A Second Wind for ATHENA

The Experiment Scheduled to Finish in 1988 is in Some Ways Just Beginning

BY SIMSON L. GARFINKEL, '87

When M.I.T. announced the launch of Project Athena in the spring of 1983, it was clearly labeled an experimental undertaking. Digital Equipment Corp. and IBM would provide $50 million in hardware, maintenance, and expertise; M.I.T. would provide faculty, students, technical staff, and $20 million in development support. Together they would find out if a network of high-performance computer workstations could be used to help undergraduates learn better.

That was an ambitious enough project, even for so impressive an alliance. But the question first posed didn't compare to the questions that were actually confronted: Could one campus system serve the needs of everyone from aeronautical engineers to students of Spanish? Could incompatible products from two or more vendors be integrated into a single system so that the differences were irrelevant to users? If so, what was the practical strategy for accomplishing that? How do you administer a system that includes 5,000 user accounts on 1,000 workstations, plus file servers, printers, and oodles of special-function hardware and special-purpose software seeping in at the sides? For that matter, how do you manage the logistics of just getting 1,000 workstations out of the boxes and running?

In July, Professor Earll M. Murman took up the reins from Athena's founding director, Professor Steven Lerman, '72, ready to steer the project through its three-year extension. This seems like a logical time to bring alumni and alumnae up to date. In a series of articles beginning here and continuing in future editions of *Technology Review*, Simson L. Garfinkel, '87, will report on what faculty, students, Athena staff, and M.I.T.'s industrial partners have to say about the project.

In 1983, there were primarily two kinds of computers at M.I.T.: mainframe "time-sharing" machines, and a growing number of desktop microcomputers, such as the IBM PC and the Apple Macintosh, that often featured interactive graphics but lacked the power required for large numerical calculations.

Project Athena envisioned using a new kind of computer—a "workstation"—with the power of a time-sharing machine on a desktop, completely at the disposal of one user at a time. In addition to high speed and compact size, these machines would have exceptional graphics, able to display whole pages of textbooks, complete with equations and drawings.

Because the fabled workstations were not available in 1983, Project Athena was broken into two discrete phases. During the first phase, says Lerman, Athena built a campus-wide fiber-optic network and operated 63 Digital VAX 11/750 minicomputers as time-sharing machines. Phase I also called for 500 experimental workstations from IBM. Terminal rooms called clusters—that would later house workstations—were carved out of every possible space. This set-up gave students and software developers a feel for how the new computer environment would eventually operate.

Phase II, in which the time-sharing VAXes and the experimental IBM machines would be replaced with workstations, was originally supposed to commence in August 1985, Lerman says. Instead, delays in hardware and software held it off until 1987.

Athena's mission was always to develop educational software that would be used

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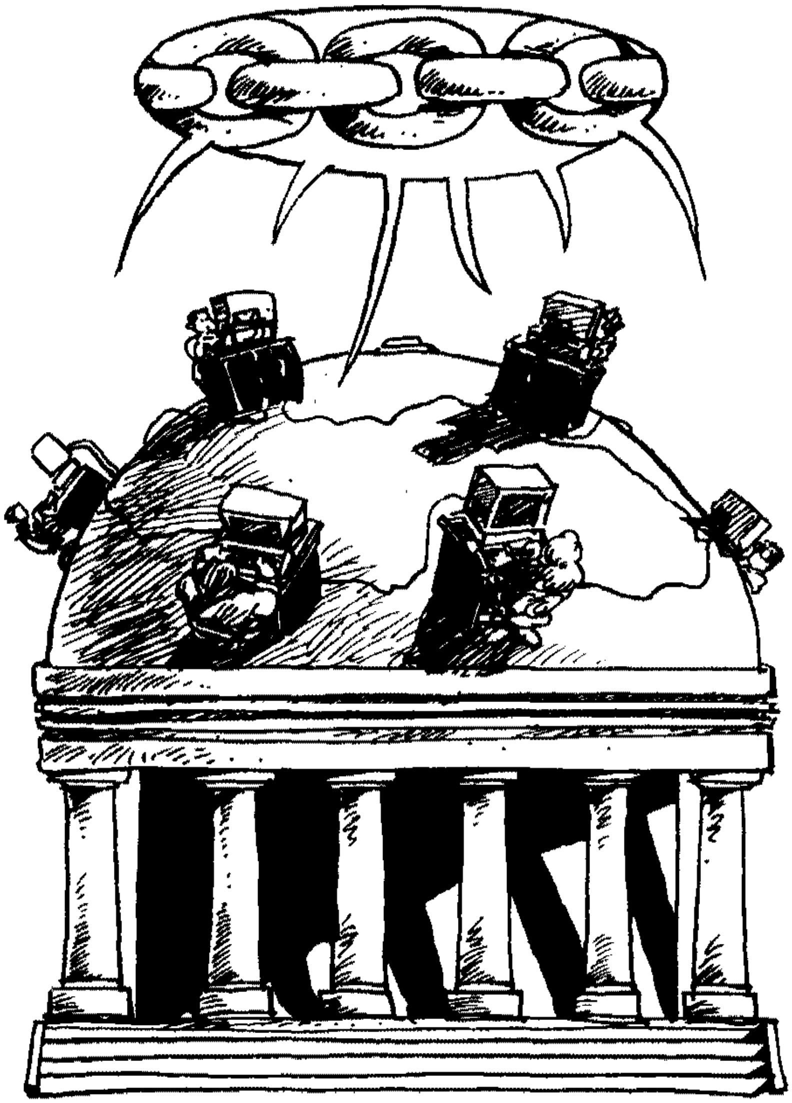


by undergraduates, not to do basic computer science research. "The purpose of Athena is to deliver computing to students to do homework," says Technical Director Jerome H. Saltzer, '61. But those involved in the project soon learned that many fundamental software developments were prerequisites to the operation of a large network of workstations. From the operating system to the screen-management system, a lot of underlying work had to be accomplished before the educational software could be developed and deployed.

Says Lerman: "[M.I.T. and its industrial partners] were talking about workstations that were in the development labs at the time. We overestimated our ability to take these and [in a relatively short time] turn them into networked workstations."

Today, Lerman proudly points to some of those basic developments as Athena's main accomplishments. The X-Window System, a program for managing text and graphic "windows" on the workstation, has become a standard throughout the computer industry. Kerberos, a system for enforcing rigorous computer security over a public computer network, has attracted interest from DEC and IBM. SMS, a database system that manages the accounts of Athena's 5000 users, and Hesiod, a system that lets any user sit down at any Athena workstation and automatically access his or her files and electronic mail, are also beginning to attract outside attention.

These are also the results that seem to have pleased Athena's sponsors the most.

"From the technical standpoint—how do you set up a large, complex, distributed system—we've learned a great deal," says Carol Crothers, manager of IBM's University Development Products, which oversees IBM's grant to Athena.

"The X-Window System has been very valuable to us. Because of our close working relationship with Athena, we were able to ship the first commercial release of X11 [an advanced version of X] on the marketplace," she adds. Next year, Saltzer says, X—in conjunction with IBM's own version of the Unix operating system—will be available on the full line of IBM's mainframe computers.

Digital, meanwhile, has incorporated the X-Window System, which it calls DEC Windows, into its entire line of VAX products. Some sources inside DEC say privately that the development of the window system alone was worth DEC's donation to M.I.T.

So far, however, the impressive technical developments haven't had a big impact on students, who continue to use the equipment primarily for word processing. According to a 1988 survey by Project Athena, students use the system an average of 1.95 hours per week for word processing, 1.41 hours for writing programs, and 1.34 hours for doing problem sets. However, as more course-specific software goes from the hands of the developers in the academic departments into the classroom, and as professors assign more problem sets that depend on Athena, the patterns of usage can't help but change.

Lerman notes that the Athena programs, or "modules," in Course XVI have been so successful that the faculty members in the Department of Aeronautics and Astronautics have virtually reworked the curriculum around Athena.

In the Beginning, There Were the Engineers

Gerald L. Wilson '61, dean of the School of Engineering, traces Athena's roots to a 1979 report from the director of the Laboratory of Computer Science, Michael L. Dertouzos. In that report, Wilson says, Dertouzos recommended "that the administration begin to think about networking a large set of mainframe computers in order to broaden the availability of computers to students, both graduate and undergraduate."

"That report was submitted at the time that [Jerome B.] Wiesner was president," says Wilson. "It died. Nothing ever happened to it."

After several years of waiting, Wilson

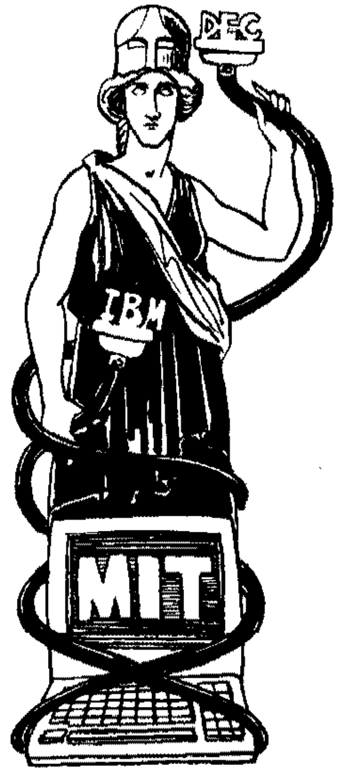
says, the School of Engineering decided to go ahead: "We in the school decided not to wait for M.I.T., but to make it our highest priority to [create] an environment in which we could explore the uses of computers in education." The school wanted to focus on undergraduates, Wilson says, because at the time undergraduates had no access to computers unless they were enrolled in Course VI subjects that specifically used the machines. Wilson thought that undergraduates were not being given a realistic education, because at the same time computers were being used all over M.I.T. in a variety of research applications.

In 1982, Wilson wrote a proposal to the major computer manufacturers looking for a partner for his school's project. Then he went to the Academic Council and spoke with the deans of other schools. "There was relatively little interest in some schools and none in others," reports Wilson. "Some of them said outright that computers are not a new tool for teaching." Frustrated by the lack of interest on the part of their colleagues, the engineers decided to go it alone.

The School of Engineering finally settled on Digital as the sole equipment supplier for its project. "When that started happening . . . the Corporation—particularly the Executive Committee—wanted to hear what we were proposing. [President] Paul Gray ['54] thought that we really should do this for all of M.I.T. . . .We were asked to go back and see if we could get additional resources to do all of M.I.T." So began a long series of negotiations with IBM, which had just formed its Academic Information Systems (ACIS), a branch of the corporate giant that had the potential to be the kind of collaborator M.I.T. would require.

As a result of those negotiations, Athena became a project for the entire Institute rather than one for only the School of Engineering. Because DEC had already made commitments to the School of Engineering, Wilson says, it was decided that IBM would have responsibility for providing equipment for use by all the other schools. (At the time, about 70 percent of the undergraduate students were majoring in engineering. The figure is about 62 percent now.)

Out of this intentional mix of hardware manufacturers was born the idea of "coherence," meaning that there would be no perceivable difference between running programs on an IBM workstation or a DEC workstation. The screens might be larger or smaller, the keyboards might have a different layout, but programs would run basically the same.



Although computer science research and technical development were never the objectives of Athena, it became obvious that Athena's requirements by way of workstations and a network could not be met until a lot of fundamental work was completed.

In 1983, coherence seemed like a radical proposal. With a few minor exceptions, computers manufactured by the two companies had never been compatible. Programs developed on an IBM mainframe simply would not run on a DEC minicomputer. Even the computers' "operating systems"—the basic programs that allow the user to instruct the computer what to do—have different vocabularies, command sets, and ways of approaching the equipment.

By developing a standard workstation environment, Athena was going to change that. "There was also some sense," Lerman recalls, "of not wanting to come out at the end of five years and find ourselves wedded to [one vendor]."

