The ATLAS Experiment
at the
CERN Large Hadron Collider
A Ten Year Plan for TeV Physics

B. Caron, D.M. Gingrich, R. Moore, J. Lu, J. Pinfold,
R. Soluk, J. Soukup
University of Alberta

D. Asner, M. Khakzad, G. Oakham, M. Vincter, Z.Y. Yang
Carleton University

D. Axen
University of British Columbia

S. Robertson, B. Vachon, A. Warburton
McGill University

G. Azuelos, G. Couture, C. Leroy, J.-P. Martin, R. Mehdiyev,
N. Starinsky, P.-A. Delsart
Université de Montréal

D.C. Bailey, P. Gourbonov, L. Groer, P. Krieger, C. Le Maner, R. Mazini,
R.S. Orr, P. Savard, P. Sinervo, M. Cadabaschi, R. Teuscher, W. Trischuk
University of Toronto

D. O'Neil, M. Vetterli
Simon Fraser University

M. Losty, C.J. Oram, R. Tafirout, I. Trigger
TRIUMF

A. Astbury, A. Agarwal, M. Fincke-Keeler, R.K. Keeler, R.V. Kowalewski,
R. Langstaff, M. Lefebvre, P. Poffenberger, R.A. McPherson, R. Seuster,
R. Sobie, K. Voss
University of Victoria

S. Bhadra, W. Taylor
York University

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A. Introduction

It is our belief that experimental high energy particle physics is about to enter an extremely exciting period. The period from the discovery of the W and Z bosons at CERN to the completion of the precision study of Standard Model electroweak parameters, has convinced us of the validity of the standard model in the accessible energy regime. For many well-known reasons, the standard model is believed to be a low energy approximation to a unified, and probably supersymmetric, theory which spans all energy domains. The great triumph of the Standard Model was the utilisation of spontaneous symmetry breaking to produce a finite, renormalisable theory of the electroweak interaction. The success of this approach implies the existence of at least one real scalar particle, the Higgs. The success of the Standard Model when confronted with experiment, combined with its known internal deficiencies, are what lead to the expectation of new and exciting physics close to the TeV scale.

How one extends the Standard Model, to overcome its known deficiencies, is an experimental issue; and it is one of most exciting experimental issues in modern science. This excitement attracted the existing Canadian ATLAS group to join ATLAS as founding members in 1993. During the following three years the group developed a coherent proposal for the construction of important elements of the ATLAS detector. This proposal was accepted by the NSERC peer review process. It has developed into a project based on an NSERC capital expenditure of $15.5 million for the completed detector construction, and an integrated operating expenditure of $15.9 million to date.

The ATLAS Canada collaboration comprises 33 grant eligible scientists, who all take an active part in the ongoing projects. Including engineers, research associates, technicians and students, ATLAS Canada is a group of some 88 people; it includes five IPP Research Scientists. Most of the faculty involved in CDF and D0 are now signatories of the ATLAS grant request. We expect that, though the number of faculty will probably increase quite slowly, the number of FTE will increase rapidly in the coming three years. The project now involves 13 Research Associates, and 21 graduate students. We expect the number of graduate students approximately to double in the next five years. At the undergraduate level, ATLAS plays a strong educational role in Canada. The average year sees around 20 undergraduate summer students working on the project.

B. ATLAS and Current Issues in Particle Physics

In the introduction we alluded to the experimental and theoretical successes of the Standard Model. There are currently a number of pressing issues in particle physics. The success of the Standard Model itself is perhaps the greatest puzzle. The current precision tests of the electroweak sector of the Standard Model are so compelling that they give strong reason to believe that the Higgs mechanism, which is so central to the model, is indeed what gives mass to the fundamental fermions and bosons of nature. Results from these precision tests also indicate a light Higgs. This is the crux of the problem. It is difficult to understand how the Standard Model Higgs can have a mass at the electroweak scale, because of radiative mass corrections. A widely accepted solution to this is the introduction of SuperSymmetry. One can argue that the success of the standard model precision tests plus the indications for a light Higgs are a strong indication for SUSY. Moreover, for the Higgs mass protection to work, the mass scale of SUSY must be close to the mass scale of the Higgs itself. And so one has a well founded expectation of observing at least one SUSY Higgs, and the superpartners themselves, if one can experimentally access the electroweak mass scale.

In recent years there have been several dramatic observational developments in our knowledge of the large scale structure of the universe. It is now well established that the space-time of the universe that we live in is flat. This establishes that the total gravitating matter density is much greater than the amount of "Standard Model" matter density. So cosmological and astrophysical observations are strong evidence for the fact that the universe is gravitationally dominated by "dark matter"; and superpartners are strong candidates for non-Standard Model dark matter. The observation of superpartners in an accelerator experiment would dramatically link the resolution of puzzling issues on the microscopic and macroscopic scales.

It has often been stated that there is no evidence for physics beyond the Standard Model. This is not true. The evidence for a light Higgs strongly supports new physics which protects the light Higgs mass; the direct observation of a light Higgs, would make this argument overwhelmingly compelling. The observation of a light Higgs and no sign of the mechanism that protects the mass would be, of itself, an extremely significant observation. It would signal that we actually do not have an understanding of electroweak symmetry breaking. Not only that, but there is now convincing evidence that neutrinos are massive, and this is a direct observation of physics beyond the Standard Model. Given the situation which we have briefly described, we believe that as the LHC commences operation, the coming decade will be one of the most exciting that physics has seen. We further believe that the results from the LHC will dominate this exciting period. In the next section we briefly describe our view of which other experimental facilities can be expected to give a window onto these exciting new phenomena in the next five to ten years.

C. Comparison with Other Experimental Facilities

There are a number of present and future experimental facilities which will have the capability of addressing the issues discussed in the previous section. Accelerators of various energies can address some of these questions, perhaps via precision measurements. Non-accelerator experiments such as those in the SNOlab can perhaps address some of the same issues. In addition, ground and space based cosmological and astrophysical observations can approach the questions in the macroscopic domain. Finally, neutrino physics may well shed light on aspects of “Beyond the Standard Model Physics”. However, we believe that physics has proceeded most directly and convincingly by direct production of the field quanta associated with new phenomena. The direct production, at an accelerator, of the lightest SUSY particle would not only be a direct resolution of the central issue of the Standard Model, it would also give dramatic insight into the nature of dark matter.

The only accelerator facilities which will address these questions in the next decade are the Tevatron and the LHC. If we focus on the question of the origin of electroweak symmetry breaking and the observation, or otherwise, of superpartners, only the LHC is in the position to give a definitive answer within the next decade. The Tevatron may glimpse a light Higgs or superpartners; but it is questionable whether the Tevatron can achieve the necessary integrated luminosity before the LHC pre-empts it. The LHC has the energy reach, the luminosity, and the detector facilities to unambiguously answer these questions. The picture we have described above is quite compelling; but only experiment will tell whether it bears any relation to reality. We believe that one cannot second guess nature. Nature may have chosen some alternative that we have not thought of. In that case the LHC will reveal this to us. Perhaps not the details of what nature has chosen; but certainly the fact that it is not the MSSM!

In the time scale of the next decade one can also look forward to a start on the Linear Collider. In this document we do not choose to speculate on the time scale of the Linear Collider. Even if it is built within the next 10 to 15 years, its approach to these questions will be very different from the LHC. We draw an analogy between an earlier period of discovery, the time from the discovery of charm to the observation of the W and Z, which changed the paradigm of particle physics and led to the development of the Standard Model; and the period when we expect the LHC to again change the paradigm. In this analogy the Linear Collider will play the role of LEP; confirmation of the precise details of the new theoretical view.

Our conclusion is that experimentation at the LHC will dominate our field for the next 10 to 15 years. ATLAS is Canada’s mode of participation in this area. We believe that this project should remain the highest priority particle physics project in Canada. This is for the simple reason that it gives the most direct window onto physics beyond the Standard Model.

D. The ATLAS Experiment

As pointed out in the last section it is unlikely that a vanilla Standard Model Higgs will be found. While many physicists expect that the MSSM is a very good candidate for the real theory, one must be prepared for other eventualities such as dynamical symmetry breaking. Taking this approach, the ATLAS collaboration is constructing a general-purpose pp detector designed to exploit the full discovery potential of the LHC at both the highest luminosity and at initial lower luminosities

The ATLAS detector is designed to meet the diverse and exacting requirements of the LHC physics programme while operating in a very high luminosity environment. This high performance system must be capable of reconstructing the energy of electrons, muons, photons and jets as well as measuring missing transverse energy. Its radiation resistance must allow operation for more than ten years of data taking at high-luminosity. Features of the ATLAS detector that are utilized in the tagging and study of heavy flavour physics are: a powerful and flexible trigger system; high resolution secondary vertex measurement; and efficient track reconstruction and lepton identification down to low transverse momentum. The physics potential is further enhanced by the ability to study more complex signatures such as that of physics involving the top quark.

