February, 1996

UPSCALE: Undergraduate Physics Students' Computing and Learning Environment: Towards the Year 2000

EXECUTIVE SUMMARY

A five year plan to take *UPSCALE* into the next phase of supplying appropriate computational technology to our students is described.

We intend to develop the capability to deliver all our instructional material in a network format. As the first step we will concentrate our efforts on the first and second year of our undergraduate program.

The first year of the plan we intend to establish a framework of communications with the *Information Commons* and other University services. We will develop and convert existing presentation material for two first year courses to electronic format. We will establish a database for our laboratory instrument specifications (important for our 1st and 2nd year laboratories). We will purchase a portable projection system and conduct workshops to educate faculty and staff.

Each of the five years of the plan is designed to be free standing, so that its success does not depend on succeeding years. The largest single continuing need will be for human resources. We anticipate that the level of support we will require to be approximately constant for each of those five years. The first year of the plan will require $41,150 in funds.

OBJECTIVE

Within five years the Physics Department intends to have the capability of delivering all instructional material in a networked format. This is intended to be a "paperless" instructional system with appropriate facilities for lectures, seminars, tutorials, problems sets, discussions, and with the exception of the physical apparatus, the laboratories.

This capability and the attendant unification of our instructional materials will achieve a great increase in the effectiveness of our educational efforts in traditional settings such as lecture halls, tutorials, and laboratories. It will allow us to extend our instructional materials into our students' homes in ways impossible without the use of this technology. It also allows us to consider an extension of our definition of *student* to include people without regular physical access to the St. George campus of the University.

Finally, current research into 'structured documents' allows for the exciting possibility that if the efforts described below are done with care, extending access to

our instructional materials to people with visual or other disabilities can be accomplished within the overall framework of the systems we propose constructing.

INTRODUCTION

UPSCALE has been very successful in integrating computing technology into our undergraduate program, and our usage by undergraduates continues to grow each academic year. The current plan, dated November 1988 and last revised November 1989, is largely implemented. However it is now approaching 8 years since this plan was developed, which is a very long time in computation. Thus, this document outlines the next steps in the use of computation by our students.

Some musings on this path were written in April 1994 as part of the Department's "White Paper" exercise. Here we 'flesh out' those ideas. As was the case for the document of November 1988, whenever possible areas of functionality are discussed, avoiding details of implementation.

