
PROJECT ATHENA: FACULTY/STUDENT PROJECTS

March 1985

PREFACE

On May 27, 1983, the Institute announced to the M.I.T. community and the general public the birth of Project Athena, a major Institute-wide experiment to integrate modern computer and communications capabilities into all phases of the educational process. Athena's principal goal is to help our students learn more creatively and fully in a wide range of disciplines. We will use powerful computational and graphics resources to help develop new conceptual and intuitive understanding and to improve and refine our teaching methods.

The goals of Project Athena are being pursued through a diverse set of educational projects, proposed and carried out by faculty and students, involving the design and development of educational software and the application of computers to the curriculum. We believe that M.I.T. faculty, working with students and with the help of support staff, can develop software tools that will result in innovative changes in the way we teach all of our academic subjects, from history to engineering to management.

This report summarizes curriculum development projects that have received Project Athena support as of February 1, 1985. Most of the projects in this report are using Athena computer resources; many are also receiving Athena funding.

In large measure, Project Athena has been made possible by major grants of equipment, software, service, research funds, and on-campus staff support from Digital Equipment Corporation and IBM Corporation. These grants will total nearly \$50 million over the next five years--an indication of the great enthusiasm both companies have shown for this endeavor.

For its part, M.I.T. has embarked on raising \$20 million to support this ambitious project, a majority of which will be spent on curriculum innovation and design. Support funds are being made available to allow faculty time to work intensively on their projects. In some cases this support is provided by the faculty member's department as part of continuing subject development efforts. In most instances, though, faculty support must be provided from new sources of funds developed especially for Project Athena. It is expected that about \$10 million of such special funds will be allocated to curriculum development over the five years of the project.

The allocation of Athena resources is the responsibility of the two Athena Resource Allocation Committees whose members are faculty and students from across the Institute. These committees solicit, review and grant Athena support to faculty proposals two to three times per year.

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Looking and Inferring When Data Are Multi-Dimensional

Principal Investigators:

Professor Aaron Fleisher, Department of Urban Studies and Planning;
and Professor John C. Klensin, Laboratory for Architecture and Planning

Looking is a very powerful help to inferring. This project intends to implement the looking by constructing and displaying two-dimensional slices of a k -dimensional data space. Students need to be able to visualize the shape of the surfaces they are exploring.

Development will focus on making programs that will filter the rows, or points, in a matrix by conditions on the columns. Two-dimensional slices will be of any thickness; projections are created by slices of infinite thickness. High-resolution graphics will be used to display these slices.

Development started in March, 1984 and continued into the Fall. Currently, no additional work is being done. The program is in occasional use in courses and special projects.

Real Estate Market Analysis

Principal Investigator:

Professor Willlam Wheaton, Economics, Urban Planning

The objective of the project was to develop four computer-based "problems" for a new class, 11.433. The course has approximately 50 students enrolled. To construct the four problem we:

- Programmed an econometric forecasting model of the U.S. national office market. Students will use the model to make market forecasts under varying conditions.
- Programmed a shopping center demand model, originally developed for mainframe use by Cambridge Systematics. Students use the model to test the impact and potential sales of a new shopping center.
- Programmed a statistical analysis of office rents. The model estimates regressions and then forecasts rents for as yet undeveloped sites.
- Programmed a statistical analysis of home prices. The model estimates regressions and then forecasts new home prices.

The project has been completed as of 3/1/85, and will be used by students in 11.433 each year in the future with only minor modification. All programs are on floppy discs, in micro-soft Fortran, compiled on the IBM-PC. Written documentation for student use is being prepared now.

Computer-Based Site Planning

Principal Investigator:

Gary A. Hack, Dept. of Urban Studies and Planning

The goal for this project is to develop a "computer assistant" for Site Planning, a key subject in environmental planning and design offerings for both architects and planners.

Site planning involves methods for the planning of roadways, utilities, grading patterns, building siting, and landscape construction, taking into account the impact on climate, natural systems, and cultural surroundings. Current teaching methods fragment the site-decision process by assigning exercises for each segment. Students do calculations by hand. As a result, they have little time to do any type of calculation more than once. It is also difficult for students to visualize how their design decisions will impact the site. Sketch designs are done by hand, a time-consuming process that makes it impossible to switch back and forth between designs for sites as a whole and more detailed analysis of systems.

Software design will focus on creating a workstation where site descriptions can "reside" in a database and be added to as more information becomes available, and where plans can be overlaid on the site data. For example, a student might quickly sketch a site plan with roads and structures, then call a program that tests road gradients to discover if they are within allowable limits, testing whether the runoff from the site will overstress adjacent drainage courses. Using these results, the student will modify the design, and do another round of tests. Along the way, a three-dimensional sketch may be requested to help visualize the site. Many trial designs will thus be possible until a satisfactory solution is found.

Development started in the summer of 1984 and will continue through 1986. Two UROP students participated in Fall, 1984, and more are anticipated. Development has been in C for new programs. Future development will emphasize graphics, using some system like BLOX. The system will be used in "Site Planning" (11.336.J/4.744J) in an experimental version in the Spring, 1985 term. This subject is taken by about 40 students.

Co-investigator: Stephen Ervin, Ph.D. Candidate, Department of Urban Studies and Planning.

PROJECTS INCLUDED IN THE GRAPHICS ENVIRONMENT: A LIST

The following projects are included within the overall effort to develop a Graphics Environment for educating architects and planners. We also note which of these are described in further detail in the next section which discusses individual projects. Other projects in Architecture and Planning which are not part of the Graphics Environment effort are described in the next section after those projects which are part of the Graphics Environment.

Harvey Bryan and Steve Lotz, *A Building Systems Data Processor*

Glorianna Davenport, *Personal Computers and Movies: Toward a graphical language for editing and interactively viewing film/video material*

E. Dluhosch, Ranko Bon and Therese Vien, *A Computer-Aided Building System*

Joseph Ferreira and Andrew Boyd, *Computer Models for Planning and Public Management*

Aaron Fleisher and John Habraken, *Design as the Exploration of Systems of Constraints* (see description below)

Gary Hack and Stephen Ervin, *Computer-Based Site Planning* (see description below)

Frank Miller, *The Educational Value of Architectural Computing in the Design Studio*

Karen Polenske and Kelly Robinson, *Techniques of Regional Economic Analysis* (see description below)

Patrick Purcell, *The Visual Information System*

Merrill Smith, *A Videodisk Resource System in Rotch Library*

William Wheaton and Lawrence Bacow, *Real Estate Market Analysis* (see description below)

DEMONSTRATIONS OF ONGOING EXPERIMENTS

We have prepared several small demonstrations illustrating the ways in which the graphics environment and design support system can be used. They highlight several themes of the project:

- linking graphic and analytic tools that help visualize and design the built environment and evaluate and anticipate the spatial impact of programs and plans;
- using modular components, as much as possible off-the-shelf equipment and software for spreadsheets, statistics, data management, video images, mapping, O.R. models, etc.;
- using stand-alone capabilities that can be augmented with the Athena network as a source of standard maps and designs, data bases, analytic tools, etc.;
- developing computer tools for "earthlings" whose Athena use is primarily within the "application" environments constructed for their coursework.

These ongoing experiments involve:

Design Studios, which experiment with the use of micro-based computer-aided drafting packages to facilitate the teaching of design in design studios. Students are provided with design studio projects using a standard set of "library" parts with associated geometry and properties. The seminar explores how certain features of the CAD package (e.g., zooming, layering, attribute tagging) influence the design strategies of the students and the pedagogy of the instructors.