The detector comprises an inner magnetic tracking system. The tracking detectors closest to the beams are silicon pixel elements arranged in barrel and wheel shaped modules. Further from the beam pipe are silicon strips again arranged in barrel and wheel shaped modules. These solid state detectors are augmented by straw tube transition radiation trackers. This whole inner tracking assembly is contained in a solenoidal magnetic field. The tracker system's ability to identify secondary vertices and identify tracks in a high multiplicity environment is a major contributor to the ability of ATLAS to address important physics at all luminosities. The ATLAS muon system is based on large barrel and forward toroid magnets. These are instrumented by barrel and forward muon chambers which cover almost $4\ \pi$. The muon system is important for physics at all luminosities; in addition it has the important feature of being able to run as a standalone detector at the very highest luminosities.

For much of the most interesting physics the calorimeter systems are the heart of the ATLAS detector. Great effort has gone into producing a radiation hard, hermetic calorimeter system, with optimised energy resolution over the whole accessible rapidity region. The electromagnetic calorimeters are central to the detection of a very light Standard Model Higgs in channels such as $H \rightarrow \gamma\gamma$. Such signals require the highest energy resolution, and the best attainable $e\ \pi^0$ separation. In both the forward region, and the barrel, ATLAS uses accordion liquid argon electromagnetc calorimeters as the high resolution, radiation hard detectors. In the barrel region, the electromagnetic calorimeters are followed by scintillator-steel hadronic calorimeter modules. In the endcap region, $2 < |\eta| < 3$, the electromagnetic accordion calorimeter is followed by a liquid argon hadronic endcap calorimeter; in the region beyond $3 < |\eta| < 5$ the hermeticity is completed by a highly radiation resistant tungsten liquid argon calorimeter. The coverage of hadronic calorimetry is central to the detection of all jet and E_T^{miss} signatures. These are key signatures in the search for new phenomena such as heavy scalars, superpartners, and states associated with dynamical symmetry breaking, such as technimesons.

E. Canadian Participation in the ATLAS Experiment

From the award of the initial Major Installation Grant by NSERC in 1997, until 2003 the major focus of the Canadian group was on the development, design, construction, and installation of the detector components for which we we had taken responsibility. This phase of the project is now essentially complete, and the group's activities are increasingly focused on the commissioning of the detector and preparations for the first phase of physics at the LHC. In this section we briefly recall the detector components contributed by ATLAS Canada, and go on to discuss the near future, and our plans for the coming decade

(i) ATLAS Canada Construction Projects

Canadian participation in the ATLAS construction phase was centred on the detector components funded by an NSERC Major Installation Grant in 1997. This MIG award was initially for \$12.22 million. This level of support allowed us to initiate participation in several components of the ATLAS calorimeter. These calorimeter systems are: The Hadronic Endcap Calorimeter (HEC), the Hadronic Forward Calorimeter (FCAL), Front End Boards (FEB) for the calorimeter readout electronics, and the cryogenic signal feedthroughs for the endcap calorimeter. The groups that worked on the HEC project were Alberta, UBC, Montréal, TRIUMF, and Victoria; on the FCAL, Carleton, and Toronto; on the FEB, Alberta; and on the feedthroughs, Victoria, and TRIUMF. Montréal also coordinated much of the work on the common problems of radiation damage and liquid argon purity.

In the 1998 competition, the GSC awarded \$1.905 million to extend the scope of the Hadronic Endcap Calorimeter project, and since 1997 has awarded an additional \$482,000 to extend the scope of the Forward Calorimeter project. This level of support allowed us to participate in each of our proposed projects at a very substantial level. Indeed, the MIG funding allowed us to meet the commitments to calorimeter and feedthrough construction that we made in the Memorandum of Understanding signed between CERN and NSERC in April 1999.

The original MIG award in 1997 included the construction and installation of the feedthroughs as a Common Project. This was tailored to Canada's Common Project responsibility as calculated from one wheel of the HEC, the FCAL, and the electronics. With the award of the second wheel, Canada became responsible for an additional Common Project amount of about \$1.5 million. It had been envisaged that this amount would come from funds in the current TRIUMF 5 year plan; these funds have not been allocated so far.

The ATLAS liquid argon calorimeter system consists of calorimeters in a barrel cryostat concentric with the beam, and end cap cryostat on either side of the interaction point. The end cap cryostats are labelled ‘A’ and ‘C’. The feedthoughs for the ‘C’ end were installed in the Spring of 2003 and the two ‘C’ HEC wheels were installed in Sept. 2003 and Oct 2003, while the FCAL was installed in Aug. 2004. The completed ‘C’ cryostat was welded closed in Oct. 2004 and cooled down and tested for 8 weeks starting in Oct. 2004. It was delivered to the ATLAS pit in Sept. 2005. For the ‘A’ end, the feedthroughs were installed in the fall of 2003, the HEC wheels inserted in Aug. and Sept. 2004, and the FCAL in Feb. 2005. The cryostat was welded closed in Feb. 2005, cold tested from May to July 2005, and moves to the pit in Nov. 2005.

Of our four projects, the front end electronics required the most development. The high radiation field at the LHC gave a degree of uncertainty as to how the electronics could meet this challenge. Initially it was hoped that the required hardness could be reached by selecting non-rad-hardened components; but it became clear that a radiation resistant processes would be required. The electronics project consisted of the development of the controller chip for the Switched Capacitor Array readout pipeline for the calorimeter front end boards. The initial R&D for these parts was in the radiation hardened French military DMILL process. However, subsequent developments led to the IBM Deep SubMicron process being adopted. This complication led to increased costs, which were covered by an additional NSERC grant of $ 568,000 in 2004.

(ii) The LHC

The LHC will be the first machine at which physicists can study the nature of matter at the energy scale of electroweak symmetry breaking, and the realization of the machine faces many challenges.

Perhaps the greatest challenge was the superconducting dipoles and the production of superconducting cable for them. At present the situation on the cryo-dipoles seems to be well in hand. The three cable manufacturers have completed production, and what was was seen as a major hurdle is now in the past. Seventy five percent of the cold masses have been produced. Of the 1250 cryo-dipoles required, 900 cold masses have been delivered to CERN, 800 dipoles have been assembled, 250 are tested ready for installation, and 100 are installed in the ring. While the cryogenic distribution line installation had problems in late 2004, these are completely overcome at the time of writing. Similarly the cryogenic quadrupoles are also well on production schedule with about 80% manufactured. The real limits on the machine schedule came not from these technically challenging devices, but from the much more technically mundane cryogenic distribution line.

At the time of writing the LHC project management is confident that there will be collisions before the end of the summer of 2007. A partial cold test of sectors 7 and 8 of the machine was performed in September 2005. A beam test of sectors 1,8, and 7 is foreseen for the Fall of 2006, installation should be complete in 2007 with the ring closed in the early summer. The significant milestones for the LHC project are summarized in Table 1.

	LHC Near Term Milestones
Aug-06	Cryoline Complete
Oct-06	First Cooldown starts
Nov-06	Cryoline leak testing complete
Dec-06	Start powering tests of dipoles
Feb-07	LHC Installation Complete
Mar-07	Vacuum Commissing starts
Apr-07	Cool down complete
Jun-07	Powering Test complete
Jun-07	Vacuum Commissioning complete
Jul-07	First Circulating Beams ($6x10^{31}$)
3 month Shutdown	
Nov-07	Start Physics run of 7 months at $2x10^{33}$
May-08	
Dec-08	1 - 10 fb^{-1} per experiment
	LHC Long Term Milestones
2008	Start to collect 300 fb^{-1}
2014	with current machine
2014	Upgraded LHC 10^{35}
2017	3000 fb^{-1}

Table 1: LHC Milestones.

(iii) ATLAS Commissioning

The ATLAS detector is an enormously complicated system, and participating in the commissioning of it will be a major activity of the Canadian group until 2008; members of the group have already been active in preparations for the commissioning. The commissioning of the detector comprises several phases.

