The University of British Columbia

Department of Physics and Astronomy

UNIT PLAN

Also available at our Web site: http://www.physics.ubc.ca/~jess/up/

February 23, 2001

Preface: STRATEGY

A condensed version of our Unit Plan, consisting of this Preface, an Introduction, a Table of Contents for the full document and an Executive Summary, will be delivered to the Dean of Science on Wed. 21 Feb 2001, at the same time as the unabridged version is made available on the departmental Web site at

http://www.physics.ubc.ca/~jess/up/

where an "active map" will display various Chapters and Sections when their respective regions of the "map" are clicked on. For those who prefer to inspect a more standard linear text version, this is also available at

http://www.physics.ubc.ca/~jess/up/UP/

where a full *PostScript* file can be downloaded by clicking on the title. This completes the initial formation stage of our Unit Plan (UP).

However, to view this milestone as our ultimate goal would render the exercise meaningless or worse. If our own UP is treated as a "conclusion" and cited in departmental meetings as a reason for rejecting new proposals or not exploiting unforeseen opportunities, it will have done us more harm than good. If, on the other hand, our UP engenders an ongoing discussion of our missions and strategies, it will have helped us overcome the natural tendency of the physical scientist to work in isolation and encouraged us to develop our equally natural tendency to share and refine ideas.

How can we create a dynamic UP in whose evolution everyone has an opportunity to participate? How can we allow for individual contributions at those unexpected moments of inspiration and still maintain a stable document which expresses a consensus? In particular, how could we submit a succinct, eloquent and well integrated paper version by mid-February 2001 and still satisfy these long-range goals?

Information Technology (IT) provides a means for developing and maintaining the dynamic version of our UP as a Web site where everyone can easily see what others have had to say and respond (or not) accordingly. We have set this up as a *WebCT* site for several reasons:

- Our aim is a sort of asynchronous, electronic version of an ongoing departmental meeting. Although such meetings are hardly "secure", they do involve some discussions that we would like to treat as "private", and a normal public Web site is visible to the entire world. *WebCT* provides a variety of control over Web access and so satisfies our need for privacy as well as our desire for accessibility.

- Some of us are already familiar with *WebCT* from using it in our courses; others may well wish to use it too. The effort of learning to use an unfamiliar technology is thus not "wasted" on this exercise alone.

- *WebCT* includes numerous tools for maintenance of content and structure, and promises to be a long-lived Web environment; thus it is plausible that this effort will not have to be abandoned or reproduced very soon.

We have now massaged the UP into a mutually acceptable form on our departmental *WebCT* site and the UP itself has been exported to a public Web site on our departmental server (see above) where it can be inspected by anyone who wishes to know the latest Plans for our Unit. The February draft document has been distilled from that version and is now presented as a "snapshot of a work in progress" which will next migrate back to the *WebCT* environment where it can continue to evolve toward improved future versions, which will periodically be released to the public, and so on. . . .

Introduction: THE FUTURE

... Then felt I like some watcher of the skies
When a new planet swims into his ken;
Or like stout Cortez, when with eagle eyes
He stared at the Pacific - and all his men
Look'd at each other with a wild surmise -
Silent, upon a peak in Darien.[1]

Without a tradition of adventure and discovery, neither Astronomy nor Physics would have been fun enough to survive the centuries of drudgery and frustration that accompanied our journey from primitive to modern magic. The future of Physics & Astronomy promises no shortage of frustration or drudgery; what discoveries and adventures will make it all worthwhile?

In the next half century, many futurists believe we will witness

- the discovery of Earth-like planets around other stars;
- the manned exploration of the Solar system;
- the direct detection of gravitational radiation;
- the development of quantum computers;
- machine intelligence superior (at least in simulation) to our own;
- neural interfaces between human minds and computers;
- nanomachines capable of
  - repairing or altering living cells from inside the body,
  - building virtually any physical object from simple raw materials
  - or replicating themselves from the same raw materials;
- the elimination of most diseases and many aspects of aging;
- an encyclopædic understanding of the human genome and the ability to manipulate it;
- a verifiable unified quantum theory of gravity and elementary particles;
- and even an explanation of how and why the universe came into being.

[1]from *On first looking into Chapman's Homer*, by John Keats (1795-1821)

Most of these draw on basic research in Physics and Astronomy. Of course, we cannot know if these predictions will come true, nor if they will be eclipsed by even more exciting developments that are not even imaginable today. On rare occasions it may happen that we find what we are looking for, but the vast majority of all real breakthroughs are surprises. This is one reason why it is so important to encourage a diverse program of basic research; another reason is that only thus may we prepare ourselves to recognize the significance of discoveries when they appear; and yet another is that such preparations produce skills that can be turned to practical use as called for.

These are some of the reasons why society tolerates the expensive obsessions of Physicists and Astronomers. But why do *we* go to all this trouble? There are probably twice as many reasons as there are Physicists and Astronomers. However, among the many answers are:

- We hate mysteries and want to know *why* things are the way they are.
- We believe this knowledge is more efficiently stored as a few fundamental principles than as an encyclopædic catalogue of facts.
- We believe our work will help solve the world's problems someday.
- We believe our work will someday inspire awe.

Each of the predicted milestones of this half century holds both a promise and a threat. The uses to which new knowledge is put are definitely the concern of those who create it; and yet the crucial choices will always be made by non-experts. The only resolution of this conundrum is in education: we must ensure that all citizens have enough understanding of the implications and limitations of physics and of science as a whole to be able to make wise decisions about its use. It is therefore an essential part of any scientist's mission to explain his or her research as clearly as possible to others, especially those who are not scientists themselves. Our Department is committed to this goal.

Contents

Chapter 1

EXECUTIVE SUMMARY

1.1 Research

The departmental research and hiring plan from January 2000, entitled *"Origins and Complexity"*, is included in the full text version of this Unit Plan and is available on our Web site (see Preface). It is not included in this Executive Summary but should be regarded as the core of our Unit Plan. Briefly, the hiring plan proposes 16 new hires in the areas of subatomic physics, astronomy, biophysics, optics, condensed matter physics and medical physics.

1.2 Hiring, Equity & Salaries

1. With 10 retirements in 2002 and 2003 it is critical that the Department immediately accelerate faculty recruiting so that we can continue to fulfill our teaching and research commitments. All opportunities offered by faculty fellowships, leaves without pay *etc.* should be exploited to bridge retirement slots. New faculty traditionally require reduced teaching responsibilities to facilitate the start-up of their research programs. Teaching loads will need to be increased or cuts made to our program even if we are successful in finding qualified faculty to replace retiring faculty.

2. The Department is committed to a hiring plan designed to maintain our position as the top Canadian Department in Physics and Astronomy, and to bring us up to the top league of such Departments in North America, in both research and teaching. We will therefore maintain a constant search for the best people from around the world.

3. As part of our committment under the preceding point, we will attempt to increase the number of female and visible minority faculty members, using tools like the NSERC UFA program to do so.

4. The Department needs an immediate and large increase in merit and PSA salary money in order to eliminate salary inequities created by rapidly escalating starting salaries.

1.3 New Medical Physics Program

The Department has submitted a proposal to expand our unofficial medical physics program and create a new medical physics graduate degree program including a CO-OP M.Sc. We propose to support this program with professional graduate tuition, with positions created through the CRC and NSERC UFA programs and with existing resources. The degree requirements for this program are distinct from conventional M.Sc. and Ph.D. Physics degrees. This program is urgently needed to meet student demand and help satisfy the unmet demand for medical physicists in BC.

1.4 Engineering Physics

Strong student demand for admission to Engineering Physics justifies a 50% increase in enrollment in this program. An increase in the admission quota from 40 to 60 requires additional support for the undergraduate project and laboratory courses as well as new faculty appointments with expertise in photonics who are eligible for P.Eng. status.

1.5 Undergraduate Education

1. In its Physics service course offerings the Department plans to continue to evolve to serve the changing needs of other Departments. In addition the Department plans to configure its service courses to appeal to students who will increasingly be taking Physics because they choose to and not as part of their program requirements. Our Astronomy service courses already operate successfully in an elective environment.

2. We plan to extend the independent project work embodied in the 4th year honours thesis project to third year with a research seminar/reading course. This will expose students to the scientific literature earlier in their academic career and give them a chance to improve their speaking and writing skills. Additional student project work requires additional faculty resources and is contingent upon our being able to make cuts in other areas or obtain additional resources.

3. New interactive learning technologies and the results of recent Physics education research will be incorporated wherever possible in our programs, especially in the large undergraduate service courses. The new learning technologies require classroom and laboratory modification and new types of ongoing technical support.

4. We plan to reduce the total number of lectures required in our programs to free up student and faculty time for more project supervision and individual contact. Students will be expected to take more responsibility for their own education.

5. The number of courses that are offered in separate sections for honours and majors students will be reduced in order to relieve pressure on our limited teaching resources and improve the learning experience for majors students.

6. As with most scientific disciplines, Physics and Astronomy have a rich history of classical material that every student of the subject must know. The challenge is to balance this with material from the forefront of the discipline. To achieve the correct balance requires continual renewal, weeding out of less critical material and replacing it with new and advanced subject matter. Recent examples of new additions include a new third year probability course and new courses in general relativity, membrane biophysics and computational physics in the fourth year undergraduate curriculum. We plan to take advantage of our broad based research strengths to achieve a leadership position in Physics curriculum development.

1.6 Outreach

1. The Department plans to continue its excellent outreach programs including tours, public astronomical observing sessions, talks, courses for high school teachers, summer camps and competitions such as the Physics Olympics and the Physics Olympiad. These activities encourage interest in science generally, in UBC and in our programs. We need to identify funding sources for these outreach activities.

2. An annual meeting with selected high school physics teachers to discuss topics of mutual interest, following a successful model in the Maritimes, is under discussion.

1.7 Recruiting

1. The wide variety of exciting career opportunities open to Physics or Engineering Physics graduates are not well understood by high school students. The demand for people trained in physics is currently very high at both the graduate and undergraduate level, with critical shortages of qualified people in areas such as photonics, medical physics and high school

teaching. Outreach and recruitment will include visits to high schools to explain the opportunities at UBC in Physics, Engineering Physics and Astronomy.

2. With more active recruiting we hope to be able to increase the enrollment and admission threshold for our honours and majors programs and in the case of Engineering Physics to increase enrollment without lowering the high admission standard.

1.8 Graduate Program

1. Aggressive recruitment of the very best graduate students, both in Canada and internationally, is a top priority for the graduate program. This will be carried out by:

   - continued sizable top-up awards for major scholarship holders (ongoing funding for top-ups needs to be identified, as competition for top graduate students continues to intensify);
   - continuation and expansion of our graduate recruitment weekend for NSERC holders; and
   - more active recruitment, both in person, by faculty members giving invited talks at other universities, and *via* our recently enhanced Web presence.

2. We are extending our efforts to collaborate with other BC universities in teaching graduate courses in Physics, Medical Physics and Astronomy. These efforts include:

   - We will extend to other courses the video-conferencing of classes at SFU and UBC that was successfully piloted in 2000. More systematic use of this option will allow is to make more graduate courses available to our students and improve efficiency in course delivery by taking advantage of courses offered by the other universities. In order to accomplish this we need to equip one classroom for video course delivery.
   - We will encourage more of our students to take such courses *via* the Western Dean's Agreement (WDA) at other universities, and continue to communicate with other universities to encourage more of their graduate students to consider enrolling in advanced courses at UBC *via* the WDA.

