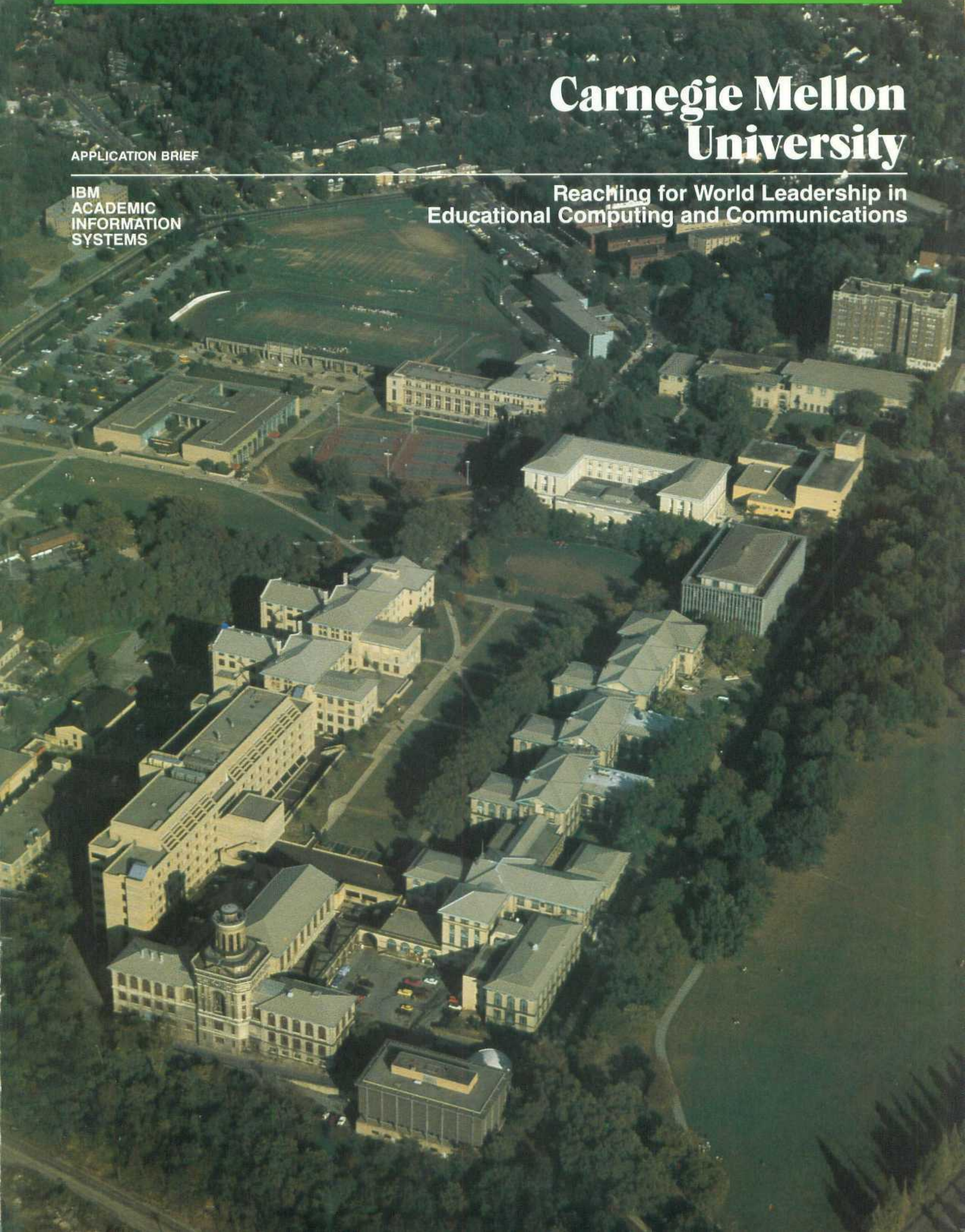
APPLICATION BRIEF

IBM
ACADEMIC
INFORMATION
SYSTEMS

Carnegie Mellon University

Reaching for World Leadership in Educational Computing and Communications



Carnegie Mellon University's history dates to 1900, when industrialist Andrew Carnegie founded Carnegie Technical Schools in Pittsburgh's Oakland section. The schools became a degree-granting college in 1912 and were renamed Carnegie Institute of Technology. A 1967 merger with the Mellon Institute of Research led to the current name and structure.

Carnegie Mellon

Carnegie Mellon enjoys international recognition for its emphasis on interdisciplinary learning. This reputation for excellence covers such areas as engineering, technology, science, liberal arts, fine arts, and public and private management.

Carnegie Mellon is home to numerous research centers exploring a variety of fields, among them robotics, biology, computer science, magnetics technology, CAD/CAM, and document design. Significantly, about 85% of Carnegie Mellon's 6,000 students regularly use computing in their educational activities.