Digital's initial shipment of 63 VAX 11/750 computers (serving a total of more than 240 users at a time) was to be matched by the shipment of 500 experimental workstations from IBM that would each consist of "a coprocessor on a PC/XT with an experimental display," and would run the Unix operating system, Lerman says. The machine would hold IBM's place on campus while IBM developed its workstation, which eventually became known as the RT PC.

Due to technical difficulties, Lerman says, the experimental machine was never produced. "The ship date for the experimental box and the RT were getting awfully close [together]," Lerman recalls. Eventually, Athena decided to simply wait for the RT and accepted a large delivery of high-performance IBM PC/AT computers

In the beginning, Digital served the School of Engineering (at the time it enrolled about 70 percent of the undergraduates); IBM was to serve undergraduates in all the other schools. Removing that division was one of many steps in the right direction.

in the meantime.

"It was our idea," Lerman says. "It let us expand the base of PCs and get some experience with something that is *sort of* a workstation." Even though the machines could only support a single user running a single program at a time, they were networked and they were "relatively high-performance." (Today, the ATs are being used to monitor and run experiments in laboratories, and some have been made available to student organizations.)

Meanwhile, a growing number of VAX-based clusters had been set up for use by students in the School of Engineering. The idea that students would use the intermediate system was at the very heart of the Athena experiment. That meant that students used prototype hardware and software. And because of the vendors' different delivery schedules and the decision to split the Institute, inequities were inevitable.

Because programs for designated Athena-assisted subjects were installed on particular time-sharing machines, students enrolled in those subjects were restricted to working in a specific cluster. These students were then free to use the equipment for word processing, to write papers for their "non-Athena" subjects. Students who were not enrolled in any Athena-sponsored classes were initially confined to the Student Center cluster, where there were often long lines to use overburdened, very slow computers and printers.

"We had a network but we didn't have a central distribution of software," Technical Director Saltzer explains. To make matters worse, at the times the lines at the Student Center were longest, students were aware that Athena computers in other clusters were often idle many hours of the day.

When the workstations began arriving in 1986, a new problem cropped up: moving programs from the time-sharing machines to the new DEC machines was trivial, but a lot of basic software had to be rewritten for the IBM RTs. The gap was further widened because Athena received the RTs six months after receiving the MicroVAXes, Lerman says; the software on the IBMs took two years to catch up with the DEC workstations.

In March 1987, the first IBM workstation cluster began operation, and by that September the entire Athena system had been shifted over to "Phase II." At that time, the last of the VAX 750s were taken out of time-sharing service and set up instead to provide files to workstations over the M.I.T. Campus Network. Because any workstation can use any fileserver on campus, the restrictions that prevented most students from using clusters other than the Student Center were removed.

"Phase I to Phase II was a very important transition," Saltzer says, "from scarcity to plenty." One student, responding to an Athena survey, wrote: "I used to complain to anyone who would listen about how bad Athena was, but the new workstations are a great improvement."

Today a student can sit down at any Athena workstation located anywhere on campus, type his or her user name and a password, and immediately begin accessing files or reading mail. According to Athena's survey, 92 percent of M.I.T.'s undergraduates have used an Athena workstation at least once—and at least 25 percent of the undergraduate community uses it every day, Saltzer says.

Also gone with Phase I was the idea of dividing the Institute between the two vendors. "It didn't make sense," Lerman says. Project Athena's new video cluster, in which IBM color monitors are attached to DEC workstations, illustrates the degree to which equipment from the two manufacturers is now being blended, he adds.

Today there are 722 workstations on and off campus that students can use, in 12 public clusters and 21 clusters reserved for departmental, living group, or other private use. "The main reason why there aren't more workstations on campus is real estate," Saltzer contends. "If someone were to wander in magically and say 'you can have 10,000 square feet in this building,' we would have 200 more workstations out in six to 12 months."

But the emphasis of Project Athena from now on will be more expansion into private settings, such as the living groups and the offices of faculty, Saltzer says. And with the cabling that is accompanying the installation of the new M.I.T. campus phone system, Saltzer says, it will be a lot easier to put workstations off in remote corners of the Institute.

Other changes from the original plan include Athena's definition of "coherence." "One of the things I found when I came on board was that there were five definitions of coherence," Saltzer recalls. "Some of the original goals of coherence were research problems," he says, and not prerequisites for an educational computer environment.

One such objective was to be able to write large programs in a variety of languages—such as Lisp, C, and FORTRAN—simultaneously, using each language for what it does best. "We decided that was not an important educational goal," Lerman explains.

"The biggest contribution to coherence has been [the X-Window System]," Saltzer continues. "It has always been the case that a Unix program written in C is mildly portable [from one brand of hardware to another]. The place you get in trouble is where you try to put things on the display." With the X-Window System to standardize display interaction, Saltzer says, "all of a sudden you discover that most programs are portable."

X has even masked seemingly insurmountable differences between DEC and IBM hardware. The DEC workstation's mouse—a handheld device that the user rolls around on the table to move a pointer on the workstation's screen—has three buttons on its top, while IBM's mouse has two. Athena's solution: DEC's middle button can be simulated by pressing both of the IBM buttons together.

If so much has been accomplished, why extend the project for another three years?

"We had more work to do," Lerman answers. Under the initial plan, M.I.T. was to have had two or three years experience with the workstation environment before having to make a decision about Athena's success. "Realistically, we only turned it on in September 1987."

While software could be developed and used by students on the time-sharing machines, programs that were originally envisioned for the project needed the power of a workstation to perform the necessary calculations. One example Lerman points to is Professor Earll M. Murman's Computational Fluid Dynamics programs, in which a student can watch the flow of a fluid over an airfoil. "Simulating what is going on with the movement of fluids really requires high performance," Lerman says.

"We're just beginning the more extensive use of color," Lerman adds. The "fish bowl"—the glass-walled cluster along the Infinite Corridor that is often ringed with campus visitors—has become the definitive video cluster, where up to 12 students can work, each with his or her own high-resolution color display and laser disc player. Video disc projects are under development in biology, civil engineering, and foreign languages, Lerman says.

And so, at least three more classes of M.I.T. students will participate in this experiment. In a sense, the challenges ahead are much more complicated than the ones that have been solved: Professors can require that students use computers to solve their problem sets, but do the students actually learn better as a result of the exercise? Will that be equally true for non-technical subjects? Will the aptitudes of most students be sufficiently improved to justify the continued maintenance expense of such an elaborate network, let alone the cost of any future upgrading? Will what has been learned at M.I.T. be applicable to other colleges at reasonable cost? In the final analysis, it is these issues, rather than the success of the window system, that will determine the project's eventual impact on education. □

MIT Faculty Learning How to Teach with New Tools

BY SIMSON L. GARFINKEL, '87

In a darkened lecture hall, a professor stands before a class of sophomore aeronautics and astronautics majors and types a few commands into an Athena workstation. Moments later a cross section of an airplane's wing (airfoil) appears on a 12-foot silver screen at the front of the classroom. A row of animated bubbles materialize in front of the wing and move across it, showing the path that air would take if the "wing" were really "flying."

"If you have a picture of a fluid flowing, and nothing very exciting seems to be [going on], what happens if you change the angle of attack of the wing?" asks James McCune, the professor in question. "What happens to [a particular] fluid particle? Does it go on top of the wing, does it go under, does it get caught in the wake? Does it exert lift?"

Lift, McCune says, is caused when air moves faster over the top of the wing than underneath it. The faster the air moves, the lower the pressure. The drop in pressure holds the airplane in the sky like a suction pump.

Only two years ago McCune might have been showing a film on lift to his class. But unlike a film, the computer can be manipulated by McCune: with just a few movements of the "mouse" at the side of the workstation he can change the simulated system. He can also turn it over to the class: One student asks him to try a different angle of attack; another wants to see what happens when the wing "moves" faster through the simulated fluid. The class comes alive, each student suggesting another possibility.

At the end of the hour, each student can go off to one of 33 Athena clusters located around campus, sit down at a workstation, and try different variations on the problem until he or she has developed an intuitive grasp of the concept of lift.

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"You're more interested if you have to make the choices," says Professor Earll M. Murman, Athena's new director. "Being given a book of pictures or a videotape is just not the same."

On the fifth floor of Building 9 is another face of the goddess. In a glass-walled room called simply "The Garden," a collection of IBM PC/AT computers, graphics screens, digitizing tablets, and a few workstations have sprouted as a result of the five-year-old collaboration between MIT, IBM, and Digital Equipment Corp. Here students in the School of Architecture and Planning use largely off-the-shelf software for drafting, building spreadsheets, and word processing.

"This idea of gluing together [commercial] application tools rather than building one [custom] package that can 'do it all' is the focus of what I have been trying to do," says Professor Joseph Ferreira, '67. Ferreira has been the driving force for this outpost of Athena.

"For planners," Ferreira says, "the time frame you have to construct a model and do a lot of 'what-if' calculations is pretty short. The spreadsheets are ideal for desktop modeling." In the Garden, the School of Architecture and Planning's students learn to use software packages similar to those they will encounter as working professionals.

All across MIT, Athena is changing the way subjects are taught and ideas are conveyed, from freshman seminars on physics to graduate classes on transportation. The real success stories of Project Athena have been programs that students can use as tools to help them solve problems.

The airfoil program is an example of such a tool. "It's a flexible electronic simulation," says Murman, who spent five years coordinating the development of the system. The "tool" is really a collection of seven tools, which examine aspects of fluid dynamics from jet nozzle design to thermodynamics. A different faculty member oversaw the development of each module; collectively they are bundled together in a package called "Todor," named for the great Hungarian aeronautical engineer, Theodore von Karman.

Murman characterizes Todor as coming about by accident, not by design. "It just happened," he says. But in fact, his department's commitment of time and attention makes this more than a fortuitous accident. In 1983 12 professors in the department took a two-day sabbatical at MIT's Endicott House. Their agenda was to think of ways of using new media to reach students—particularly those for whom subjects like fluid dynamics can be a struggle.

"At the end of that retreat, we had narrowed [the uses for computers] to seven project objectives." And by the end of 1985, each faculty member had developed a module. When they found an approach that worked, Murman says, it was put into the system.

Similar to Todor is the Department of Civil Engineering's program GROWLTIGER, which enables students to "build" structures, such as buildings and bridges, on the computer's screen and analyze the forces on them. The program can tell a student which buildings will stand and which will fall. like Todor, it is an electronic laboratory. But unlike Todor, GROWLTIGER was written by one person, John Slater, '78.

(Slater now works at Stone & Webster, a Boston engineering firm founded by MIT graduates and involved in construction of MIT's Cambridge site. But from 1982 until last spring, he was a professor of civil engineering.)

Slater spent a thousand hours between

Now you can graph differential equations on a screen. No more tables!

March and September in 1984 writing the first version of the system. GROWLTIGER now contains more than 80,000 lines of code and, like Todor, can be run from most of the workstations at the Institute.

"A student can sit down for two hours, learn it, and actually be productive," Slater says. The system is powerful enough to help both undergraduate and graduate students solve problems, he adds.

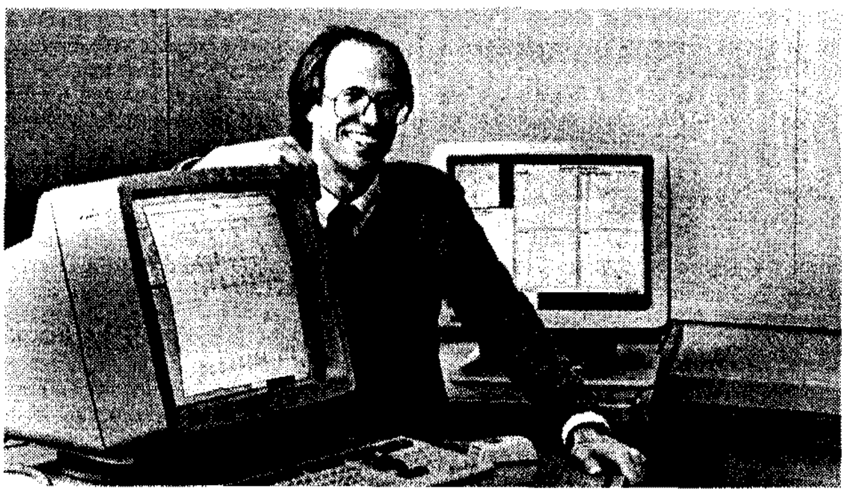
After teaching himself C in order to write GROWLTIGER, Slater introduced C as a programming language to 1.00 (Introduction to Computers and Engineering Problem Solving) in fall 1985. He reports that when C, which was seen as the language of the future, replaced FORTRAN in the class, enrollment grew from 85 to 260 students within a few years. "That's a real impact."