3. A CO-OP M.Sc. program is under consideration, building on the success of our undergraduate CO-OP program. A sizable fraction of our graduate students elect to obtain a Masters degree and then go directly to employment in industry. Work experience combined with an advanced level degree would be an attractive option for some students.

1.9 Physical Infrastructure

1. The physical infrastructure of the Hennings building was described by the external review committee as more appropriate to a Third World country than to Canada's leading Physics and Astronomy Department. Services such as heating, ventilation, electrical power and washrooms are substandard. A new Physics and Astronomy building is needed.

2. In the meantime we need to upgrade the lecture theatres and improve the æsthetics of social space (departmental coffee room, PhysSoc space). The physical layout of the undergraduate labs in the Hebb building, designed in the 1950's, needs to be remodeled to meet the needs of the more effective interactive learning styles of today.

3. The 42 cm telescope needs to be moved from the roof of the Geophysics and Astronomy Building to the roof of the Hebb building. This is an important and popular outreach facility as well as a teaching tool.

4. We plan to make the interior of the Hennings building more attractive and interesting for students with poster displays of departmental research projects.

1.10 Technical Support and Staff

1. To support the diverse research needs of the Department we need to maintain excellent computer support as well as excellent machine and electronic shops; we must also strengthen technical support in new areas such as advanced instrumentation and microfabrication — increasingly important tools for a variety of current and projected experimental research programs at UBC. A number of technical support positions have been lost due to budget cuts over the past 15 years.

2. We plan to work with our neighbour, the Department of Chemistry, wherever feasible to maximize the effectiveness of our technical facilities and technical staff. For example, the Department will provide a limited number of Chemistry graduate students with access to our student machine shop.

3. To support the changing teaching needs of the Department and new learning technologies, we need to strengthen current computer, laboratory and demonstration support that has been cut back in recent years.

4. The Department encourages staff to take relevant, cost-effective training courses to update their technical skills and learn new ones.

1.11 Computer Infrastructure

A continuing investment in computer hardware, software and networking facilities is essential to the learning and research environment of the Department.

1.12 Interaction with Other Units

1. Many of the faculty members who do research at TRIUMF will be retiring in the near future. We need to rebuild our relationship with TRIUMF, an important laboratory whose research mission has been evolving since the commissioning of the new ISAC facility. One possible avenue for collaboration in the future would be through joint appointments.

2. The Department plans to use faculty positions associated with CRC clusters as a new basis for interdisciplinary collaborations with other units.

3. We would like to continue our productive links with the Canadian Institute for Advanced Research (CIAR) by hiring people who qualify for participation in their programs where possible.

Chapter 2

UNDERGRADUATE EDUCATION

2.1 Physics

(McCutcheon, Carolan)

2.1.1 Overall Programme

The Science programme in Physics and Astronomy is composed of two programmes, Majors and Honours. Graduates of both should have an excellent preparation for employment in many areas of business and industry where problem solving skills are valued. Graduates of the Honours programme should also be well prepared to pursue graduate studies. The Honours programme is more focussed than the Majors, and requires more high level courses; the Majors programme offers greater breadth. The undergraduate Physics program now has about 45-50 students graduating, about 60% of these being Majors students. The Honours students can pursue a Combined Honours Physics degree with Chemistry, Math, Astronomy, Computer Science, and Oceanography. Our recently established Biophysics programme is becoming increasingly popular. A Majors student can pursue a Double Majors degree with another Department in Science, or a Majors in Physics with a Minor in either a Science or an Arts subject.

In addition, the Department teaches a range of Introductory Astronomy and Physics courses to students in Science, Applied Science, Arts and several other Faculties.

The Department's commitment to broadly based teaching has been noted in several Department reviews. We continually attract to our first year programmes many talented, well prepared students. Over the past several years, the Department has participated in several teaching innovations within the Faculty, including Science One, the Integrated Science Programme, Co-operative education and the Coordinated Science Programme. The introductory courses in Astronomy for Science as well as for Arts have experienced increasing enrollments. The Department has been experimenting with promoting more active learning in the classroom. Efforts are being made to break down the ineffective passive learning mode characteristic of the impersonal large lecture.

2.1.2 Difficulties

Difficulties faced by the Department in its efforts to serve such a broad range of students are due to decline in numbers of Faculty and Staff, and decrease in infrastructure support. New hires are helping to slow the decline, but the lack of bridging funds is severely hampering the Department's ability to carry out its mission for the undergraduate programmes. The decline in infrastructure support is apparent in the facilities. It is not possible in the main lecture halls of Hennings to employ anything but the most rudimentary audio-visual teaching aids. Forty years ago, the labs in the Hebb building were state of the art, but now the style of lab in Hebb is is far from ideal for introductory courses. As an example of what can be done with proper funding, a new astronomy lab that is much more conducive to experiential learning has been constructed in Hennings.

2.1.3 Curriculum

The curriculum is constantly being reviewed and updated. Several new elective courses have been added recently. The planned changes to first year

Science requirements and the proposed re-crediting of courses presents challenges to the Department. Courses such as ASTR 101 and 102 may have to scale back the very successful lab component to make the course "fit" the number of credits for students in various faculties. The removal of PHYS 101 as a required course for Science students will probably result in lower Physics enrollments. The relaxation of first year Science requirements may lead to a weaker background for students studying Physics in subsequent years. Partly in response to the changing first year requirements, the Department is currently restructuring the core courses PHYS 101 and 102 to incorporate biophysical applications. This is in line with the increased emphasis and expertise in biophysics and medical physics in the Department.

2.1.4 Challenges for the Future

There is always a job market for good physicists, and in the current period, the market is particularly hot with demands from the Information Technology sector. We should be teaching and training more physicists. Attracting more bright high school students is one of the challenges; more aggressive recruiting would be helpful here. We must always strive to attract the best students to maintain the excellence of our programs. The quality of the undergraduate programme will be improved with better teaching. In addition to the exploration of new methods of teaching mentioned above, the Department should expand the training for TAs in more up to date pedagogy. The Department should develop a better sessional policy that will contribute positively to the Department's teaching programmes.

2.2 Astronomy

(Scott)

The Honours Programme in Physics & Astronomy is intended to introduce students to a comprehensive range of areas of astrophysics. This provides an excellent preparation for employment in many areas of industry and business where broad problem-solving skills are valued, as well as the laying the groundwork necessary for pursuing graduate work in astronomy. This programme should remain focussed and high-level so as to continue to satisfy the goals.

The Majors Programme in Astronomy is meant to to expose students to a diverse range of astronomical topics, but with less emphasis on physics. We hope to expand this programme, and to introduce a greater element of interactive teaching. A more formal CO-OP program in astronomy could also be established, and this could be extended to include the majors programme.

We would also like to pursue ideas of how astronomy courses could play an integral role in more interdisciplinary and less traditional degree programmes (in science but possibly also in arts and professional faculties). One simple example would be a course on "Life in the Universe" in the overlap area with the biological sciences.

Astronomy courses offered as electives, particularly to students outside the Faculty of Science, are of growing interest to today's undergraduates. We plan to continue to offer such courses, both as an introduction to the grander vision of the Cosmos, and as a vehicle for exposing the students to the methodology and rigour of the physical sciences. There is even greater potential here for improving the involvement of the students in hands-on activities, plus increased use of multimedia tools and distance learning. To teach these courses efficiently there should be an upgrade of the lecture rooms in Hennings to include modern electronic teaching aids.

Research in Astronomy and Astrophysics is currently at a very exciting time, when many new observational and computational facilities promise big breakthroughs. UBC astronomers are playing important roles in many of these developments. We will continue our Masters and Doctoral programmes in Astronomy, where students are taught through high-level courses and perform their own cutting-edge research projects. Graduates from this programme go on to successful research careers, as well as jobs in imaging and computer companies, education and communications. In the area of graduate teaching we intend to pursue video-conferencing possibilities with neighbouring (and perhaps more distant) institutions.

Astronomy research is carried out for purely reasons of intellectual curiosity, and the strong appeal of astronomical concepts for the general public means that outreach must always be a strong component of an active Astronomy programme. At UBC we encourage participation by Astronomy faculty and students in public events through schools, teachers groups, local astronomy clubs, public science centres, like the H.R. MacMillan Space Centre and Science World, and many other avenues. We also maintain good connections with the media at local, national and international levels. People are fascinated with the Heavens, and seeing the night sky for oneself through a professional telescope is a constant attraction. Our 42cm diameter telescope at the UBC Observatory is widely used on weekly public viewing nights (10s to 100s of people each Saturday). It is used extensively on pre-arranged visits by schools and other groups, and has regularly attracted more than 1000 people at a time for special events, such as comet appearances.

With the merging of Astronomy with the Physics Department, the astronomy presence in the Geophysics & Astronomy Building will soon come to an end, except for the telescope in its dome on the roof. In the long term it is important that this facility be moved to be physically close to those who use and maintain it. A site on the roof of the Hebb Building has been identified, and we plan to pursue all possible funding sources to enable the telescope to be moved in the near future.

2.3 Engineering Physics

(Young)

2.3.1 Background

The Engineering Physics Program at UBC has a 55 year tradition of attracting some of the best young minds in the province and challenging them with a rigorous, broad-based education founded in both science and engineering. Its graduates include astronauts, CEO's of major high-tech companies, award-winning researchers in academia and industry, and numerous medical professionals. The Program has in many instances led the development of project-based-learning at UBC: it is generally recognized as a fertile recruiting ground for superior students who, in addition to their technical abilities, possess excellent teamwork and communication skills. These are just some of the reasons why there has been an unfulfilled demand from 1st year students wanting to enter the Program over the past decade.

The relevance and importance of the Engineering Physics Program increases steadily as the contributions of the high-tech sector to the provincial and national economies grow. We would like to increase the number of students trained in this area at UBC, and we provide the following proposal for how that might be accomplished.

2.3.2 Recruiting

We strongly believe that an expansion of the Engineering Physics Program can only be successful and sustainable in the long-term if we do not compromise on the quality of the entering students. Much of its success is based on the reputation of its graduates. By simply accepting more of the students who currently apply to get into the program by dropping the minimum entry requirements, we will either increase the attrition rate markedly, or we will have to make the program "easier". Neither alternative makes any sense in the long term, hence a rigorous recruitment program must be put in place if we are to increase the number of Engineering Physics graduates. The Faculty of Applied Science (FASC) has just this year initiated a process by which high school students applying to the FASC with exceptional grades can be guaranteed access to the Engineering Program of their choice in their 2^{nd} year. This makes it feasible for Engineering Physics to directly recruit at the high-school level. We are optimistic that a vigorous high-school recruiting initiative will result in more top-level students seeking admission to Engineering Physics, enough to increase the enrollment from 40 to 60 students per year, while keeping the minimum entry grade out of first year at no less than 75%. A successful high-school recruiting process is essential to a successful expansion of the Program. Minor modifications we are making to the curriculum, that include increasing the project-based-learning experience to the junior level, and incorporating more photonics material, should contribute to the success of this recruitment exercise.

2.3.3 Additional Resources

To the Physics and Astronomy Department

The Department of Physics and Astronomy offers 18 courses to Engineering Physics students. The pure lecture courses, and the lecture component of some of the combined lecture/lab courses, could absorb a 50% increase in student numbers fairly easily. The main concern here is the possible reduction in the quality of the learning environment associated with larger class sizes, but this should not be a major problem if the instructors make explicit efforts to avoid negative consequences. The need for access to larger lecture rooms will likely have the biggest impact on the system from increased enrollment in these lecture courses.