Site Planning, which involves the development and linkage of subroutine libraries, applications packages and information filters that enable students working on site plans to call on a variety of analytic modules and graphic editors. Examples include displaying contours derived from digital terrain maps, using spreadsheets to do cost calculations and summary sheets, and running earthworks modules.

Building Technologies, which enables students to subject their designs to various analytical models that examine construction cost, energy efficiency, sunlighting, etc. For example, a design developed on a CAD system using "library" parts can be sent to an energy analysis module that extracts the needed data, runs the energy analysis and uses a spreadsheet to summarize the results and display them via business-style graphics.

A Graphics Environment for Educating Architects and Planners

Coordinating Committee:

Professor Joseph Ferreira, Principal Investigator; Professor Patrick Purcell; and Frank Miller

SUMMARY

This project serves as the "umbrella" project for that portion of the School's efforts aimed at developing an integrated graphics environment and design support system. We expect that more effective use of computers in educating architects and planners will require a mix of graphics hardware, analytic modeling capabilities, access to shared data bases, and flexible, interactive software. While examples of the pieces exist in one form or another within the School and across the two professions, they are not integrated into a computing environment that suits the needs - and budget - of the curricula. As a result, students cannot apply, to a common set of problems, the design skills and analytic capacities they develop across several classes. They are also limited in their ability to visualize and explore the spatial implications of their designs and plans in a sufficiently interactive setting.

The core of the proposed graphics environment is a design support system and a related data base structure for describing physical objects that depends on certain unique features of the planned Athena environment. For a variety of cost, size, ease of use, and staffing reasons, we expect such an environment to involve (a) extensive networking (of local processors, file servers, and I/O devices); (b) the capacity for borrowing, with a minimum of effort, software tools developed elsewhere (CAD, analytic models, data bases, etc.); and (c) an assortment of local processors with differing capabilities for graphics, color, local storage, videodisc control, computational power and the like. In its initial form, the design support system is a set of filters that enable analytic models and physical designs to exchange information through a standard data base manager and associated C programs. Wherever possible, the system will employ standard software packages. These packages will run in their natural environment (e.g., on an Athena file server, a local IBM workstation, a local graphics workstation, etc.) and will be integrated over the Athena network via the design support system.

Initially, the links will not be interactive. For example, a designer would start working on a design, save the description of the objects that make up the design in a database on an Athena server, and logout. She would then move to a workstation that supports a particular sunlighting or energy analysis package, and run the analysis of the stored design. Over time, the design support system will add more sophisticated capabilities that can support interactive interchange of information and a more active role in suggesting when to run analyses of a design, what parameters to use, and how to interpret the results.

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Demographics by Eye

Principal Investigators:

Professor Phillip Herr, and Mo Charles, Dept. of Urban Studies and Planning

We have developed a system of aids to demographic forecasting at the local level, using graphics as a primary tool. Through a series of menu choices which select graphs, the user is guided in identifying the appropriate demographic category for his community. Each category has a characteristic total population growth shape (flat, linear increase, logistic, etc.) and a pattern of age-specific migration rates associated with it. The user then makes an overall growth rate selection, again with visual aids, and the system produces forecasts of population by age group for selected future years.

Two steps remain to be completed. The final linking of overall rate selection and migration rate has yet to be done, and a descriptive manual has yet to be written.

SCHOOL OF ENGINEERING

Computer-Aided Instruction in Space Flight Dynamics

Principal Investigator:

Professor David L. Akin, Dept. of Aeronautics and Astronautics

This project is divided into two sections. The first is based on interactive demonstrations of space flight dynamics. In the current implementation, the 16.81 instructor can use dedicated programs to graphically represent spacecraft motion in various phases of flight, such as launch, orbit changes, rendezvous, and atmospheric entry. For convenience, all of this work has been implemented on an IBM PC (DOS 3.0) in DeSmet C. The IBM allows ease of computer access during development, simple graphics, and specialized input devices such as digitizing pad stylus.

The second phase is a knowledge-based system for computer tutoring in orbital motions of spacecraft. This program will have a natural language interface, and will respond to students' questions with text and diagrams of motion. An associate investigator has looked into frame-based expert systems as the basis of the software. Some preliminary effort on this has been done in IQ-Lisp on the IBM PC. The actual system will, by current plans, be implemented in ExperLisp on the Apple Macintosh. This machine/language combination is fast enough for real-time interaction, with extensive graphic capabilities and pull-down menus for routine interaction.

Motion Visualization under Coordinate Transformation

Principal Investigator:

Professor Walter M. Hollister, Dept. of Aeronautics and Astronautics

The purpose of this project is to be able to display complicated three-dimensional motion and coordinate transformation for the teaching of the sophomore dynamics portion of Unified Engineering. The project will enable classroom demonstration of the concepts of relative motion, orbital mechanics, rigid body rotation, and aircraft and spacecraft trajectories. Additional application to the undergraduate teaching of guidance and control of aircraft and spacecraft attitude and position is envisioned.

To visualize motion, an observer must fix himself in a reference coordinate frame. Under coordinate transformation, the observer changes his position and orientation. It is desirable to be able to display motion, either simultaneously or in instant replays, as seen by observers in two distinct coordinate frames, in which the frames themselves can translate and rotate relative to one another, all in three dimensions.

In teaching advanced undergraduate courses involving the guidance and control of aircraft and spacecraft attitude and position, it is desirable to show the motion of a vehicle under a particular guidance or control law relative to another vehicle for the purpose of performance evaluation. The idea is illustrated by a class project in which three teams were formed to design the steering logic to put a given rocket into circular orbit. The winning team was the one with the final orbit with the highest perigee altitude. Each team generated its own computer program for the guidance and trajectory calculation. As a result, only the guidance logic statement and the terminal conditions were directly comparable. With the proposed capability, it would be possible to display and observe the performance of the three guidance logics relative to one another throughout the trajectory, providing considerably more insight. Students could, in effect, guide their rockets in head-to-head competition as a means of better understanding guidance principles.

To date, this project has been funded only to explore ways in which the Athena system can be used to display three-dimensional dynamic graphics. However, four students have developed programs which display the orbital motion of bodies in close proximity under various conditions of gravity anomalies, differential drag and tethering. These programs have been written on non-Athena machines using Fortran and Basic.

It is planned to have classroom demonstrations ready for the 1986 Spring term in the dynamics portion of "Unified Engineering" (100 students) and in 16.40, "Principles of Flight Dynamics" (25 students).

The overall strategy is to develop computer-based educational modules within each of these topical areas. A module will consist of a few closely related ideas embodied in a software program which would have the following attributes:

- Part of the module will be suitable for in-class demonstration for the lecturer to illustrate the principle involved by using interactive graphics.
- Part of the module will be a tutorial for out-of-class use by students taking the subject or others who need to review the material in preparation for exams. These might also be used in recitations.
- Part of the module will consist of problems which are done interactively, giving the student direct feedback and practice with the material.

The module will be written in Fortran with some use of simple Lisp concepts for symbolic manipulation.

These modules will eventually be used in the Department's undergraduate fluid mechanics subjects including 16.001-16.004 Unified Engineering, 16.02 Aerodynamics, 16.06 Space Gas Dynamics, and 16.04 Fluid Dynamics of Flight and Reentry Vehicles. About 150-200 students per year take these subjects. The modules will be introduced gradually over a period of years.

Co-investigators: Professors Baron, Covert, Harris, Wachman, McCune, Harltonidis, Louis, Greber (AY 1985).

These areas of fluid mechanics are not limited to the curriculum in Aeronautics and Astronautics, but are also part of subjects in Mechanical, Ocean and Civil Engineering. A School of Engineering ad hoc committee has been formed to coordinate efforts and information between departments on this topic. Professor Wesley Harris, Jr. is the chairman of this committee.

