one GSC. The subatomic physics envelope was steady at \$19.6M from 1991-95; the effects of federal funding cuts to NSERC and the first reallocations exercise have resulted in a steady decrease of the envelope to \$17.3M in 1997. The funds in support of experimental work are usually awarded in the form of Project Grants, with a single three-year budget for each experiment. In contrast, theoretical work is supported mainly in the form of Individual Research Grants. A breakdown of NSERC[5] and non-NSERC funding contributions to subatomic physics in 1997-98 is shown in Table 2; note that the total investment in subatomic physics is about 3 times the NSERC contribution, mostly coming from other federal sources.

4 Proposals for Funding

4.1 Canadian Contribution to ATLAS: \$1.25M Capital

By the time the ATLAS experiment begins to take data in 2005, roughly half of the Canadian high energy physicists are expected to be working on this project. ATLAS is a very large, cylindrically symmetric detector that will surround the interaction region where the LHC's high energy proton beams will collide. Canadian groups have made very important contributions to the design and implementation of prototype detector modules for ATLAS that will measure the energy deposited by strongly interacting particles produced in the collisions and to elements of the readout electronics for these devices. Their proposed contribution to the liquid argon calorimeter system – the so-called hadronic endcap and forward calorimeters – is crucial to identify the decay modes of the Higgs boson, the discovery of which is a prime motivation for the LHC and ATLAS projects.

Despite the high scientific priority of ATLAS and very strong endorsements by an international expert review panel, financial pressures drove the GSC to award an capital budget for ATLAS that is only sufficient to build one half of the proposed detector contributions, which were based on elements that had been designed and prototyped in Canada. This is far less than the international ATLAS collaboration was expecting, and has caused severe problems for the experiment as a whole. The shortfall is particularly severe in the case of the forward calorimeter, since the Canadian team had sole responsibility for this device. It is proposed that an additional \$1.25M capital contribution to ATLAS be made from Reallocation funds, to build the missing second half of the forward calorimeter. This represents a 10% increase in the capital funds awarded to ATLAS, but the corresponding increase in the scientific contribution of the Canadian team to the experiment will be much higher. Even with this increase in equipment funds, the total proposed Canadian contribution to ATLAS (\$13.45M) is modest in comparison to other participating countries – for example, the total US investment in the LHC physics programme is more than three times the proposed total NSERC investment on a per capita basis.

4.2 DRAGON – Doing Science at ISAC: \$0.6M Capital

While several complementary avenues of research will be pursued at ISAC, the centrepiece will be the nuclear astrophysics programme, which will focus on measurements of key nuclear reaction rates under conditions comparable to those taking place in the core of the sun. The success of these experiments hinges on a dedicated high resolution facility that will identify the scientifically interesting reaction products interest amidst a huge background of unreacted beam particles and other species. The proposed facility for this purpose is DRAGON, a 'Detector for Recoils and Gammas Of Nuclear reactions'. It consists of a gas target surrounded by an array of high-efficiency,

[5] Note that the total NSERC investment in 1997-98 exceeds the defined envelope due to reprofiling of major capital investments from 1997-2001, as explained on page 2.

very fast gamma ray detectors, and followed by a high resolution electromagnetic spectrometer. The total estimated cost is almost $3M.

The GSC was able to identify $1.9M in equipment funds towards DRAGON, allocated over the 3 year period 1998-2000. Together with a $0.5M contribution from TRIUMF, this should be sufficient to construct the electromagnetic spectrometer. However, the gamma detector array is urgently needed to increase the resolution of the facility by three orders of magnitude, which would open up a new window for the study of low reaction rate processes. Because of the severely constrained financial situation, the GSC was not able to earmark the funds needed to provide the gamma array, postponing its construction until the year 2002 at the earliest.

The DRAGON proposal was evaluated by two expert international review panels assembled by TRIUMF in July 1997 and NSERC in December 1997, and it received strong endorsements from these review panels and from the TRIUMF Experiments Evaluation Committee. The capabilities of a fully instrumented DRAGON would enable Canadian scientists at ISAC to be world leaders in the field of nuclear astrophysics research. Additional equipment funds of $0.6M from the Reallocations Exercise are requested to complete this important new facility on a timescale that is commensurate with the availability of radioactive beams at ISAC beginning in 2000.