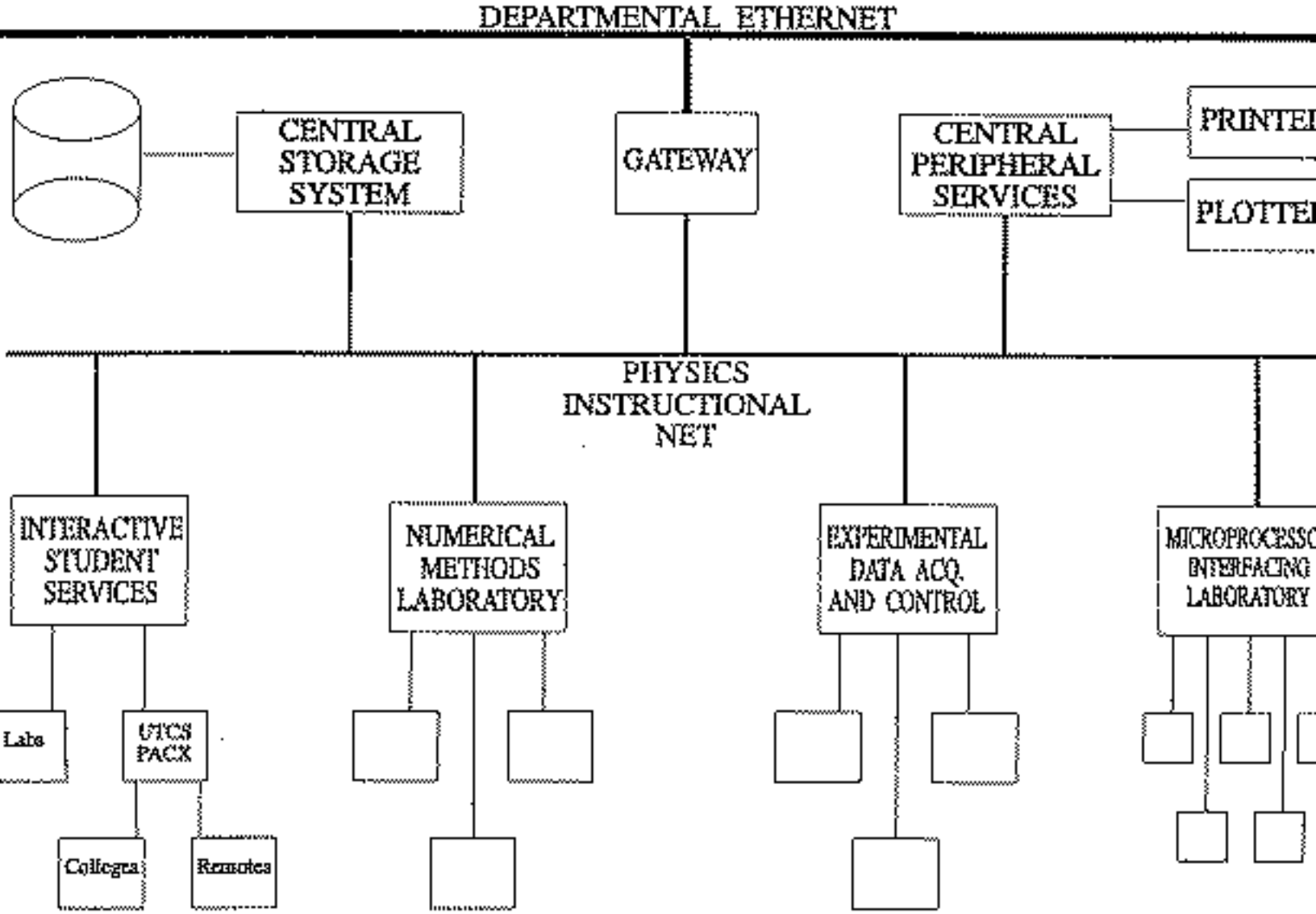
The central questions being addressed here are the same ones we asked in 1988: *"How do we teach young scientists-in-training how to make use of computers in a sane and sensible manner? That is, how do we teach them to use computers correctly to enhance their physics rather than as a crutch to avoid thought or to cover mistakes?"*

OVERVIEW

One change from the view of computing we had in 1988 is that we now tend to analyse the appropriate uses of the technology in terms of two broad areas: (1) Numerics; and (2) Information. Note that *communication* is one important aspect of *information*. *UPSCALE* has been active in both of these areas for well over a decade.

The spread of computer access and networks has led to a re-evaluation of the methods by which information is distributed. Instructional material is part of this information. Whilst realising that the mission of the University is the transmission of knowledge and ideas rather than brute facts, it is also important to use the most effective means possible to disseminate information in order to concentrate maximal resources on more significant issues that are strongly dependent upon instructor/student interaction.

The figure on the next page is from the document of 1988. It should be noted that the blocks are functions, **not** hardware. It is a reasonable description of the current *UPSCALE* facility, with one exception. In 1988 we were thinking of Interactive Student Services largely as an adjunct to the laboratory program. Now, with computational assignments pervading our lecture courses, particularly in the upper years, Interactive Student Services are equally important to both our



UPSCALE Functionality Defined in the 1988 Plan

laboratory and our lecture courses. This has meant that we are now supplying a higher percentage of our "seats" in a general access terminal room than in our laboratories.

A list of staff active in *UPSCALE* and the services we currently provide our students is contained in Appendix A.

The fact that the *Information Commons* is also on the network and that powerful PC's and high speed modems are affordable allows us to consider extending our service into student homes in ways not possible with our existing PACX dial-in service. As the usage of *UPSCALE* grows, this in turn allows us to off-load some of the burden of providing increasing numbers of seats to our students within the building. This same network capability, already being used to provide access to *UPSCALE* from the satellite campuses, allows us to consider offering selected services to a broader base than just the University of Toronto. In particular we are thinking of the possibilities of distance education.