Athena's projects in the School of Science have tended towards small programs that let students solve specific problems, rather than the large-scale electronic laboratories like GROWLTIGER and Todor. Graduate students in the Department of Earth, Atmospheric and Planetary Sciences (Course XII) adapted a publicly available program called STARCHART to the Athena system. STARCHART, says James Klavetter, a graduate student in the department, displays on the computer's screen a picture of the night sky. The chart can then be printed and carried by students up to the roof of the Green Building for the night-time lab in "Observational Techniques of Optical Astronomy," a subject jointly offered by Course XII and Physics (Course VIII).

Since September 1986, students taking 18.03 (Differential Equations) have used another tool-like program to graph differential equations. The program replaces the time-consuming task of plotting differential equations by plugging numbers into a calculator and writing down the results. "When the calculator solved the differential equations, you got tables," says Professor Arthur Mattuck, who teaches the subject and supervised the development of the program. "That was totally unacceptable for teaching; freshmen can't handle tables of data."

"Now there is no data; the output is a curve on the screen," Mattuck says. "Instead of an exact answer—that often teaches you nothing—the graph gives you qualitative information. Does the solution increase, take off, or go to zero? How does it behave?" By typing a few numbers into the workstation, students can find out.

A project in the Department of Physics gives students an opportunity to observe the effects of relativity. VISUAL APPEARANCE presents students with the view from the front window of a simulated spaceship traveling near the speed of light. Objects on the computer's screen seem to distort and change in color—from purple to blue, light blue, green, and finally red—as the spacecraft accelerates and moves past them. Another program allows students to see how a clock sent to Alpha Centauri would tick slower than a clock left behind on Earth, explains Edwin Taylor, a senior researcher who supervised the project.



Mechanical Engineering Professor William K. Durfee has found that Athena can take most of the grunt work out of designing the lighting for theater productions.

A Few Flies in the Ointment

When it announced Project Athena in 1983, MIT stated that the people who would write the next generation of educational software would come from within the Institute faculty and student community. While Athena did hire a technical staff, that staff's primary purpose was to develop the underlying operating system.

In many cases that proved a workable system. The Todor program, for example, was the combined work of 39 students, nearly all of them undergraduates, 14 professors, and only two full-time programmers. But many projects outside of the School of Engineering have not been so fortunate.

Although Professor William K. Durfee teaches in the Department of Mechanical Engineering, he also harbors a passion for the theater. Since September 1986 he has been supervising the development of a program on Athena to help designers plan the placement of lights in theater productions.

"The creative part ends when you have a visual picture of what the stage should look like," Durfee says. "After that . . . it's all grunt work." Durfee estimates that without a computer, more than 80 percent of a designer's time is taken up by drafting lighting plans.

Durfee's biggest headache on the Athena project has been finding students who both know the subject material and are capable of writing the software. At first, Durfee worked with students who knew a lot about theater design. "They [would] spend most of their time learning how to program." Turning to computer hackers wasn't any better, because they had to be taught the ins and outs of the theater from the ground up. Eventually, he says, he "found a couple of people who are theater people and Unix techies, but that mix is really hard to find." (Unix is the Athena operating system.)

Durfee's frustration has been shared by many across the Institute. One of the subtle ironies of the computer age, it seems, is that it is very difficult to write a program that is easy to use. Although Project Athena's X-Windows system made it possible

PHOTOS: MARVIN LEWITON

MIT hoped to export Athena software, but that is almost impossible in some subjects.

to write programs that could exploit the graphics capabilities of the workstation, X-Windows didn't make it easy.

Unlike good teachers, who are priceless, software can be copied and sold relatively easily. One of the early hopes for Project Athena was that the programs developed at MIT could be transported to other universities and make a significant impact on American education. For some projects this hope has been realized: Last summer professors from 19 schools, predominantly teaching colleges, participated at an NSF-sponsored workshop at MIT where they learned about Course XVI's Todor program. Everybody who came got a copy of the software, reports Murman. Everybody who came could run the software, too, because one of the requirements of attendance was having access to advanced workstations.

Programs that run on IBM personal computers have also been distributed. Working with funds from both Project Athena and the International Masonry Institute, Professor Eric J. Dluhosch oversaw the development a program that lets students draw a building and calculate how much it will cost. That program is being distributed to every school of architecture in the United States, Dluhosch says. The packages come complete with a video disc that can show students photographs of buildings similar to the one they are designing.

But in other cases, Athena's choice of high-performance workstations has limited the distribution of the software produced here. In the Department of Political Science, Professor Hayward Alker has overseen the development of a program enabling students to analyze arguments and a game simulating the impact of the international arms buildup on negotiations of war and peace.

"The biggest problem for its [dissemination] is not its specificity to one course," Alker says. The problem is that "it's written in Unix and in C for relatively powerful professional workstations." Social scientists at schools like Wisconsin, Chicago, and North Carolina—a logical market for this software—use the MS DOS operating system that comes standard with IBM personal computers, according to Alker. Even at many universities that have high-performance workstations, access to these machines is restricted to the engineering and science departments.

Alker's concern with portability is mild compared with that of at least one of his MIT colleagues:

"The workstations are totally useless, in the sense that if you write programs for them, nobody else in the world can use them," says Edwin Taylor in the Physics Department. Taylor says he feels "ambivalent" about Athena: while the project provided $165,000 to fund his release time and hire programmers for the relativity programs, it also dictated what kind of computers he had to write them for. Indeed, Taylor's request for additional funds for his Athena project was rejected: he wanted to write programs for IBM PCs and Apple Macintosh computers instead of Athena-sanctioned workstations.

"I'm not going to spend all this time to write programs that can only be used at MIT," Taylor says. "It's like doing research where the results can only be reported at MIT."

Some of the most exciting projects are still a year or more from deployment in the classroom. One of the more ambitious is the Athena Language Learning Project, under the direction of Janet H. Murray, principal research scientist in the MIT Writing Program. The project really consists of three independent sections: one section, designed to help non-native students learn English, will use digital voice processing to "display spectrograms of student utterances and allows them to check their pronunciation of key phonemes against the ideal pronunciation," Murray says. They get a visual signal that tells them how close they are to correct pronunciation.

A second phase of the project will use artificial intelligence to allow the students to carry on text-based conversations with imaginary characters in the machine in Spanish, French, German, or Russian.

And the third section is a pair of video discs designed to help students learn French and Spanish. The first disc starts with a game in which students help a Frenchman named Philippe to either make up with his girlfriend or find a new apartment in Paris. "It's a modern difficulty," Murray explains. "On the other side [of the disc], the student can explore a neighborhood in Paris and listen to a variety of people . . . talk about their lives, professions, and neighborhood." In the second disk, called *No recuerdo* (Spanish for "I don't remember"), a student plays the role of someone who meets a doctor from Colombia who is suffering from amnesia. The student must talk to the doctor and help him to regain his memory before a disaster occurs.

With two and a half years remaining for Project Athena, there's still plenty of room for the development of brand-new applications, as well as the completion of others in the pipeline. In the next article, we'll see what impact these programs and the 722 workstations scattered about the campus and in the living groups have had on their intended targets: the MIT student body. □

Architecture students nationwide now have a program that lets them draw a building and calculate its cost, thanks in part to Professor Eric J. Dluhosch.

MIT

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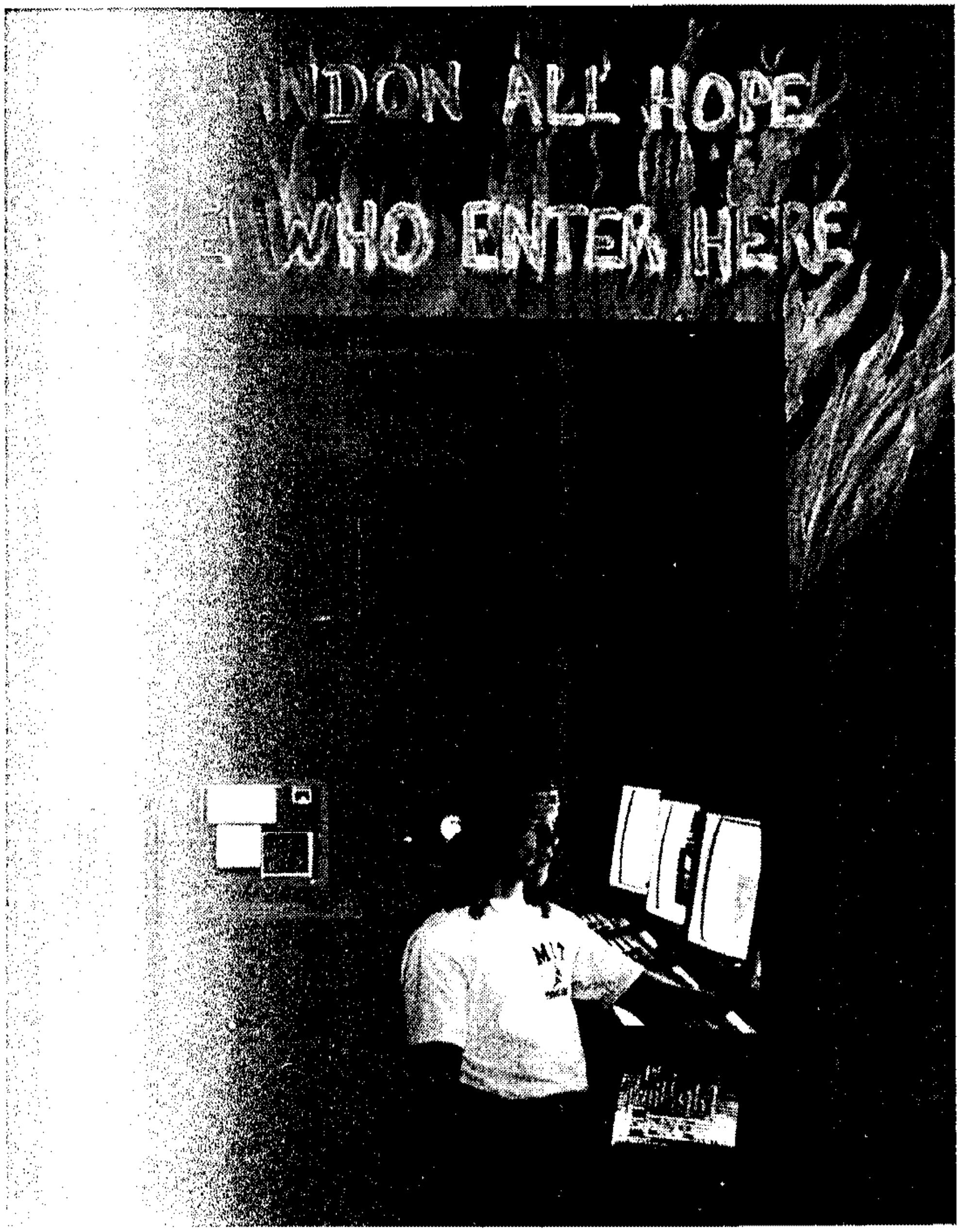
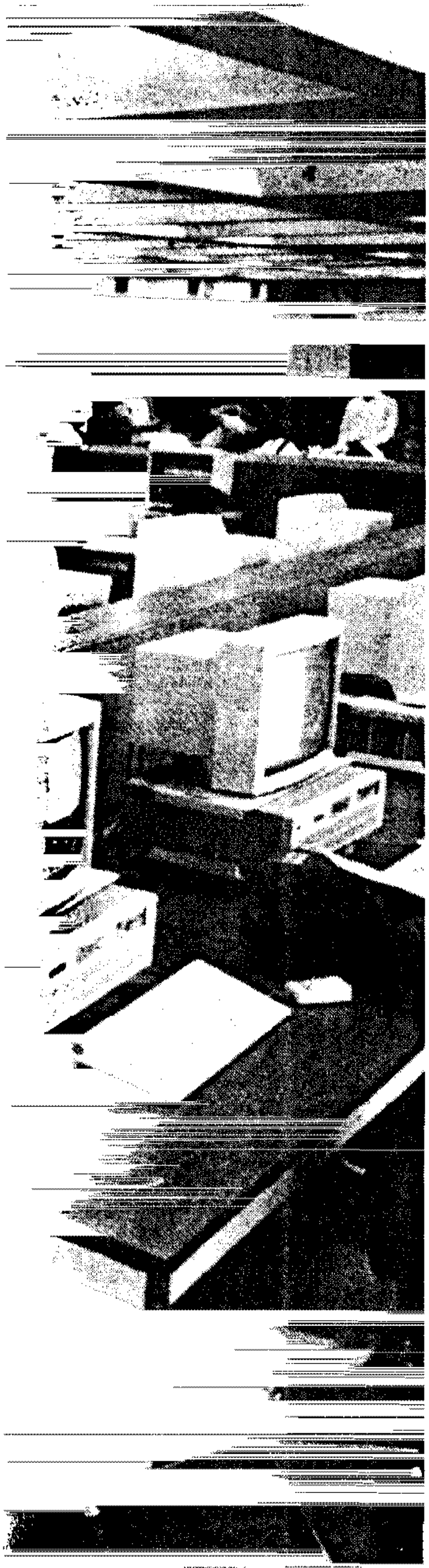