Molecular Graphics Modeling

Principal Investigators:

Professor Ulrich W. Suter, Dept. of Chemical Engineering and Professor Gregory A. Petsko, Molecular Graphics Laboratory, Department of Chemistry

Existing molecular graphics modeling software and its availability for modification and use in undergraduate education is investigated in this project.

The need for this endeavor stems from the lack of educational material that would allow the student of molecular phenomena to perceive the complex three-dimensional structure of the molecules and atomic arrays. Wood and plastic models have often been used, but they have proven to be unwieldy and they cannot simulate and visualize intra- or intermolecular interactions.

Development started in March, 1984, and is continuing. Several software packages have been thoroughly scrutinized, but no existing solution has been found to be satisfactory yet. The search is continuing.

In the meantime, the investigators have modified a public domain program, PLUTO 78, from the Cambridge Crystallographic Datafiles, to run in the Athena environment. The program is in its final adaptation stage, and it is expected that it can be released to the student population at the end of the Spring 1985 term. Together with the graphics program, a collection of structural data on simple molecules will be made available for display and manipulation by the program. This zeroeth approximation to Molecular Graphics Modeling will then be used in several courses. The experience thus obtained will guide the further developments.

Co-investigator: Vikram A. Chaudhary

ATHENA CATS: A Computer-Aided Teaching System for Structural Engineering

Principal Investigators:

Professors John H. Slater and Jerome J. Connor, Dept. of Civil Engineering

ATHENA CATS is an ongoing research effort in the Constructed Facilities Division of the Department of Civil Engineering aimed at the development of a *Computer Aided Teaching System* for structural engineering. We are building an integrated set of intelligent programs to enhance material on structural behavior and design presented in lectures, recitations and assigned readings. This will allow students to explore engineering problems which would have been far too time consuming or far too difficult to tackle with present capabilities.

The primary goal, which will have a major impact on technical education, is the incorporation of an ability within the software to act as an advisor and tutor. This poses substantial research challenges and requires the application of artificial intelligence techniques. A secondary goal of ATHENA CATS is the elimination of present difficulties associated with the use of unfriendly software packages for structural engineering. This will increase the productivity of time spent by students with the computer and allow them to concentrate more effectively on learning.

Several pilot projects have been developed:

- Rule based tutoring methods: MACAVITY, an intelligent tutor for helping students solve determinate beam problems, is operational. MACAVITY combines a problem generator with an expert tutor capable of explaining errors in student solutions. MACAVITY will be used in subject 1.04 in Fall, 1985. A tutor for trusses and frames is under development.

- User friendly interactive graphics oriented programs for the analysis and design of buildings, bridges, foundations and earth works: GROWLTIGER, used in subjects 1.04, 1.50, 1.52, 1.542, models and analyzes trusses and frames, plots deflected shapes and moment diagrams. CINAP, to be used in subjects 1.30 and 1.368, helps in the design of foundations. CINAP combines numerical and heuristic analysis schemes with practical design information.

Development of Freshmen Computer Electives

Principal Investigators:

George Kocur, Dept. of Civil Engineering

Dan Ottenheimer, Dept. of Mechanical Engineering

The goal of this project is to adapt the Freshmen Computer Electives, courses 1.00 and 2.10, to the new computational possibilities being provided by Project Athena. These two courses are taken by over 500 students per year and form an introduction to computation for most non-electrical engineers at M.I.T.

The project has produced a draft text, which is used by both courses, which teaches computing in a language-independent manner by relying heavily on pseudocode. 1.00 is taught in Pascal, and 2.10 is taught in Fortran. Because the day is past when an engineer can expect to see only Fortran as a language, we are developing general skills in algorithm development, program structuring, and use of external routines as key, central elements of the courses.

In the main portion of 1.00 and 2.10, we give students broad exposure in a variety of areas, ranging from basic use of the Unix operating system and Emacs editor, through the use of multilingual programs and external packages (e.g., Pascal users call Fortran NAG numerical routines and Fortran Penplot graphics routines from their programs), and several languages (Lisp and C in addition to Fortran and Pascal). The focus of both 1.00 and 2.10 is to provide a balanced and comprehensive introduction to MIT students in all areas of computation that are supported by Project Athena.

The draft text covers many engineering and scientific applications which are the major themes of the courses. Programming language elements are introduced as necessary to support the applications. The text covers: digital hardware, pseudocode, basic algorithms (cryptography is used as an example), recursion, numerical methods (matrices, roots, integration), discrete and continuous simulation, data structures, sorting and searching, and graphics.

The text is supported by a series of ten video-terminal demonstrations of key algorithms. These use a split-screen format. One window displays the algorithm, and the current line is shown in reverse video. The other window displays current variable values and/or graphics that summarize the state of the problem. The user can control several parameters of the demonstration, such as its execution speed.

We also offer minicourses of four weeks' duration at the end of the term, in which students have an opportunity to learn a second language, such as C, Lisp or Fortran (for 1.00 students). The use of pseudocode facilitated the learning of these second languages greatly when we taught the minicourses in the fall of 1984.

Computation as a Conceptual Framework for Learning Linear Algebra

Principal Investigator:

Hal Abelson, Department of Electrical Engineering and Computer Science

This project requested funds to support the development of a version of the Scheme dialect of Lisp for use on Athena VAXes. The purpose of this is to make Scheme available to the MIT community at large. In particular, we have been investigating Scheme as a vehicle for a computer-based reformulation of courses that deal with linear algebra and linear systems.

The Scheme development has been making good progress. During the Fall semester, 1984, both 1.00 and 2.10 made use of our prototype Scheme implementation on the Athena VAXes. We are currently completing an upgraded version of VAX Scheme, and are about to release Scheme as an Athena-supported language for general MIT use.

Development of the linear systems material itself has focused on the EECS Signals and Systems subject 6.003. The EECS department has secured dedicated computational resources for this subject, so our work in 6.003 will not require Athena resources, although the availability of Scheme on Athena will mean that much of what we develop will be directly usable by other subjects in the Institute.

Machine Vision -- Eyes for Athena

Principal Investigator:

Berthold K. P. Horn, Department of Electrical Engineering and Computer Science.

The goal of this project is to provide students with the basic tools to experiment with algorithms presented in the Machine Vision course. Material in this subject is presently taught by analyzing physical systems and formulating mathematical models. Algorithms are difficult to learn about without access to computing resources -- such large amounts of image data are required that hand simulation is impossible.

Students presently see computers as "number crunchers" and symbol manipulators. It is desirable to show students ways of using a computer which allows it to interpret information about its environment. This will help prepare students for novel applications of computers as found, for example, in robotics.

Software will develop displays of binary images and line drawings. Programs will be created to transfer image files over local area networks from various image sources, such as the Lisp machine in the Artificial Intelligence Lab. An interactive system will be designed to function as an "electronic blackboard." This will illustrate more effectively the concepts of binary image processing, machine vision, and scene analysis. Students will be able to do problem sets at workstations, and easily experiment with different approaches.

This project will allow the emphasis in the machine vision course to be shifted from mathematical analysis to computer algorithms. Students will be provided with a firmer understanding of basic principles, and thereby be able to design new algorithms based on novel combinations of available modules.

Development took place from January through August of 1984. The software was written in Franz Lisp. The program was intended to be used in "Machine Vision" (6.801/6.866) starting in the Fall, 1984 term, but is not in use.

Co-investigators: Walter Gillett and Jay Adams.

Dynamic Models for Quantitative Physiology

Principal Investigators:

Professor Roger G. Mark, Department of Electrical Engineering and Computer Science, and Professor Roger D. Kamm, Department of Mechanical Engineering.