4.3 Funding of New Initiatives in Subatomic Physics: $0.2M/year

Typical subatomic physics projects span over a decade in time from inception to final data analysis. The initial phases of a project often involve a significant amount of new instrumentation development. A mechanism is clearly needed to support both those projects that are well underway and those that are considered "new initiatives". Severe financial pressures in recent years have driven the GSC to reluctantly scale back its allocation of R&D funding to detector development and smaller new initiatives. Only $50K was awarded in this category in the last competition, leaving over 10 excellent proposals completely unfunded. This unfortunate situation urgently needs to be addressed for the long term health of the discipline in Canada. Excellent candidates for such funding arise at every grants competition. In the words of the CAP/NSERC Review of Physics Assessors' Report,[6] *'... As the ongoing programs cannot be further cut without wasting intellectual and material investments, this requires a modest but significant increase of the subatomic physics envelope.'* It is proposed that Reallocation funds be earmarked for support of detector development and smaller new initiatives in subatomic physics, at the level of $0.2M per year.

4.4 Additional Operating Support: $0.5M/year

The subatomic physics community in Canada entered the first year of the previous Reallocation cycle with 213 funded researchers[7] in the 1995-96 competition. Since that time, the number of researchers has remained stable but the funds available to support their operations decreased by 11% over the same period – from $14M to $12.5M – despite the GSC's attempt to free up resources by phasing out its support of the SAL facility. The fixed envelope funding system implies that operating budgets have to be severely curtailed whenever a major capital investment is undertaken; even with a five year financial plan, the need to make major capital investments in SNO, ISAC and ATLAS simultaneously has led to major cutbacks in operating support to even the top researchers in the field over the past few years. This situation has been particularly harsh on young researchers (10

[6] Assessors Report on the Canadian Subatomic Physics Program, J. Deutsch et al., 5 June 1997, p. 2

[7] NSERC Staff Report: Discipline Dynamics, 1997, Table A1.

new individuals since 1995) who have entered the discipline seeking funds to initiate new projects or to enhance the scope of existing projects, which would normally come out of operating funds. Since it has lacked the resources to support new applicants adequately, even though many of them are young people who show great promise for outstanding research careers, the GSC has reluctantly left the new experimentalists to join existing projects without increasing the corresponding Project Grant budgets; new applicants in theory are generally funded below the average levels. This situation urgently needs to be addressed by a modest increase of operating support to the GSC at the level of $0.5M per year.

4.5 Consequences of No Reallocation Funding

The consequences of not receiving an increase in the subatomic physics envelope due to Reallocation, i.e. of retaining a constant envelope at the 1997-8 level of $17.3M for the next four year cycle, are clear. The maximum impact of the ISAC science programme will be delayed beyond 2002 because it will not be possible to fully instrument its premier research tool, the DRAGON facility, before that time even though beams will be available two years earlier. The Canadian contribution to the ATLAS detector will remain disproportionately small. The GSC cannot continue to underfund promising young researchers who enter the field as new applicants, nor can it postpone R&D work and smaller new initiatives indefinitely. Since major capital commitments have already been made for the next 5 years, operating funds to ongoing projects and established research teams will have to be sacrificed further to correct these imbalances.

The consequences of the maximum possible decrease in the subatomic physics envelope as an outcome of this Reallocations Exercise would be particularly severe. Since major capital commitments have already been made to international projects, most of the shortfall (70%) would have to come out of operating funds with the remainder absorbed by delaying equipment purchases for ISAC. The latter would severely hamper the development of the science program at a premier new facility that represents a substantial investment of federal and provincial construction funds. It would also be necessary to reduce operating funds to facilities – cuts to SNO would be particularly damaging just as the detector begins to acquire data after a lengthy construction period, and would likely trigger a proportional reduction in the US contribution to site operations. This would have very damaging implications for Canada's ability to act as a partner in international scientific collaborations. It is difficult to forsee that a healthy Canadian subatomic physics research community could be maintained at the present size by the end of the second Reallocations cycle in the event of a maximum possible decrease to the GSC envelope.

5 Concluding Remarks

The proposals for new funds discussed above have been carefully selected to optimize the scientific impact of NSERC expenditures in subatomic physics and to help ensure the long term competitiveness of the Canadian research program in this discipline. The pressures on the subatomic physics envelope in recent years have been extraordinary, and the requests presented here are relatively modest: with funding for these four proposals, the subatomic physics envelope in 2002-3 will still be $1M smaller than it was in 1994-5. Considering the size and scope of the overall effort and investment in this field by Canada, of which NSERC contributes roughly 30%, the modest additional investment requested here will generate a high scientific return and is worthy of support from the Reallocations Exercise.