ATHENA AT HOM



Students Log On to ATHENA:

Test Subjects, Technicians, and Critics

BY SIMSON L. GARFINKEL, '87

In the basement of a house in Cambridgeport, there is a tiny room with black walls, a black light, two mattresses on the floor and a pack of wintergreen Life Savers taped to the wall (they spark in the dark if you crush them). The room's entrance is set off from the rest of the basement by a black curtain. On the back wall is a door leading deeper still, with the words "Abandon All Hope Ye Who Enter Here" painted in fluorescent green letters.

Behind the door is a larger room housing seven Project Athena workstations, two file servers, a laser printer, a gateway that connects the cluster by telephone lines to the MIT Campus Network, and a futon. This is a Project Athena "living group cluster" at an independent living group known as pika. The black room is called the "de-nerdification zone."

Pikans have achieved something that may prove significant: they have personalized the anonymous Athena computer room, making it conform to the house style.

One element of the Athena experiment was to see how students react to living with the machines. In spring 1986, Athena solicited proposals from interested living groups: five of the 19 submissions were awarded grants of equipment and a network connection.

"It was a question of costs," explains Steven R. Lerman, '72, who was Athena's director at the time. The living group program was a pilot project paid for by a special grant from the Provost's Office, Lerman says. "Five groups were all we could manage, handle, and afford." Today, in addition to pika, there are clusters in three fraternities—Zeta Beta Tau, Delta Upsilon, and Theta Delta Chi—and one dormitory, 500 Memorial Drive.

Heidi Burgiel, '90, who lives at pika, is glad that the computers are not in students' rooms. "That way, we would be living with the computers instead of visiting them."

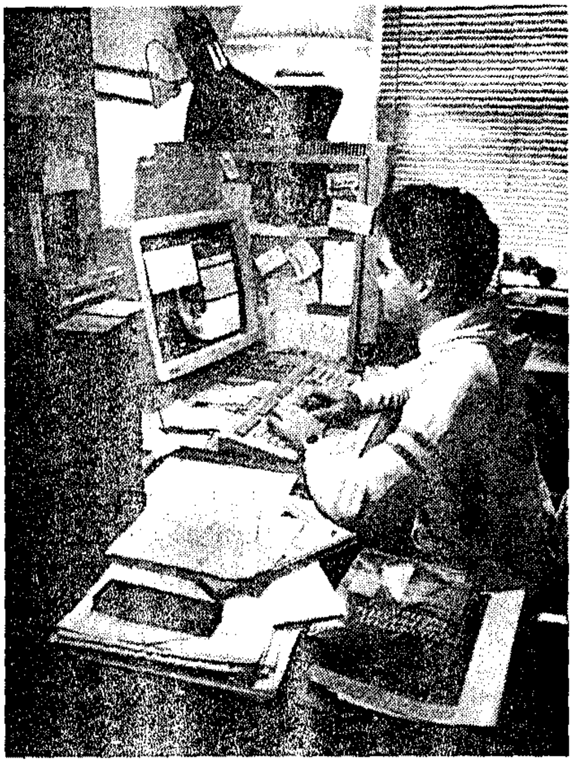
But Burgiel wouldn't want to be without the workstations: "It's awfully nice to have them there," she says. "You don't have [a 20-minute] walk to the Institute to do your homework. You can eat next to [the computers] and nobody complains."

Students in the other living groups that have the machines agree, but when they try to attract new freshmen during the first week of school, they don't heavily advertise their Athena connection.

Pikans opted for the basement cluster in part because they were concerned that a machine in every room would increase the likelihood that freshmen would choose the living group for its computers instead of for its people and lifestyle. TDC, the

SIMSON GARFINKEL is a freelance writer based in Somerville, Mass. He joined the SIPB in 1984 and remained an active member until May 1987.

PHOTOS: L. BARRY HETHERINGTON



Above: Zain Saider, '92, lives at Theta Delta Chi, one of the few living groups participating in experimental placement of Athena workstations in individual student rooms. Right: Aaron Goodisman, '90, is working in the equipment-jammed offices of the Student Information Processing Board.

fraternity that has an Athena workstation in every student's room, uses the machines as a filter during rush: any freshman who seems too interested in the computers is politely asked to look at another living group. "We were worried about a hacker subculture," says Zain Saider, '92, TDC's Athena liaison.

Problems in the Hinterlands

Saving that 20-minute walk to campus has had its price. Since September 1987, there have been major improvements to the Athena operating system that made the machines at pika and DU—still running the old software—largely incompatible with the workstations on campus. Workstations in those living groups cannot use much of the course-specific software that Athena has struggled to develop, nor can they automatically access files stored on campus.

It's an authentication problem, explains Jeffrey I. Schiller, '79, Athena's manager of operations. If the updated operating system were installed on the remote machines (those too far away to be hard-wired into the network), each time the special phone lines were down—which can happen for days at a time—Athena would be unable to authenticate student passwords. In that case, students would not only be barred from the network, they would be unable to log on to the machines in their own living group. Until the technical problems can be solved, the remote living groups are sticking with an obsolete version of the operating system, but one not entirely at the mercy of the phone links.

To date, however, the inability to run course-specific software hasn't been a big issue for the living groups. For most students who have used Athena in the past five years, "courseware," as the software is called, has not been a central feature of the Project. According to Athena's 1988 student survey, 65 percent of the students used Athena for personal purposes, compared with 49 percent who used it for courses.

In general, more students used Athena for word processing and electronic mail then for any other function. Even when a class assignment called for use of Athena machines, 47 percent of the students simply used standard application programs, such as word processors and spreadsheets that were not written for the Project. Another 22 percent wrote their own programs. Only 37 percent of the students using Athena for a subject ran course-specific programs.

Student Information Processing Board: A Distinctly MIT Organization

Before Project Athena, MIT students who wanted to learn about computers but didn't have access to the machines in a subject or a laboratory could apply for a grant from the Student Information Processing Board (SIPB). No cash changed hands, but students were given dollar-value accounts on MIT's mainframes, most often a machine called *Multics*.

SIPB's resources came from MIT's Information Processing Services (IPS), says

Weston Burner, a past director of the service. SIPB's assignment was to screen students who wanted to use the computers for independent projects from those who needed machines for course work.

IPS didn't want to fund student work that was within a class assignment, Burner says. If a professor at MIT wants the students to use the computer for a class, the students should be allocated computer time through the instructional budget. IPS saw students as being better able to determine how computer time would be used than administrators—a distinctively MIT mode of operating.

SIPB's sponsorship of *Multics* accounts was originally limited to students who wanted to learn how to program. Then in the early 1980s, that restriction was lifted and SIPB began funding word processing. By 1984, says Jon A. Rochlis, '85, a former chairman of the organization, SIPB was sponsoring accounts for nearly 2,000 students—almost half the undergraduate population.

In the fall of 1984, one of Athena's VAX-750 machines, known as *Charon*, was designated for SIPB's exclusive use.

"The idea was to give students a place for experimenting with the lowest levels of the Unix operating system," Rochlis says. For example, SIPB made *Charon* the only Athena machine able to communicate with MIT's home-built network called CHAOSNET, thus able to talk to the Artificial Intelligence Laboratory and the Laboratory for Computer Science. But SIPB's main use of the machine was as a test-bed for developing software that could be used by the entire Athena community.

Among the SIPB products was a program that enabled students anywhere on the Athena system to typeset papers using IPS's high-speed Xerox laser printers, at a time when no such service was provided by Athena. SIPB members also designed a computer bulletin board for the workstations called "Discuss," which allowed students on different workstations to participate in electronic discussions on a variety of topics. When computer games began to absorb too much time on *Charon*, one SIPB member wrote a program that automatically terminates any games that are underway when the system is running too slowly. This program was adopted by the rest of the Project before the move to workstations.

SIPB was filling in the cracks, Rochlis says, between what students needed and what Athena was providing. When it felt that Athena's instruction manuals were inadequate, SIPB wrote its own and made it available to students. When students demanded the ability to call Athena from their living groups, but Athena had only budgeted modems for faculty and staff, SIPB used its own capital budget to purchase modems for Athena computers.

SIPB also offers consulting services to students with problems or questions, which generated some friction. "The Athena consulting staff . . . didn't want a volunteer organization like SIPB to come in and consult," Rochlis says. "[Athena] had to control the quality of answers. . . . [By discouraging the volunteer efforts of SIPB] I think Athena missed a big opportunity."

MIT students can be harsh critics of activities, particularly technical activities, in their surround, and SIPB members were not the only MIT students who had strong opinions about how Athena should be implemented. In the early years of the program, Athena staff functioned in an environment of frequent complaints from students.

Case in point is the experience of Experimental Study Group, a self-paced, tutorial-based alternative academic program for freshmen and some sophomores. In 1985, ESG applied for a small Athena cluster, says Joseph Harrington, '88, (the fourth generation of that name to graduate from MIT) who was a freshman in the program at the time. "There weren't any workstations, so they gave us IBM PC/ATs to hold us over," says Harrington.

Having the machines installed was another matter. For starters, ESG students wanted to lay their own wiring. "We wanted to get things moving as quickly as possible, and installing pieces of coax cable is a relatively simple thing to do," Harrington says. But Athena had forbidden them to do so.

Finally one day the network installer showed up. "He looked at his crimping tool, looked at the wiring kit, looked at us, and said, and I quote, 'Do you know how to use this?' " Harrington recalls angrily. The students showed the installer how to use the tool, and he proceeded to wire their cluster.

"We waited a long time for him to come, and it turned out we could have done the job ourselves," says Harrington.

The problem, Steven Lerman explains, is that "it is easy to screw up a cabling installation, and it's very hard to support an installation that you didn't install." In any event, many students and faculty believe that the new Campus Network is the property of Project Athena, but it is actually owned and operated by the MIT Telecommunications Systems. Athena is just one of the network's customers.