Carnegie Mellon University, one of the most computer-intensive campuses in the world, is also a leader in the development and deployment of automated academic communication systems.

Through its emphasis on communications, particularly on integrated network methods and tools, Carnegie Mellon embodies the academic ideal of the university as an information utility—an institution which exists primarily to collect, produce, and disseminate information. To achieve this end, Carnegie Mellon's efforts are well advanced to effectively link all computers on campus into one commonly shared communications system.

The university also is working with like-minded educational institutions that are striving to establish standards for shared computer networks and educational software on a global scale.

RICHARD M. CYERT IS PRESIDENT OF CARNEGIE MELLON UNIVERSITY.

Computing Demand Helps Develop Concept

As early as 1981, computer use on campus had become so widespread that the university was finding it difficult to keep up with the demand for computing cycles on its traditional time-shared mainframe computer. Departmental systems were proliferating and, by 1984, students were buying microcomputers at a rate that, together with the university's own rapid build-up of workstation clusters, would soon result in 5,000 computers on campus for some 7,000 students, faculty, and staff—all without campus standards and all with limited interconnectivity.

Carnegie Mellon President Richard M. Cyert responded in September 1981 by creating a multi-disciplinary task force to consider the proper role of computers on campus. The task force recommended that Carnegie Mellon aggressively direct the trend. The group also stressed the importance of communications among computers as a means of efficiently sharing information and resources. In looking at the popularity of microcomputers, it further suggested that it was time to experiment with a major shift to personal computing.

The recommendations of the task force—recommendations bolstered by earlier experiences with networking within the Computer Sciences Department—stimulated the administrative decision to create a campus-wide network of all computers and information systems.

"We were interested in seeing the campus so saturated with computers that there would be one per person," Cyert notes. "We had faith that it would lead into some interesting developments. We also wanted to take advantage of the trend by developing educational software for students. But the original driving force was communications. We always thought in terms of the network, and never were really interested in having students randomly bring in personal computers."

He explains that the decision was made early to provide computing services as a centrally directed campus utility—making intelligent workstations generally available to everyone. The objective was to have an optimum synthesis of time-sharing and personal computing.

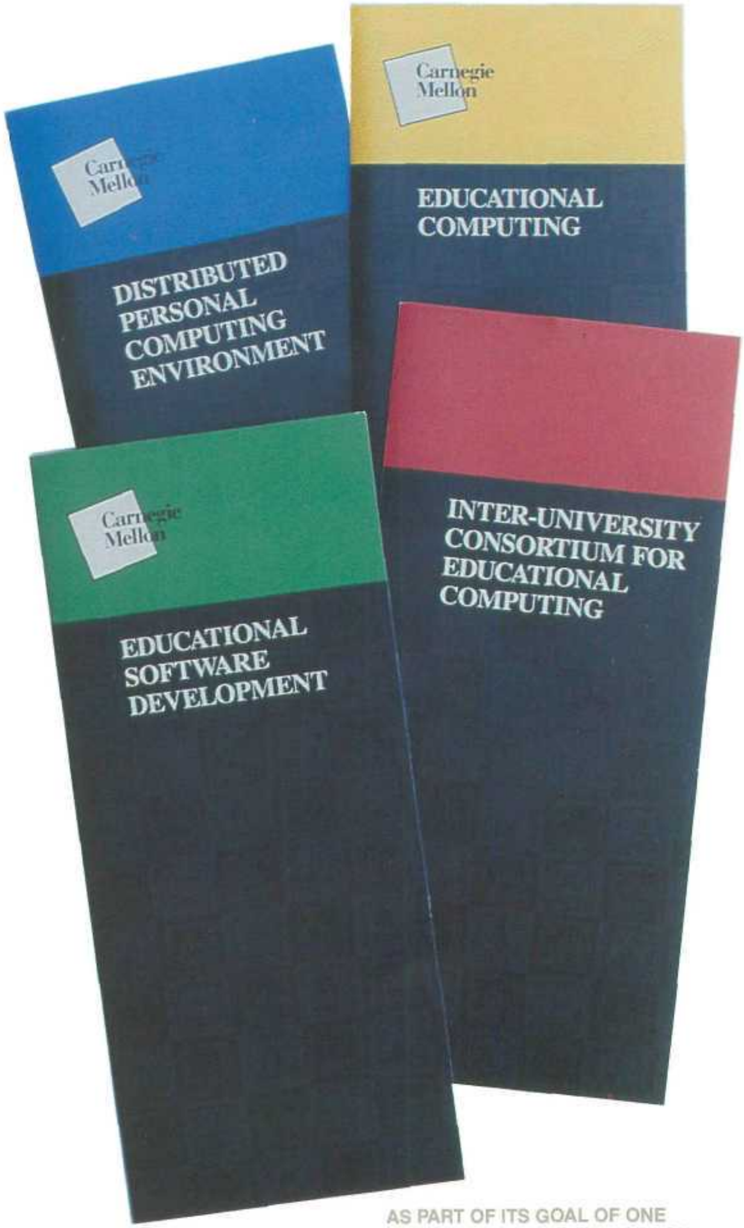
"When we started," Cyert continues, "we realized we were possibly talking about the world's largest local area network. Even after talking to IBM management about joining us on the project, it wasn't clear that it was possible. But, after a four-month feasibility study, both parties decided to go ahead with it."