This project will complete the development of dynamic physiological models of the cardiovascular and respiratory systems. First-generation software has already been developed, was tested during the Fall 1983 and Spring 1984 terms, and was successfully transported to Athena hardware during the Fall of 1984. The project will explore the benefits of using dynamic computer-based models of complex physiologic systems in teaching Quantitative Physiology to engineering students and to students in the HST/MD program.

Lumped parameter engineering models have commonly been used in teaching physiologic concepts. Although far simpler than the actual biological systems, such models are sufficiently complex that their dynamic behavior is difficult to grasp on the basis of lectures and problem sets.

This project will implement the models in software, and provide students with graphical and numerical solutions of system variables (such as flows, pressures, and volumes). Students will be able to arbitrarily vary system parameters to simulate a variety of normal and pathological states. Although the courses will continue to provide students with be the primary method used to teach basic system dynamics.

Work during the Fall 1984 and Spring 1985 terms is focusing on improving the first generation software by: adding a physiologic control system to the cardiovascular model; improving the methods used to solve system differential equations, in order to increase execution speed and permit changes in circuit topology; improving user machine interfaces and the quality of graphics; and developing additional teaching materials, such as problem sets based on the simulator and lecture handouts. Future work will attempt to combine the respiratory and cardiovascular models and possibly other organ systems as well, such as the kidneys.

The project is creating a number of efficient and effective tools for teaching in this field. The models under development will provide students with a deeper understanding and intuitive sense of the nature of dynamic physiologic systems.

Programs were used in "Quantitative Physiology: Organ Transport System" (6.022J, 2.792J, and HST 542J) in the Fall 1984 term. This subject is taken by about 20 to 25 students. In addition, the cardiovascular simulator will be used in "Cardiovascular Pathophysiology" (HST 090), taken annually by 40 to 45 students.

Programs will be written in C.

Computer-Aided Exercises in Quantitative Physiology

Principal Investigators:

Professor Thomas F. Weiss and Assistant Professor Raphael C. Lee,
Department of Electrical Engineering and Computer Science

This project developed a computer-aided exercise for use in teaching the subject "Quantitative Physiology: Cells and Tissues." The subject covers five major physiological topics: transport of matter through cellular membranes; electrical properties of cells; communication between cells; mechanical properties of muscle; and electrical, chemical and mechanical properties of connective tissues. Specifically, programs were written for one topic covered in the subject, the Hodgkin-Huxley model of the excitation of electrically excitable cells. This model is highly successful in explaining electrical properties of cells in terms of the electrical properties of their membranes. However, this model is sufficiently complex that its behavior is difficult to understand analytically. Examinations of numerical solutions of this model gave students an enhanced understanding of the workings of the model and hence an insight into how neurons and muscle cells produce electrical activity.

The software consists of three programs. One program allows setting parameters of the model such as the membrane capacitance, the maximum membrane conductances for membrane ionic channels, kinetic parameters for each of these channels, the concentrations of all relevant ions, the temperature, etc. The program then computes the membrane potential, displays parameters of the computed responses, and allows simultaneous graphic display of several variables as a function of time, including the membrane potential, membrane-current components, membrane-conductance components, activation and inactivation variables. This program also creates a file containing the results of the computation. Another program prints both parameters of the model and of the responses. A third program allows simultaneous graphic display of several files so that the results of several computations can be compared. All programs are written in C.

The software was used in two ways in the subject. First, interactions with the computer and the results of the computation were projected in color on a large screen in the lecture room. Since the computations took only a matter of a few seconds, all the computations were performed live in the lecture room. This introduced the students to the use of the software. The computations that were demonstrated were an integral part of the lecture on the synthesis of the Hodgkin-Huxley model. The students were already familiar with the experimental basis of this model as well as with the mechanical components. Thus, they could appreciate the success of the model in explaining properties of electrically excitable cells. Second, the students used the software to complete an assignment that was graded and accounted for 1/8 of their grade in the subject.

Enhancing Thermodynamics Education through the Use of Computers

Principal Investigator:

Gretchen Kalonji, Dept. of Materials Science and Engineering

To improve the teaching of "Thermodynamics of Materials" (3.20), a graduate subject in the Department of Materials Science and Engineering, we have chosen to incorporate computer simulations in classical and statistical thermodynamics. This course is part of the graduate core curriculum in the Department. It is offered every fall and approximately 80-100 graduate students and senior undergraduates take it.

Thermodynamics is unique among basic subjects in that it is difficult to provide students with 'hands-on' experience. Many students find that the lack of practical knowledge makes the basic concepts of the subject difficult to grasp and undermines the comprehension of more advanced concepts. To remedy this, we are designing software that will provide the student with 'virtual laboratory' exercises and projects designed to demonstrate the underlying rules of thermodynamics. We expect that simulations will provide the background for better understanding.

We have several projects in progress:

- The design of a 'thermo workbench,' a framework for the construction of simulated experiments in classical thermodynamics;
- The adaptation of a phase diagram construction and database system from Sweden;
- The adaptation of molecular dynamics programs for use in teaching statistical thermodynamics.

As the undergraduate curriculum evolves, we expect that much of the work we do will migrate into other courses on thermodynamics and statistical mechanics. Toward this goal, we have concentrated on writing general-purpose tools for building simulations, and not on the simulations themselves.

We have been working on Project Athena since January 1984, and several of our programs have been taken from parallel ongoing research efforts. We expect that development will continue through Fall 1985, when we plan to use the programs for the first time in the classroom. We have been using Lisp, C, and Fortran for software development. We also intend to use Blox to provide user interfaces for some of our programs.

Co-investigators: Kenneth Meltsner, Research Assistant, and Dr. Reza Majafabadi, Research Engineer, Dept. of Materials Science and Engineering.

Computer Applications in Mechanics of Materials

Principal Investigator:

David Roylance, Professor of Materials Engineering, Dept. of Materials Science and Engineering

This project seeks to provide computational exercises in support of subject 3.11, "Mechanics of Materials." The exercises are intended to assist the student in visualizing the mechanics concepts presented in class, to introduce him or her to the modern computer-assisted techniques now dominant in mechanical design and analysis, and to provide a means of developing familiarity with computer operations in general. The projects are not necessarily geared toward student programming, although they do form the basis for programming projects some students might elect as part of UROP or thesis work.

As of January 1985, the project includes three principal pieces of Fortran code: a menu-driven tool for performing transformations and finding principal values in three-dimensional stress states, a finite-element code capable of two-dimensional truss or plan stress problems, and a prompt-driven preprocessor for preparing input data sets and for the finite element code.

By the time 3.11 meets in September 1985, we hope to have implemented graphics supplements to the above codes, so the concepts can be visualized more easily.

A New Methodology of Thermodynamic Analysis for Efficient Computer-Aided Modeling and Processing

Principal Investigators:

Professor Joseph L. Smith, Jr. and Gilberto Russo, Department of Mechanical Engineering

The general goal of this work is to develop a computer-based methodology of thermodynamic analysis for efficient computer-aided modeling, processing and numerical solution of a wide variety of thermodynamic problems. This method is to be easier to understand, learn and use than conventional techniques.

The first phase of the research (calendar year 1984) has focused on the conceptualization of the method and its application to the solution of two broad classes of thermodynamic problems: relaxation and quasi-static problems. Thermodynamic systems are modeled as closed, isolated problems by including in the system all interacting parts, including reservoirs. The thermodynamic model is a closed, ordered assemblage of interconnected standard elements. The entire process of thermodynamic analysis is incorporated into the constitutive relations of the elements and the topology of their interconnection. This standard representation of the model allows one processing and numerical system algorithm to efficiently solve a wide range of problems. The processing consists of generating one set of system's equations out of the various sets of elements constitutive relations. In this process, all routine aspects of modeling, such as conservation and continuity, are performed by the computer. This allows for one standard, physically driven numerical solution algorithm to efficiently solve the model. A number of new elements, not explicitly considered in thermodynamics, have been defined and allow us to model and interpret all relaxation and quasi-static problems including cycles, multicomponent mixtures and chemical equilibrium.