The laboratory and project courses are central to the Program and their quality absolutely must be maintained, or hopefully improved during this process of expansion. Our analysis of the anticipated impacts of increased enrollment in the laboratory and project courses indicates a requirement for:

- $160,000 one-time equipment costs.
- $10,000 one time labour costs associated with setting up the new labs.
- $30,000/yr increase in the consumable expenses associated with these courses.
- $25,000/yr increase in the TA budget (7 additional TAs @ $3,500).
- 2 additional faculty assignments/yr (full responsibility for ApSc 479 and additional sections in Phys 259, and Phys 257).
- Overall increase of 50% in the faculty supervision duties for project courses (ApSc 459 and 479) and CO-OP site visits.
- 1/2 additional technicians for added lab work.

There will also be an administrative cost associated with the increased enrollment. The current Engineering Physics secretary is periodically pushed to the limit to meet various deadlines. Access to occasional assistance would be needed if the enrollment increases.

- 1/4 secretary.

Finally, 2 new faculty members with expertise and interest in the Engineering Physics program are needed to help deliver the course content, which is both increasing in volume, and shifting to include more "engineering science and design" to use the official terms of the Canadian Engineering Accreditation Board. People in photonics and nanotechnology would be preferable.

- 2 new faculty members, both of whom could be expected to be registered as Professional Engineers.

To other Departments

Engineering Physics relies heavily on the Math, Electrical and Computer Engineering, Mechanical Engineering, and the Computer Science Departments to offer essential courses in the curriculum. The proposed increase in the Engineering Physics enrollment would increase the number of Engineering Physics students in all of these service courses by roughly 50%.

2.3.4 Timescale

Assuming the required resources are made available, we could ramp the enrollment from 40 to 60 students per year over the following 3 years. This somewhat conservative timescale is designed to minimize the negative impact of a sudden increase that is not immediately supported by a successful recruiting exercise, and a fully enhanced laboratory/-project base.

2.4 Physics Curriculum

The following proposal tabled by Gordon Semenoff is an example of the sorts of radical revisions often debated by our Department. It addresses only the Physics curriculum but its consequences would be far-reaching. It is included here to emphasize that we are not content to merely propagate the status quo, but are always seeking to identify potential changes which, if deemed workable and desirable by the Department, might help us do a better job of Undergraduate Education.

The duties of an undergraduate program in a major scientific discipline such as Physics at a large public university such as the University of British Columbia are twofold. First, it should provide an education for the science student which prepares her or him for a productive role in Society at the Bachelor of Science level. Second, for those students with the high degree of talent and motivation such that they might become scientists themselves, it should provide a pathway to a good post graduate education. These are the two needs that the undergraduate teaching programs of the Department of Physics and Astronomy are designed to serve. Both of these needs have evolved somewhat and changes in our curriculum, emphasis and teaching style are inevitable to take into account this evolution.

The undergraduate program presently has two main streams, Physics Major and Physics Honors.

1. **Physics Major**

   The Physics Major program is designed give the student a liberal education with some degree of concentration in Physics. It is intended primarily for the student who will enter the job market at the Bachelor of Science level. It is also a reasonable preparation for professional schools and those wanting to pursue a career in science education, and sometimes for graduate school in engineering, computer science or physics. The program has a small core of required physics and mathematics courses and substantial space for options which allow a student to obtain a broad, liberal education or to develop a second major.

2. **Honors in Physics**

   The Honors program has traditionally been the venue for the student with the degree of talent and motivation that they have to potential to someday be research scientists themselves. The program is designed to prepare students for entry to graduate schools. The curriculum for such a program has a reasonably standard content which is adhered to fairly uniformly in North American universities. There is a large amount of material that a student destined for graduate school must master and this material practically fills the teaching hours of an undergraduate degree.

There is also the Honors on Biophysics program which is designed to address the special needs of a student who want to pursue a career in biophysics, medical physics or bio-engineering.

There are also combined honors programs with Computer Science, Mathematics and Chemistry. These programs have somewhat lighter requirements for Physics courses and are designed to prepare students for graduate work in either subject. Over the last ten years, these have been very popular with students.

2.4.1 Recent History

The division between the Major and Honors streams is now not as sharp as it once was. The trend over the last few years has been toward a gradual integration of the two programs. This is partially driven by manpower constraints and has involved the amalgamation of courses which were once offered exclusively to one or the other group.

Along with this evolution, the Honors program has been re-worked somewhat during the past few years. There has been an attempt to streamline the teaching to free up some time for students to either broaden their education or to pursue specialized topics in modern physics. Streamlining has occurred both in physics courses where two mechanics courses were compressed into one and in the mathematics courses which are offered to physics students. In that case, a long and rather slow moving pair of second year calculus courses were compressed into one course, and some of the material re-distributed among some of the other required math courses. The result has been an opening up of several spaces for options in the fourth year of the honors program. We have encouraged undergraduate students to use this opportunity to either accelerate their specialization by taking graduate courses of interest to them or to develop a second major, examples of which are applied mathematics, computer science, medical physics or astronomy.

The Honors in Biophysics program was recently created to address the demand by students for an education in that subject. Both the research world and the commercial job market have a need for manpower with a biological physics education. The Department has recognized this need and an undergraduate program which addresses it is now in place.

2.4.2 The Future

The plans of the Department for the near future involve radical changes to the way that it teaches physics. We believe that, given sufficient resources and latitude, we can make significant innovations. These innovations should make the UBC experience the very best that a science student can get. Concrete plans are listed below:

1. **Involvement of students in research**

   One of the goals of our planned curriculum reform is to give the undergraduate student much more access to the research programs of the Department.

   The Physics and Astronomy Department of the University of British Columbia has probably the most diverse array of research programs of any such Department in Canada. Many of these programs are among the strongest in the country and some are among the strongest in the world. This gives it a strategic advantage over its competitors. It can offer a student access to high quality, cutting edge research on a very wide variety of topics and in an environment where real discoveries are being made. This advantage is currently utilized in the form of a senior year thesis project for Honors physics students. During their fourth year, students are required to undertake an independent research project under the guidance of a faculty member.

The Department plans to revise its curriculum so that it can offer undergraduate students a greater direct involvement in its ongoing research programs.

2. **Amalgamation of Majors and Honors programs**

   This is a proposal to combine all of the teaching of Physics Major and Honors students into a common core of courses. This also will either eliminate the Physics Major program entirely or make the distinction between a Major and Honors degree one based on marks or some other simple to manage criterion.

3. **Streamlining of classroom teaching**

   This is a proposal for a major streamlining of the classroom teaching programs of the Department. All undergraduate physics teaching beyond the freshman year would be a small number of core courses which should be taken by both Majors and Honors program students.

   The streamlining of teaching will liberate time in the Majors and Honors programs for students to participate in the research of the department. It will also liberate time of faculty members. This time will be used in supervising research projects and mentoring students.

4. **Development of special programs**

   The department has already developed an Honors in Biophysics program to address the demand for a biophysics education. It also plans to develop a Computational Physics program. Computational Physics will be presented mostly through project based learning.

2.5 Outreach and Recruiting

(Schleich)

Our Department has a long history of initiating innovative outreach activities aimed at increasing public awareness and understanding of the impact and excitement of physics and astronomy and, in part, at recruiting bright, interested students into our undergraduate and graduate programs.

Through the Michael Crooks Outreach Laboratory,

http://physics.ubc.ca/˜outreach

we currently offer summer camps and the mini-University to engage students aged 7 - 17 in physics and astronomy and to introduce them to exciting areas of new research through tours and talks. We run the International Physics Olympiad regional training camp and the Canadian Association of Physicists Exam for highly academically inclined grade 11 and 12 students. We also are actively involved in the International Physics Olympiad itself, annually serving as team leaders; we organized the 1997 Olympiad in Sudbury, Ontario. One of us currently serves as secretary of the international organization.

We offer science teacher workshops to introduce new and exciting ideas for physics and astronomy teaching to those in primary and secondary education. We also have a course in the development of new physics demonstrations for undergraduates interested in becoming teachers. We host high school students in work placements and job shadowing opportunities that allow them to experience the everyday life of a scientist.

For 24 years we have organized the Physics Olympics,

http://noether.physics.ubc.ca

an all day competition for almost 400 high school students that fosters teamwork and Physics understanding through a set of creative, hands-on physics challenges. This activity is also notable for bringing teams to UBC from all over BC.

We hold Saturday night open houses at the Astronomy Observatory,

http://astro.ubc.ca

that allow the public to experience the wonders of our universe for themselves.

In addition, we run astronomy and physics shows and tours of our observatory and research laboratories for school groups, community groups and the public in general. We also co-sponsor events in Astronomy with the H.R. MacMillan Space Centre and maintain active connection to the media, with faculty members contributing to radio, television and print articles on exiting topics in physics and astronomy.

Thanks in part to programs like Science World's "Scientists and Innovators in the Schools" program and the UBC Speakers' Bureau, our faculty members also frequently visit primary and high schools in the Vancouver area to expose children's minds to the wonders and mysteries of our Universe, from the impossibly small to the infinitely large.

These activities currently reach thousands students, teachers, and members of the general public each year. They have direct impact on our image in the community and the image of UBC as a whole. They are also invaluable in recruiting; many of our best undergraduates have come to us from the Physics Olympics, Olympiad and CAP programs, during which they first became aware of the Department of Physics and Astronomy. In particular, approximately 40% of our Physics and Engineering Physics undergraduates participated in one of these activities. In addition, all of our programs address the recruiting issue at least obliquely. For example, the 12 and 13-year-old students who attended our first summer camp in 1996 are now applying for undergraduate courses. Indeed, some older high school students who volunteer at the summer camps also come to us as undergraduates.

We will to continue our current commitment to these outreach activities and programs. Plans for the future include the following improvements of our facilities for outreach:

- Moving the Observatory to the roof of Hebb.
- Installing a coelostat (already in our possession) to project a real-time image of the Sun in a lab or public area of the Hennings or Hebb building.
- Expanding the public facilities (perhaps with a visitor centre).

We would also like to expand our outreach programs. For example, we would like to spur participation in ALTA,

http://www.physics.ubc.ca/~waltham/alta/

an unique innovative mixed research and education project in which high school students participate in cosmic ray research through a network of detectors based at high schools.

Additionally we are exploring the introduction of a Master's degree directed to high school science teachers interested in gaining experience in research while furthering their careers in education.

We are working on creating a joint position between UBC and the H.R. MacMillan Space Centre, which is part would coordinate our outreach and education efforts with those of the Space Centre and the community.

We have also participated in the pilot project of a "Science 101" course for residents of the Downtown Eastside; we hope to expand on that project in the future. Our Department and the Space Centre are actively seeking funding to enable regular free evenings at the Space Centre, hosted by UBC astronomers, especially for the Downtown Eastside community and other Vancouver communities that may never have felt that facilities like UBC and the Space Centre are accessible to them. We are making overtures to the community centres to provide more astronomy and physics education material and opportunities for young people who need an outlet for their curiosity and interest.