Cyert emphasizes that the school did not set out to design a network with specific ideas on how it would be used: "We took a purely technical approach. We saw it as our job to provide an environment—a set of tools that our students and faculty could use as they pleased. We also decided to let them continue with their own systems. It thus became the administration's problem to try to adapt the departmental devices and software to the network, rather than the other way around."

From Concept to Creation: An Exercise in Ingenuity

"The problems were immense: conceptually, socially, and technically," says William Y. Arms, Vice President for Academic Services. "It's a university-wide project which interacts with many other universities. We have over a hundred different makes of computers on campus, innumerable types of network systems, workstations, and so forth. The scale of the project is unprecedented."

The "unprecedented" effort was code-named "Andrew," after Carnegie Mellon benefactors and namesakes Andrew Carnegie and Andrew Mellon. (Andrew,



AS PART OF ITS GOAL OF ONE COMPUTER FOR EVERY PERSON ON CAMPUS, CARNEGIE MELLON HAS CREATED A SERIES OF INFORMATIONAL BROCHURES ON COMPUTING THAT ARE DISTRIBUTED TO ALL INCOMING STUDENTS.

WILLIAM Y. ARMS, VICE PRESIDENT FOR ACADEMIC SERVICES, DESCRIBES CARNEGIE MELLON'S EFFORT ON THE ANDREW PROJECT AS 'UNPRECEDENTED.'

developed under a joint development agreement, is owned by IBM.) In October, 1982, Carnegie Mellon and IBM teamed up to create an on-campus software development group called the Information Technology Center (ITC).

ITC's mission was to develop the central part of the Andrew system, the network, file system, and workstation software. Meanwhile, others at Carnegie Mellon were developing the interfaces that would tie Carnegie Mellon's polyglot of microcomputers in varied library, telecommunications, computing, and information systems into one neat and transparent digital communications package.

Some 30 people were assigned to the ITC to design and develop Andrew—20 Carnegie Mellon employees, including the project director, and 10 IBM employees.

Concurrently, Carnegie Mellon assigned strong support roles to several existing campus groups. The Computation Center would deploy and maintain the system; the Center for Development of Educational Computing would support courseware development; and the Telecommunications Office would install cabling systems throughout campus. Simultaneously, a social sciences committee was formed to study the social, organizational, and educational effects of the Andrew project. To this team, then, went the challenge to have the network ready for general use by fall 1986.

Four years after it began, the vision has proved to be more than a dream: "It works," says Arms. "In fact, the effort is now starting to pay off with some significant, demonstrable successes. But that is not to say our earlier vision was flawless."

He points out two big differences between what was accomplished and what was planned. "At first, there was an emphasis on striking a balance between personal computers and host computers. But as we found that more and more things could be done on the microcomputers, host computers were downplayed."

Arms is quick to add that large mainframes still have some role to play. But their role as network controllers and file servers diminished as the capabilities of microcomputers increased.