"If any one player screws up [the network]," Lerman says, "everybody loses service." For that reason, Telecommunications Systems had a firm policy to support only networks that it installed.

After the machines were installed later that summer, ESG and Athena struggled over how they would be used. Project Athena had supplied the IBM PC/ATs with a standard software package and a program called "SAFE," which automatically deleted any non-Athena program from the computer. "The first thing we did was delete that program," Harrington says.

ESG students wanted to run off-the-shelf software, Harrington says, like "Wordstar"—programs that Athena specifically told them to avoid. He says the Athena staff feared students might become dependent on MS-DOS programs, making the transition from MS-DOS to the Unix operating system that much more difficult.

That wasn't all. Students wanted to keep their files on the PC/ATs' hard disks, but Athena demanded that they use floppy disks. Floppies were slower and not large enough to store the computer pictures with which the students were working.

Harrington saw a tug of war between Athena, which wanted all of its PC/ATs on campus to be standard, and the students in ESG, who wanted to use the machines in their classrooms as they saw fit. The difference of opinion was no small matter.

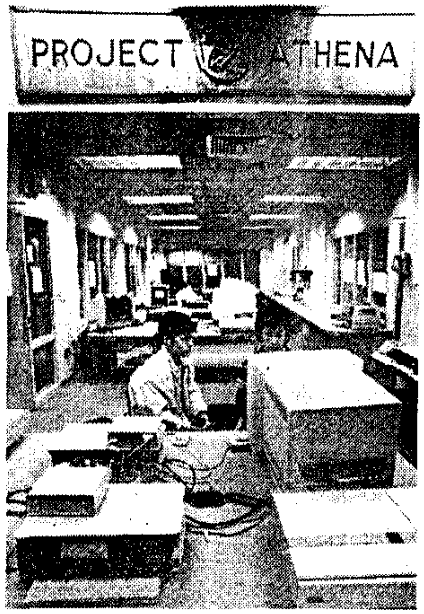
The ESG students started ignoring Athena's proclamations. "We knew what we wanted to do," Harrington says. When Athena staff came through, the students loaded their data from the hard disks onto floppies and deleted the changes from the PC/ATs. Tensions finally eased in March 1988, when the PC/ATs were replaced with two Digital and three IBM workstations. Finally Athena had achieved its goal of installing standard Athena workstations in ESG, and this time they were workstations that the students could use without modification.

Lerman denies that Project Athena ever had a policy forbidding the use of outside software on the ESG computers. He points to the School of Architecture and Planning's successes in using commercially available programs as proof that no such policy existed.

But Lerman isn't surprised that Harrington and others inside ESG had such misperceptions. "That's very common at the Institute," he says, dubbing it "policy by myth-vention."

"Myth-vention," says Lerman, is when "a myth becomes established and people view it as a stated policy. It reflects the difficulty of communicating with large groups of people about rapidly changing things." Myth-vention was rampant at Athena.

"I always had problems communicating the current policy. . . . So many downstream problems were created by bad communication—people believing things to be true that weren't, or not knowing things that were [true]." There are now Athena officers with specific responsibilities for sharing information with faculty and students, but if he had to do it over again, Lerman would have hired someone to handle communication at the very beginning of the experiment.



The "Fishbowl" cluster in Building 11 is equipped with state-of-the-art video workstations assembled from IBM, DEC, and Paralax components.

Some students have found themselves in the enviable position of being paid to use Project Athena. These were the students who wrote programs and who were the Project's paid consultants, developers, and operations staff.

The computer code for nearly every Athena faculty project was written by students. The Department of Aeronautics and Astronautics' fluid dynamics system was written in part by 38 undergraduates. "Some [students on that team] worked out extraordinarily well, some were extraordinarily unsuccessful, and most made some contribution," says Professor Earll M. Murman, who supervised the project. "All learned something about fluid mechanics and something about Unix. They all ended up ahead."

At the same time, Athena itself was developing a small band of top-flight computer hackers to do system development and fix bugs in critical pieces of software. David C. Grubbs, the Athena systems programmer who hired them, called them "watchmakers"—a catchy name he borrowed from a science fiction novel, *The Mote in God's Eye*, by Larry Niven and Jerry Pournelle.

"I remembered [watchmakers as] this group of little creatures who sort of dived into anything and optimized it," says Grubbs, who today works for Digital's Ultrix Group.

Athena's watchmakers performed much the same function. Grubbs would give them a list of things that needed to be done and set them loose. "If you want to do any of these," he would say, "go to it. If you don't, tell me why." It was a pretty free environment, Grubbs believes, but very demanding. "The students may have thought that I was pushing them at times—which I did when I needed help. They were my only resource."

Responsible for Athena's software releases, Grubbs often found himself working 80 to 140 hours per week and sleeping in his office 10 to 15 nights per month. Every once in a while, he would say to his student staff, "Look, I need help. I don't care how you get the time, but come help me." The students would pull through, even if it meant staying all night to get a piece of software or one of Athena's time-sharing machines working again.

The watchmakers lived on after Grubbs left, but they gradually assumed a less important role.

"I use them in all phases of what I do here," says Daniel E. Geer, Jr., '72, who has managed system development for the last three years. "Athena would not get by without them, frankly. That is not to say that they are the only show in town, as I think they were when David Grubbs was around."

Geer says that he has restructured the system development group, which has grown from 20 to 30 people since his arrival, so that projects are now developed by small teams. Students are on the teams and are occasionally team leaders. "The point here, however, is that the students can't be expected to take long-term, full-time responsibility for things. It doesn't fit in with being a student," Geer believes.

A third group of students, the gremlins, were hired to patrol the clusters, inspect the equipment, and perform periodic backups. Like the other students on Athena's payroll, their principal motivation wasn't the pay, but the fringe benefits: virtually unlimited access to Athena's resources at a time when other students were barred from the system or limited to using the crowded machines at the Student Center.

For the student staff and SIPB members, Athena was an adventure—for some the pivotal experience of their undergraduate education. But for the majority of students, the first four years of Athena were at best unnoticed, at worst a major frustration. □

The HACKERS are still ahead

BY SIMSON L. GARFINKEL, '87

I-Ching Wu, a sophomore in chemical engineering, is taking an expository writing course which meets in Project Athena's "electronic classroom." On the desk in front of her is a $10,000 Athena workstation on which she does all the work for this subject. Every student in the classroom is similarly equipped.

Students use the network to send copies of their assignments to each other and to the instructor, who can insert comments and criticism directly into the documents and electronically return them to the authors. From the instructor's workstation, student essays can be projected onto a large screen for the entire class to read and discuss.

Wu is skilled in using Athena's editor, text formatter, and the special programs she must use to send and retrieve her essays. But when she writes assignments for her other classes, she prefers to use an IBM/PC that she shares with a friend in her dorm.

Wu complains that Athena workstations take a long time to start up, and that occasionally it is impossible to use the system at all because of problems with the network. But her real fear is spending hours typing in a paper and then being unable to save it because of problems beyond her control—network failures and file server crashes. Her fears came true once, she says, costing her a night's work. Next semester, Wu says, "I think I will use a PC . . . . If something goes wrong, I can deal with it. . . . I don't like to take chances."

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"If you really know what you are doing, your files will be saved someplace."

BRETT MASTERS, '91

Brett Masters, '91, on the other hand, often works in the electronic classroom for hours after the writing class has ended. On a typical afternoon he alternates his attention between reading electronic mail and writing a program to solve a homework problem for Unified Engineering. He uses Athena for all of his subjects because he finds the system to be fast, powerful, and reliable. "You can't lose things," he says. Even if the system crashes, "if you really, really know what you are doing, [the file] will be saved someplace."

Lose a night's work or never lose anything? Who's got it straight? Both, as it turns out. How well Athena works depends to some extent on what you know . . . or who you know. Masters says that he is comfortable with Athena not because he is a master hacker himself, but because he has friends who help him. One in particular is a fraternity brother who works for Athena. "He did all kinds of things to my account," Masters says, setting it up so it would be easier to use and so files would automatically be saved.

Athena does have a backup system. However, the backup system is designed to restore not individual files but whole disks, in situations like a disk crash or a fire, according to Jeffrey Schiller, '79, Athena's former manager of operations. "It is usually easier for a user to retype a file than for us to get it off the backup tapes," Schiller says.

When people come to Schiller crying that they have accidentally deleted their theses, the staff often makes the effort to retrieve it. But in an environment of limited resources, Athena hasn't the staff to retrieve documents for everybody, certainly not in the time frame most students need. At least, that's the story for Athena's

PHOTOS: PAULA LERNER

user community. Those on Athena's staff with access to the backup tapes could salvage their own work or that of their confreres. Although Athena is designing a new backup system that is more oriented toward serving user needs, Schiller says, it isn't a top priority.

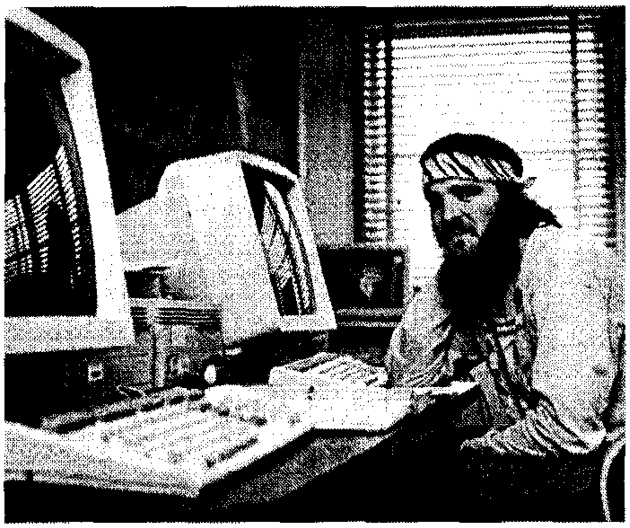
To Steven R. Lerman, '72, Athena's first director, the wide range of student reactions to Athena is quite understandable. "It's a story of diversity," Lerman says. "The students have a wide range of needs, requirements . . . and financial resources. It's unlikely that one system could accommodate them all."

One of Athena's objectives, according to Dean of Engineering Gerald Wilson, '61, was to minimize the effort students would have to invest in just learning to use the system—freeing them to concentrate on the educational subject matter. But in fact, after nearly six years of existence, Project Athena has not been successful in leveling the differences between hackers and the students who are less facile with computers. In order to survive in the complicated workstation environment that the project has created, users find it difficult to remain "computer naive."

Most students, says Dave Custer, '83, the teaching assistant for the writing course, "get burned once or twice. Then there are a couple of options: you can stop using Athena because it eats your file every couple of weeks, or you can [learn more about the system]."

How willing MIT students are to invest time in Athena depends in part on what their options are. One popular alternative seems to be the Apple Macintosh, which students can buy at the MIT Microcomputer Center at discounts of up to 36 percent off list price. In many ways, the easy-to-use Mac fulfills Wilson's requirements more than Athena.

Todd Ogawa, '87, now a medical student at the University of Colorado, bought his Macintosh in September 1984. He couldn't use Athena at the time because it was only open to students in special subjects, and he wasn't enrolled in any of them. By the time Athena made accounts available to all students in March 1985, Ogawa was a confirmed Mac fan.



"You can stop using Athena because it eats your file every couple of weeks, or you can learn more about the system."

GRADUATE STUDENT DAVE CUSTER, '83

"I felt that the Macintosh was a lot more user friendly," Ogawa says. "I couldn't do lab reports and stuff with Athena very easily. I didn't know how to use any of the software, and I got the impression that it was harder to learn than the Mac."

It's just as well Ogawa wasn't interested in Athena; he might not have been able to get near it much before he graduated. Project Athena opened its first cluster for general student use on March 19, 1985—three months late. It was heralded by a four-page advertisement in *The Tech* that encouraged students to use the Student Center cluster for writing papers, sending mail, and playing games. Demand quickly escalated as Athena expanded its staff of student consultants to answer questions and offered a series of "mini-courses" that would give students a jump start on mastering the system.