A further implication of the existence of the *Information Commons, Cquest* and an ever growing list of facilities providing computation to undergraduates is that many students accessing *UPSCALE* are the same people that are using the other facilities. Thus, efforts to maintain consistency in the ways in which the services are delivered is worthwhile both in terms of the human factors for the students but to allow sharing of effort among the various organisations within the University.

There are a number of issues which must be addressed in order to achieve the objective of this plan. The first is to recognise that all efforts to "computerise" the delivery of material must have as pre-eminent objective the enhancement of the learning process. The second is that it is not clear in all cases what is the most effective method of enhancement. Finally there is the steady requirement for resources. Although there are gains in operating efficiency in some ares, there are also real, continuing costs in equipment and especially human resources associated with this transition.

Students are also well aware of the capability of electronic distribution - some of our students are ahead of us in this area and fully aware of the efforts at other universities. This can easily lead to a perception that our university is "behind the times" and that our quality of education is inferior. This is not necessarily a rational conclusion, but one which is widely shared by students, politicians, and the public at large.

We close this section with a specific example. One of our applications provides students in our largest course, PHY138Y - *Physics for the Life Sciences I*, access to scans of problem set, test, and examination solutions. So far this year, still only

three quarters complete, the application has been accessed 15406 times by 910 different students. Just before a test in that course, we would require literally hundred of terminals to satisfy demand. Instead, since students in other courses and laboratories require access to *UPSCALE*, we have been forced to limit the times during which the application can be accessed. Re-engineering the application so it is network accessible would allow the large and growing number of PHY138Y students with the necessary hardware and software to access the solutions from their homes. It similarly makes the application available anywhere on the network. Many students are now asking us to provide this capability. This capability will also reduce the need for *UPSCALE* to provide an ever increasing numbers of "seats" for our students.

PRIORITIES

In order to achieve an orderly, cost-effective approach to our goal, it is important to identify the priorities. In broad measure the effort of converting or producing course materials is only somewhat dependent upon the number of students enrolled in a given year. Therefore our first priority should be our first and second year courses, which have the largest numbers of students who can benefit from electronic formats. It should be noted that the resources required to deliver electronic information are driven by the number of students and this implies that the resources for the delivery of information must keep pace with the conversion effort.

A second priority is to encourage faculty members who wish to use electronic systems. This group, which already encompasses a significant fraction of our faculty, is already using electronic presentation in some form but are held back from doing more by lack of resources. By tapping the enthusiasm of this group we will effectively be able to explore possibilities in a most effort-effective manner. What is required for these people is the means to deliver the products.

The resource requirements for networking are not extreme, but the ability to use electronic media in the classroom is undoubtedly going to be an important issue. Since the Faculty lacks the resources to convert all classrooms to multimedia capability immediately, we will purchase a portable projection system which can be used for this purpose.

By allocating resources to:

1. Convert the material for the first two years of our undergraduate program
2. Provide resources for those materials to be accessed
3. Enable the use of electronic formats in the classroom

we will be able to progress in an orderly, cost-effective manner towards our goal.

The allocation of these resources should "pace" the course development to ensure that the appropriate delivery systems are in place as required.

OVERALL STRATEGY

In 1988 we wrote:

> Obviously we cannot do all things at once. However in the context of a long-term strategy it is important to have a long-term plan in place to ensure that the various "modules" of usage are compatible and fit together. If we do not adopt an overall strategy, then we shall end up with an expensive hodge-podge of incompatible bits.

The plan discussed in that document has served us well, particularly in supplying numeric processing to our students.

Similarly, the task discussed here must be accomplished in a step-wise fashion, guided by an overall plan. The overall strategy is: (1) To make maximum use of what we have. (2) To make maximum use of enthusiasts within the faculty and student body. (3) To tackle problems directly, with regular assessment of whether an effort has succeeded or failed. (4) To be inclusive rather than exclusive in our approach.

Whilst this bottom-up approach is believed to be the one with the best chance of success, it also has weaknesses. The network and multimedia area are still in the development stage and will not mature for many years. As a department and a university we have no real chance to influence the development of the market, which at present is driven more by business than by academia. This will lead to multiple attempts to solve the same problem (for example the multiple World Wide Web browser programs) with no clear "winner" in the near-term. This, combined with people's preferences, will lead to a fragmented approach with multiple support for the same task. However the alternative - imposing a single structure on the task - also has weaknesses: we could choose the wrong and path and would alienate some enthusiasts whose efforts we need. Overall the losses from a single standard outweigh the gains and we advocate accepting some (but not infinite) diversity.