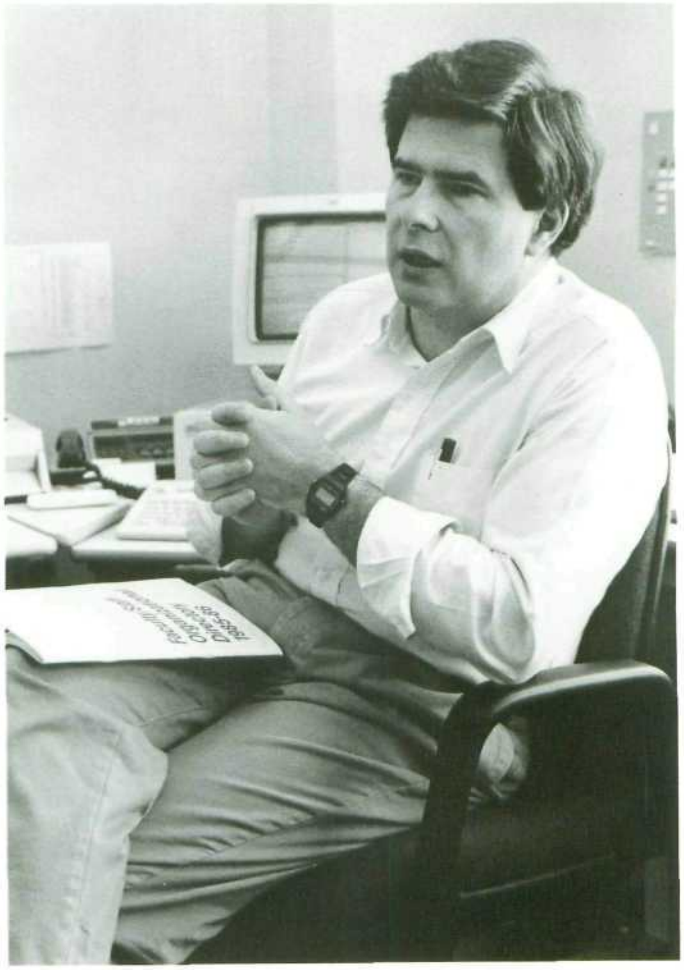
"The other big change," he says, "is that the plans assumed there would be nothing else on campus except Andrew. This model ideal was comparable to building an expressway across Wyoming, working with virgin territory, when in fact we were talking about running one through something like Chicago. The unavoidable interrelationship with other computer systems on campus was not foreseen. The way around the problem is to use standard protocols that make the network accessible to everyone, but it is a big task."

James H. Morris, Carnegie Mellon Director of the ITC, agrees that the Andrew project has been influenced in unforeseen ways by the rapid growth of microcomputing power.

"The Carnegie Mellon program had its earliest beginnings with something called the SPICE Project, which, among other things, was the Computer Science Department's specification for an ideal workstation. We assumed that we would have to take a hand in developing such a machine ourselves. Carnegie Mellon consulted extensively on the design of the IBM RT PC, which exceeds the specification in many ways.

"Basically, the ITC was to produce innovative software applications," Morris notes. "In fact, I would say that about half our efforts have supported educational applications, word processing, and communications—such things as electronic mail and bulletin boards. The other, probably somewhat larger half, has gone into the network and the file system.

"Rather than develop a new operating system, we adopted 4.2 (Berkeley UNIX*) as our basic operating system for a lot of reasons," Morris explains. "We wanted an operating system that could run on a variety of hardware, and was supported by several software organizations."



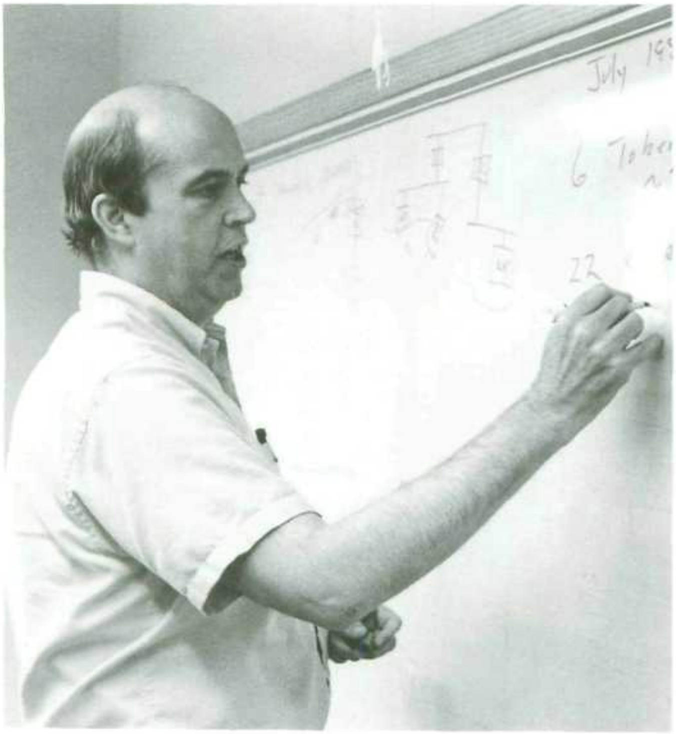
JAMES H. MORRIS, DIRECTOR OF CARNEGIE MELLON's INFORMATION TECHNOLOGY CENTER, THINKS ANDREW's EVOLUTION HAS BEEN INFLUENCED BY THE RAPID GROWTH OF MICROCOMPUTING POWER, PARTICULARLY THE IBM RT PC, WHICH EXCEEDS CARNEGIE MELLON's OWN SPECIFICATIONS FOR A HIGH-FUNCTION WORKSTATION.

Morris notes that a massive file system—which is the central communications backbone of Andrew—had to be built underneath 4.2. Files and file servers, scattered throughout the network, all work together to provide the illusion of one giant database that everyone on campus can access.