The earliest commissioning activity was the extensive program of beam tests of the calorimeter systems. This was an activity stretching from 1998 until 2004. It started with tests of prototype modules and culminated in a combined beam test of all the calorimeter elements in the endcap. This combined beam test not only allowed a system test of the detectors and their electronics, it also was crucial in starting to integrate the offline software and building an understanding of calibration procedures.

On the surface assembly building (the former West Hall) all the liquid argon systems have been cold tested, and in the pit elements of the detector are already undergoing system tests. For example, the scintillating tile barrel calorimeter has already taken data with cosmic ray muons. In the coming year all parts of the detector will be commissioned as separate systems, and integrated with the trigger and DAQ. Starting in the late summer of 2006 we will perform a global commissioning of the detector in order to integrate it into a single system. This process will culminate in a cosmic ray run from October to December in 2006, with ATLAS ready for beam in April 2007. Obviously any time between that, and the turn on of the first beam, will be put to good use in tuning up the detector. The cosmic ray runs will also allow us to do initial real tests of the offline software and the computing system in general.

Even the earliest beam circulating in the LHC will be invaluable for ATLAS. Single beam running will produce beam halo muons and beam-gas events. These will be used for the initial calibration of the end cap systems, which do not see a very high rate from cosmic muons. Significant dates for the commissioning of the detector are shown in Table 2

	ATLAS Milestones
Mar-06	TileCal Commissioning Complete
Aug-06	LAr Commissioning Complete
Dec-06	Start Global Commissioning for 3 months
Mar-07	Two Month Cosmic Run
May-07	ATLAS Ready For Beam
Jul-07	First Collisions
Nov-07	First Physics Run
Dec-08	~ 10 fb^{-1}
2014	300 fb^{-1}
	ATLAS Upgrade Milestones
Mid 2006	Start Upgrade R&D in Canada
2010	Request funds for upgrade construction
2011	Start upgrade construction
2014	Upgrade Installation

Table 2: ATLAS Milestones.

(iv) Plans for ATLAS Physics

The ATLAS Canada group has been very active over the past decade in simulation studies, and this is reflected in our interest in a wide variety of physics topics. The main thrust of the group will certainly be directed at discovery physics in the areas of symmetry breaking and SUSY.

The activities described in the previous section are in a very real sense already physics. However, when collisions start we will be faced with developing our understanding of the calibration and efficiencies of the detectors. The Canadian group will be particularly well placed in the area of calorimetry as we have built, and beam tested the detectors. We also have experience of this commissioning process at the Tevatron experiments. The first step will be to collect "engineering" samples to tune the calibration, measure efficiencies, and tune up the simulation. Even with initial luminosities we will be able to collect large samples of minimum bias, jets at various trigger thresholds, Z and W bosons, and events with photons and jets. The copious production of heavy flavours, even top, will be invaluable. While understanding the detector, the samples will also allow us to make important early measurements of multiplicity distributions, and W and Z production cross sections. Since this is terra incognito, the simplest early measurements will contain interesting physics. Calorimeter based physics has the advantage that we expect the calorimeters to be relatively well understood at a quite early stage. We anticipate being active in early high profile analyses using jets and a missing transverse energy signature. This will give an early insight into exciting areas such as SUSY, or large extra dimensions. The calorimeters will also allow early searches for high mass resonances such as Z' and W', excited leptons, and other exotica.

In order to produce physics from jets plus missing transverse energy, we will need to understand the calibration of the calorimeters in a local and global way. This will be done using minimum-bias events to understand the uniformity of the tower-to-tower response. In order to understand the corrections necessary to get an accurate, unbiased jet energy scale, we will collect very large samples of events with jets. Similarly, in order to understand the electromagnetic scale will will use large samples of events with photons and jets. The transverse energy balance in these events will allow us to cross correlate the hadronic and electromagnetic scales at high energy. The copious production of Zs will allow us to use Z- jet balancing in order to confirm the absolute energy scale. After calibrating the calorimeters we will have to understand the processes which can give fake missing transverse energy signals. These are many, and are basically detector deficiencies such as hot towers, discharges in the read-out chain, holes, and cracks. In addition, there will be the "mundane" backgrounds such as cosmics, and beam halo and beam gas. Members of the group the group already have wide experience of this at the Tevatron, and also in preparatory "detector pathology" studies at ATLAS.

Members of our group have been active in Higgs simulation studies for several years. In fact, two Canadian Ph.D. theses have been written on these studies. In the mass range where the Higgs is "expected" vector boson fusion is a dominant discovery channel. Observing the Higgs in this production process relies on forward jet tagging, the provenance of the HEC and FCAL. Again members of our group have real experience in this are. For example, the is an ongoing search/study at the Tevatron of $H \to WW \to l\nu l\nu$.

We have only given a sketch of the physics we are aiming at. Clearly, as the nature of physics at the TeV scale starts to be revealed, we will respond to these new observations. Table 3 gives an overview of how one might expect the physics output of ATLAS to evolve over the years.

Physics Milestones

(Date Luminosity for Physics is available)
(Discoveries most likely limited by detector understanding)

Mar-08	Calibration Understood Minimum Bias Physics $\sigma_{Tot}, \frac{dN_{ch}}{d\eta}, \frac{dN_{ch}}{dp_T}$
Jul-08	t-quark observation at 300 pb^{-1}
Jun-08	SUSY @ 1.3 TeV
Jul-08	SUSY @ 1.8TeV
Jul-09	Standard Model-like Higgs 115 - 200 GeV
2014	SUSY @ 3 TeV
2016	Higgs Self-Coupling
2017	Compositeness @ 40 TeV scale

Table 3: ATLAS Physics Milestones.

(v) Future ATLAS Upgrades

Given the LHC schedule, ATLAS and CMS could expect to collect $10fb^{-1}$ by early 2008 and, depending on the evolution of the machine, the experiments could each have collected $200-300fb^{-1}$ in five or six years from 2007. Given the long lead time of machine and detector upgrades, the community around the LHC has already started to give some thought to these issues. Two possible options have been discussed for a LHC upgrade. One envisages a higher energy. The LCH can reach $\sqrt{s} = 15\ TeV$ if the present magnets are cooled to give the limiting field of 9 Tesla. One possibility would be to develop 17 tTesla magnets giving $\sqrt{s} = 28\ TeV$. This would be an ambitious undertaking needing much R&D and the expenditure of millions of CHF. A more achievable goal would be a luminosity upgrade. Studies have shown that, with feasible modifications to the machine, a luminosity of $\sim 10^{35} cm^{-2} s^{-1}$ would be achievable. This would necessitate some modifications to the detectors, particularly the calorimeters. Members of the Canadian group are interested in this undertaking, and we foresee starting a modest R&D program later in this decade. At present discussions centre around a change to this SLHC in the time frame of 2012 to 2014, and the subsequent collection of $\sim 3000fb^{-1}$ per experiment in three to four years of data taking. Some of the milestones for upgrading the machine are shown in Table 1, and for the detector on Table 2. Studies have shown that such a machine could be quite competitive with a 0.8 TeV linear collider. These studies are summarized in Table 4.

A luminosity upgrade of the LHC will be challenging to many detector subsystems, the liquid argon calorimeters are no exception. There are essentially two aspects; whether beam heating or whether the increased irradiation will cause problems. We intend to start early R&D on these problems in the time frame of 2007/2008 (see Table 5). Before this

Indicative Physics Reach

Ellis, Gianotti, ADR
hep-ex/0112004+ updates

Units are TeV (except $W_L W_L$ reach)
$\int$ Ldt correspond to 1 year of running at nominal luminosity for 1 experiment

PROCESS	LHC 14TeV 100 fb^{-1}	SLHC 14TeV 1000 fb^{-1}	SLHC 28TeV 100 fb^{-1}	LinCol 0.8 TeV 500 fb^{-1}	LinCol 5 TeV 100 fb^{-1}
Squarks	2.5	3	4	0.4	2.5
$W_L W_L$	2σ	4σ	4.5σ		
Z'	5	6	8	8†	8†
Extra Dim (δ=2)	9	12	15	5 - 8.5†	30 - 55†
q*	6.5	7.5	9.5	0.8	5
Λ_{comp}	30	40	40	100	400
TGC (λ_γ)	0.0014	0.0006	0.0008	0.0004	0.00008

† indirect reach
(from precision measurements)

Approximate mass reach machines:
$\sqrt{s}$ = 14 TeV, L=10^{34} (LHC) : up to ≈ 6.5 TeV
$\sqrt{s}$ = 14 TeV, L=10^{35} (SLHC) : up to ≈ 8 TeV
$\sqrt{s}$ = 28 TeV, L=10^{34} : up to ≈ 10 TeV

Table 4: Comparison of various LHC upgrades and two possible Linear Collider scenarios.