The second phase (calendar year 1985) will deal with the details of the methodology and its implementation. We will establish the basis of a structured, axiomatic discipline of computer-aided thermodynamic analysis by defining the formal aspects of the method, such as rules, theorems and definitions. We will also develop a physical interpretation of phenomena that is consistent with the modeling technique and vocabulary. Finally, the method will be applied to the solution of at least one practical problem either not efficiently solved or substantially unsolved with conventional modeling techniques.

The educational goal is to develop a computer-aided modeling technique that will minimize the extensive modeling experience required when using conventional ad hoc techniques. As a consequence, the student will be allowed to focus on the physics of the problem, leaving all routine aspects and chores of modeling to the computer. We are developing a plan for the introduction of the methodology as an experimental, optional section of an Undergraduate Thermodynamics course (2.40) for the school year 1985-86.

An Interactive Videodisk for Undergraduate Education in Mechanical Engineering

Principal Investigators:

David Gordon Wilson, Profesor of Mechanical Engineering; Seichi Tsutsumi, Industrial Liaison Officer

The aim of this project is to produce a videodisk and computer program that would be operated on the DEC Ivis system by students in mechanical engineering. The topic chosen for this first try at design instruction is that of bearings: definition, types, physics of each type, failure modes, selection, design, and system design.

The particular appropriateness of the interactive-videodisk system for this topic results from the increasing diversity of undergraduate students. Some have tinkered with bicycles, automobiles, and other machinery, and have taken engineering drawing in high school. Others, coming from very different backgrounds, cultures and countries, totally lack this experience. They may, however, constitute one-half of the 180 students in a typical class in "Introduction to Design" (course 2.70). Textbooks cannot fill the lack of experience. An instructor who aims at one of these two groups in the class probably loses the interest or involvement of the other group.

While an interactive-videodisk system is also no substitute for experience, it seems to be, like democracy, the best of the possible choices. Students faced with an assignment in bearings could use the system at any time, selecting their own routes through the assembly of descriptions, demonstrations, simulations and models that suit their own situations.

The project, started in mid-1984, also involves two members of the mechanical-engineering design faculty: Ernesto Blanco and Woodie C. Flowers. The status at the end of 1984 is that a fairly detailed design of the "main route" of the sequence has been agreed on, and that the story-board layout has started. The next stages are the set-up and filming of various instructional sequences; the incorporation of existing film sequences; the devising of computer models; the programming of the controlling system; and the production of the disk and system.

Our aim is to complete this in time for the September, 1985, offering of course 2.70. The program will also be available to the 160 students who take course 2.73.

The program is written in Ivis Producer Language for use on the DEC Pro 350 with Ivis additions.

Co-investigator: Michael O'Keefe.

"Defects in Crystals" (3.33), "Electron Microscopy: Image Interpretation" (3.30), "Introduction to Electron Optics and Electron Microscopy" (3.32), "Integrated Circuit Fabrication Technology" (6.774), and "Submicrometer Structures Technology" (6.781). About 100 students take these subjects annually.

Programs will be written in Fortran and Lisp.

Development of a Fast Computer Simulator for Nuclear Power Systems

Principal Investigator:

Andrei L. Schor, Assistant Professor, Dept. of Nuclear Engineering

The objective of this project is the development of a software package capable of economically simulating an entire nuclear power system.

The extreme complexity of such a system poses a considerable challenge when attempting to provide a qualitative grasp of various issues raised by the design and operation of the system. The intricate interrelationships between various components, phenomena, and control actions lead often to what might appear as counter-intuitive system behavior. Homework and lecture examples are therefore highly idealized and simplified, and a considerable effort is required to extrapolate the knowledge so gained to understanding real systems.

The computational capability that is being developed should provide a truly user-oriented educational tool of broad applicability: it will help students understand the behavior of a very complex system; provide a powerful design aid to facilitate the investigation of various approaches; and constitute a testbed and framework for development of improved models and numerical methods.

The computer simulator will be highly interactive: the objective is to shorten considerably the necessary learning time, especially for the casual user. Graphics will be used extensively to display the results.

These programs will be used in the undergraduate subject "Engineering Design of Nuclear Power Systems" (22.03) to introduce the undergraduate student to the basic principles of nuclear engineering as applied to power plant design. Almost every topic in the course could make extensive use of the simulator through classroom demonstration, problem sets, and projects.

Development started in April 1984. Program writing and testing will take place over the next two years. Developments will then continue in response to curriculum integration requirements. Programs will be used in several undergraduate and graduate subjects in addition to 22.03. Experimental use of these programs will start in 22.03 in the Fall 1985 term. This subject is taken by about 15 students annually.

The programs will be written primarily in Fortran and possibly C and Lisp as well.

Co-investigators: Scott Free and Joseph Sasson, graduate students, Dept. of Nuclear Engineering; Christiana Lui and Jae Hee Kim, undergraduate UROP students.

Curriculum Development of New Subject on Computational Methods in Materials Science

Principal Investigator:

Professor Sidney Yip, Department of Nuclear Engineering.

The purpose of this project is to develop a new subject, "Computational Methods in Materials Science," that will provide students with powerful computational techniques for modeling the properties and behavior of complex physical systems.

Students are presently hampered by having to master numerical analysis and write sophisticated computer programs.

Emphasis in this subject is on the atomistic simulation techniques of molecular dynamics and Monte Carlo, but finite element methods and continuum system modeling are treated also. User-oriented simulation codes are being developed for students to gain hands-on experience and an appreciation of the common principles, as well as complementarity of the different modeling approaches.

This subject (22.44J/3.74J) was offered in 1984 on a trial basis and is offered as a full course in the Spring 1985 term, with 18 students. It is intended to serve the needs of all students at the Institute whose studies or research involve basic materials properties. The course format consists of regular lectures and a term project in which the students will use the computer and existing simulation programs to carry out computational projects of their own choice. Development of the subject contents and the associated computer programs is expected to continuously evolve over the next few years. Students in the course also participate in further program development.

Co-investigator: Professor Gretchen Kalonji, Department of Materials Science and Engineering.

Computer-Aided Hydrostatics and Hull Surface Definition

Principal Investigator:

Professor Justin E. Kerwin, Department of Ocean Engineering.

This project's goal is to create a new course in computer-aided hydrostatics and hull-surface definition. This course will become the cornerstone of programs in the Department of Ocean Engineering and will stress the major role of computer-aided analysis, design, and manufacture in ocean engineering. It will also serve as Ocean Engineering students' first introduction to the department, and will bring mathematical surface definition into the undergraduate curriculum.

Hydrostatics is an essential element in the design of ships and offshore platforms. A typical problem would be to devise an optimum arrangement of watertight subdivisions to insure that the platform will float under a variety of damage conditions. Students must do numerous tedious calculations by hand or by inefficient "batch mode" computation; these hamper their ability to make intelligent design decisions. The traditional way of creating ship lines is on the drawing board, and the mathematical procedures for actually generating ship lines are in their infancy.

Development will focus on creating interactive software that will ask students to solve "design" problems. One package will require students to determine optimum proportions for a sailboat which requires large stability in order to sail fast under certain conditions, but which is required to be self-righting if capsized by a large breaking wave. The other software package will deal with the problem of mathematical representation of surfaces. Realistic representations of three-dimensional ship surfaces will be developed, as well as algorithms for translation, rotation, and perspective transformation. Integration and differentiation formulas will be derived, thus allowing for computation of hydrostatic forces and moments for realistic shapes. At the end of the subject, students will generate a mathematically-defined hull, and then use it as input to an industry standard computer-aided ship hydrostatics package.