"The most shocking thing to many people is that there is no host requirement," says Morris. "Instead, we have divided the Andrew system into two parts: the backbone, which we call VICE (Vast, Integrated Communications Environment), and the applications software driving the workstation clusters hanging from the backbone, which we call VIRTUE (Virtue Is Reached Through UNIX and EMACS)."

VICE, according to Morris, is a collection of communication and computational resources serving as the information sharing core of a user community. VICE

*UNIX is a trademark of AT&T



DON SMITH, SENIOR IBM ENGINEER, LINKED IBM's TOKEN-RING NETWORK TO CARNEGIE MELLON's COMMUNICATIONS STRATEGY. THE UNIVERSITY IS UNITING VARIOUS LANS AND DISPARATE COMPUTING EQUIPMENT ACROSS THE CAMPUS INTO AN EFFICIENT SYSTEM THAT CAN EXPAND AS NEEDS GROW.

also can be envisioned as one large file system with a number of services carried out by individual personal computer workstations.

"We wanted to avoid tying up the big mainframes with mundane communications tasks," Morris says. "This system does have bottlenecks—which are the computing capacity of the file servers—but this is easily overcome. What's important is there's no single bottleneck that will become white hot as we ramp up this year to 3,000 users."

The Communications Network: A Perspective on VICE

The glue holding VICE together is Andrew's network protocols. Because many departmental mainframes already use DARPA (Defense Advanced Research Projects Agency) Internet Standard protocols for communications, and because the Berkeley 4.2 UNIX operating system has implementations of the Internet protocols, DARPA Internet became the obvious choice as a standard for Andrew.

Thus, any machine and software configuration can hang from the network, but provisions have to be made to implement those protocols with the 4.2 operating system via Internet. In order to communicate with various IBM systems, for example, the ITC implemented SNA (Systems Network Architecture) under UNIX. This package is used to drive the network's IBM 3820 laser printers and other shared devices.

Don Smith, a senior IBM engineer who has worked on Andrew since its inception, was impressed with the eclectic nature of Carnegie Mellon's computing environment. "As the Andrew project really got rolling in 1983," he recalls, "there were about 15 Ethernet* and two Pronet† LANs on campus.

"These were mostly independent networks, spread all over campus in individual buildings. Some were small, but others were quite large. The Computer Science net, for example, had 300 to 400 computers online. And, anywhere in this jumble of networks could be products from a dozen different vendors. Missing was a connection among the different networks. Also, we had to have a way to gracefully add dozens of personal workstation clusters," says Smith.

Hence, from an ITC perspective, four basic pieces of the network needed to be pulled together. First came the need to define and develop an intelligent workstation approximating the SPICE specifications. Second was the need for software standards that would permit

*Ethernet is a trademark of Xerox Corporation
†Pronet is a trademark of Proteon Corporation

JOHN LEONG, CARNEGIE MELLON ASSOCIATE DIRECTOR OF NETWORK DEVELOPMENT, INCORPORATED ELECTRONIC DEVICES IN ANDREW THAT ROUTE DIGITAL TRAFFIC BETWEEN FILE SERVERS AND EACH OF THE NETWORKED LANS.

communications between the various LANs without restricting the continuance or addition of otherwise incompatible departmental systems. Third, the distributed file servers and file server disks had to be incorporated to unify them and make them transparent to the entire Andrew installation. Fourth, a large build-up of microcomputer workstation clusters, utilizing IBM's Token-Ring Network technology and serving thousands of microcomputers, had to be introduced into the system in a non-disruptive manner.