R&D, there is really no conception of how severe the upgrade requirements might be. They could range from minor improvements entailing no mechanical changes, through changes to the end cap cooling and high voltage distribution, to perhaps a major upgrade of the end cap. This major upgrade could even entail a change of the active medium to liquid krypton, or even a gas.

(vi) Role of Canadian Group in ATLAS Management

Our group is extremely active within the ATLAS collaboration. This activity is reflected in our participation in the management and organization of the ATLAS Collaboration at all levels. This participation has been long-standing, dating from the earliest days of the collaboration. For example, during the construction phase of the Hadronic Endcap, C. Oram was first co-convenor, and then convenor of the HEC group.

At the present time, we are represented at the highest level of the collaboration with Oram now deputy chair of the Collaboration Board, and Chair from 2006. In this position, Oram is a member of the ATLAS Executive Board; the highest level decision making body. The formal relationship between the ATLAS Collaboration and the Canadian group is the role of the National Contact Physicist, R. Orr, who also advises NSERC at the Resource Review Board. Members of the group participate in the management of all aspects of our projects - a complete list would be lengthy, and changes with time. For example, we play central roles in the commissioning of the detector; R. McPherson is ATLAS Offline Commissioning Coordinator, P. Krieger is one of the Liquid Argon Phase III Commissioning Coordinators, and S. Chekulaev is Liquid Argon Detector Control Systems Coordinator. Since 2003 R. Teuscher has coordinated the cosmic ray commissioning of the TileCal; this activity will continue in 2006 with the combined commission of the LAr and TileCal. In the vital area of computing, M. Vetterli is a member of the LHC Grid Management Board and M. Losty is ATLAS Computing and Software Planning manager. In the area of our newest projects B. Vachon is co-convenor of the high level trigger missing transverse energy working group. Looking to the future, M. Vincter is Chair of the ATLAS Publications Committee.

(vii) Operating Funds

The ATLAS Canada group has been, to date, well-funded by NSERC. The capital funds awarded since 1998 have allowed us to participate in the construction of ATLAS at a level matched to our abilities and aspirations. In addition to these capital funds, NSERC has allocated funds to cover the Common Fund, membership payments, and the cost to completion. The operating component has also allowed us to maintain our presence at CERN, and steadily increase the number of Research Associates and students. The funding over the past three years is shown in Table 5. Also in this table we show how we would hope that the operating budget increase over the next ten years. As we have pointed out, this will most likely be an epoch making period in high energy particle physics. We feel that it is vital to have sufficient people based both in the home institutes and at CERN, so that we can fully participate in this exciting period for our subject. The operating budget in Table 5 has been produced in the same bottom-up fashion that we develop the budgets in our grant requests to NSERC. It covers fully the travel and salaries of the group; but very little in the way of equipment. It also includes the substantial increase in the maintenance and operating payments to CERN. These payments will constitute around 30 % of the operating budget by 2007, and account for a large proportion of the increase in the budget. This table shows Common Fund, Cost to Completion, and Membership in the period 2006 to 2009 for which NSERC has already committed funds in the form of three RTI grants. We also show proposed capital expenditure on the High Level Trigger system. This is discussed in more detail in the section on new projects.

As we have discussed in a previous section, it is likely that the LHC will undergo a luminosity upgrade leading to high luminosity running around the middle of the next decade. The ATLAS Canada group will certainly be a part of this activity. The exact form of our R&D plans are at a very early stage, and there is little idea on what we will have to construct. Nonetheless, we would hope that our participation would be at a level comparable to our initial construction projects. The table reflects this.

(viii) Personnel

The number of faculty members active in ATLAS Canada has grown steadily over the years. As we enter the era of TeV scale physics, we anticipate that the FTE count will continue to increase. We expect that the major component of this increase will be due to faculty members increasingly moving their focus from, for example, TeVatron physics to the LHC. This demographic shift is reflected in Table 6. This table also tries to take account of new positions opening up in the next ten years. The table does not try to accurately reflect retirements in this period. We have taken the optimistic view that retiring members of our group will be replace by new faculty members at the universities concerned.

During the period of the development and construction of our detector components, ATLAS Canada has played a major educational and training role. In a typical recent year we hade 20 undergraduate summer students, 31 graduate students, and 13 Research Associates. Over the past decade we have also had many technicians and engineers pass through the group. To show the magnitude of this educational role we list in Table 7, 8 all non-faculty who have been associated with the project since the the award of the initial MIG in 1997. We fully expect this educational role to increase as we start to see the exciting physics from ATLAS.

ATLAS Canada k$	Year 1 2003-04	Year 2 2004-05	Year 3 2005-06	Year 1 2006-07	Year 2 2007-08	Year 3 2008-09	Year 4 2009-10	Year 5 2010-11	Year 6 2011-12	Year 7 2012-13	Year 8 2013-14	Year 9 2014-15	Year 10 2015-16
Operating Costs	1,926	2,059	2,200	2,600	4,500	5,500	6,400	6,200	6,200	6,300	6,300	6,300	6,300
Common Fund	170	170	170	170	170	170							
Cost to Completion			750	375	375								
Membership	87	87	87	94									
High Level Trigger					500	1,000							
Upgrade R&D					200	200	200	200					
Upgrade Construction							200	1,000	2,500	4,000	4,000	1,000	
Capital Total k$	257	257	1,007	639	1,245	1,370	400	1,200	2,500	4,000	4,000	1,000	0
ATLAS Canada Total k$	2,183	2,316	3,207	3,239	5,745	6,870	6,800	7,400	8,700	10,300	10,300	7,300	6,300

Table 5: ATLAS Canada Projected Budget (K$)

	ATLAS FTE PROFILE												
		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
A. Astbury	Victoria	1.00	1.00	1.00	1.00	0.50	0.50	0.50					
D. Asner	Carleton	0.20	0.60	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
D. Axen	UBC	1.00	1.00	1.00	1.00	0.50	0.50	0.50					
G. Azuelos	Montreal	0.75	0.75	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
D. Bailey	Toronto	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S. Bhadra	York	0.10	0.10	0.20	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
M. Dobbs	McGill			0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
F. Corriveau	McGill		0.10	0.10	0.20	0.30	0.40	0.50	0.50	0.50	0.50	0.50	0.50
G. Couture	Montreal/UQAM	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
D. Gingrich	Alberta/TRIUMF	0.75	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Keeler	Victoria	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Kowalewski	Victoria	0.10	0.20	0.40	0.60	0.70	0.80	1.00	1.00	1.00	1.00	1.00	1.00
P. Krieger	Toronto/IPP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
L. Kurchaninov	TRIUMF		0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.80	1.00	1.00	1.00
M. Lefebvre	Victoria	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C. Leroy	Montreal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M. Losty	TRIUMF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			
J.-P. Martin	Montreal	0.30	0.30	0.50	0.50	0.50	0.50	0.50	0.50	0.50			
R. Moore	Alberta	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. McPherson	Victoria/IPP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
G. Oakham	Carleton	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
D. O'Neil	Simon Fraser	0.25	0.50	0.75	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C. Oram	TRIUMF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Orr	Toronto	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
J. Pinfold	Alberta	0.65	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S. Robertson	McGill/IPP	0.20	0.50	0.70	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P. Savard	Toronto/TRIUMF	0.20	0.60	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
P. Sinervo	Toronto	0.30	0.40	0.50	0.50	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Sobie	Victoria/IPP	0.50	0.50	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Tafirout	TRIUMF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W. Taylor	York	0.10	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R. Teuscher	IPP/Toronto		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
I. Trigger	TRIUMF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
W. Trischuk	Toronto	0.50	0.50	0.75	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
B. Vachon	McGill	0.40	0.60	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M. Vetterli	Simon Fraser/TRIUMF	0.75	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
M. Vincter	Carleton	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
A. Warburton	McGill	0.10	0.20	0.40	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TBA				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TBA					1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TBA						1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TBA							1.00	1.00	1.00	1.00	1.00	1.00	1.00
TBA							1.00	1.00	1.00	1.00	1.00	1.00	1.00
TOTAL		**21.70**	**25.75**	**30.20**	**33.35**	**35.40**	**38.00**	**38.30**	**37.30**	**37.90**	**36.60**	**36.60**	**36.60**

Table 6: ATLAS Canada FTE profile.