In addition, we plan to increase recruiting efforts directed toward advertising the wide variety of career opportunities open to Physics, Astronomy or Engineering Physics graduates. These opportunities are not well understood by high school students. We plan to address this need by arranging recruiting visits to high schools to explain the opportunities at UBC in Physics, Engineering Physics and Astronomy. An annual meeting with selected high school physics teachers to discuss topics of mutual interest is under discussion. We are optimistic that a vigorous high-school recruiting initiative will result in more top-level students seeking admission to Physics, Engineering Physics, and Astronomy.

Note that continuation and expansion of our outreach activities will take additional resources, both in funding of equipment and supplies and in technical staffing and faculty time needed to carry out the current programs and any of these future initiatives.

Chapter 3

GRADUATE PROGRAM

The main objective of the Ph.D. programme is for students to learn the techniques and develop the intellectual skills required to produce good, original research, preparing them to leave UBC with the necessary skills and background to conduct and publish their own research in industry or academia.

3.1 Recruitment

We have attracted many excellent students in the past, and recent sizable top-up awards for major scholarship holders have helped in recent recruitment.

Presently, we have the capacity for at least 20-30 more graduate students. We have approximately 70 faculty members (including associates and adjuncts) who can supervise graduate students, and 140 graduate students would be a healthy enrollment number which would not stretch our resources (we currently have a shortage of TAs, due to the fact that a sizable fraction of our graduate students are major scholarship holders who don't need/want extra TA funding). This number of students would not be a problem for our guaranteed funding policy, as long as a similar fraction of our students continue to hold major scholarships.

We must not lower our standards in order to increase enrollment.

3.1.1 Recruiting Weekend

Our first major recruiting weekend last spring went well. We managed to contact over 40 of the 52 NSERC PGSA Physics and Astronomy winners last year, invited them to visit UBC. Thirteen of these NSERC holders did come for a visit and we paired each with a current graduate student mentor/guide. Several who visited said they probably would not have considered UBC had we not invited them for a visit. Several non-NSERC holders were also invited, and a number of our own undergraduates attended. We propose to continue this event and expand it by inviting senior honours undergrads here and at SFU to participate.

3.1.2 Undergraduate Exposure

We have had a presence at the Canadian Undergraduate Physics Conference (CUPC) for the past 3 years, sending a faculty member and literature with the undergrad delegates, and we have received good feedback. We recently sent one faculty member to the Atlantic Undergraduate Physics and Astronomy Conference (AUPAC) as well. We must continue and expand these recruitment efforts, to include Canadian Association of Physicists (CAP) and Canadian Astronomical Society (CASCA) annual meetings, and other undergraduate conferences, keeping in mind that it is often the very best undergraduates who attend these meetings.

3.1.3 Top-ups

The recent turnaround in graduate enrollment numbers is at least partially due to the excellent NSERC top-ups we have offered in the past two years. We propose to keep NSERC top-ups at an attractive level, regardless of the university/Dean's top-up contributions.

3.1.4 External Seminars & Colloquia

We encourage faculty giving seminars and colloquia at other universities to take along recruitment information. Several faculty members have done such recruiting with notable success, including specific visits to other universities' undergraduate societies. A Graduate Program poster is currently in the design stages, and we will have grad advertising packages available to give to faculty members who visit other universities for colloquia and seminars.

We shall work on extending our aggressive recruiting to American undergraduate students, as there is an untapped market of excellent young scientists just south of the border.

3.1.5 Web Site

Our Web pages are a great advertisement for our Graduate Program and we shall continue to explore opportunities to use this Internet technology to our advantage. The Graduate Co-ordinator has done a professional-looking job with the Web page design and layouts. We/she get thousands of inquiries per year concerning our Graduate Program. The ever increasing volume of applications lead her to implement a pre-screening application interface on our Web pages. This pre-screening has helped greatly reduce the number of underqualified applications, easing the admissions workload. She has also interfaced the full FOGS application online forms to our application info Web pages, making the application procedure very simple for applicants. Despite all this stream-lining, numbers of applications to our Graduate Program are still up in the past 2 years. The creation and and frequent updating of over 40 Web pages for graduate students and potential graduate students in Physics and Astronomy has helped in eliminating many standard inquiries. We have put our P&A Graduate Program info/brochure into PHYSLINK and PhysicsWeb, which are well-used public shopping grounds for Graduate School information in Physics and Astronomy.

3.2 Course Offerings

3.2.1 Course Organisation

In the past two years, we have split all but one of the full-year graduate courses into 1 term courses and have cross-listed several 4^{th} year courses as graduate courses. Recent additional flexibility in the 4^{th} year honours program allows strong undergraduates to take some graduate courses. These changes have helped keep enrollment numbers in graduate courses above the minimum required.

3.2.2 Videoconferencing

Videoconferencing has been used in a graduate course for the first time in 2000 in Physics and Astronomy. The course used as a test was an advanced level graduate course, taught at SFU by an SFU professor connected here to UBC on the Subatomic Videoconference system. This worked acceptably well, and we and SFU have both expressed a desire to consolidate some more advanced level courses in the future. This term we are consolidating with a course taught at TRIUMF by a SFU professor. We plan to extend this to several more courses in the future and look into getting other universities also involved.

3.2.3 Attracting "outside" students to our Graduate Courses

In 2000/01 we have about 10 students (mainly from SFU and UNBC) taking graduate courses here in our Department under the Western Dean's Agreement (WDA) — this represents a big increase over the past years, due to aggressive advertising of our graduate courses at both of these universities. These WDA students increase our graduate enrollment figures, enabling us to offer several courses which would otherwise be cancelled due to low enrollment. The program has also enabled some of our students to take advanced level courses not offered at UBC at other WDA universities.

We should also actively promote our broad interest graduate courses to students in other Departments at UBC, and promote our specialized advanced level courses to students at other universities participating in the Deans' Western Agreement exchange program.

3.3 Graduation Requirements:

The present Graduate program requirements are:

M.Sc./M.A.Sc., Physics or Astronomy: 18 credits M.Sc./M.A.Sc. Each student must make at least one public oral presentation of his/her thesis work. This may be at a conference or at a seminar at UBC.

Ph.D. Physics: 12 credits of course work required after Masters degree. Each student must have an annual committee meeting, which serves also as an Oral Comprehensive Exam.

Ph.D. Astronomy: no additional course requirements. Each student must have an annual committee meeting, which serves also as an Oral Comprehensive Exam.

We also have a requirement that all students take the core of two graduate courses Quantum Mechanics, except for medical physics students, who must only take the one of these two. Astronomers didn't have any requirements before joining our Department, but currently must take at least one of the two Quantum courses.

3.3.1 Written Standardized Comprehensive Exam - or Standardized Core of Courses?

Once a graduate student is accepted into our program, there is no standardized minimal level of achievement. Our admissions standards are sufficiently high that this is normally not a problem, however it has been noticed that a few students do not perform as well as their admissions references and transcripts would lead us to expect. We are investigating setting up a mandatory written Graduate Comprehensive Examination or having a mandatory set of graduate course requirements that ensure that each student is not only an expert in his/her own area of research, but is a general well rounded scientist that we are proud to put forth to the world as a UBC graduate.

3.4 Courses

Students have expressed some unhappiness with uneven standards, workloads and expectations in graduate level Physics and Astronomy courses. Quite a few "Directed Studies" courses are offered to a few students each term, and in some cases, the students say these courses are easy credits for little work. Having a standard broad core of required courses should alleviate this problem.

Additionally, several students have requested a laboratory/practical graduate course offering; this will be investigated.

3.5 Time

A growing concern is the length of time required for students to obtain a Ph.D. Shortening the average Ph.D. time to completion to four years is extremely desirable.

3.5.1 New Medical Physics Program

A new Medical Physics Graduate Programme will be introduced in the department of Physics & Astronomy, with a goal of preparing students with strong Physics, Biophysics and Engineering Physics undergraduate degrees for a career in medical physics. The Master of Science degree program will be offered as a research masters degree or as a course work masters degree with an 8 month CO-OP work term. Graduates of the M.Sc. Programme will be prepared for the academic component of the Canadian College of Physicists in Medicine (CCPM) exam. The CCPM (`www.medicalphysics.ca`) is the professional certification body for medical physicists in Canada. Many graduates of the M.Sc. program will continue on to the Ph.D. Programme in Medical Physics. While M.Sc. graduates should be able to find good jobs, the Ph.D. degree is required for jobs that involve independent research.

Medical physics graduate student entry requirements and course requirements are the similar to those for other Physics & Astronomy graduate students.

Students in the CO-OP masters Medical Physics programme will take 24 credits of courses during two or three academic terms, primarily from the medical physics courses. In addition they will have a medical ethics course and a research practicum. At the end of their 8 month CO-OP term they will write a report worth 6 credits. The CO-OP M.Sc. program will be attractive to students who wish to obtain employment in medical physics but are not interested in pursuing a research career.

Ph.D. students will take an additional 12 credits of courses and, at the discretion of their supervisory committee, complete a Ph.D. thesis showing evidence of an ability to do original research.

3.6 CO-OP M.Sc. program

Introduction of a CO-OP Master's degree program is a serious consideration. As a contingent of our graduate students elect to obtain only a Master's degree and then go to industry, the importance of industrial and work experience, coupled with an advanced level degree, would be seen by a number of graduate students as a very attractive program. The undergraduate CO-OP program is very successful; extending this to the Master's level is a possibility.

3.7 Additional Resources

With the advent of the Web and more frequent inquiries from potential graduate students, the ever-increasing amount of paperwork that has been shifted back to the Departments from the Faculty of Graduate Studies (and on very tight deadlines), and the increase in administrative jobs now done by the Graduate Co-ordinator that were previously done by other departmental assistants, the administrative workload has increased significantly, to the point where the Graduate Co-ordinator (Janet Johnson) must frequently catch up on paperwork and student email inquiries on her own time at home. We are working to increase our graduate enrollment as well, which will only worsen this situation. Access to part-time assistance is already greatly needed, especially during the very busy winter season when hundreds of graduate applications and thousands of inquiries arrive, and during the very busy beginning of term periods three times/year. A quarter-time secretary/assistant would help alleviate the overburdening workload at peak times of the year. It would be advantageous if this assistant were the same person as the part time Engineering Physics assistant, as many of the databases and administrative tools used are common to both.

Chapter 4

RESEARCH & HIRING PLAN

(Bonn, Richer)

4.1 ORIGINS & COMPLEXITY — Hiring Plan 2001-2004

4.1.1 Overview

Human curiosity about the Universe probably began when in prehistoric times an early hominid raised its eyes to the sky and wondered about the **origin** and nature of the bright sources visible there. This sense of wonder has blossomed into a more sophisticated quest for an understanding of our relationship with things that we see around us. The questions that people are interested in are the fundamental ones, "What is the Universe made of?", "What are the fundamental laws which govern the origin and behaviour of matter?", "How were the elements produced?", "How did our Solar System form and evolve?", "How do simple atoms assemble to give complex phenomena?", "How did life arise?" It is the desire to more fully comprehend these basic questions that has driven the vision contained in the Department of Physics and Astronomy's hiring plan.

The current basic model of the Universe is the Big Bang in which the Universe had an initial extremely hot phase and has expanded and cooled since then. This paradigm has had remarkable success in predicting the existence of the Cosmic Microwave Background (the ubiquitous radiation field of the Universe), the abundances of the light elements in the Universe and its expansion. Together with the Standard Model of particle physics and the Theory of General Relativity, we now have a very solid framework in which to describe a wide range of physical regimes within the history of the Universe.