This same technology also has the potential to address another historical vestige of *UPSCALE*. Currently our primary user interface, which gives our students access to our applications, is a locally-written character based menu system, designed before we began using windowing systems. Many other undergraduate computing facilities at the University are beginning to use the technology discussed here to provide access to their applications.

Finally, we intend to offer a series of training sessions to our staff and students to inform them about this plan, outline some of the options and choices that are available, and give instruction in the use of the software tools proposed in this document. This will be partly done by *UPSCALE* staff. However, we are in the early stages of building an alliance with a Toronto software house that specialises in electronic information software, and they have expressed interest in participating in these sessions.

REQUIREMENTS AND EXPECTATIONS

This section sketches in broad terms what *UPSCALE* will require to implement this plan, and our expectations of what the Department, Faculty and University will provide in support of our efforts.

Fortunately, most of the capital expenditures for computers, terminals etc. have already occurred through a combination of donations from vendors and Departmental, Faculty, and University funds. With two exceptions, we do not see the need for major upgrades in our hardware for a few years.

The exceptions to this is our Experimental Data Acquisition and Control module, and our Microprocessor Interfacing Laboratory, both of which are based on badly obsolete hardware and software. Efforts are currently underway to find funding and/or donations to effect an upgrade.

We do predict that *UPSCALE* will require additional disc storage and memory in the very near future. The costs are relatively minor.

The cost of the conversion and extension of our information services described above is not trivial in terms of of required human resources. The *Physics Computing Services* group will be able to help us with some of the work, but lack the resources to do it all. Partnerships with the *Information Commons*, *Cquest*, etc. can also help somewhat. However, the bottom line is that some short-term human capital will be required for at least a few months for the conversion, and further manpower at a more minor level will be needed to maintain and extend the facility once it is implemented.

Finally, some commercial software will be essential in order to facilitate the preparation and delivery of these new materials. The costs are not huge and the possibility of University site licenses is very real.

We are very excited about the University's commitment to the *Information Commons*, which we expect will become an increasingly valuable resource. We expect the *Information Commons* to continue to supply a sufficiently large pool of high-speed modems, to distribute appropriate software (i.e. browsers, communication and email packages) to our students, and enable high speed network

connections from the *Commons* to *UPSCALE*. We also expect the *Commons* to provide technical and pedagogical advice to *UPSCALE* on implementing some aspects of this plan.

We expect the University and the Faculty to continue the conversion of classrooms to multi-media capability, just as the now-overbooked MP134 was converted last summer. While this work continues, we budget below for a portable high-resolution projection system.

We expect the Department to continue its extensive infrastructure support of *UPSCALE*. We already have significant academic involvement in this exercise and expertise within the departmental support services; some personnel currently involved are listed in Appendix A. For example, Departmental services this year have converted a large fraction of the overheads for PHY138Y - *Physics for the Life Sciences I* to electronic form. Similarly, our Physics Lecture Demonstration Office, which coordinates multimedia/audio-video services, has been actively involved in the design, planning and implementation of electronic delivery systems, most recently the electronic classroom MP134. The Department recognises and accepts that this proposal will involve extending its support of *UPSCALE* in these areas.

IMPLEMENTATION

The technology changes so rapidly that detailed predictions for even a few years in the future is difficult. Thus, we present a detailed plan only for the first of the five years of this plan; the second year is somewhat more vague, and succeeding years are even less specific. Nonetheless, the greatest single cost of the proposal is in human resources, and we predict that our budgetary requirements for these in succeeding years will be very similar to those necessary for the first year. At some point we will surely saturate the computing power we have available and some hardware upgrades will be required. This will certainly require resources external to the department.

The five year plan is divided into five distinct steps, organised by years. We have designed each step to be essentially free-standing, so that each step's success does not depend on later ones. The overall strategy is to begin with projects which (1) we feel reasonably confident we know how to do; and (2) concentrate on services to our largest number of users, our first year students. The second year extends the project into selected upper year courses, and involve some questions for which we are not yet sure of the answers.