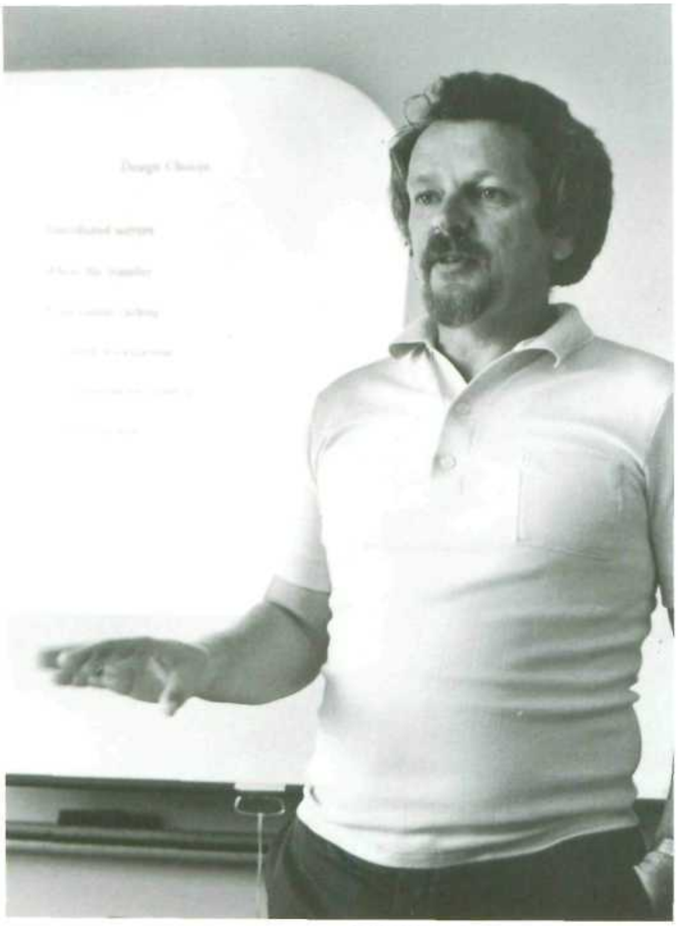
The IBM Token-Ring Network has been operating at Carnegie Mellon since January, 1986. According to John Leong, Associate Director of Network Development, the IBM Token-Ring Network has proven to be very stable, and its extensive, well thought-out network management functions have greatly facilitated operation.

An important element of the networking activity is the interconection of a large number of local area networks to allow widely dispersed workstations to communicate effectively with the file servers. This is achieved by routers developed jointly by the Computer Science and Electrical and Computer Engineering departments. The routers were deployed under the direction of Leong. "The routers are base on off-the-shelf hardware components such as 68000 multibus systems and the IBM PC/AT," Leong says. "They are equipped with appropriate local area network interfaces. The basic idea was that we could put a router up for interconnecting three networks at a cost of about $4,000. They are quite cost effective and can handle roughly 500 packets per second."

According to Leong, "routers are best described as very simple dedicated processors that look at the headers of the data being transfered and then shove them down the appropriate cable, depending on the destination address. Because of the simplicity of the hardware and software, it is a very stable piece of equipment. We have suffered few failures over the past two years."

The IBM Token-Ring Network may be a relative newcomer to Andrew, but it has become the system's fastest-growing segment. From six installations at mid-year, supporting about 50 IBM PCs and 150 IBM RT PCs, the network now carries some 20 IBM Token-Ring clusters supporting about 1,000 IBM microcomputers. Another 1,000 microcomputers and workstations of various types are supported by approximately 23 Ethernet clusters.

VICE File System: An Overview



MIKE WEST, IBM MANAGER, HAS WORKED TO MAKE THE VICE FILE SYSTEM COST-EFFECTIVE, EFFICIENT, AND EASY TO USE.

Mike West, IBM Manager of the VICE file system, has worked on the project since December 1982. "Our goals were many," he explains. "First, we wanted it to be relatively inexpensive. We now serve more than 50 workstations per server, so that goal was met.

"We also wanted a graceful degradation under load. In fact, we've now gotten VICE to where it slows down and gives us a chance to correct problems, but doesn't crash. Our next goal was to achieve performance levels that would exceed those of timesharing. This meant that we wanted VICE to appear as though all files were local. Next, we established minimum targets for the system of 5,000 workstations and 10,000 users.