In the earliest moments of the Big Bang, the Universe is predicted to have been remarkably isotropic and homogeneous, and yet the Universe that we see today is very inhomogeneous on all except very large scales. This inhomogeneity is of course profoundly important, it led directly or indirectly to the emergence of **complexity** in the Universe on different scales and to the existence of essentially all phenomena that are studied in science, including life. The generally successful theoretical paradigm for the development of inhomogeneity is that small amplitude density variations, perhaps the result of quantum fluctuations in the early Universe, grew through the process of gravitational instability. As the local density grew, eventually other physical forces became important in forming the structure and governing the complex behaviour on the small scales that we see around us today.

This complex behaviour of matter on local scales has, until recently, been studied mainly to understand some of the really extraordinary collective phenomena like superconductivity, magnetism, or coherent light (lasers) that occur in quantum systems. The frontiers now have shifted. Physicists are using the general laws of collective behaviour to make fundamental new advances in other fields such as in biophysics. An understanding of how to force distinctively quantum behaviour into the macroscopic realm is also nearing reality. Quantum Theory still has some rather deep mysterious, and experimental and theoretical work in the last decade has shown how it may be possible to make even macroscopic objects show quantum properties like quantum coherence. This work has fundamental implications for problems like the unification of gravity with quantum theory, and for the relationship between quantum mechanics and classical theory. It has also led to great excitement because of the idea that one might deliberately construct a whole new world of quantum objects at the macroscopic scale. Foremost amongst these possibilities has been the suggestion of a "quantum computer", which theoretically would have exponentially greater computing power than its classical counterpart. It is presently thought that such computers would involve a combination of nanomagnetic, nanosuperconducting, and quantum optical components.

The combined hirings in our "Origins and Complexity" initiative will reach across all subdisciplines in the Department and encompass 14 of the proposed 15 new departmental positions over the next few years. During the period 2000 — 2004, a major fraction of the current members of the Physics and Astronomy Department will retire, the present hiring plan takes advantage of this situation by building on existing strengths and directing the Department into a few major new and exciting areas for the beginning years of the 21st century such as quantum computing, planetary astronomy and the origin of matter.

This "Origins and Complexity" initiative, although research driven, also meets programmatic needs of the Department by focusing on areas of great current interest to students.

4.1.2 The "ORIGINS" Initiative

A major objective of the Departmental hiring plan involves the establishment of an important group that will be internationally recognized in the area of "Origins". It is envisioned that eight new hirings in this area will be made over the next few years and that this group will address fundamental questions about our place in the Universe. The new faculty members will augment existing researchers in areas of the high energy frontier, cosmology, nucleosynthesis and stellar astrophysics and provide bold initiatives into the fields of planetary formation and evolution, and the origin of matter in the early Universe. Some specific issues to be considered will be:

- **How did the Universe begin and what is its structure?**
- **How did matter arise in the high energy environment of the early Universe and what are its forms? How did the fundamental forces of nature decouple?**
- **When and where did the heavy elements form and how has this provided the chemical environment that nurtured the evolution of life?**
- **How were galaxies, the basic building blocks of the Universe, assembled in the distant past?**
- **How do stars and planetary systems form within galaxies and are there terrestrial-type planets around nearby stars?**

The Origins of Matter

The basis of physics is the quest for an understanding of the origin of matter, its motion and change from one form to another. This quest has led us from the earliest concepts on the nature of matter to the present "Standard Model" which provides a consistent picture of all currently observed phenomena in particle physics. But this theory is neither complete, nor plausibly the final model. From a theoretical perspective gravity and quantum mechanics have not as yet been combined into a unified scenario. Experimentally, we continue to search for a missing constituent of the Standard Model: the Higgs boson that generates fundamental particle masses. In addition, there are patterns within the Standard Model that hint strongly at some underlying order, reminiscent of those in the periodic table of the elements that are now explained by atomic substructure. We expect new physical phenomena to become apparent at an energy scale which will be directly accessible at the next generation of accelerators. By contrast, the early Universe produced energies of a magnitude that will never be duplicated on Earth, so a combination of accelerator, cosmologically produced particles and theoretical astroparticle research can provide a more unified picture. At lower energies, the question of the origin of the elements remains incomplete and UBC physicists are in a unique position here with the ISAC facility at TRIUMF which can provide neutron-rich nuclei critical in characterizing nucleosynthesis in stars and supernovae.

The hiring thrust here will be 5 positions for researchers working in the area of the "Origins of Matter". New faculty, both theoretical and experimental, will be recruited into such overlapping areas as string theory, astroparticle physics, experimental subatomic physics and nuclear astrophysics.

The new positions in this thrust of the "Origins" initiative will be drawn from the following areas.

- **The exciting new field of string theory which deals with the origin of the properties of matter.**
- **Particle astrophysics, a remarkable and unexpected area of research that explores the subtle connections between the very small (elementary particles) and structure on the largest scales (cosmology).**
- **Particle physics at the high energy frontier. Among other areas, this research will involve the search for the origin of fundamental particle masses.**
- **Nuclear astrophysics which helps determine which nuclei and particles are produced in the Big Bang, supernovae explosions and in stellar interiors. Data of this sort are critical to our understanding of the chemical evolution of the Universe.**

Our Department is largely lacking in a central and extremely promising new area of research, string theory. String theory aims to incorporate gravity in a quantum field theory and such a theory has been sought from the times of Einstein to the present day.

String theory is a promising candidate for the ultimate Grand Unified Theory, and could eventually lead to a fundamental theory of the physical world. It is arguably one of the most active and challenging areas of basic research and is attracting the best minds in theoretical physics. String theory has recently solved the problem of divergences in quantum gravity, gives interesting explanations of hypothetical properties of black holes and actually comes tantalizingly close to providing a derivation of the Standard Model based on a mirror array of new fundamental particles. String theory, with its potential ability to impact an enormous variety of physical problems in the high energy arena, will draw strength from UBC's strong theoretical groups active in particle physics and General Relativity, and its internationally recognized experimental particle physics effort.

One of the surprises of the past 20 years is how fruitful the interaction between particle physics and cosmology has been. While superficially so disparate (particle physics being that of the very small, while cosmology the study of the largest observable structures), the two fields have found vast areas of common ground. Limits on the number of neutrino species came first in cosmology and then were demonstrated in particle physics experiments. Inflation, the most promising scenario for describing the large scale structure of the Universe, took its theoretical insights from condensed matter and from particle physics (together with Einstein's "failed" theory of the large scale behaviour of the Universe). With the Cosmic Microwave Background results giving us actual observations of the earliest stages of the Universe, one also has the possibility of testing these theories, but this will require deep insight into the possible ways in which particle physics influenced the early development of the Universe. At the same time, developments in the early Universe constrain possible theories of elementary particle physics.

The energy frontier of particle physics has enormous potential for discovery due to the upcoming entry into uncharted energy domains. At present, the ground-based high energy frontier is the Tevatron collider at Fermilab, where the top quark was discovered. Upgrades to the intensity in its beam and its detectors will increase its energy reach. The Large Hadron Collider (LHC) with a much higher energy and beam current is presently under construction at CERN (European Laboratory for Particle Physics). Its quarry is the discovery of the Higgs boson (which has been predicted to generate fundamental particle masses) and the measurement of its properties. Much higher energies are potentially available from particles produced in the early Universe and both theory and observations in this area hold the promise of new discoveries. Indirectly, the energy frontier can also be accessed by precision experiments at existing accelerators. All these experiments at the energy frontier probe the most basic aspects of particle physics and may have profound implications for such questions as the origin and fate of the Universe. They also potentially allow access to entirely new mass scales, and to a new level of sensitivity to novel physics effects. A recent exciting example is the possible evidence for a non-zero neutrino mass from atmospheric, solar and accelerator-based experiments. Although these results remain in flux, awaiting further exploration, the outcome will have far-reaching consequences for both particle physics and cosmology.

Nuclear astrophysics encompasses a broad field including stellar energy generation, the solar neutrino problem, nucleosynthesis and event diagnosis such as x- and γ-ray bursts. Understanding the energy generation and heavy element production in stars, and in more explosive astrophysical events, requires a synthesis of input from such diverse fields as nuclear experiment, neutrino interaction physics, and plasma fluid mechanics. The new ISAC (**I**sotope **S**eparator and **AC**celerator) facility at TRIUMF has great potential for advancing the state of the art in important aspects of nuclear astrophysics measurements and providing unique data on the origin of the elements. However, theoretical input and guidance is crucial to the choice of areas of experimental study. For instance, theoretical identification of what information is needed about nuclear reactions and decay properties is vital to guide experiments on nucleosynthesis. One exciting area is in Big Bang nucleosynthesis. Theoretical analysis of the ratio of helium to hydrogen produced in the Big Bang predicted the existence of 3 light neutrino species. More exotic variations on the Big Bang, for example inhomogeneous Big Bang models, require input from reaction experiments with light, neutron-rich nuclei available at the unique ISAC facility.

The initiative to hire experimental and theoretical high energy physicists will be enhanced by the engineering and technical facilities and staff at TRIUMF which are unique in Canada and provide world-class capabilities in many crucial areas of advanced technology germane to particle physics and accelerators. Few other Departments in the U.S. or Europe have such close access to essential facilities such as test beams, clean rooms, magnet, accelerator, and detector development laboratories specifically designated to support particle physics experiments.

The Origins of Structure in the Universe

The study of structures in the Universe from that on the largest cosmological scale down to planet formation is presently generating enormous excitement. The Canadian Government has recognized the strength and vision of the astronomical community's efforts in these areas and will invest almost \$250M in new international facilities for Canadian astronomers over the next decade. These international observatories will be designed to study the structure and evolution of extra-solar planetary systems, stars, galaxies and the Universe.

The rate of new astronomical discoveries has been truly exhilarating. Over the past several decades these have included quasars, the cosmic microwave background radiation, neutron stars, black holes, dark matter, young galaxies in the early Universe and, perhaps most exciting of all, planets around nearby stars. It now appears that such planetary systems are ubiquitous in our Galaxy. The proposed new faculty members will have at their disposal the revolutionary and novel observatories that Canada has committed to in their investigations of these questions. The three new positions in this section of the "Origins" initiative will be drawn from the following areas.

- **The study of planets and small objects (*e.g.* comets and asteroids) to elucidate the formation of our own Solar System, as well as comparative studies of newly discovered extra-solar planetary systems.**
- **Computational astrophysics which, among other areas, models and helps interpret current star/planet formation scenarios and, further, using a wealth of novel computational**

techniques, impacts on all aspects of the "Origins" program.

- **Observational cosmology, one aspect of which investigates the manner in which gas in the early Universe is collected into galaxies and how galaxies then provide the environment for the formation of stars and their associated planets.**

While the techniques currently being used worldwide in the successful searches for extrasolar planets were developed at UBC, there is currently no major Departmental presence in the exciting areas of planetary searches and star formation. There exists a very strong observational stellar group within the Department doing work on stellar seismology, structure and evolution which will anchor the thrust into this rapidly developing field. A planetary system astronomer will contribute to a deeper understanding of the Solar System in which we live and, simultaneously, work on searches for and characterization of extra-solar planetary systems. The ultimate goal of such research is the detection of a terrestrial planet around a nearby star and confirmation that life could be present on that planet. Such an observation would galvanize the general public and have a profound effect on political, philosophical and religious thought.