YEAR ONE

The tasks which we expect to accomplish in the first year, the technology to be used, and the academic staff member overseeing the work are:

- Establish network connectivity between the *Information Commons* and *UPSCALE*. This will probably be a network connection through the *Physics Computing Services* facility. Managed by Prof. Pekka Sinervo.
- Write the top level interface to *UPSCALE* applications. This will be a "home page" using *HTML* technology. However, in addition to supplying passive access to information materials this document will also replace our existing character-based menu system as the primary interface which allows our students to access the applications. Managed by Dr. David Harrison.
- Convert and extend the overheads, other lecture presentation materials, and solutions for PHY138Y - *Physics for the Life Sciences I* to network accessible form. The presentation format will be *HTML*, although this format may be achieved by filtering an *SGML* format in which the task is written. Managed by Dr. John Pitre.
- Extend the existing overheads and other lecture presentation materials for PHY140Y - *Physics!* in network accessible form. The technology will be based on *Acrobat/PDF*. Managed by Prof. Bob Holdom.
- Convert and extend the existing instrument specifications for all common instruments in our undergraduate laboratories to network accessible form. The specifications, including color images of the apparatus, will be 'tagged' in *SGML*, which will be filtered to *HTML* as the presentation format. Managed by Dr. David Harrison
- Explore the use of the software package *fun@learningphysics* in our first year courses. This software has three interactive components: (1) lessons rich in graphics and color; (2) computer animations of physical phenomona; and (3) multiple-choice questions automated with appropriate feedback to student. he author is currently producing interactive simulations written in JAVA, which will be ideally suited for electronic distribution. Managed by Prof. Bob Holdom.
- Conduct one or more in-house training sessions for staff and students in what we are doing, what technology we have available, and information on how to use the technology. Organised by Prof. J.R. Drummond and Dr. David Harrison, the list of presenters is not yet fixed, but may well include a contribution from a Toronto software house specialising in electronic information with which we are beginning to explore a possible alliance. We also hope to

involve the *Information Commons* in these sessions.

As already discussed, the Department will be supporting our efforts in this and succeeding years through infrastructure support.

BUDGET		
What	Cost	Comment
6 person-months	$12,000	Summer students or co-ops.
128 Megabytes RAM	$5,100	For our central computer.
Acrobat Distiller software	$3,000	For producing Acrobat documents.
SGML/HTML development software	$3,000	For producing HTML documents.
fun@learningphysics software	$1,750	First year dynamics materials.
Portable projection system	$12,500	Bridging the gap while more multi-media classrooms are constructed.
SubTotal	$37,350	
Taxes	$3800	
TOTAL	$41,150	

YEAR TWO

The list of projects for Year Two is technologically much more ambitious than those for Year One. We do not anticipate a need for new software or hardware at the level required for Year One, but the need for human resources will be much greater.

- Convert our current X-based 'point and click' applications to a similar interface that is network accessible. This may involve technology such as *Java*.
- Convert PHY307F/407F - *Computational Physics I*. This course is *Mathematica* based. The lectures make extensive use of the capabilities of room MP134 to project *Mathematica*-based demonstrations. The laboratory component, which will use our new X-terminal equipped classroom MP121E, has the students doing "experiments" using Mathematica. All course notes, etc. are currently in *Mathematica* Notebooks. We believe that in a year's time technology will exist to make all of these materials network accessible. We may also be in a position to explore the concept of distance education with the laboratory component of this course.

- At present PHY252S - *Thermal Physics* makes use of *Mathematica* in problem sets, classroom demonstrations using *UPSCALE* and MP134, and in the course notes. A set of simple simulations have been written in *Mathematica* that model thermally interacting systems, and students investigate these using *UPSCALE*. A web-based interface to the existing electronically available course material would be developed. The existing simulations would be recast in the form of *Mathematica* notebooks and all past year problem sets, exams and solutions would be made accessible via the web browser. The existing course notes would be made available on the web, with the appropriate links to allow students to access additional examples, problems and other relevant information on the topics presented in the notes. Much of this effort is parallel to the work in PHY307F/407F discussed in the previous item, and the rest builds on the technology developed in Year One for PHY138Y.
- Physics Olympiad. This programme is aimed at preparing the best Ontario high school science students for participation in the Canadian and International Physics Olympiad. There are 30-40 high schools that currently participate in this programme, involving over 100 students province-wide. The preparation materials are currently available on the web through the Physics Department's home page. The complete book of problems and solutions developed by the Physics Department would be made web-accessible and assistance would be provided to high schools to access this information in the most effective manner. Currently, the Canadian Physics Olympiad programme only has web pages at the National office and the University of Toronto.
- Convert overheads and other lecture presentation materials for PHY251H - *Electricity and Magnetism*.