A Name	B Type of HQP Training and Status	C Years or	D Title of Project or Thesis	E Present Position
Alberta				
Ahmed, Hossain	Doctoral (in progress)	2005 -	ATLAS	Graduate Student, Physics, University of Alberta
Ali, Mohamed	Summer Student	2004	ATLAS	Undergraduate, University of Alberta
Archambault, John Paul	Doctoral (transferred)	2004 -	ATLAS	PhD Student, Carleton University
Braden, Jonathan	Summer Student	2004, 2005	ATLAS	Undergraduate, University of Alberta
Buchanan, Norm	Doctoral (completed)	1999 - 2003	Radiation Qualification of the ATLAS SCAC	Postdoctoral Research Associate, South Florida University
Buchanan, Norm	Master's (completed)	1996 - 1998	Study of a Readout System for a LAr Calorimeter at ATLAS	Postdoctoral Research Associate, Florida State University
Buchanan, Norm	Summer Student	1996	ATLAS	Postdoctoral Research Associate, Florida State University
Caron, Bryan	Doctoral (in progress)	1995 -	ATLAS	Graduate Student / Faculty Service Officer, Physics, University of
Chen, Li	Doctoral, Electrical Engineering (completed)	2000 - 2004	Radiation Tolerant Design with 0.18-micro CMOS Technology	Assistant Professor, School of Mines and Technology, South Dakota
Clark, Heather	Summer Student	2004	ATLAS	Undergraduate, University of Alberta
Cojocaru, Claudiu	Doctoral (transferred)	2002 -	Radiation of Electronics Using An X-Ray Accelerator	Graduate Student, Carleton University
Cojocaru, Claudiu	Master's (completed)	2001 - 2002	Radiation of Electronics Using An X-Ray Accelerator	Graduate Student, Carleton University
De Jong, Jeff	Doctoral (in progress)	1998 -	ATLAS	Graduate Student, University of Alberta
Dowler, W. Blaine	Master's (completed)	1999 - 2003	ATLAS	Education
Gish, Douglas	Summer Student	2002, 2003, 2004	ATLAS	Graduate Student, Engineering, University of Alberta
Gish, Treena	Summer Student	2004	ATLAS	
Ho, Thanh	Assistant Machinist	2001-2002	ATLAS machining	
Hunter, Brian	Summer Student	1996	ATLAS	
Ing, Joanne	Undergraduate	2004	ATLAS	
Kayal, Philip	Master's (completed)	1994 - 1996	ATLAS	Director, Refractions Research Inc., Victoria, B.C.
Kayal, Philip	Summer Student	1994	ATLAS	Director, Refractions Research Inc., Victoria, B.C.
Kwan, Alex	Summer Student	1993, 1994	ATLAS	Graduate Student, Medical Physics, University of Alberta
Laroque, Matt	Undergraduate (completed)	2004	ATLAS	Graduate Student, Medical Physics, University of Alberta
Leung, Kaston	Master's, Electrical Engineering (completed)	2003-2005	Effect of Radiation on IDDQ Testing for DSM Devices	
Liu, Shengli	Postdoctoral (completed)	2001 - 2004	ATLAS	High Tech Industry at Chalk River
Lu, Jiansen	Postdoctoral (in progress)	2004 -	ATLAS	Research Associate, University of Alberta
MacDonald, Dawn	Master's (not completed)	1997 - 1999	Calibration of the HEC Using Top Quark Delays	
MacPherson, Alick	Postdoctoral (completed)	1996 - 2000	ATLAS	Staff Scientist, Paul Sherrer Institute, Switzerland
MacQueen, Daniel	Master's (completed)	1997 - 2000	Total Ionizing Dose Effects on Xilinx FPGAs	Graduate Student, Physics, University of Toronto
MacQueen, Daniel	Summer Student	1997	ATLAS	Graduate Student, Physics, University of Toronto
Martin, Travis	Summer Student	2004	ATLAS	Undergraduate, Engineering Physics, University of Alberta
Merritt, Deven	Summer Student	2004	ATLAS	
Murphy, Aaron	Undergraduate (completed)	1998 - 1998	ATLAS	
Ngo, Thanh	Assistant Machinist	2001-2002	ATLAS machining	
O'Neil, Dugan	Master's (completed)	1994 - 1996	Calorimeter Optimization and Heavy Higgs Reconstruction in ATLAS	Assistant Professor, Simon Fraser Unviersity
Parlin, David	Assistant Machinist	2002-2004	ATLAS machining	
Pasay, Eric	Summer Student	1998, 1999, 2000	ATLAS	
Reil, Kevin	Summer Student	1997	ATLAS	Graduate Student, Physics, University of Utah
Sibley, Logan	Master's (in progress)	2005 -	ATLAS	Graduate Student, Physics, University of Alberta
Sibley, Logan	Summer Student	2005	ATLAS	Graduate Student, University of Alberta
Soluk, Richard	Postdoctoral (in progress)	2001 -	ATLAS	Research Associate, University of Alberta
Springer, Wayne	Master's (completed)	1994 - 1997	ATLAS	Assistant Professor, University of Utah
Steeves, Kory	Undergraduate (completed)	2001 - 2001	ATLAS	PhD Student, University of Alberta
Swedish, Stephen	Summer Student	2004, 2005	ATLAS	Undergraduate, University of Alberta
Syed, Wasif	Undergraduate (completed)	2002 - 2002	ATLAS	PhD Student, Physics, Cornell University
Ting, Wei-yuan	Doctoral (in progress)	2002 -	ATLAS	Graduate Student, Physics, University of Alberta
Tomasevic, Boris	Assistant Machinist	1999 -	ATLAS	Senior Assistant Machinist, University of Alberta
Tran, C	Summer Student	1994	ATLAS	
Wheeler, Sarah	Postdoctoral (completed)	2001 - 2004	ATLAS	Research Associate, University of Alberta
Yao, Yushu	Master's (in progress)	2002 -	ATLAS	Graduate Student, Physics, University of Alberta
Zemp, Roger	Summer Student	1997	ATLAS	
Zhang, Bo	Postdoctoral (completed)	2001-2002	ATLAS	Enkikia LCC, New Jersey
Carleton				
Heelan, Louise	Doctoral (in progress)	2005 -	ATLAS project	Carleton U.
Schram, Malachi	Doctoral (in progress)	2002 -	The ATLAS experiment	Carleton U.
Strickland, Vance	Engineer (in progess)	2001 -	Instrumentation for Particle Physics	TRIUMF/Carleton
Jack, Bill	Computer Supp. (in progess)	2000 -	Computer support for HEP	Carleton U.
Dowler, Blaine	MSc(completed)	1999-2003	ATLAS HEC Beam test	School Teacher
Khakzad, Mohsen	now: School Teacher	2000 -	The ATLAS detector	Carleton U.
Gravelle, Philippe	Technician (in progess)	1995 -	Instrumentation in Particle Physics	Carleton U.
Jasper, Blair	Undergraduate (completed)	2005 - 2005	ATLAS project	U grad at Manitoba
Neuheimer, Ernie	Electronics Spec (completed)	1998 - 2005	Instrumentation for Particle Physics	Carleton U.
Lee, Lik Hang	Undergraduate (completed)	2004 - 2004	ATLAS FCAL Beam Test	Undergraduate student in Canada
Inrig, Elizabeth	Undergraduate (completed)	2003 - 2003	ATLAS FCAL Beam Test	Undergraduate student in Canada
Hortop, Frank	Designer (completed)	2002 - 2002	Instrumentation for Particle Physics	High Tech Industry in Ottawa
Rankin, Alasdair	Undergraduate (completed)	2002 - 2002	ATLAS FCAL module construction	Undergraduate
Belanger, Guillaume	Master's (completed)	2000 - 2002	The Atlas Forward Calorimeter	Ph.D. Program in Astro Physics
Middleton, Alex	Undergraduate (completed)	2001 - 2001	ATLAS FCAL module construction	Undergraduate
Krieger, Peter	Postdoctoral (completed)	1999 - 2001	The ATLAS detector	Research Scientist in Canada
O'Neill, Morley	Engineer (completed)	1995 - 2000	Instrumentation for Particle Physics	Breconridge Manufacturing Solutions
McGill				
Ouraoui, Dalila	Undergraduate (completed)	Supervised summer 2005	The ATLAS experiment	Undergraduate in France
Rheaume, Pascal	Doctoral (in progress)	Supervised 2005-	The ATLAS experiment	McGill University
Montreal				
Celine Lebel	MSc (completed)	Supervised 2000-2002	Radiation studies ATLAS	Univ Montreal
Celine Lebel	Doctoral (in progress)	Supervised 2002-	Radiation studies Pixel ATLAS	Univ Montreal
Marie-Helene Genest	MSc (completed)	Supervised 2001-2002	ATLAS Phyiscs Studies	Univ Montreal
Marie-Helene Genest	Doctoral (in progress)	Supervised 2003 -	ATLAS Phyiscs Studies	Univ Montreal
Rashid Mazini	Doctoral(completed)	Supervised 2001 -	ATLAS Phyiscs Studies	Univ Toronto
P.-H. Beauchemin	Doctoral(completed)	Supervised 2000-	ATLAS Phyiscs Studies	Univ Toronto
Sebastien Charron	MSc (in progess)	Supervised 2004 -	Radiation studies Pixel ATLAS	Univ Montreal
Jonathan Ferland	MSc (completed)	Supervised 2000 -	ATLAS Phyiscs Studies	Univ Montreal
Jonathan Ferland	Doctoral (in progess)	Supervised 2005 -	ATLAS Phyiscs Studies	Univ Montreal
John Idarraga	MSc (in progess)	Supervised 2004-	ATLAS Phyiscs Studies	Univ Montreal
Elena Leon Florian	Doctoral(completed)	Supervised(1996-2001)	Radiation studies LAr ATLAS	Medical Field New York
Rachid Mehdiyev	Postdoctoral (in progress)	Supervised 1999-	ATLAS Phyiscs Studies	Univ Montreal
Pierre-Antoine Delsart	Postdoctoral (in progress)	Supervised 2003-	ATLAS Phyiscs Studies	Univ Montreal
Kamal Benslama	Postdoctoral (completed)	Supervised 2001-2002	ATLAS Phyiscs Studies	Columbia Univ. USA
Gaiane Karapetian	Postdoctoral (completed)	Co-Supervised 1998-2003	Software ATLAS	Prof. College Montreal
Bertrand Brelier	Doctoral (in progess)	Supervised 2005 -	ATLAS Phyiscs Studies	Univ Montreal
Marie-Noelle Seguin	Summer Student	Supervised (2005)	Radiation studies Pixel ATLAS	Cegep Bois-de-Boulogne Montreal
Aldee Charbonnier	Summer Student	Supervised (2005)	Radiation studies Pixel ATLAS	Ecole Polytechnique Montreal
Myriam Gosselin	Summer Student	Supervised (2004)	Radiation studies Pixel ATLAS	Univ Montreal
Sebastien Charron	Summer Student	Supervised (2003)	Radiation studies Pixel ATLAS	Univ Montreal
Tristan Carrier	Summer Student	Supervised (2003)	Radiation studies Pixel ATLAS	Univ Montreal
Marie-Elisabeth Sicard	Summer Student	Supervised (2002)	Radiation studies Pixel ATLAS	Univ Montreal
Philippe Hamel	Summer Student	Supervised (2002)	Radiation studies Pixel ATLAS	Univ Montreal
Karine Jean-Louis	Summer Student	Supervised (2001)	Radiation studies LAr ATLAS	Medical
SFU				
Walker, Rod	Postdoctoral Fellow	2003-	ATLAS Computing	
Bieri, Marco	Master's (in progress)	2003-	Tests of the ATLAS End-Cap Calorimeters	
Schouten, Doug	Master's (in progress)	2004-	Response of the ATLAS Calorimeters	
Rezaie, Erfan	Master's (in progress)	2005-	TBD	
Stewart, Travis	Master's	2006-	TBD	
Aikema, David	Undergraduate	2003-2004	ATLAS Computing	
Costin, Tudor	Undergraduate	2004	ATLAS Computing	