A computational astrophysicist working on a broad range of problems including modeling the formation of stars and planets from the gas in the interstellar medium, will provide theoretical support within the "Origins" theme. Five years ago there was no obvious connection between the star and planet forming process, but new observations (gaseous and dusty proto-planetary disks around stars, ubiquity of extrasolar planets) and theoretical developments (modeling the evolution of planets within solar systems) have now shown that they are intimately connected. A modern computationally inclined astrophysicist can, with similar techniques used in the star formation analysis, also study such widely diverse subjects as the creation and evolution of large scale structure in the Universe and the dynamical evolution of self gravitating systems such as star clusters and solar systems. Several astrophysical problems are amongst the most computationally intensive in all the physical sciences and astrophysicists currently use about 20% of the world's supercomputing time. Astrophysical research has been the source of innovative new algorithms such as "tree codes" and data mining techniques as well as inventive new approaches to image analysis. There are the beginnings of a computationally intensive group within the Department already and this position will find a natural home.

Working on the largest scale within the "Origins" group will be a hiring initiative to attract an outstanding observational cosmologist. This field has among its unsolved problems that of galaxy formation which requires studying remote galaxies at times when the Universe was only about a tenth of its current age. The connection here to planetary formation is direct; the interstellar medium, that gaseous fraction of a galaxy which has not as yet formed into stars, is a major component of young galaxies and with time is both enriched in heavy elements due to stellar evolution and slowly depleted due to star formation. Thus galactic evolution chooses the correct cosmic time for the formation of planetary systems which might contain life; a time when there are sufficient heavy elements required for the life process, but still enough gas to form sizeable numbers of stars.

The existing cosmology group within the Department of Physics and Astronomy are world leaders in the areas of the Cosmic Microwave Background, galaxies, gravitational lensing, dark matter and instrumentation. The new faculty member will provide an added dimension by exploiting for extragalactic research the international astronomical facilities just being commissioned by Canada and her partners (*e.g.* CFHT Mosaic Camera, Gemini Telescopes) and be a major force in using the telescopes that will become operational in about a decade's time (NGST — an 8m replacement for the Hubble Space Telescope, ALMA — 64 12m dishes acting as an interferometer, Square Kilometre Array — huge cm-wave array with a collecting area of one square kilometre, VLOT — with an effective diameter of about 35m).

4.1.3 The "COMPLEXITY" Initiative

Alongside questions regarding the fundamental origin and building blocks of the physical world, physicists also study the principles that govern the collective behaviour of those constituents when they are assembled together. Even the study of a relatively simple assembly, such as the ordered array of silicon atoms in a semiconductor crystal, has had the far-reaching consequence of generating our modern electronics revolution. More complicated assemblies of several types of atoms give us materials with wholly new properties such as magnetism and superconductivity. At an even higher level of complexity, nature makes use of extraordinary structures, such as proteins and membranes.

The spirit of this area is embodied in the concept of emergent phenomena, the idea that when one joins together the fundamental building blocks of nature, these assemblies exhibit phenomena that must be understood in terms of new principles appropriate to the higher level of complexity. Physicists strive to make progress in this area by trying to discover and exploit the fundamental principles governing behaviour at different levels of "Complexity". The work is often highly interdisciplinary, since it makes use of the tools and research style of physics to address problems that are also of interest in biology, chemistry, and a wide range of engineering disciplines.

Conversely, techniques and discoveries in these areas provide physicists with new tools to help make progress in the fundamental understanding of matter. Some key questions are:

- **What controls the loss of quantum coherence when we combine atoms into more complex structures?**
- **Is it possible to build a macroscopic object that exhibits quantum mechanical behaviour?**
- **What controls the formation of complex structures in biological molecules built from simple chains?**
- **Can we control complex molecules to assemble nanostructures?**
- **Can we build a quantum computer?**

New positions envisioned within the "Complexity" program are focussed in two initiatives outlined below. One involves an area of biophysics which is concerned with the extraordinary properties achieved by assembling the simple constituents that make up biological materials. The second area is concerned with quantum coherence, the bridge between the quantum world of individual atoms and the classical world of macroscopic matter. The connection between the two areas is that both involve the rapidly moving field of nanostructures, our new ability to manipulate matter on the atomic and molecular scale.

Biological Complexity

Biological systems are prime examples of what is meant by the term "Complexity", where structures built from simple constituents demonstrate properties and behaviour far more complicated than the underlying building blocks. Biopolymers, such as proteins and nucleic acids, are long chains of simple sub-units, but they demonstrate functions ranging from chemical catalysis to antifreeze. Recent advances in physics, chemistry and biology are now enabling the application of techniques and ideas from each of these fields in this exciting interdisciplinary area. In recent years, techniques such as nuclear magnetic resonance, atomic force microscopy and optical tweezers have all moved from the physics into the biology laboratory. These new techniques also figure prominently in the condensed matter physics initiatives outlined below.

Conversely, such research also leads to new physics such as the protein folding problem which has the goal of predicting the shape of a large protein from knowledge of its sequence of amino acids. This also has the potential to provide physicists with new tools such as biomolecular self-assembly to engineer nanostructures.

- **We plan to fill two positions in biophysics in the near future centred around the common goal of understanding the complex folding and binding behaviour of large biological molecules. This far-reaching topic requires a level of understanding that needs to be achieved at an atomic level, drawing heavily on the expertise of physicists.**

The involvement of physics in the understanding of biopolymer function will result in major breakthroughs within the next two decades and will have great impact in both biology and physics. For biology, it is a key aspect of the origin and functioning of life. The essentials of life revolve around large assemblies of atoms behaving in ways unique to biological systems. Understanding how proteins and RNA chains fold into functional structures and the way these conformations change in response to the environment are problems of the underlying physics of biological molecules. The role of these structural problems in processes such as the regulation mechanisms within cells will deepen our understanding of life and its origins. For physicists, new understanding in this area will also enable the use of biological molecules for nano-fabrication. Given the current state of protein engineering, it is likely that nano-fabrication and development of materials and devices using self-assembling, engineered, biological molecules will become an enabling technology in physics in the near future. A key component of this emerging technology will be the requirement to predict protein structure and binding properties from amino acid sequences.

The existing biophysics group at UBC is small. It was built from a core of ground-breaking work in membranes, and presently includes two of our newest faculty members. However, UBC is uniquely positioned to build a leading international effort in biophysics, in part due to the extensive infrastructure and existing programs in the Vancouver area, including the Laboratory for Molecular Biophysics, the Biotechnology Laboratory, the Centre for Molecular Medicine and Therapeutics, the BC Cancer Research Centre, and AMPEL. The recruiting advantages of outstanding local facilities and collaborators, along with the momentum they are now generating and the potential support offered by the Biotech Lab and the BCCRC, can all be leveraged in the short term, before competition for quality researchers rises out of reach.

Complexity in Inorganic Matter

Condensed matter physicists study the structure and properties of matter lying between the small scale of subatomic physics and the large scale of Cosmology, Astronomy and Astrophysics. Since there are almost limitless ways in which matter can be configured, the study of condensed matter is a particularly large and diverse area of physics. At the present time, a number of revolutionary advances are setting the current path in the field. These include the exploitation of several powerful new probes of matter, such as synchrotron radiation and the wide range of new microscopies that are capable of imaging on the atomic scale. Perhaps most exciting is our new-found ability to deliberately assemble and manipulate matter at the atomic level. This ability is surfacing through a diverse set of techniques being developed in chemistry and physics, plus new methods for assembling structures discussed in our initiative in biological complexity. For the condensed matter physicist, the remarkable convergence of these fields on the nanometre length scale provides a unique opportunity to understand how to make the connection between the quantum mechanical world of atoms and the macroscopic world of materials.

We plan to fill four positions that provide the broad base for an initiative into the area of quantum coherence, a frontier concerned with pushing distinctively quantum behaviour into the macroscopic realm.

- **An experimentalist working in the area of nanostructures will provide key technical capabilities for producing and studying small structures used to study phenomena at nanometre length scales.**

- **Another experimentalist will pursue problems of quantum coherence. This is a broad field related to the fundamental problem of how the world of quantum mechanics at the atomic level merges into the classical world at larger scales.**

- **Two more positions will provide the theoretical foundation for the initiative in quantum coherence. Such individuals will play a key role in tying together our existing activities and the new direction presented by the positions in nanostructures and quantum coherence.**

At the present time, the size of structures used in computer technology is dwindling rapidly into the nanometre length scale. Already, the leading-edge research in the field is producing structures involving very small numbers of atoms, where quantum effects play a significant role in the properties of the structure and devices being built. Thus, the research pursued in this field will have direct impact on the semiconductor industry as it miniaturizes down to the scale of only a small number of atoms in a device. Currently, the perspective of the field is inevitably shifting towards trying to make explicit use of the quantum phenomena that can be realized in nanostructures, rather than viewing them as a roadblock that limits what can be achieved. In order to play a role in this new area, the technical ability is required to produce and study small structures, abilities that can be provided with a combination of existing activities in the AMPEL building, a new position in nanostructures, and the synergy that can be developed with biophysics, chemistry and biochemistry. Infrastructure for this research is already developing in AMPEL, including a clean room, film growth apparatus and a wide range of atomic resolution microscopy facilities.

The central idea leading to the use of quantum phenomena on a macroscopic scale lies in the area of quantum coherence. In trying to make macroscopic objects exhibit quantum properties the key problem lies in the tendency for them to get "entangled" with their environment, in a way that causes quantum coherence to be lost. Experimentalists and theorists in this field are striving to prevent this decoherence. The theoretical leap required is to understand how this entanglement and loss of coherence occurs, an area that brings us to the edge of our understanding of the fundamental meaning of quantum mechanics. Guided by this theoretical work, the experimental task is a technically demanding one, involving a large number of possible approaches ranging over areas such as quantum optics techniques, superconducting nanostructures, and mesoscopic magnets. Each of these fields brings its own set of specific theoretical and experimental problems, on top of the overall issue of decoherence. For instance, an approach centred on mesoscopic magnets would require expertise in the chemistry of such materials and considerable work on the theory of such exotic magnetic structures. Work on superconducting nanostructures would involve UBC's existing strength in superconductivity, coupled to new initiatives in nanostructures and theoretical work specific to the nature of the superconducting state.

Our position as the foremost research group in condensed matter physics in Canada, the facilities in AMPEL, and the condensed matter program at TRIUMF and ISAC all provide us with the opportunity to play a leading role in this field. Success in this field will have far-reaching implications. It brings us to a confrontation with fundamental issues in quantum mechanics that are of great interest at the foundations of theoretical physics. A proper understanding of quantum coherence and the ability to control it is also the key step required in order to realize the first functioning quantum bit, the basis for realizing a truly quantum computer.

4.1.4 Additional Programmatic Requirements

Engineering Physics

The engineering program draws much of its strength from the diverse activities that constitute applied physics in the Department. Many existing members of the Department spend some fraction of their research time in applied physics and such activities will continue to follow naturally from the hiring plan outlined here.

There are a number of aspects of the "Origins" initiative which have a potential engineering component to them, including the development of new astronomical facilities.

The field also makes heavy use of leading-edge computational and image processing tools, areas where there are certainly strong opportunities for students.

Much research in biophysics is highly applied in nature, involving the application of state-of-the-art tools and techniques to diverse problems in biology.

Our new initiatives in condensed matter physics, particularly those related to nanostructures, also lie at the frontier of present application of physics. In this area, physicists are working on the materials that will be at the heart of future technologies.