This project will allow students to be exposed to design problems and to gain experience in using modern design tools. It will also make possible the development of a completely new approach to the teaching of hydrostatics and hull-surface definition, an approach that will be educationally superior and far more interesting from the student's point of view. Software developed could subsequently be used by undergraduates in connection with design subjects and special projects, and possibly in graduate design subjects.

Development started in January of 1984 and is expected to continue through 1985. A set of substantially completed programs was used in "Computer-Aided Hydrostatics and Hull Surface Definition" (13.00) in September 1984. This new

Spread Sheet Analysis: Dealing with the Inexperienced Undergraduate

Principal Investigator:

Henry S. Marcus, Associate Professor of Marine Systems, Dept. of Ocean Engineering

Faculty members wishing to take advantage of Project Athena facilities in a non-computer undergraduate subject face two problems: (1) developing a computer application to perform the necessary calculations, etc. and (2) getting the students to 'painlessly' use this computer application without first spending large amounts of time in class related to computer training. The purpose of this project is to apply standard computer spread sheet analysis software to a specific problem for the subject 2.96J/13.52J, "Management in Engineering," with the goal of helping to solve both problems.

The specific application concerns choosing between propulsion plants (i.e., steam turbine versus diesel) for a new vessel. Techniques to be applied by the students include: net present value methodology, internal rate of return, breakeven analysis and sensitivity analysis. The computer program will be part of a homework assignment.

The computer program will contain a tutorial which trains students to use the spread sheet analysis program without having prior computer experience. This program will be written and revised through testing with individual students during the spring and summer 1985 terms. Then it will be applied in the Fall 1985 term in the undergraduate subject 2.96J/13.52J (about 90 students) and the graduate subject 13.68, "Management of Marine Systems," (about 20 students). Questionnaires will be used to determine the degree of success of the program.

The program will be written on the 20/20 spread sheet software program.

Co-investigator: David Hault, co-instructor in 2.96J/13.52J.

A School-Wide Elective in Engineering Systems Analysis

Principal Investigators:

Professors Richard de Neufville and Joel Clark, Technology and Policy Program

The goal of this project is to effect a substantial improvement in the presentation of the subject "Engineering Systems Analysis," a school-wide elective taken by 40-50 students annually in the Fall term. Presently, the multidimensional techniques central to systems analysis cannot be applied realistically without computers. Use of computers for instruction in this area at MIT has been costly and impractical. As a result, there has been a substantial gap between the methods discussed and the applications offered by way of illustration or problem sets.

Developments will focus on creating a computer library of applications of systems analysis which students will use as a part of the instruction. Students will be able to call a help menu for the systems analysis subject, select a method, receive prompts indicating how to set up the program, and obtain results. This will enable students to see examples and make use of, for example, Linear Programming, without having to learn the peculiarities of a particular program.

The content of this subject is now being substantially redone. The project will try to modernize the presentation of the material and make realistic applications available to the student. Integration of computers into this subject will have a strong effect both within and outside MIT.

The initial focus of this effort has been to implement an interactive set of tools for decision analysis, specifically a means to assess preferences and subjective probabilities effectively and to present the results in convenient form. Starting in February 1985, the practicality of these processes will be tested in a classroom context by means of an undergraduate seminar. More complete implementation will take place in the summer as part of an intensive version of the "Engineering Systems Analysis" course, prior to full implementation starting in September 1985.

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

Computer Applications in the Economics Core Curriculum

Principal Investigators:

Henry Farber, Associate Professor of Economics, and James L. Powell, Assistant Professor of Economics

This project's goal is to accomplish a major revision of the undergraduate economics core curriculum by integrating computers into four core subjects.

Students need a firm grounding in economic theory and how it can be used to analyze pressing economic problems of the day. These problems include inflation and unemployment on a macroeconomic level; and energy, the environment, and regulation on a micro level. It is desirable to be able to simulate a market on a computer network and to demonstrate principles of optimization by individual agents.

Development will focus on surveying the existing use of computers in economics education, on developing interactive computer models on micro and macro economic behavior that would be suitable for use in the curriculum, and on creating new software. Programs will take several forms, such as computer games that simulate the behavior of consumers or producers, simulation models that show how the economy could react to different policy regimes, or data analysis packages used to uncover the "stylized facts" of economic behavior.

This project will enable the department to treat four core curriculum subjects as an integrated whole and to introduce computer techniques and applications into them in a coordinated fashion. It will also provide students with more hands-on experience with how a market economy actually works.

Development started in March of 1984 and will continue through September 1985. Programs will be used in "Economic Principles" I and II (14.01/02) starting in the Spring 1985 term, and will be introduced in "Applied Microeconomics" (14.03) and "Intermediate Macroeconomic Theory" (14.06) in the Fall 1985 term.

Programs will be written in Fortran, Pascal and C.

This project will create computer exercises that are based on a communicative approach to teaching languages. The result will be the design of innovative materials that could set a different standard for the use of computers for language-based applications.

Development started in July of 1983 and will continue through December 1989 under a grant from the Annenberg/CPB Project. The following programs will be in experimental use starting in the Fall 1985 term: *Dominos*, in French, German, and Spanish; a *Simulation Exercise*, in Spanish; and a *Document Analysis Exercise*, in French. Other programs will become available over the course of the project; eventually, all will be integrated into the FL&L curriculum. Experimental use will affect about 100 students in ESG and FL&L sections; once programs are a part of the curriculum, nearly all students taking FL&L subjects will be affected (about 1000 students per semester enroll in FL&L subjects).

Programs will be written in Lisp.

Co-investigators: Catherine Chvany, Associate Professor of Russian; Ruth Trometer, Director of the Language Laboratory; Claire Kramsch, Senior Lecturer in German; Douglas Morgenstern, Lecturer in Spanish; Kathy Irving, Lecturer in English as a Second Language; Gilberte Furstenberg, Lecturer in French; Suzanne Flynn, Assistant Professor of English as a Second Language.

The Center and Workshop will serve as a model of the pragmatic, efficient application of computer technology to the teaching of writing. In addition to creating more technically advanced writing aids than those currently available, we hope to demonstrate the appropriate role (including the limits) of computer technology as an aid in human communication. The Center and Workshop will be a model environment in which tutors and teachers can use the computer as a tool without danger of overwhelming the student with a machine-centered writing environment.

Work is already well underway on the windowing environment (which will be used first in the writing coop program in mechanical engineering) and the outlining tool. Starting in Spring, 1985, work will begin in the etymology and poetry exercises. The Center and Workshop should be built sometime in 1986.

Programming is in C and Lisp.

Co-investigators: Robin Becker, Assistant Professor of Writing; Robert Berwick, Assistant Professor, Artificial Intelligence Laboratory and Department of Electrical Engineering and Computer Science; Joe Haldeman, Visiting Associate Professor of Writing; David Lampe, Editor, the MIT Report, Industrial Liaison Program; James Paradis, Associate Professor of Writing; Harriet Ritvo, Assistant Professor of Writing; Steven Strange, Lecturer in Writing and Director, Writing Center; William Unkel, Associate Professor, Department of Mechanical Engineering; Bonnie Walters, Coordinator, Committee on the Writing Requirement; Joanne Yates, Lecturer and Coordinator, Sloan School of Management Communication Program.

The major part of the user interface will be written with Digital's VAX-Producer package, which is composed of Design, an instructional language, and Draw, a graphics language. Any external programs necessary to augment Design's capabilities will be written in C.