Table 7: ATLAS Canada Training of Highly Qualified Personnel.

A	B	C	D	E
Toronto				
Mayer, John	Postdoctoral	1993 - 1998	ATLAS FCAL	Data Processing Manager - Apotex, Toronto
Gorbounov, Petr	Postdoctoral	2003 -	ATLAS FCAL & Commissioning	
Mazini, Rachid	Postdoctoral	2003 -	ATLAS Software & Physics	
Le Manier, Christophe	Postdoctoral	2005 -	ATLAS Commissioning & Physics	
Joo, Kwang Kung	Postdoctoral	2000-2002	ATLAS FCAL	Korea National University
Khakzad, Mohsen	Postdoctoral	2000 -	ATLAS FCAL	Carleton U. Scientist
Groer, Lesie	HEP Computer Support	2004 -	HEP Linux Cluster	
Stairs, Gavin	Engineer	1993 - 1999	FCAL Engineering	
Cadabechi, Mircea	Engineer	2000 -	FCAL Engineering	
Vincent, Kenneth	Technologist	1998 -	FCAL Engineering	
Coley, Keith	Designer	2001 - 2004	FCAL Design	
McLean, Kenneth	Computing Support	2000- 2002	HEP Linux Cluster	Deceased
Li, Jay	Computing Support	2004 - 2005	HEP Linux Cluster	U. of Toronto Network Services
Martens, Kalen	Ph.D. (continuing)	2000 -	Simulation of non-SM CP violation in ATLAS	
MacTavish, Carolyn	M.Sc. (complete)	1999 - 2000	Analysis of ATLAS FCAL Test Beam Data	Grad Student at UofT
Atamer, Alan	summer student	1999 - 2000	FCAL	Grad Studet at MIT
Kamnitzer, Joel	summer student	1998	FCAL Test Beam	
Ashby, Robert	summer student	2000 2001	FCAL	
Glen, David	summer student	2000	FCAL	
Woodley, John	summer student	2000	FCAL	
Laforet, Martin	Summer Student	2001	FCAL	
Li, Tim	Summer Student	2002	FCAL	
Hinks, Adam	Summer Student	2003	FCAL	Grad Student Princeton
Hamidian, Mohammed	Summer Student	2003	FCAL	Fgrad Student Caltech
Groszkowski, Petr	Summer Student	2003	FCAL	
Quiggly, Callum	Summer Student	2003	FCAL	Grad Student UBC
Cheung, Manjin	Summer Student	2004	FCAL	UG at Toronto
Dumoulin, Robert	Summer Student	2004	FCAL Test Beam	Grad Student Stanford
Sung, Kevin	Summer Student	2005	FCAL Test Beam	UG at Toronto
Dhaliwahl, Saminder	Summer Student	2005	ATLAS Data Simulation	UG at Toronto
Sidhu, Jaspreet	Summer Student	2005	ATLAS Data Simulation	UG at Toronto
Higgins, Carmen	Technician	2003	FCAL Assembly	
Bolen, Ryan	Technician	2003	FCAL Assembly	
Toth, Paul	Technician	2003	FCAL Assembly	
Fong, Mea Li	Technician	2003	FCAL Assembly	
Solomons, Harlod	Technician	2002 - 2004	FCAL Assembly	
Makram George	Technician	2002 - 2004	FCAL Assembly	
Bakos, Akos	undergraduate	2001 - 2004	FCAL Assembly	UG at Toronto
Christie, Doug	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Guler, Metin	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Hussain, Asif	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Mohammed, Greg	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Zayyani, Shariar	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Satar, Sakila	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Sunday, William	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Iskander, Samir	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
Kavitz, Markus	undergraduate	2002 - 2004	FCAL Assembly	UG at Toronto
TRIUMF				
Hans-Peter Wellisch	Postdoctoral (completed)	Supervised 1995 - 1997	ATLAS Project & GEANT4	CERN Staff Member (?)
Myron Rosvick	Postdoctoral (completed)	Supervised 1997 - 1998	ATLAS Project	Computing Professional, EOptimise
Monika Weilers	Postdoctoral (completed)	Supervised 1998 - 2003	ATLAS Project	Research Scientist, Rutherford Lab, UK
Keith Hoyle	Technician (completed)	Supervised 1995 - 2003	Instrumentation in Particle Physics	TRIUMF
Ed Pattyn	Technician (completed)	Supervised 1995 - 2003	Instrumentation in Particle Physics	TRIUMF
Rick Maharaj	Technician (completed)	Supervised 1995 - 2003	Instrumentation in Particle Physics	TRIUMF
Tatiana Sytchougova	Technician (completed)	Supervised 1999 - 2003	Assembly of Instruments	TRIUMF
Valerey Stan	Technician (completed)	Supervised 1999 - 2003	Assembly of Instruments	TRIUMF
Cris Baartsch	Technician (completed)	Supervised 2000 - 2003	Assembly of Instruments	Team Leader, Tree Planter
Mike Thompson	Technician (completed)	Supervised 2000 - 2003	Assembly of Instruments	Self Employed, Computer Disk Recovery
Denice Deatrich	Computer Scientist (in progress)	Supervised 2004 -	GRID Project	TRIUMF
Roy Langstaff	Engineer (In progress)	Supervised 1994 -	Design, Construction, and Installation of HEC	TRIUMF/Victoria
Doug Schouten	Summer Student	Supervised Summer 2004	ATLAS Computing	Graduate Student SFU
Victoria				
Seuster, Rolf	Postdoctoral (continuing)	2005 -	ATLAS Calorimetry and Physics	Victoria
Voss, Kai	Postdoctoral (continuing)	2005 -	ATLAS Calorimetry and Physics	Victoria
Weilers, Monika	Postdoctoral (completed)	2003 - 2004	ATLAS Calorimetry and Software	RAL - UK - tenure track
Kanaya, Naoko	Postdoctoral (completed)	2000 - 2003	ATLAS Calorimetry and Software	RA at Kobe U. on ATLAS
Sbarra, Carla	Postdoctoral (completed)	1999 - 2001	ATLAS Calorimetry	Tenured Scientist at C.N.R. Bologna - Astrophysics
Poffenberger, Paul	RA (continuing)	1998 - 2004	ATLAS Endcap Feedthrough Project	Victoria
Fincke-Keeler, Margret	RA (continuing)	1996 -	The ATLAS Detector	Victoria
Ince, Tayfun	Ph.D. (continuing)	2005 -	ATLAS Physics Studies	Victoria
Dobbs, Matt	Ph.D. (completed)	1999 - 2002	ATLAS Physics Studies	CRC Tier-II appointment at McGill
Vanderster, Daniel	Ph.D. (continuing)	2003 -	GRID Software	Ph.D. Elec and Comp. Eng. / Physics at Victoria
O'Neil, Dugan	Ph.D. (completed)	1996 - 1999	ATLAS Calorimetry and Physics	SFU - Asst Prof - Physics