The most important thing about the Student Center, says Toby Sanders, '89, has been its availability. "Athena is awesome," she says, "because it's open 24 hours. You can't expect hackers to stop and close up." Indeed, when Schiller closed the clusters over one spring break in response to a string of equipment thefts, the students voted him Alpha Phi Omega's Big Screw award.

But the Student Center, which had more terminals than any other cluster on campus, had only five time-sharing computers. It was, in the words of Andrew S. Gerber, '87, who worked there as an Athena consultant, "the pits. It was plagued by very high loads and people playing games to all hours of the night." To make a bad situation worse, accounts in the Student Center cluster were originally given only 250 kilobytes of disk storage—less space than is on a single PC floppy disk. That space was eventually increased to 600 kilobytes. (New equipment that should allow the Project to increase student file space to at least three megabytes may not be on line until fall 1989 or later.)

Of course, not all students were limited to accounts in the Student Center. Between 1984 and 1987, an increasing number were enrolled in classes that used Project Athena for assignments. These students were given accounts in other, less crowded clusters, with correspondingly higher allocations for disk storage. Then there was a small group of students who were abe to get friends who worked for Athena to build them accounts in other clusters.

Likewise, Gerber says, there were the students like Ogawa who could afford to purchase their own computers, and others who had access to word processing or other computer resources through their part-time jobs. Harold A. Stern, '87, for example, an editor of the student newspaper, wrote his essays on *The Tech's* typesetter during off hours.

In essence, says Gerber, the early years of Athena saw the development of a "caste system" among students, in terms of the computing power and convenience to which each had access.

In the spring and summer of 1987, relief seemed to be at hand. Project Athena replaced the terminals all over campus with high-performance workstations—solving the problem of high loads and sluggish response time by giving each user a dedicated computer—and opened all clusters to all students. But use of the system has continued to climb, and crowding in the clusters has actually increased with time. Indeed, by the end of the 1988 fall term, clusters all over campus were as crowded as the Student Center had ever been.

"I can't tell you what the exact availability of workstations is at this time," said Director of Athena Earll Murman in December 1988. "We don't monitor that on a daily basis. We did note that early in the semester, some of the more frequently used clusters, like the Student Center and Buildings 11, 4, and 66, had all of their seats taken in the after-dinner hours."

By the end of the fall 1988 term, there were days that every workstation in a cluster would be in use at 5 am—still occupied by students who had been there from the night before. In recent surveys, 92 percent of MIT undergraduates report having used an Athena workstation at least once; at least 25 percent used a workstation every single day during the last two weeks of the 1988 spring semester.

To ease the overcrowding, says Murman, Athena plans to install 20 more workstations in the Student Center, a new cluster of workstations in the Hayden Library, and groups of two or three workstations wherever he can find the space around the Institute.

If there is a positive side to overcrowding, it is as a measurement of Athena's popularity: If students will stand in lines to use computers that offer less storage per user than a floppy disk, Athena must be doing something right.

Next to word processing and solving problem sets, the third most popular use of Project Athena is electronic mail. At pika, an independent living group with an Athena cluster in its basement, students use e-mail to keep in touch with alumni who have moved across town and across the country. And Dan Schmidt, '91, is one of a growing number of students who use Athena to write home—his mother works at a university and his father works for Digital, and both have access to computer networks that are linked to Athena.

Another attraction of Athena is games. Although Athena's 1988 survey found that students average only half an hour a week playing games, walking through a cluster or speaking with students suggests far more. "I'd say that a third of the usage is playing games," says Mark Kantrowitz, a senior majoring in mathematics and philosophy. "Every time I go up [to the Student Center cluster] looking for a terminal, I see people playing games."

Mark Eichin, '88, a former Athena systems programmer, believes that the amount of game playing is significant, but his estimate is more like 10 percent. "I would say that half of the use is word processing. What's left is split among reading news and electronic mail, course work, and games," Eichin says.

Many of those games take special advantage of Athena's high-performance graphics and network. Games like "X-tank" and "X-trek" let students at different workstations command tanks or starships, fire missiles at each other as fast as they can hit the buttons on their mice, and watch the results on their graphics displays. For the less belligerent, a game called "mboggle" lets students compete with each other in a fast-paced word game. Athena has even set up a special file server that stores games for use from any workstation.

> *"Athena had an enormous communication problem. I think it missed an opportunity to listen."*
>
> *ATHENA STAFF MEMBER KAREN COHEN*

Although game players are supposed to vacate their workstations when there are other students who want to do serious work, few students are willing to bump somebody off the system. "You would have to be really obnoxious to do that," Kantrowitz says.

Out of Athena's original $70 million budget, $50 million was allocated for equipment. The rest was divided equally between system development and curriculum development projects. "That's really a sizable amount of money," notes Earll Murman. "We had more proposals [for curricular development] than we could fund, but in general [money] was not a problem."

In the past few years, dozens of those individual proposals have become programs that students now use daily. The most successful have been special-purpose calculation and simulation programs, which let students solve traditional problems faster than they ever could without a computer.

In the undergraduate chemistry laboratory, for example, a task that used to average two nights of work now takes 20 minutes on the computer. In aeronautics and astronautics, a program called Clascon has shaved weeks off the teaching of classical control theory. And last fall, 564 students in a class on differential equations used a program on Athena to graph equations in seconds that would have taken them half an hour or more to do by hand. What's more, says Dan Schmidt, watching the computer graphing the equations is actually fun—something of a revolution in the study of mathematics, surely.

As a result of these dramatic reductions in time, teachers say, it is possible to assign problem sets that are oriented more toward design and creative thought, and less toward running numbers through a calculator. Students claim that speed enables them to learn a subject more thoroughly because they have the time to study more examples.

But is faster always better? Margaret

MacVicar, '65, dean for undergraduate education, has a note of caution: "It depends on what the results of 'faster' are," she says. "Faster often hides the assumptions and the guts. By hiding the guts of the calculation, [the computer encourages you] to believe what the program tells you, even if it isn't correct."

MacVicar worries about damages to the learning process when students use computers for their calculations. She cites the example of a student who uses a calculator instead of looking up trigonometric functions in tables. With tables, she says, "you see the values before the number being looked up and after. It is impossible not to notice how nonlinear the function is. The tables give the engineer a feeling for the function in a way that a calculator button marked 'SIN' simply can't."

And some subjects, MacVicar says, simply require a lot of time to absorb. "One must marinate in a subject," she says. Teaching a subject quickly by using Athena could be robbing students of that seasoning.

Samuel J. Keyser, MIT's associate provost, is similarly concerned when students are encouraged to rely too heavily on a computer program. "Every program is defective," he says. "We must develop our intuition about how the world really works. And that requires dependence on our own brains, not on some subset of our brains that has been programmed into the nearest PC."

For all of the anecdotal accounts, actually measuring Project Athena's impact on undergraduate education is difficult. For Athena's first five years, staff member Karen Cohen was in charge of surveying student response to the Project, but her questionnaires were confined to patterns of usage. Cohen says that Steven Lerman ruled out questioning students or individual faculty members about how well they thought students were learning the material in particular Athena-supported subjects.

"We didn't want to put Athena into the position of evaluating faculty performance. That isn't what we were there to do," Lerman said.

"Every time I go to the Student Center cluster, I see people playing games like 'X-trek,' 'X-tank,' and 'mboggle.'"

MARK KANTROWITZ, '89

Unfortunately, by insisting that any real attempt to measure the impact of Athena machines and software in particular subjects would amount to evaluating the teachers of those subjects, the Project hobbled its own attempts to document its value. "I don't think faculty would have minded filling out a questionnaire," Cohen says, but even that was forbidden. "[Athena had] an enormous communication problem. I think it was a missed opportunity to listen."

Lerman denies that he forbade simple surveys; he just didn't think they would find anything useful. "I was very skeptical that we would get anything by sending out surveys. . . . We had enough trouble getting the faculty to describe their projects!" Athena did conduct some informal studies, he says, they were confidential, intended solely for the information of faculty members themselves.

Sometime within the next two years, Provost John Deutch, '61, plans to appoint a committee consisting of faculty and staff—and possibly students to assess the impact that Project Athena has had at MIT. "The committee will be charged with reviewing the evaluations that have already been undertaken of the Athena Project—its achievements, its deficiencies, and most important, its future potential—and structuring a set of options for how we might proceed," Deutch says.

"There is no doubt in my mind that we will have to provide access to computation, communication, and word processing for our students after [the conclusion of the experimental phase of] Athena," Deutch says.

But just what form that "access" might take is still anyone's guess. Athena might continue in its present form. Alternatively, it may be broken up into MIT's departments and administrative structure and offered on a fee-for-service basis. Already, operations that have been thought of as part of Athena—including the network, the mail system, and the Kerberos Authentication System—are operated by MIT's Office of Telecommunications.

Within two years, says George Champine, who heads Digital Equipment's five-member team at Project Athena, a workstation capable of running the Athena operating system might cost less than $2,500. Students may be asked to purchase their own hardware and plug it into the campus network. Alternatively, the cost of that hardware might be factored into tuition. The beauty of Project Athena's technical accomplishment is that it supports a multi-vendor environment—the workstations that students purchase need not be manufactured by IBM or Digital.

Deutch estimates that the cost of maintaining Athena in something like its present state might run as high as $6 million per year. Such a high cost, agrees Gerald Wilson, will not be accepted by the faculty unless they are convinced the system is of educational value. If the primary use of the system is for word processing, Wilson believes, MIT doesn't need a campus-wide network of high-performance workstations. For Athena to earn its keep in the years ahead, it is going to have to demonstrate that its subject-specific software and clusters of workstations have a significant positive impact on the MIT educational experience. □

Ripples across the Academic Computer Market

Almost six years ago, Digital Equipment Corp. and IBM could see that college students and teaching faculty were a large—and largely untapped—market for their products. But it was not at all clear how that market would develop, what would be its priorities or its most important innovations.

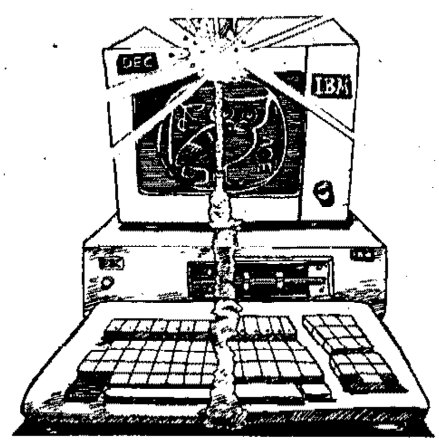
Today, after DEC and IBM invested more than $50 million in MIT's Project Athena, there are state-of-the-art workstations all over the MIT campus, students and faculty are using the computers regularly, and much has been learned about large, multivendor networks in academic settings. But the academic market is almost as open-ended as it was in 1983.

IBM and DEC have had very different approaches to Athena, even though both chose to provide the primary funding for the project for similar reasons—to improve higher education and to establish a showplace for their first generation of high-performance workstations in that setting.

"Everybody was convinced that there was going to be a feverish level of activity," says Lesin Comeau, who oversaw IBM teams at both Project Athena and Brown University from December 1984 until February 1987. (Comeau has since left IBM to become the manager of the Academic Computing Facility for the Harvard–MIT Health Sciences and Technology Program.) IBM anticipated "lots of PC-style computers, tied together with networks," he says. "Besides benevolence, there was the idea that this was going to be one hell of a big market."

DEC had similar objectives: "It was abundantly clear that the advent of workstations was going to change dramatically the way computer services were implemented," says George Champine, who directs the DEC Athena group based on campus. DEC "wanted to be part of an early implementation of a large-scale system," he says. But DEC also wanted to "make a contribution to improve the quality of higher education. . . . That sounds very altruistic, but it is true. We get our professional work force from the higher education system, so we like to improve it to any extent possible."