In order to maintain accreditation of the popular and successful Engineering Physics program, the Department will need to have at least 2 more faculty with professional engineering qualifications over the period of this plan. There are several avenues open towards achieving this goal. It is desirable that possible status as a professional engineer be considered in hiring decisions, particularly in the areas involving the applications of physics. Secondly, an initiative in the Department among existing faculty should be undertaken to certify those that are likely candidates. At least 3 such faculty members have been currently identified.

Medical Physics

Medical physics is essentially an area of applied physics aimed at issues of human health. The problems tackled range over issues of fundamental understanding of the human organism, as well as the diagnosis and treatment of disease. Physicists and astronomers play key roles here, the most well known ones involving the development of increasingly sophisticated imaging techniques and the therapeutic use of radiation.

A medical physics program has a number of special needs arising from the direct contact with patients and the enormous need for well-trained physicists to meet BC's clinical needs. The present academic direction of the group is to meet this crucial need by moving towards a formally accredited program in medical physics. In many institutions, such a program operates within a medical school, but there are substantial advantages to keeping it more closely connected to its roots in a physics Department. This is perhaps best illustrated by the fact that programs outside of physics Departments often produce superb students at the M.Sc. level who then must come to a program like that at UBC if they want to go further into the realm of innovative research. TREK 2000's goal of close ties between the university's research and education activities are well met by a strong medical physics program, with its roots in the Department of Physics and Astronomy.

The Department's research and academic activities in this area involve only one faculty member with a partial appointment in Physics and Astronomy, plus a large number of adjunct members working in hospitals and the BC Cancer agency. This structure in principle is advantageous because of the need to have close connections with these agencies and access to facilities and patients. As the group moves towards an accredited graduate program there is a clear need for at least one new appointment with a substantial fraction in the Department of Physics and Astronomy. Such a person is needed for this expansion in a program that already involves about 20 of our graduate students. The physicist hired into this position will play a strong role in furthering the Department's research excellence at the forefront of the field.

4.2 Connections to Other Units

(Michal)

The Department has close connections to many other units on campus through a variety of teaching and research initiatives and cross-appointments.

4.2.1 Undergraduate Education

[See earlier Chapter.]

In the area of undergraduate education, Physics and Astronomy works closely with Botany, Chemistry, Computer Science, Mathematics, and Zoology in presenting Science 1

http://www.science.ubc.ca/~science1/

and the Coordinated Science Program

http://www.science.ubc.ca/~csp/

These programs have met with considerable success since their introduction and now account for a significant fraction of the 1st year undergraduate teaching load. In later years, Physics 438 (Zoological Physics) is cross-listed as Biology 438 and co-taught with a faculty member in Zoology. Physics 455 (Statistical Mechanics) has recently been combined on an experimental basis with Chemistry 407/503.

The Honours Biophysics program

http://www.physics.ubc.ca/~birger/ubro_bp.htm

has forged new links between this Department and the various Life Sciences Departments involved. After just three years in existence, this program already rivals the Honours Physics program in enrollment. Further growth will allow the creation of courses tailored for the program, possibly in collaboration with faculty in the Life Sciences, Chemistry, or Engineering.

4.2.2 Research Initiatives

Canada Research Chairs

With the announcement of the Canada Research Chairs

http://www.chairs.gc.ca/

program, the Department has invested heavily in expanding and solidifying its links to other units. The Department has taken the lead in the "Quantum Structures and Information" cluster,

http://www.physics.ubc.ca/CRC/quantum.html

which involves Chemistry and Computer Science. The first proposed appointment in this cluster is to 50% joint appointment between Physics and Chemistry, as a Tier 1 CRC chair.

The Department is also leading the 'Origins and Mathematical Structure' cluster,

http://www.physics.ubc.ca/CRC/origins.html

with which Mathematics is involved.

The Department is involved in the Biotechnology and Genomics cluster,

http://www.physics.ubc.ca/~andre/crc/genomics_cluster.html

as well as the Neuroscience and Cognitive Systems cluster. In the former, there is a strong possibility of a joint appointment with Chemistry and in the latter, the Department will be joint home to the director of the newly funded (CFI, BCKDF) Magnetic Resonance Imaging Center.

While the CRC program is an important part of the Department's plans for strengthing our inter-unit links, it is by no means the only avenue by which we are pursuing such initiatives. In addition to a variety of current joint appointments (Evan Evans, Pathology; William Hsieh, Earth and Ocean Sciences; Alex MacKay, Radiology; Andre Marziali: Biotech lab; Tom Tiedje, Electrical and Computer Engineering). The Department has recently made an offer of a 50% joint appointment to the incoming head of Chemistry, and submitted a UFA nomination for Vesna Sossie, who is an important part of the TRIUMF/UBC PET program

http://www.triumf.ca/pethome/pethome.htm

Other initiatives the Department is pursuing include an expansion at the interface of Nanoscience and Biophysics. The marriage of semiconductor fabrication technologies with the self-assembly and specific binding properties of biological molecules promises to revolutionize sensor, diagnostic and micro-array techniques. As such research will have a profound impact on the fields of genomics and proteomics, discussions have been ongoing with the Biotechnology Laboratory on how best to leverage our joint strengths.

The research activities of many other Department members are connected to other units on campus through a variety of formal and informal arrangements. Some examples include:

The Institute of Applied Mathematics

http://www.math.ubc.ca/Grad/iam.htm

The IAM designs and oversees interdisciplinary M. Sc. and Ph. D programs for graduate students from different Departments working with applied mathematics. The IAM also supports colloquia and seminars, maintains a computer lab, and provides consulting to those using applied mathematics in their research. The IAM involves approximately 16 Departments on campus.

Pacific Institute for the Mathematical Sciences

http://www.pims.math.ca/

PIMS "is dedicated to promoting all aspects of the mathematical science by stimulating, coordinating and facilitating the activities of the mathematical scientists in Alberta and BC [and Washington]." PIMS involves the theory group of this Department, and connects to other Mathematically oriented groups both on campus at UBC as well other Universities in BC, Alberta, and Washington State. PIMS currently supports three postdoctoral researchers working in this Department (Luis Lehner, Sumati Surya, and Konstantin Zarembo), as well as the string-theory seminar series.

Advanced Materials and Process Engineering Laboratory

http://www.science.ubc.ca/~ampel/

AMPEL is a multi-disciplinary materials research facility housing faculty from Physics and Astronomy, Chemistry, Electrical and Computer Engineering and Metals and Materials Engineering. The facility encourages interaction between laboratories of the various groups housed within. Much of the growth forseen in the Department in the fields of Nanoscience and Condensed Matter Physics will have strong connections with existing faculty and facilities here. In addition, the initiative joining Biophysics and Nanoscience will depend on the strengths in this facility.

Laboratory of Molecular Biophysics

http://laue.biochem.ubc.ca/lmb/index.html

The LMB is a recently funded (CFI, BCKDF) collection of research infrastructure hubs for the study of biological molecules. Members of the Department involved with the LMB to various extents include Bloom, Evans, MacKay and Michal. As the department's committment to Biophysics expands as described above, it is expected that our participation in the LMB will see a concomittant growth.

High-Performance Computing

The Department is home to a 128 processor Beowulf cluster as described in the Computing Research Facilities section. This cluster has users from a variety of Science and Engineering departments on campus, and plans for the expansion of the cluster and its impact on campus are underway.

TRIUMF

http://www.triumf.ca

While not a "unit" of UBC, TRIUMF has a significant presence on the UBC campus. A wide variety of research from this Department takes place here as evidenced by the list of Department members involved: Auld, Brewer, Bryman, Craddock, Hasinoff, Hearty, Johnson, Kiefl, Mattison, McKenna, Measday and Waltham. In addition, TRIUMF staff members, J. Ng, and S. Yen have adjunct or Associate status in this Department. This involvement spans a range from fundamental subatomic physics to medical and condensed matter physics.

BC Cancer Research Centre

http://www.bccancer.bc.ca/research/

Again, while not a unit of UBC, the BC Cancer Research Center is the source of many interdisciplinary initiatives with which the Department is involved. Researchers R. Durand, E. Grien, C. MacAulay, P. Olive, B. Palcic, and L. Skarsgard all have Associate, Adjunct or Honorary Professor status in the Department.

Medical Physics Program

The teaching and research core of the Medical Physics program is carried out by a large number of Associate, Adjunct and Honorary professors in the Department from the BCCRC and the Cancer Hospital (BC Cancer Agency), namely B. Clark, S. Flibotte, and E. Grien, along with J. Aldrich (Radiology), A. Celler (Radiology), A. MacKay (Physics/Radiology) and Qing San Xiang (Radiology) form the teaching and research core of the Medical Physics program. All of these faculty have affiliations with the local teaching hospitals. About 1/5 to 1/4 of the graduate students in the department work in this area. The success of this program from both a teaching and graduate research point of view has inspired the creation of a formal Medical Physics graduate program, described in the Graduate Program Section.

4.2.3 The CIAR

(Affleck)

This Department currently has nine faculty members who are members of three different Canadian Institute for Advanced Research (CIAR) programmes: Cosmology & Gravity, Superconductivity and Nanoelectronics. These memberships provides the faculty members with teaching relief and networking; they also enhance the visibility of our Department and provide the Department with a powerful tool for recruiting new faculty.

The large number of CIAR members with reduced teaching loads provides both a rationale and a need for bridged faculty appointments. A potential danger is that the CIAR funding is plentiful but very soft. Part or all of it could be cut off at any time with very short notice due to faculty members leaving the Department or changing priorities at CIAR. In principle CIAR funding of programmes and appointments is generally for five years with renewals possible but increasingly difficult. However, the CIAR has been known to reduce funding at unexpected times. The Cosmology & Gravity programme is up for its five year review this year and the Superconductivity programme is to be reviewed next year.

The ongoing and potentially new CIAR programmes provide opportunities for future recruitment of faculty members. A new programme in Quantum Computing is under consideration by CIAR. Two of its three proponents are Bill Unruh, presently in this Department and Raymond Laflamme, a CRC nominee. In addition, expansion of the Nanoelectronics programme looks quite likely as do personnel changes in the two older programmes, if they are renewed.

Chapter 5

COMPUTING

(Choptuik)

5.1 Departmental Servers

The Department's main general-purpose computing facility is a SUN E3000 4 processor server, equipped with 2 Gbyte RAM and about 100 Gbyte of disk storage. All Department faculty, staff and graduate students are eligible for accounts on this machine, as are undergraduate students majoring in Physics or Astronomy. The server is intended for interactive use, such as e-mail, Web browsing, and running of various software packages (*Mathematica, Matlab etc.*) in instructional contexts. As a result, even given the large number of users, the system is currently running quite smoothly, with relatively few complaints reported by the departmental system administrators. One key advantage of the "single server" approach is that software licensing fees are kept to a minimum.

Although the departmental server is currently performing adequately, the machine is now almost four years old, and some sort of upgrade or replacement will be necessary in the next few years. In addition, the installation of a high-performance, network storage facility, coupled with a high-speed tape backup facility would significantly enhance the departmental computing infrastructure, and thus is viewed as a high priority. Finally, it would also be advantageous to off-load some services, such as mail relaying and DNS, to another smaller server, leaving the main machine to function solely as an applications server. Funds on the order of $125,000 would be required to carry out these plans.