Choi, Herve	M.Sc. (continuing)	2005 -	ATLAS Physics Studies	Victoria
Edmonds, Keith	M.Sc. (continuing)	2005 -	ATLAS Physics Studies	Victoria
Shaw, Warren	M.Sc. (continuing)	2003 -	ATLAS Calorimetry	Victoria
Ince, Tayfun	M.Sc. (completed)	2002 - 2005	ATLAS Calorimetry	Victoria
Starke, Tamara	M.Sc. (completed)	2002 - 2005	ATLAS Calorimetry	
Fortin, Dominique	M.Sc. (completed)	1997 - 2000	ATLAS Calorimetry	RA at UC Riverside
Bishop, Shawn	M.Sc. (completed)	1995 - 1998	ATLAS Calorimetry	RA at RIKEN, Japan
Robertson, Steve	M.Sc. (completed)	1992 - 1994	ATLAS Calorimetry	IPP Scientist, McGill
White, John	M.Sc. (completed)	1991 - 1993	ATLAS Calorimetry	Research Scientist, Helsinki Institute of Physics
Hodges, Terry	TRIUMF Senior Engineer	1996 - 2003	The ATLAS Detector	
Langstaff, Roy	TRIUMF Senior Designer	1996 - 2005	The ATLAS Detector	TRIUMF staff at Victoria
Lenckowski, Mark	TRIUMF Senior Technologist	1996 - 2002	ATLAS Endcap Feedthrough Project	TRIUMF staff at Victoria
Birney, Paul	TRIUMF Senior Technologist	1996 - 2003	ATLAS Endcap Feedthrough Project	TRIUMF staff at Victoria
Dowling, Alisa	Research Technician	1998	ATLAS Endcap Feedthrough Project	TRIUMF Staff at Victoria
Dowling, Aaron	Technologist	1998 - 2002	ATLAS Endcap Feedthrough Project	Project Manager, George Street Steel, Australia
Vowles, Greg	Technologist	1998 - 2002	ATLAS Endcap Feedthrough Project	Staff, U of Toronto Physics Department
Holness, Fiona	Technologist	2001 - 2003	ATLAS Endcap Feedthrough Project	BCIT training, Vancouver
Rensing, Michael	Computer Analyst	1997 - 2000		Industry
Van Uytven, Jan	Computer Analyst	1999 - 2004		Industry
Agarwal, Ashok	Computer Analyst (continuing)	2001 -		Victoria
Enge, Ryan	Computer Analyst	2004 - 2005		Staff at the U. of Victoria
Peng, Howard	Computer Analyst (continuing)	2005 -		Victoria
Groulx, Sarah	Co-op / summer student	summer 1998	The ATLAS Detector	
MacDonald, Rob	Co-op / summer student	summer 1999	The ATLAS Detector	
Lindner, John	Co-op / summer student	fall 2000 and spring 2001	The ATLAS Detector	
McDonald, Robbie	Co-op / summer student	summer 2000	The ATLAS Detector	
Girard, Guillaume	Co-op / summer student	summer 2001	The ATLAS Detector	
Muzzeral, Erica	Co-op / summer student	summer 2001	The ATLAS Detector	
Gable, Ian	Co-op / summer student	summer 2002 and 2003	The ATLAS Detector	
Smecher, Graeme	Eng. / Physics Co-op	spring 2002	GRID Development	
Wiggins, Wendy	Co-op / summer student	spring and summer 2002	The ATLAS Detector	
Zwiers, Ian	Eng. / Physics Co-op	summer 2002	GRID Development	
Allan, Jennifer	Eng. / Physics Co-op	spring 2003	GRID Development	
Benning, Manj	Eng. / Physics Co-op	spring 2003	GRID Development	
Klektau, Lila	Eng. / Physics Co-op	summer 2003	GRID Development	
Quinn, Matthews	Eng. / Physics Co-op	spring 2004	GRID Development	
Lindsay, Clayton	Eng. / Physics Co-op	fall 2004	GRID Development	
Dimopoulos, Alex	Eng. / Physics Co-op	summer 2004	GRID Development	
Yuen, Marco	Eng. / Physics Co-op	spring 2005	GRID Development	
Desmarais, Ron	Eng. / Physics Co-op	summer 2005	GRID Development	
Cox, Graham	Co-op / summer student	summer 2005	The ATLAS Detector	
Norton, Angela	Eng. / Physics Co-op	fall 2005	GRID Development	

Table 8: ATLAS Canada Training of Highly Qualified Personnel.

(ix) New Projects

In addition to the completed projects in the area of calorimetry, the group is participating in two newer projects.

(a) The High Level Trigger

At the LHC, proton bunches will cross at a frequency of 40 MHz and approximately 23 interactions per crossing will occur at the design luminosity of $1 \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The trigger system is designed to cope with the unprecedented large collision rate that will take place in the ATLAS detector. It must provide an efficient, flexible, robust and unbiased selection of different types of events. As a crucial component of the ATLAS experiment it needs to be completed and fully operational for first collisions in 2007.

In order to achieve these challenging goals, the ATLAS trigger was designed as a three-tiered system that makes use of data buffering and parallel processing techniques. The Level 1 sub-system is implemented in custom hardware components and designed to reduce the 40 MHz input rate to about 75 kHz based on information from the calorimeter and muon detectors. The Level 2 and Event Filter are collectively referred as the High Level Trigger. They share a similar framework and hardware implementation in off-the-shelf commodity computers, and differ mostly in their input data and the complexity of algorithms. While the Event Filter has access to the entire event information, the Level 2 is largely limited to analysing specific regions of interest in the detector identified by the Level 1. The Level 2 and Event Filter will reduce the Level 1 input rate to approximately 2 kHz and 100 Hz, respectively.

The ATLAS Canada group has been involved in the development and implementation of the High Level Trigger since 2001. New members of ATLAS Canada have recently joined the existing efforts to further consolidate the Canadian contributions to the High Level Trigger. Contributions to the High Level Trigger have been made in the areas of physics studies and technical development of the system. Among the technical developments have been early work on hardware implementation, a prototype system for the combined beam test, and tests of remote filtering.