SIMSON GARFINKEL is a freelance writer living in Cambridge, Mass. This completes his series on Project Athena.



BY SIMSON L. GARFINKEL, '87

The two computer manufacturers promised MIT both hardware and on-site personnel for the duration of the experiment. In return, the companies got a national showcase for their equipment, the rights to use any system software developed by Athena, and—perhaps most important—much needed experience with the applications of workstations at a technically oriented university. But the experiences of DEC and IBM in integrating the knowledge they have gained back into their corporate operations have been very different.

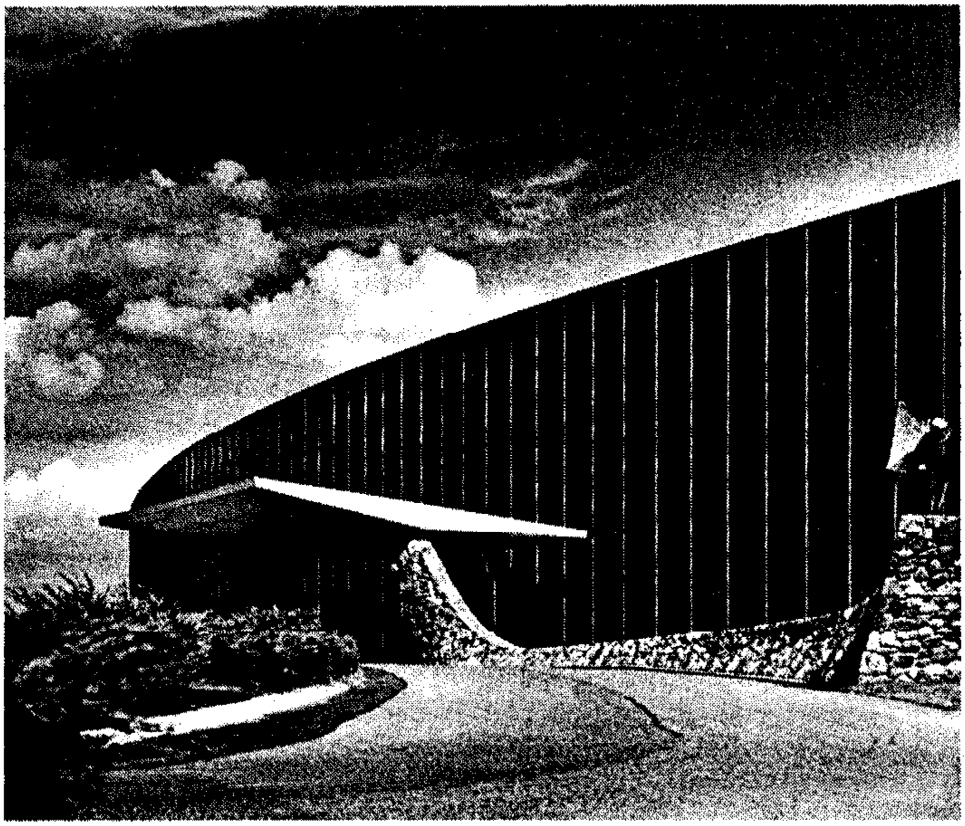
The DEC Athena group was managed by Digital's External Research Division, a group designed to "bring back interesting and useful things to the company," according to Steven R. Lerman, '71, Athena's former director.

At the end of Athena's first five years, DEC assigned a full-time technical writer to the job of preparing an eight-volume internal report on Project Athena. The company ensured that the X-window system, Athena's most important single achievement to date, would be fully functional in the new VAX Station 2000 by having Jim Gettys, a DEC employee who was a key contributor to X, serve on the design team for the VAX 2000.

Further, Digital is applying Athena's "coherence" concept to its own commercial offerings and assigning 1,200 software engineers to the task of transporting the X-window system to both Ultrix, the company's version of Unix, and VMS, a proprietary operating system. "It was the largest software project ever undertaken by DEC," says Champine.

IBM's contribution to Athena, on the other hand, has shifted among several groups. Originally it was the province of the IBM Academic Information Systems (ACIS), but ACIS was broken into two different IBM divisions—one for sales and marketing, the other for technical systems support. "[These units] are less closely tied to the products," Lerman says, and they "don't have a corporation-wide charter" to push for the adoption of outside technology.

Another issue was hardware. Athena software was developed to run on DEC's standard line of workstations. But the equipment that IBM provided to Athena—the RT—is simply not the mainstay of the company's line of high-performance desktop computers, and software written for the RT will not run on



It was difficult to lure engineers based at IBM's T.J. Watson Research Center in Yorktown Heights, N.Y., to the company's on-campus Project Athena team because it meant relocating to the Boston area for a year.

other new IBM machines.

"The result is that DEC has gotten more out of Athena," Lerman concludes, "not because it has more rights, but because it was better structured to use it."

Even their locations—DEC's corporate headquarters are less than 25 miles from MIT; IBM is based in New York State—worked better for the former. As IBM's project manager at Athena from 1983 until 1985, Richard Parmelee, PhD '66, was responsible for staffing. "I had a very hard time getting people," he says, noting that "we don't have a Maynard nearby"—a reference to DEC's research center in Massachusetts.

"The list of people to draw from is very limited. Relocation is hard. . . . We hired new people, but in the new-hire market, there is an awful lot of competition for good Unix people. We tried to get support out of research, but mostly people who are in Yorktown [IBM's research center in New York] don't want to come here for a year."

Parmelee maintains that his search for qualified engineers was further compounded by MIT's insistence that the company would not own the fruits of the IBM group's Athena work. Inside IBM, he says, patents and developments contribute to an engineer's prestige and career advancement. But no such advancement was to be had for those working at Athena. Because of this, working at Athena for an engineer "was nearly the same as going on an educational leave."

James D. Bruce, MIT's vice-president for information systems, sees "different corporate cultures" at the root of the variations in Athena's interactions with IBM and DEC.

"Ken Olson ['50] learned very early that ideas out of the university were very valuable in the marketplace," Bruce says. He notes that Digital showed its commitment to MIT early in its history, when it gave one of the first PDP-1 computers to the Institute.

"IBM is far more market driven," Bruce says, "and therefore a different culture. It had greater difficulty adapting that culture to Athena, and I think it shows. It shows in the way the staff interacted with the project, and the difficulty of getting an IBM workstation. [It also influenced] the rate at which technology developed at Athena flowed back to the corporation."

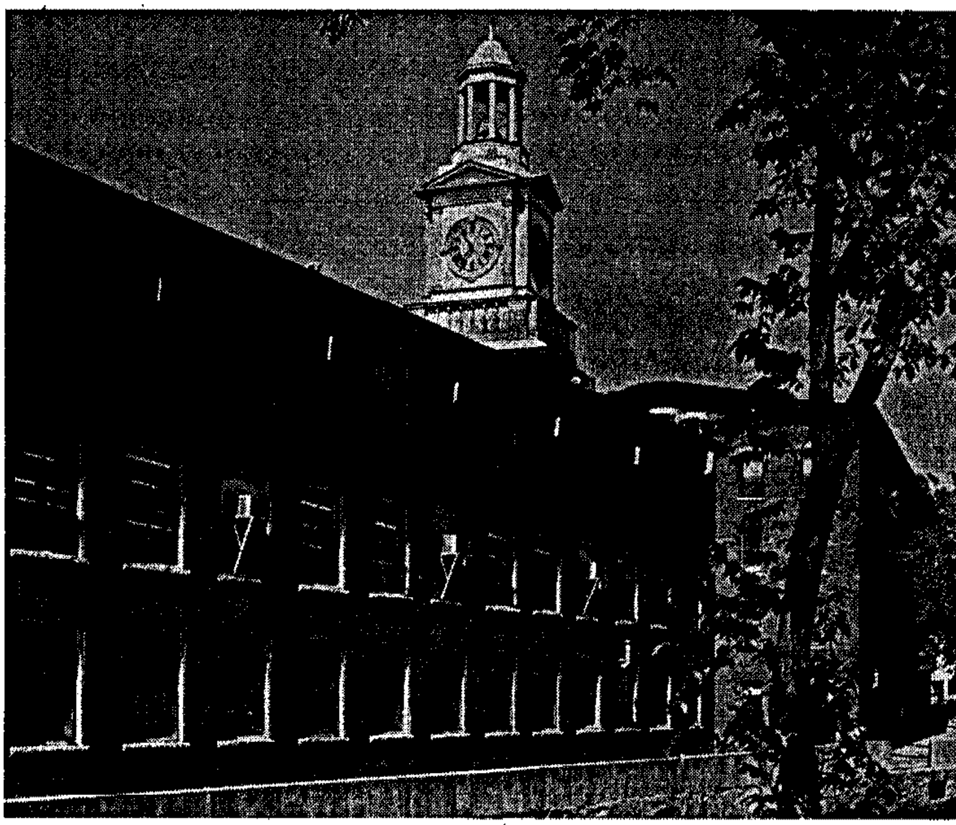
Nevertheless, says Carol Crothers, IBM's manager of technical computing development projects, which oversees projects at several universities, "We learned a great deal from the experience at MIT. One of the things we learned is that there is a growing need for Unix-based distributed (networked) systems." IBM expects that its PS/2 personal computers, which run either MSDOS or the IBM Unix operating systems, will fill that niche very well, Crothers says. As for the RT, Crothers says that machine seems destined to be used as a high-performance network file server.

Nearly all of the $20 million that MIT originally raised for Athena curriculum-development projects has been spent. And while DEC and IBM agreed to continue their support of the project for three years beyond the original 1988 deadline, they are not funding curriculum development.

"It took longer to develop the educational software then was expected," says DEC's Champine. "The [policymakers for Athena] made a big push to develop educational software before the system was ready; now the system is in really good shape, but the money is gone."

To solve that problem, Athena is once again looking for outside funds. "What we are trying to do, and it is a continual challenge, is assist faculty members in locating [their own] curriculum development funds," says Earll Murman, Athena's present director. "Honestly, I don't think we have found that many sources of funding yet."

PHOTO: IBM



Digital Equipment Corp.'s offices in Maynard, Mass., were the setting for massive efforts to incorporate lessons from Project Athena into their products.

But there are a few shining examples of private funds at work. One such program is the Athena Language Learning Project, which secured a $1,415,000 grant from the Annenberg/CPB (Corporation for Public Broadcasting) Project to help fund three large-scale systems for teaching foreign languages on workstations. (*See Athena Part II, January 1989, page MIT 13.*)

"Our project is especially interested in making education accessible to people who can't get to campus on a regular basis," explains Stephen Ehrmann, '71, the Annenberg officer supervising the project. "So a teaching method that allows students to work more on their own, both directly with the materials and using the capacity of the workstation as a communications device, is quite promising."

The Annenberg contract wasn't designed to help Project Athena fund curriculum development per se, Ehrmann notes. It was designed to fund a particular system for computer-assisted instruction, to be developed by a group of people at MIT who just happened to be using Athena.

Funds from the International Masonry Institute supported development by the MIT Department of Architecture of a system that allows students to draw buildings, calculate the construction costs, and look at buildings with similar features using a video disc. That software was written for the IBM PC, so that it can be used by schools of architecture across the country.

What of the MIT undergraduates—the people for whom Athena is intended? On the job market, says Robert K. Weatherall, director of the MIT Office of Career Services, Athena's primary benefit has been to those who have worked for Athena as programmers and consultants—not for the students who have simply used the computers in their classes.

Prospective employers who know of Athena, Weatherall says, know only of its technical accomplishments. Companies who come recruiting at MIT—particularly those who already own equipment from more than one vendor—"would love to find" students who know how to build large-scale, networked computer systems using equipment from different manufacturers, Weatherall observes.

Athena's intention to improve undergraduate education at MIT is unknown. "I haven't heard anybody talk about that," Weatherall says. The outside world perceives MIT students as superior: Athena contributes to the intellectual atmosphere of the Institute, but so does UROP and the senior thesis that most students must write. "The outside world doesn't ruminate on *why* MIT people are so good."