The Department also maintains a 15-user-license NT server, which was funded by the Dean of Science, and hence is available to any Science student who requests an account. However, it is mainly used by first year P&A students. This system is very outdated and requires an upgrade as soon as possible (see next section on Undergraduate Facilities).

Finally, certain computer peripherals, such as color printers, scanners, CD-ROM burners, digital cameras *etc.*, while very useful to large numbers of Department members, are typically not used frequently enough by any given group to warrant a group-dedicated purchase. The Department should maintain its policy of acquiring and managing such devices, as it has done, for example, with the departmental color printer and scanner.

5.2 Undergraduate Facilities

Undergraduate access to the departmental servers is provided through approximately 35 X-terminals located in two rooms in Hennings. In addition, the Department has a 12-seat lab equipped with NT machines. These facilities are heavily used and additional stations are clearly needed. Lab space for an additional 32 seats has been identified, although it is not yet clear what type of equipment will be installed. On the basis of typical usage of the current facilities, X-terminals (or cheap PCs running as X-terminals) would probably be the most cost-effective solution, again, particularly when software licensing fees and system administration costs are taken into account. If this route is taken, then a new terminal server, capable of serving both Unix and Windows applications, will be a high priority. Approximately $100,000 would be needed for the new equipment (*cf.* 2001/2002 Academic Equipment Proposal).

5.3 Graduate Facilities

The Department maintains a small lab with 2 X-terminals and 2 PCs for graduate student (and faculty) use. This has served the needs of those students who do not have access to machines in their labs or offices fairly well. However, a strong case can be made for a moderate expansion of these facilities, which would also provide improved resources for computational physics courses offered at the senior undergraduate and graduate level. An estimated $15,000 would be needed for this upgrade.

5.4 Research Facilities

The Department does not currently have any general facility for research-level computing. However, members of the Department can access the large Beowulf cluster which was recently installed in the Klinck building using CFI funds awarded to Choptuik (Physics & Astronomy), Bushe (Mechanical Engineering) and several other co-investigators in Science and Applied Science. As in other disciplines in science and engineering, high performance computing needs within the Department are likely to grow significantly for the foreseeable future. It is clear that the best way to ensure access to the requisite level of computing power is for the Department to continue to be aggressive about partnering, not only with other units within the University, but with other research institutions in BC, and across the country.

5.5 Networking Facilities

Currently, the departmental networking situation is quite good, with an internal 100 Mbit fabric, and 1 Gbit + 2 100 Mbit connections to the campus backbone. As equipment with Gbit capability begins to be installed over the next few years, there will be a need for Gbit switches, and upgrades of the 100 Mbit external connections to Gbit. Funds on the order of $25,000 would probably be adequate for this purpose.

5.6 Personnel

The two current system administrators for Physics are extremely busy. The completion of the merger with Astronomy, which currently has a single full time system administrator, has the potential to ameliorate this situation somewhat. However, it is clear that additional personnel support for computing will only be of benefit to the Department. One very cost effective approach would be to appoint one or more graduate TAs who would be trained by the permanent staff specifically to do day-to-day system administration.

5.7 Information Technology

(Brewer)

In the last decade, information technology (IT) has not only revolutionized the way humans communicate but also helped clarify the distinctions between information, knowledge and understanding. Inasmuch as the goals of the University include the illumination of these distinctions, the creation of new knowledge, the organization of information and the communication of understanding, it behooves us to use IT wisely in our work and to help guide its evolution. If we are careless or incompetent, the exponential growth of useless information may drown the spark of understanding, and commercial exploitation of educational IT may undermine the very *raison d'etre* of Universities and the face-to-face (F2F) educational experience. If we are ingenious and diligent, we can facilitate the distillation of raw information into useful knowledge, and IT may be used to eliminate much of the uninspiring drudgery of education, liberating resources for dramatically enhanced F2F interactions.

For our Department in particular, IT presents the following strengths, weaknesses, opportunities and threats:

5.7.1 Remote Communication & Distance Education

The *World Wide Web* was invented around a decade ago at the CERN high energy physics laboratory, culminating a long tradition of leadership in IT from Physics and Astronomy. However, the subsequent commercial impact of the Internet and the Web has led to an explosion of IT development by other sectors, with the result that the frontiers of IT today are much broader.

Particularly dramatic growth is underway in the educational IT sector, mostly in what is called "distance education". The leading application software for course delivery over the Web is *WebCT*, developed at UBC and now used by nearly 150,000 faculty at over 1,500 colleges and universities in over 60 countries to deliver course materials to nearly 6 million students. We at UBC are entitled to free use of *WebCT*.

While distance education is a welcome innovation for people who, for one reason or another, cannot attend the University in person, it is a pale substitute for the real thing. Here at UBC, the advantages of tools like *WebCT* lie in their potential to relieve instructors' logistic burdens, improve communications with and between students, offer easier access to supplementary information or exercises, and thus free more class time for effective F2F instruction, which will probably always be superior for synergistic interaction and pedagogy.

The obvious threat is for shortsighted politicians to mistake economics for efficiency and imagine that the availability of a good *WebCT* course presentation could take the place of the faculty member who created it. Pressure might then be applied to University administrators to implement such replacements.

5.7.2 Management and Presentation of Information

In the last few years all practical barriers to bulk information storage have evaporated. Today a typical hard drive holds 20 GB, enough for about ten thousand 500-page books of text or a similar number of high resolution images. For a few hundred dollars anyone can store a library it would take a lifetime to read.

Using the Web, this store of information can be delivered to anyone who requests it, in formats at least as pleasing to the eye as the most expensive paper textbooks. There are also a wide variety of presentation tools (such as *WebCT* and the various Web browsers) that allow the server and the user to organize that information and optimize the efficiency of its retrieval.

Advances in hardware have greatly improved the delivery of information when the user already knows where to look for it; but with literally billions of Web pages now accessible, the problem of *locating* information becomes central. Commercial "portal sites", whose main purpose is to advertise clients' Web sites, simply add to the confusion.

Fortunately, many *search engines* have been developed to help people find the information they seek on the Web, with increasing success. Whereas the first such public services tended to deliver a huge number of links in arbitrary order, most of which pointed to sites with useless content, the latest engines employ ingenious algorithms to produce a link list in decreasing order of relevance or quality. They often succeed, but not always. Moreover, even the best sites are not necessarily appropriate to the purpose at hand. Most of the information on the Web is either pedagogically useless or just plain wrong.

There is therefore a growing need for *custom databases* containing information that is (a) presented efficiently and ergonomically; (b) appropriate to a specific use; and (c) certified as reliable by people who ought to know.

This was the rationale for the *HyperTextBook* project developed for the *Science 1* program with support from TLEF and our Department. The *HyperTextBook* is both a collection of pedagogical material appropriate to First Year Science (Mathematics, Physics, Chemistry and Biology) and a Web-accessible database of links to and between the "pages" of that material. Its purpose and use are most easily explained by trying it out at

http://musr.physics.ubc.ca/~htb/

Our Department would like to take an increasingly active role in the development of such pedagogical and research tools using IT.

The End of Authority?

Even if information becomes more easily located and categorized, there is another profound problem presented by the IT explosion: *which information can be trusted?* Anyone can present any nonsense they like on a Web site just as glossy as any at the University. Is there a way to "vet" information that takes advantage of both the democratization of the Web and the established authority of great educational and research institutions? If not, public trust in intellectual authority may decline until support for those institutions is withdrawn. Today the University has a great deal of the most valuable commodity in the Information Age: *credibility*. If we fail to earn, manage and apply this wealth wisely, we will lose it. We cannot afford to neglect the Web as a primary ground upon which this crisis will be played out.

5.7.3 IT in Research

Today's research groups are frequently geographically dispersed, especially in megaproject-oriented fields. This has created an urgent need for efficient remote access to large, highly specialized databases. This need has been recognized for several decades; in fact, subatomic physics and astronomy have led the way to modern IT, the most dramatic example being the *World Wide Web* itself, which was invented at CERN.

A new trend has now appeared toward remote networking in smaller research groups. This has been made possible by the availability of inexpensive hardware and easy-to-use software for database creation, manipulation and delivery over the Web. For example, all the μSR data every taken at TRIUMF (over 80,000 "runs") can now be searched, displayed and analyzed using any Web browser from anywhere in the world. To try this out, visit http://musr.triumf.ca and click on "Find runs".

5.7.4 IT in Administration

Our Departmental Web Site at http://www.physics.ubc.ca/ is the main window through which the world sees our Department. Its maintenance and continuous improvement are essential to recruitment, public relations and communication. At the same time, we are developing tools for *gathering* information more efficiently, such as a "Web Wizard" site where administrators or lecturers can interactively create Web surveys, including the HTML form presented to their staff or students, the database in which responses are stored, and the PHP script which displays text and statistics from the results stored in the database.

5.7.5 IT Personnel

As mentioned earlier, Physics & Astronomy currently employs two system administrators who are overloaded with the task of keeping Departmental systems operational and secure. Almost all IT projects are undertaken by faculty or students in their spare time. It might be worth considering the appointment of an Information Officer whose task would be to coordinate these enthusiastic volunteers and ensure that their contributions to the Department's Web presence are competent and fit together in a coherent whole.

Chapter 6

TECHNICAL SUPPORT

6.1 Physics and Astronomy Shops and Services

Along with IT support, the Department provides skilled technical and shops support. Presently, the shops include the main machine shop with six full-time technicians, equipped with computer controlled lathe and milling machine, the electronics shop with a supervising engineer and three technicians, the well-equipped and supervised (50% by one of the 6 shop technicians) student machine shop, and the shared-technical services facility that provides liquid helium, maintenance of research equipment, and limited glass-blowing services.

Use of the shops costs researchers $10/hr for technician's time with materials provided at or near cost.

The Department also has its own store room with a part-time store-keeper providing consumables and electrical and mechanical parts.

6.1.1 Strengths, Weaknesses, Opportunities and Threats

Strengths:

- The people!
- Skilled technicians, high quality work
- Well equipped machine and student shops
- Good connections between shops (*e.g.*, construction of balloon gondola).
- Variety of services provided: the shops will take a project from conception to finished product, or will help faculty or students with any step along the way.
- Training of students in student shop

Weaknesses:

- Budget cuts have forced some contraction in the services provided. STS is down to one technician from two. The glass shop is all but closed.
- physical separation of different shops in different areas hinders sharing of equipment.
- some duplication of services and equipment between shops and STS. Consolidation of STS with the other services should be considered.

Opportunities

- The upcoming influx of new faculty members should produce more new projects for shops. Enough work should alleviate most of the Threats.
- investment in renewal of aging and obsolete equipment will enhance shop capabilities, professional development for staff.
- Possible addition of overhead support from NSERC could support improvement in shop equipment and reduction of shop rate.
- Expansion of capabilities and support for microfabrication and advanced instrumentation such as electron microscopes, NMR spectrometers, optical spectrometers and lasers.

Threats

- With the recent hiring freeze and aging faculty, the shops (especially electronics + STS) have been doing less design and construction and more maintenance work. This is less interesting work, and stifles professional development of the staff.
- As integrated circuits become ever smaller and faster, the infrastructure and skills required to design and construct circuits becomes ever greater. In the near future this will pose a serious problem to the electronics shop, as the facilities for building modern projects with surface mount technology do not currently exist in the Department.
- further erosion of departmental support would require cuts to the level of service provided.
- retention of hard-to-replace staff.