From a physics point of view, Canadians have led the efforts in the development of trigger algorithms designed to identify jets, tau leptons, missing transverse energy, electrons and photons. A large fraction of this work culminated in direct contributions to the Technical Design Report of the ATLAS High Level Trigger. Many new collaborators who recently joined ATLAS Canada are active members of the two Tevatron experiments and therefore have significant experience in hadron collider physics and aspects of triggering in this unique physics environment. New members of the group are pursuing and consolidating previous involvements in physics algorithms development, particularly in the areas of jets and tau leptons.

Contributions to the High Level Trigger from members of ATLAS Canada are expected to increase proportionally with the anticipated growth of our group over the next 5 years. Due to limited resources, the current trigger installation plan calls for the purchase and installation of a scaled down trigger infrastructure in 2007 for first beam. A Canadian hardware contribution could provide a significant increase in available computing resources and have a direct impact on the physics reach of the experiment as a whole.

(b) ATLAS Beam Conditions Monitor

Since 2004 members of ATLAS-Canada have been involved in the development and installation of the ATLAS beam loss monitors and beam abort system. This work built on our long-standing involvement in radiation hardness studies of ATLAS components and more recently our studies of the radioactive activation of the pixel detector as it relates to access and repair scenarios. The LHC has its own beam loss monitors that will trigger an abort if there is a failure in the accelerator system. However, these do not cover every possible situation. In particular, beam losses that could be very harmful to the ATLAS inner detector may not be fully protected against. With our background in radiation hardness studies and radiation hard sensor materials we have begun to investigate the use of Chemical Vapour Deposited (CVD) diamond sensor material for beam loss monitoring applications. These sensors have several advantages: they can be made small, they have a fast response and most importantly, they are radiation hard, exhibiting little or no leakage current even after 10 years LHC equivalent radiation dose, so they will allow us to make a robust distinction between actual beam losses and detector noise. A further advantage of CVD diamond sensors as radiation monitors is their fast response, allowing them to trigger a beam abort quickly in case of excessive beam losses.

The Canadian group has produced the mechanical design that supports a set of eight BCM detector assemblies – four each in the forward and backward regions of ATLAS. We have also provided half of the CVD diamond sensors. The modules are being assembled and tested. The BCM will provide an adequate set of measurements to characterise the beam losses in the ATLAS tracking volume and make well informed decisions about whether it is necessary to abort the beam to protect the tracking detectors.

(x) Resources Contributed by Institutes.

The ATLAS Canada collaborating institutions have shown their support for this science by making substantial contributions beyond the NSERC awards. The support from TRIUMF has been very substantial. The HEC and feedthrough design and development has been carried out by two engineers on the TRIUMF payroll. TRIUMF also contributed a third full time engineer to perform FEA studies of the FCAL. Engineering support is expensive and in short supply in ATLAS. These contributions from TRIUMF have had an enormous impact on our ability to accept responsibility for these projects.

The production of the HEC modules has relied heavily on TRIUMF infrastructure, as was foreseen in the initial NSERC award. Two clean rooms were refurbished for the project, and personnel has been supplied in terms of manual labour, and technicians. In addition, the laboratory has supported the project through the salaries of two research associates.

For the feedthrough project, the University of Victoria has supplied the necessary space, and subsidized machine shop time. Alberta made a major contribution to the HEC by entering into an agreement with TRIUMF, and ATLAS Canada, to finance the purchase of a large NC milling machine, and also to provide manpower to operate it. This $1 million machine is installed in the Centre for Subatomic Research at Alberta. ATLAS Canada received an extremely advantageous hourly rate to produce all the copper plates for the HEC modules; and the machine reverted to the ownership of Alberta at the end of the project. The Alberta group also used about 70% of their MFA funded manpower on this project.

Both Toronto and Carleton have contributed substantially to the FCAL project. Toronto paid for the construction of a complete clean room and assembly area for FCAL construction, and also provided a full time machinist from the Department of Physics, at a subsidized hourly rate. Again some 75% of the MFA funded manpower at Toronto was devoted to this project. In Carleton, the SNO cleanroom and assembly facility was made available to the FCAL project. CRPP provided substantial support in terms of one engineer, a draftsman, and a technician.

(xi) Future Role of TRIUMF

The past participation of TRIUMF in the ATLAS collaboration has been crucial for the successful execution of the MIG projects. With the completion of the HEC and feedthrough projects, TRIUMF's role has changed into that of the Tier-I computing facility for Canada. There have already been two new hires associated with this role. The ATLAS Canada group hopes that TRIUMF will not concentrate solely on computing support, but that it will develop an active physics group. We enlarge on this role of TRIUMF in the next section. In the longer term future, it seems clear that construction related to the LHC luminosity upgrade will depend on TRIUMF resources, just as the HEC and feedthrough projects did.

(xii) Physics Analysis and Computing

In order to fully participate in the process of extracting physics from the ATLAS data, the Canadian group is in the process of assembling the necessary computing resources. This is a formidable task, and its success is, in a large measure, dependant upon TRIUMF.

ATLAS will collect a few Pbytes of data per year. Reconstructing this data, and storing the reconstructed data, is beyond the resources even of CERN. This has driven the ATLAS collaboration to adopt a completely new paradigm to satisfy its computing needs. The computing model is based on a logical layered, or tier, structure. This is a world wide network implementing a staged analysis model and utilizes the grid concept to realize this structure. The tier structure comprises a tier-0 facility at CERN, eleven tier-1 centres in the major geographical regions, and an as yet undetermined number of tier-2 centres which serve groups of ATLAS institutes throughout the world.

The tier-0 centre at CERN will be the major centre for the reduction of the raw data. Between 2006 and 2010 its processing resources will increase from 2400 kSI2K to 26200 kSI2K. The storage resources will undergo a similar development, with disk reaching 1800 TBytes in 2010 and tape 3390 TBytes. The result of processing at the tier-0 centre are the Event Summary Data (ESD). The tier-1 centres range from being comparable to the tier-0 (UK and USA) to being around an order of magnitude smaller (Canada, Nordic countries, Taiwan). The role of the tier-1 centres is to store copies of the raw data in a distributed fashion, to store Monte Carlo data, and to perform the second pass analysis resulting in the Analysis Object Data (AOD). Finally the regional tier-2 sites run Monte Carlo simulation, and store and make available the AODs to the regional physics analysis groups.

The Canadian group has taken the approach that its physics analysis efforts should not depend on a tier-1 centre in another country, so we have directed our efforts towards the realization of a Canadian tier-1 centre. In addition to being the site of very substantial computing and storage resources, a tier-1 centre is required to provide round the clock service, with minimal down time. The tier-1 centres also act as a distributed repository for the raw data. Given these major responsibilities, the Canadian national laboratory, TRIUMF, seems the natural location for the Canadian tier-1. A tier-1 computer centre formed part of the proposal for the current TRIUMF five year plan. Unfortunately, the budget allocated by Cabinet was not sufficient to fully fund the tier-1 centre at TRIUMF. Nonetheless, TRIUMF management has devoted funds to make a start on the development of the tier-1 centre. The full funding is the subject of a request to the Canada Foundation for Innovation, which is supported by all the ATLAS universities.

As we have described, during the planning and construction of ATLAS, TRIUMF has played a major part in realizing the plans of the Canadian group. It seems natural to us that the national laboratory should not only provide computing infrastructure in the future, but that it should also be an intellectual centre for actually doing physics at ATLAS. To this end, the ATLAS Canada group has urged TRIUMF management to support an active, high quality, in-house physics team.

The ATLAS computing model envisages that tier-2 centres will mediate between the tier-1 and the university physics groups. The tier-2 centres and the regional physics groups are where the real work of extracting physics from the data will be done. In Canada we envisage at least two tier-2 centres; one in western Canada, and one in the Ontario/Quebec region. It seems unlikely that these centres can be funded by NSERC. Again, we envisage that that will be funded by the CFI. It is most likely that they will be part of the current round of consortium applications to the CFI. The evolution of the ATLAS computing enterprise is shown in Table 9.

	ATLAS Computing Milestones
Jun-05	Computing TDR
Sep-05	Service Challenge3 (SC3) *50% of computing model resources tested*
Dec-05	Computing MoUs signed
Dec-05	Tier-I Network Operational *mass storage recording at 750 Mbytes/sec*
Apr-06	SC4 Throughput test *Tier-0,Tier-1, major Tier-2 operating at Target* *100% computing model validation*
May-06	SC4 Service *Initial LHC Service in Stable Operation* *mass storage recording at 1.6 Gbytes/sec*
Apr-07	LHC Service Commissioned

Table 9: ATLAS Computing Milestones.