The project began in September, 1984, and will be completed by September, 1986. Demonstration of graphic images will occur during the summer of 1985. A pilot system will be available for student use during the fall of 1985.

Playing and Analyzing Sequential Prisoner's Dilemmas

Principal Investigator:

Professor Hayward R. Alker Jr., Department of Political Science.

The goal of this project is to adapt, deepen, and augment approaches to political analysis and argumentation that are central to Professor Alker's teaching within the Political Science Department. Specifically, this will involve developing interactive software for playing, recording, and analyzing mixed-interest political interaction games, such as Sequential Prisoner's Dilemma (SPD) games.

These games are used by students to explore the relative merit of various actual or hypothetical strategies for resolving international security problems, in particular in the technologically unstable world where nuclear defense policies are no longer based on Mutually Assured Destruction. They are also used as a way for students to develop and analyze modes of cooperative play. It would be helpful for undergraduates to be able to do routine behavioral analyses of their own game play. Individual differences in best-predicting explanatory models need to be a part of these analyses, along with assessments of the extent to which each participant is subject to the pressures generally described in the literature on game play. Time constraints along with data gathering, transcribing, and analysis costs have made this difficult to accomplish.

Software, written in C, has been developed on interactive game defining and data recording tasks associated with having game pairs playing simultaneously over the Athena network. Four or five pairs can play the game on one VAX. Subsequent work, for which funding has been requested, will focus on interactive modeling of individual players and their interactions, including play versus preprogrammed "intelligent" strategy routines. Axelrod's programmed player competition could also be implemented in an accessible way. Another task will be to record and analyze move justifications and the political arguments they engender.

Development started in January of 1984. Programs are currently in experimental use in "Just Wars, Total Wars, Nuclear Wars" (17.401) with 80 students in the Spring 1985 term. They will be used in "Formal Logics and Political Arguments" (17.803) starting in a later term.

Programs will be written in Fortran, Lisp, and the C-shell programming language.

Co-investigators: Kevin Oliveau and Thomas Homer-Dixon.

Computer-Based Tutorial System for Systems Analysis

Principal Investigator:

Professor George Rathjens, Dept. of Political Science

This project will introduce computer based techniques and tutorial programs into the course 17.487/488 "Systematic Policy Analysis." The course teaches the fundamentals of systems analysis (applications of probability and statistics, linear programming, game theory, monte carlo methods, and sensitivity analysis) as applied to arms control and defense issues. Students will be introduced to the use of computers in systems analysis both through the use of prepared programs and through the design and use of their own programs and spreadsheets. Thus, students will develop the skills necessary to use computers in their own research work.

The methods of systems analysis can involve fairly complex mathematics, and the challenge is to present these methods to a class of students whose background in mathematics varies widely. A computer-based system such as we are developing can assist in this task by allowing the students to experiment with programs that embody the basic concepts, and to thereby gain more insight into the relationships between assumptions and results. Thus, basic concepts may be experimented with by those whose mathematical background is weak, while those with a more advanced background may model more complex systems and gain experience with them. The capability to display the results graphically is also of great importance to understanding the behavior of the systems.

Most of the software developed for this course makes use of the RS/1 software package donated to Project Athena by BBN Software. This software enables the user to easily generate spreadsheets, create two- and three-dimensional graphs, and to write programs using a C-like structured programming language. Its user-friendliness and extensive on-line help facilities will enable students who are unfamiliar with computers to quickly become familiar with the system and start to use it.

A number of small programs have been written to illustrate basic problems and methods, and some procedures will be provided so that students can easily write their own programs incorporating them. The programs include: marginal analysis of strategic forces, monte carlo methods applied to ballistic missile defense, general monte carlo methods, and linear programming. (The latter will be written in C so as to utilize NAG routines, but will be accessible through an interface to RS/1.) Special spreadsheet templates will also be provided to introduce the students to the uses of spreadsheets and to encourage them to develop their own applications.

First use of the system will be the Spring term of 1985. As of January, most of the programs were under development or finished, and documentation was in

SCHOOL OF SCIENCE

Interactive Videodisc Teaching of Biology

Principal Investigator:

Sheldon Penman, Biology

The subject content of biology presents unique problems to teaching, especially in a reductionist milieu such as MIT. The material is often broad, diffuse, sometimes vague and given to syntheses based on soft facts. Nevertheless, the subject is fascinating and important in the training of future basic scientists and medically associated professionals.

The potential of computer-aided, interactive instruction in biology is especially attractive. Serious lacunae in student training may be addressed effectively and creatively through this medium. This is particularly true in the areas of higher organism biology, where it is most difficult to apply the rigorous methods of biochemistry and molecular biology and where the absence of appropriate laboratory experience is most keenly felt.

Two major challenges seem obvious in the material of higher organism biology. One is the vast amount of detailed pictorial materials that must be managed and presented in a coherent, didactical manner. The second is the data that can only be presented in time lapse microphotography. Both of these aspects of teaching can be addressed effectively by the video disk. In collaboration with Professor Edwin Taylor, I have been developing teaching techniques based on the video disk material now available. Eventually, interactive programs using personal computer terminals should be developed. These would use the data base management capabilities and the ability to superimpose computer generated graphics on the video disk image to create a unique instructional environment.

Using the initially limited resources available, the video disk potential is being explored by employment in classroom demonstrations. Time lapse segments from several disks are being shown in courses in cell biology, developmental biology and biophysical chemistry. The enormous advantages of the video disk over film is already apparent, since detailed sequences portraying, for example, embryo development or cell division can be played, stopped, reversed, stepped, etc.: options that traditional film or videotape do not offer. Tape recordings of the professorial discussion accompanying each presentation offer a record of the instructional material in each sequence. In collaboration with Professor Taylor, didactic graphics will then be developed using the Visage board for the IBM PC and will constitute a base on which interactive, instructional routines will be developed.

Observational and Dynamical Meteorology and Oceanography

Principal Investigators:

Randall Dole, Kerry Emanuel, Glenn Flierl, Paolo Malanotte-Rizzoli, and Richard Lindzen, Professors in the Department of Earth, Atmospheric and Planetary Sciences.

This project is developing software for teaching the observational and theoretical aspects of modern meteorology and physical oceanography. Project Athena computers will be used to archive, display, and analyze data for students in the synoptic meteorology and physical oceanography courses.

Much of the current research in these fields involves handling large volumes of data with complex numerical schemes. Often, in order to teach these methods, the problems must be tremendously oversimplified so that hand calculations can be made.

Development will focus on adapting objective analysis routines, contouring packages, map-drawing procedures, and statistical packages, such as empirical orthogonal eigenfunction analysis. In addition, forecasting records of students will be kept as part of a "forecasting game." Skill scores from simple forecast models and the results from complex models, such as that employed at the National Meteorological Center, will also be entered into the system. Programs for teaching ocean thermodynamics, Coriolis forces, Eulerian versus Lagrangian approaches to the equations of motion, and wave motions in a fluid are planned. For more advanced students, a program for solving the vertical structure equations for atmospheric or oceanic waves is being developed.

This project will lead to dramatic changes in the procedures (now involving mostly hand-drawn contouring and map manipulations) for teaching synoptic meteorology. It will also allow students to deal with realistic situations, rather than over-simplified models.

Development started in March of 1984 and will continue through May of 1985. Programs will be used, on an experimental basis, in "Wave Motions of the Atmosphere and Oceans" (12.801), "Physics of the Ocean" (12.21), "Synoptic Meteorology" (12.811/.812/.844) and the Undergraduate Forecasting Seminar during the 1984-1985 school year.

Programs will be written in Fortran and C.