YEARS THREE, FOUR, AND FIVE

We predict that by Year Three, the expansion of services due to our efforts in the first two years, plus the normal continuing expansion in the usage of *UPSCALE*, will mean that demand for access will begin to exceed our supply capability. Problems in network bandwidth, overall computational power, and possibly the number of available "seats" may occur.

It is virtually certain that by Year Three new technology, new understanding of existing technology and its appropriate uses for education based on our experiences, plus creative input from a growing number of staff will mean that we will be beginning projects that at this time are difficult to predict. In addition, extending the base of technology and understanding from the first two years of this plan into a growing number of courses will require significant effort. Thus we believe that it will take about three more years of effort to finally achieve an approximation of our

goals.

We also expect that by Year Three, academic staff in the Department will be producing much more advanced material. Some of the areas that likely will be addressed at this stage, and some guesses about reasonable target dates, are:

- The use of sound in networked instructional materials (Year Three).
- An increasing use of animation instead of the static displays such as digital overhead transparancies (Years Three and Four).
- Digital VCR's. This could include "videotapes" of lecture demonstrations, laboratory demonstrations, and even lectures themselves (Years Four and Five).
- A further exploration of the effectiveness of these materials in a context of "distance education" (Years Three, Four, and Five).

Appendix A
UPSCALE Academic and Support Staff
and
Computational Services Currently Supplied
to Undergraduate Students

A significant fraction of academic staff in the Department are involved in using *UPSCALE*. Substantial contributions have been made by:

1. Prof. R.C. Bailey.
2. Prof. J.R. Drummond.
3. Dr. D.M. Harrison.
4. Prof. B. Holdom.
5. Prof. W.R. Peltier.
6. Dr. J.M. Pitre.
7. Prof. T.G. Shepherd.
8. Prof. P. Sinervo.
9. Prof. J.E. Sipe
10. Prof. S.S.M. Wong.

In addition, the following members of our support services have provided important services to *UPSCALE*:

1. Mr. Raul J. Cunha
2. Mr. Khader Khan.
3. Mr. Howard Okada

Usage of *UPSCALE* grows every academic year. In 1994-95 we had 1660 active student accounts, and provided nearly 13,000 connect hours to these students; this academic year will break those records by a substantial margin. The major applications and uses of *UPSCALE* are:

- Fitters, graphers, Fourier transforms, and other data analysis tools for the undergraduate laboratories. These range from the very simple for our I Year Lab to more sophisticated tools for our upper-year labs.
- Data pre-checkers for simple experiments in the I Year Laboratory.

- Access to problem set solutions, specifications of laboratory instruments, conversion of units, Webster's Collegiate Dictionary, nuclear constants, *UTLINK*, and other information services.
- Email services.
- *Mathematica*, a computerised system for doing mathematics. In the coming academic year we will also be supporting the similar program *Maple*. *Mathematica* is now routinely used by many if not most of our upper-year students in doing their regular problem sets.
- The foundation for PHY307F/407F - *Computational Physics I* and PHY308S/408S - *Computational Physics II*. In September 1996 the course PHY309F/409F - *Computational Physics III*, currently under development, will be added.
- The foundation for PHY 406H - *Computer and Interface Systems Lab*.
- Examples and required problem sets in PHY252S - *Thermal Physics*.
- Required problem sets in PHY351H - *Classical Mechanics*.
- Required problem sets in PHY460H - *Nonlinear Physics*.
- Optional problems and tool sets in PHY355H - *Quantum Mechanics I*.
- Lecture presentation materials in JPU200Y - *The Way of Physics*.
- Access to the World Wide Web for our upper-year students.
- Print and file server service for our networked PC's which act as laboratory instruments.

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