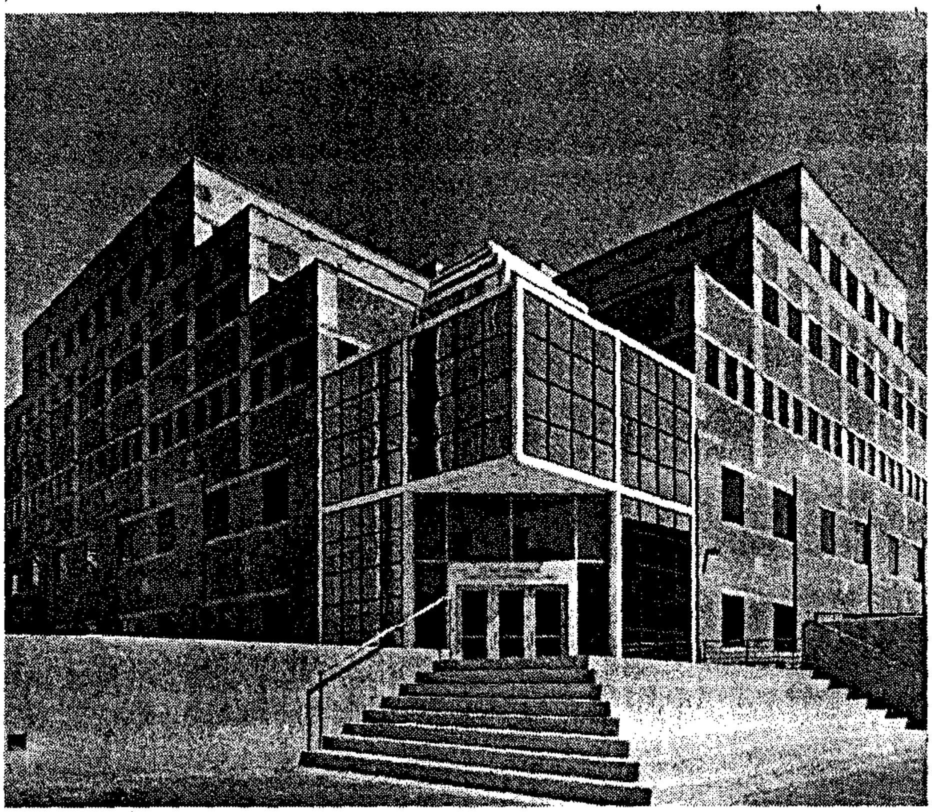
Athena Is Not the Only Show in Academe

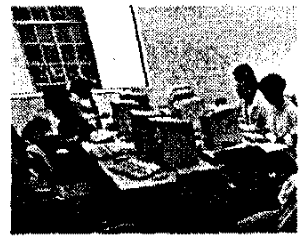
From its inception, Athena was intended to be a contribution the general university education. It was not to be just a local phenomenon. That makes computer use on other campuses of more than passing interest to anyone involved with Athena.

MIT is the only American university that is trying to "do it all" in undergraduate computing: massive deployment of high-end, networked machines; system development; and creation of course-specific software. But several schools have undertaken collaborations with industry that focus on one or two of those areas, and many colleges and universities of all sizes have launched programs to give their students and teaching faculty access to personal computers.

IBM, for example, funded major workstation projects at two other universities at about the same time that it funded Project Athena. One, the Information Technology Center (ITC) at Carnegie Mellon University, set to the task of creating a network file system that would serve

PHOTO: DIGITAL EQUIPMENT CORPORATION





At left is the Watson Center for Information Technology at Brown University, where a project to put a workstation on the desk of every faculty member set the stage instead for a successful personal computer network.

campus workstations. The other, the Scholars' Workstation Project at Brown University's Institute for Research on Information for Scholarship (IRIS), investigated ways to involve faculty in using the machines.

But IBM's arrangements with ITC and IRIS were unlike those the company had with Athena. "IRIS and ITC were joint studies," explains Richard Parmelee. "There was a quid pro quo," which gave IBM exclusive rights to software developed by those projects. Indeed, IBM now sells both the file system and the programmer's tool kit that CMU developed. (IBM even required CMU to change the name of the file system from "Vice" to Andrew File System, AFS, "because some IBM marketing people thought that AFS was better," says Alfred Spector, director of the ITC.)

MIT wouldn't agree to a joint study, Parmelee says. "MIT takes very sternly its intellectual independence. It is not going to become a development organ for IBM or DEC."

MIT exerted its independence in other ways. At Brown, for example, steel screens on the windows and high-security locks on doors provided the security that IBM required before it delivered any unannounced products. But MIT would not accept delivery of any product it could not display in the open, Parmelee says, so Athena did not receive the pre-release versions of the RT. Similarly, Athena had no pre-release equipment from DEC, says Ron Orcutt, Athena's executive director.

Athena's tough stand on off-the-shelf hardware and nonproprietary software was a key ingredient in the project philosophy, says Steven Lerman. By avoiding experimental hardware, Athena also avoided the expensive and time-consuming headaches of hardware development and debugging. And by demanding that neither IBM nor DEC assert intellectual property rights to programs developed at MIT, Athena ensured that its software could be distributed inexpensively. The policies at least made it possible that educational software written under Athena sponsorship could be adopted at other institutions—as textbooks written at MIT have been for generations.

Intentions of Grandeur

Whereas Project Athena has directed its energies toward many small efforts that added up to a single useful system, says Spector, CMU "embarked on a more grandiose effort at the beginning."

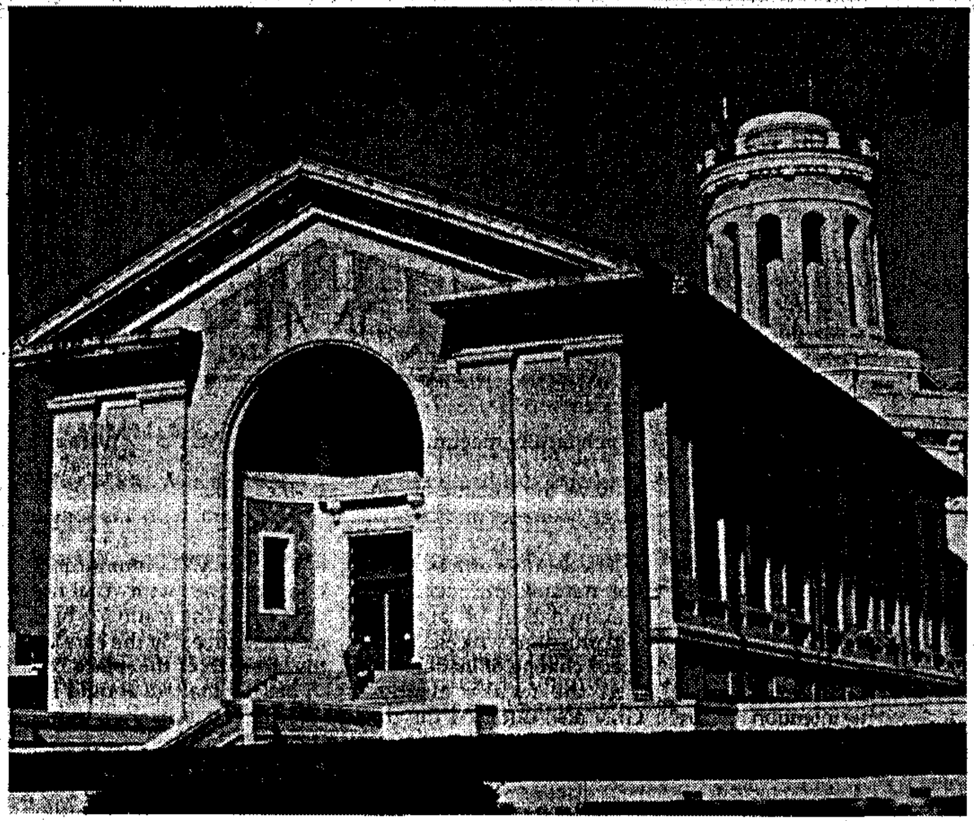
With the promise of $4 million per year from IBM for at least seven years, ITC set out in 1981 to build a file system that could support 10,000 machines, says Spector. What they created is a file system that shows promise of becoming the standard for networked workstations.

Today, the Andrew File System (AFS) is used throughout CMU—any AFS-programmed computer that is on the network can access files on any other. AFS presently supports SUN, VAX, and IBM machines.

"Our file servers are in use more widely than at MIT," says Spector, noting that the file servers operated by the CMU Psychology and Statistics Departments can be accessed as easily as files on machines in the Computer Science Department. At MIT, in contrast, file servers at the Laboratory for Computer Science, the Artificial Intelligence Laboratory, and the Media Lab cannot be accessed easily from Athena workstations.

Moreover, AFS was designed to be a nationwide file system, Spector says. Every file in every Andrew file server the country has a unique name that can be reached from any other Andrew file server that is connected to the Internet. AFS was also designed to overcome many of the problems that have plagued Project Athena, such as poor service to remote work stations connected by slow network links.

PHOTO: JOHN FORASTE



Carnegie Mellon University's tightly focused project with IBM created the Andrew File System, which can support any machine on the Internet network.

Students at CMU don't even need high-performance workstations to use AFS: "People on PCs can get access to the Andrew File System using something called PC server," Spector says. There are provisions for people on PCs and Macintosh computers to send and receive electronic mail, and Spector expects that Macs will have access to AFS in the very near future.

Every student at CMU automatically gets an account on Andrew with one megabyte of storage (compared with 600 kilobytes on Project Athena). And students who need more storage simply request it, says Robert Cosgrove, director of computing systems at CMU.

ITC, however, limited its efforts to system development and did not try to develop course-specific software to use on the network. Even though some software has been developed by other groups at CMU, says Spector, "there hasn't been a campus-wide effort on the scale of MIT's—not even close."

Despite the differences, both Athena and ITC may be growing toward a similar system, each project taking the best parts of the other's work. Recently, ITC modified AFS to use Project Athena's Kerberos authentication system. And AFS is being considered as a possible replacement for Athena's current file systems.

Meanwhile, in Providence

Brown University's Institute for Research on Information for Scholarship (IRIS) occupies a turn-of-the-century converted house in Providence, Rhode Island. IRIS was started as a self-supporting research institute—"something new at Brown," says its director, Bill Shipp—to help bring computers into the educational process at a primarily liberal arts institution.

IRIS was the vehicle for the "The Scholars' Workstation," part of a $20-million-project designed to put IBM workstations on the desks of all faculty members and encourage them to use the machines in their research.

"What we were trying to do was begin to articulate the type of computing environment—personal computing environment and campus environment—that we thought the faculty at Brown should have," says Shipp.

IRIS concentrated on the faculty, in the hope that teachers who used the computers themselves would introduce their students to the machines via mandatory assignments. But IRIS had problems.

"We were waiting for an RT that had a sufficient number of applications to meet people's demands," says Shipp. "The RT in the shape and form and with the software that was available [when IBM delivered it] . . . only met a very small fraction of the faculty's needs. There were no applications."

Frustrating as it was for the Brown community to work with those computers, lessons learned from the Scholars' Workstation Project enabled the university to set up the network it has today, Shipp says, with campus-wide file and print servers. But the machines on the network are Macintoshes, IBM PS/2's, SUNs, and MicroVAXes. "You walk through a lab at Brown that has RTs and most of [the machines] are sitting in the corner," Shipp reports.

The outcome of all this experimentation, IBM's Carol Crothers believes, may be a "coming together" of low-end personal computers and high-end workstations into moderately priced machines with some high performance and network abilities.

"I think there is going to continue to be a need for very low-cost desktop computing, just to do word processing and generate reports," she says. And as far as the high performance machines go, she thinks that "you will see the leadership campuses like MIT and CMU continuing to push the frontiers." □

PHOTO: KEN ANDREYO