An Interactive Statistical Package

Principal Investigators:

William Nazaret and Stephan Morgenthaler, Mathematics
Department and Statistics Center

This project intends to support the teaching of probability and data analysis in introductory courses.

The backbone of the project is an interactive statistical package called *isp*. It allows the user to perform many classical and robust data analytic tasks. Part of the project was the expansion of *isp*. It now includes pseudo-random number generators.

On top of *isp* we have written a collection of macros which call a sequence of *isp* commands. The goal of each such macro is to explain a specific probabilistic concept or a statistical method. These educational *isp* macros are called from a main program which is menu driven and at each state gives the user a choice as to what he wants to do next.

The basic didactic idea is to learn through pictures of the effects of simple pseudo-random mechanisms. This way a student has a chance to really understand the meaning behind mathematical theorems which usually fill the text books on probability theory and statistics.

The main program is written in C, most of *isp* is in Fortran. The program is on VAX.

Currently, this program is not in use, though it was used in the Fall, 1984 term. Further work may be done on this package to enhance its usability.

SLOAN SCHOOL OF MANAGEMENT

Multi-Robot Games

Principal Investigators:

Thomas W. Malone, Assistant Professor, Sloan School of Management, and Gerald Barber, Research Associate, Artificial Intelligence Laboratory.

The goal of this project is to develop educational games in which students program teams of simulated robots to compete against each other in various activities, such as business simulation.

The games will provide a highly motivating laboratory in which students can experiment with various forms of organizational structures (for example, centralized vs. decentralized decision-making, broadcast vs. directed communication) and immediately see the results in different settings. For management students, this will provide an unusual opportunity to practice designing effective decision-making organizations, rather than just practicing making decision themselves (as in current management simulation games). For computer science students, this will provide a particularly concrete way of learning abstract principles that can be applied in designing parallel and distributed computer systems.

These programs will be used in an advanced graduate seminar on principles of organizational design for human organizations and computer systems. The students in this class are primarily from the Sloan School of Management and the Electrical Engineering and Computer Science Department. The first version of the program will be available by December 1985, with experimentation to continue for one or two more years.

Programs will be written in Lisp, and will make heavy use of graphic displays.

Co-investigators: Randall Professor Michael Cohen, Department of Political Science at the University of Michigan.

INTERDEPARTMENTAL AND ACADEMIC SUPPORT

Computer Literacy Program

Principal Investigators:

J. Kim Vandiver, Associate Professor and Director of the Experimental Study Group; Holly Sweet, Associate Director of ESG; Raj Jain, '87.

This project used ESG to develop new techniques of teaching computer literacy to people with little or no previous computer experience. Its objectives are to study the effectiveness of these methods and to provide a self-contained package of instructional materials to other potential computer users.

Significant portions of the student body are not comfortable or familiar enough with computers to use them effectively in the classroom. Given the advent of increased computer use in education at MIT, stemming from the initiation of Project Athena, a computer literacy program could provide these students with a much-needed service.

The underlying philosophy of the program has been to provide a "bottom-up" view of computers, starting with basic machine functioning and building to higher-level uses, one of which is programming. This approach was used so students could understand the underlying foundations of computer use, such as where computers derive their power from and what their limitations are. Anxiety about computers, one of the larger obstacles to literacy, was lessened by the students' understanding of the workings of computers.

After having established this base, students went on to learn about operating systems, UNIX in particular, and were exposed to uses such as word processing, games, and other software packages. Students became proficient at dealing with documentation and on-line help facilities at this point and became comfortable with their own abilities at the terminals.

Programming was taught last. It was emphasized that programming was just another use of computers, rather than the ultimate goal of computer literacy. Pascal was used because of its structured style and the ability to use abstraction and modularity as programming techniques. Students used these methods to learn proper technique from the beginning.

The classes were taught in two, one-hour sessions a week. The first session included lectures, exercises and discussion, and the second session included a lab or demonstration of the concepts taught in class. The program lasted twelve weeks, although lessons were kept modular after the first few weeks to enable students to concentrate on their areas of interest.

A shortened version of this program ran in Spring term 1984 and a complete version was taught in Fall term 1984. A self-paced study program, composed of

Interfacing Academic Laboratories with Project Athena

Principal Investigator:

Professor Jerome H. Milgram, Dept. of Ocean Engineering

The long-term goal of this project is to bring computer support into the academic laboratories of MIT. This will enhance the education of students enrolled in laboratory subjects, both through direct support and through the development of improved teaching methods that will be possible with computer support. A balance is sought between the ideas that come with diverse approaches, and advantages in implementation, maintenance and portability associated with hardware and software coherence.

Although every engineering or science department involved in teaching undergraduates has one or more laboratory subjects, computational resources are not widely used in the laboratories. The addition of computer support can markedly improve education by widening the scope of possible experiments and by allowing students to focus more of their attention on the intellectual aspects of the activity, since the computer can take over the otherwise tedious tasks of repetitive calculations and graph preparation.

This project is creating an Institute-wide system to serve a variety of subject types, ranging from pre-structured laboratory experiments to those in which students plan and build their own individual experiments. Already, this project has provided computer support in the School of Engineering to over 100 students in the following subjects:

2.671	Measurement and Instrumentation
2.672	Project Laboratory (with pre-structured experiments)
13.902	Ocean Engineering Project Laboratory
13.621	Experimental Projects (with student-planned experiments)

Plans have been made to extend the Project Athena laboratory computer support to the Departments of Chemical, Civil and Nuclear Engineering in the immediate future. Close liaison and idea-sharing takes place between the School of Engineering effort and related activities in the School of Science, where computer support (with the same type of computer hardware but with different software) has been implemented in one chemistry subject and two physics subjects.

The laboratory machines used thus far are IBM-XT's with suitable real-time interfacing hardware and with software generated by this project, which has also generated software for VAX computers to be used when these machines become available in the labs. In addition to computer-supported activities in the laboratories, especially real-time data acquisition and control, this project involves subsequent data analysis, simulation and high quality graph preparation with the Athena VAX computers.

Academic and Personal Support Programs for Freshmen

Principal Investigator:

Peter H. Brown, Assistant Dean for Student Affairs.

The Office of the Dean for Student Affairs (ODSA) is developing an array of academic and personal support programs designed to help freshmen sort out the range of social and academic possibilities that exist at MIT. These programs will add another dimension to the way that students receive information and guidance from this office.

PROGRAMS

- o *Pathways.* Detailed information on Institute requirements and "roadmaps" of possible college and career paths. Written with faculty and alumni input, this program encourages positive, long-range planning in making academic and career choices.
- o *Personal Assistance Modules.* A variety of workshops focused on personal development issues, such as stress reduction techniques and study skills.
- o *Profile.* A community opinion forum designed to quickly register and evaluate feedback and commentary on a wide spectrum of issues.
- o *Bulletin Board.* Centralized information on current Institute happenings.
- o *Chat Line.* An avenue for students to articulate problems, and receive advice and suggestions.

The ODSA is hoping to reduce the "paper blizzard" of information that currently greets freshmen, and to distribute ideas and services more efficiently. Students will have unlimited access and time to explore personal and academic options, in addition to personal contact with staff and faculty. The ODSA also sees an opportunity to extend support to those students currently not taking advantage of the office's services. Beyond this, the project will explore the most practical use of computers in the field of academic support and students affairs, and will be a pioneering effort in this area.

Programs will be written in C, and will use display panels and graphics. Initially, this project will involve the freshman class and eventually, the entire MIT community.

Development started in March of 1984 and will continue indefinitely. *Pathways*, planned as the first package to be completed, is not complete as we have been unable to find a good graphics generator package that will call text.

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Fraternity Support System

Principal Investigator:

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**A Library of Computer Algorithms for Operations Research and
Management Science**

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