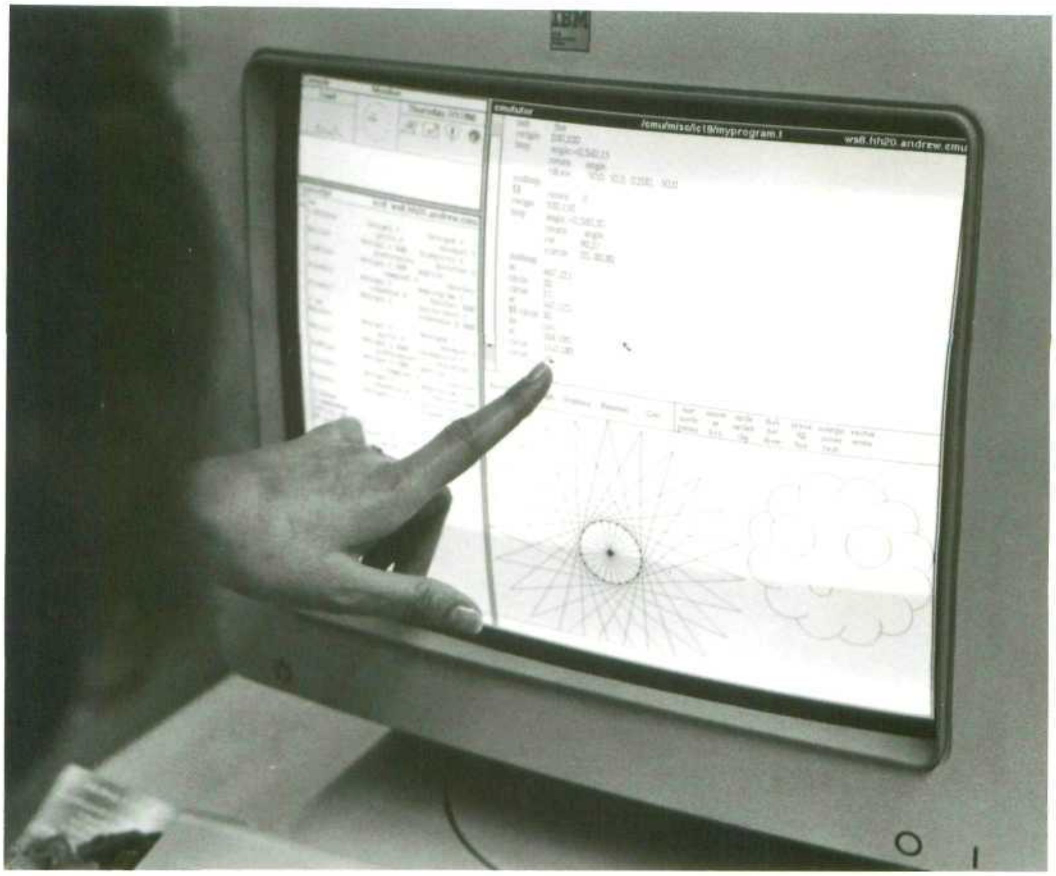
"Finally," West continues, "we wanted VICE to be easy to operate. We didn't want it only to be accessible to specialists or hackers. In other words, the system is designed to more or less run itself.

"The local file emulation feature was achieved by a process of full file transfer," West explains. "Whenever you ask for a file in VICE, the entire file is copied to your local disk. From then on you run with it locally. When finished, you copy it back to the file server. This gives us simplicity and high performance. It runs as fast as the local disk, because it *is* the local disk. It's also secure, because a copy of the master file is always retained in VICE—until you update it."

The full file transfer process is combined with a sophisticated workstation caching technique to build Andrew performance. This caching procedure eliminates the need for access to the network for small, commonly used files. They're always resident on the workstation.

"Allowing a user to have secure access to his own files was also a major goal," continues West. "Since we do not have control over the workstations, we do not trust the workstations to authenticate the users for VICE. Instead, during log-on the user is validated to VICE and the workstation is only trusted as an agent for the user."

To implement much of this, authentication was built into the remote procedure-call mechanism.

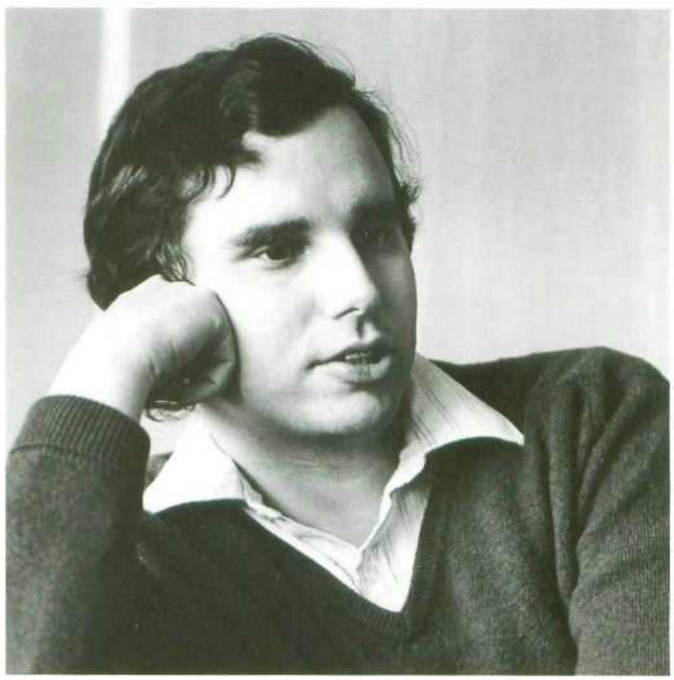


THIS WORKSTATION, ONE OF SEVERAL IBM RT PCs CLUSTERED ON AN IBM TOKEN RING NETWORK, HAS IMMEDIATE AND 'TRANSPARENT' ACCESS TO THE ANDREW SYSTEM.

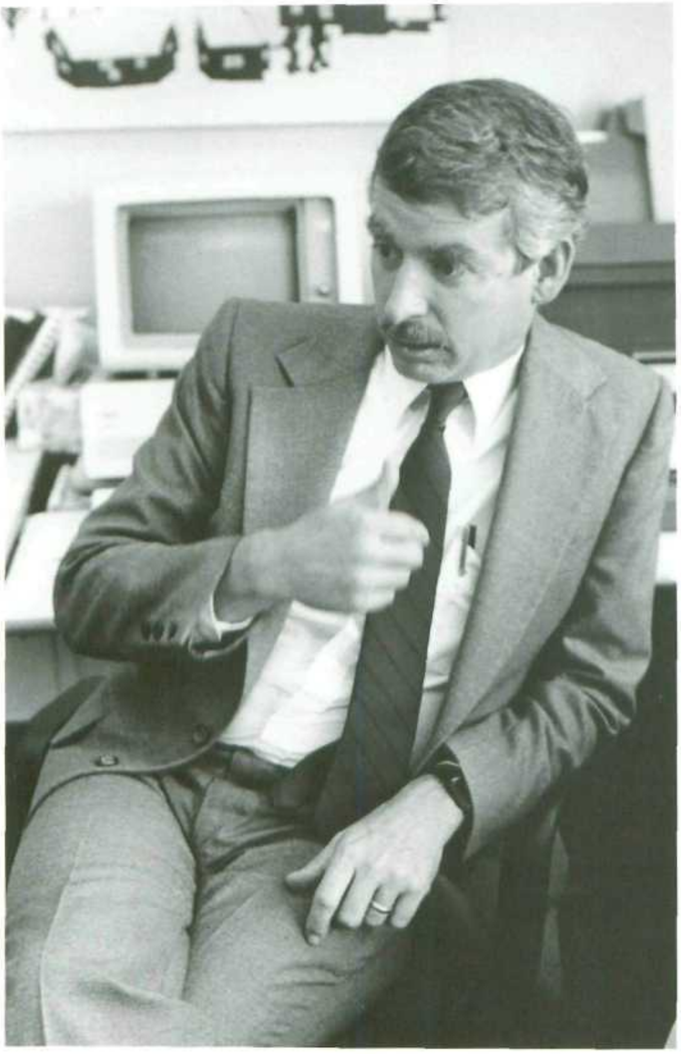
A Perspective on VIRTUE

VIRTUE is the component of Andrew that brings the power of UNIX and of advanced personal computer workstations, such as the IBM RT PC, within the grasp of the network user.

According to Andrew Palay, Carnegie Mellon Manager of User Interface Software Development, "VIRTUE provides a consistent user interface across all three general classes of academic user applications: general utilities—such as text and drawing editors, mail, and bulletin boards; courseware authoring tools—such as CMU Tutor; and specific courseware itself—such as The Great American History Machine, which provides graphic representation of demographic information, and the Notecard System, a writing development tool."



ANDREW PALAY IS MANAGER OF USER INTERFACE SOFTWARE DEVELOPMENT.



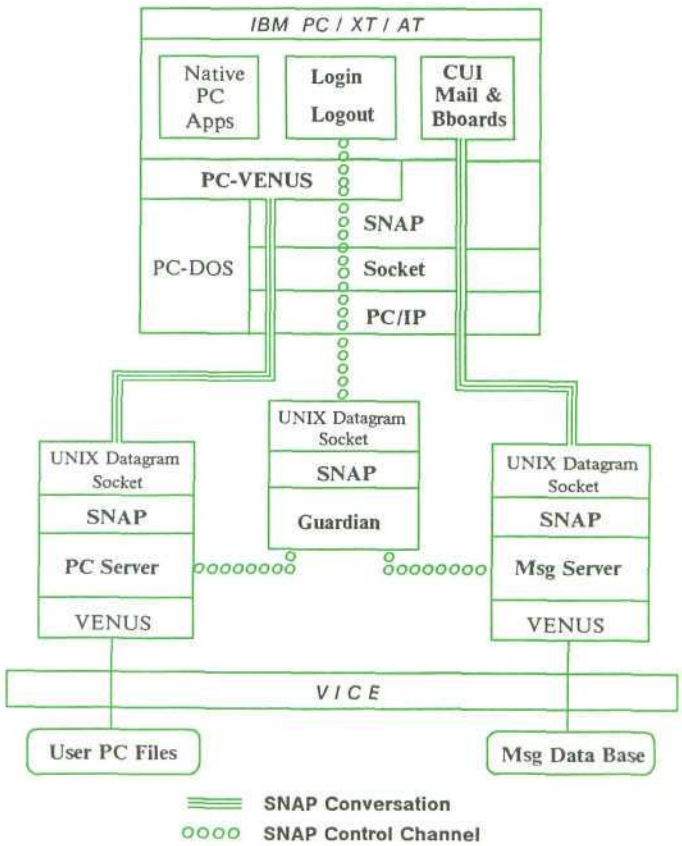
JOHN H. HOWARD, IBM INFORMATION TECHNOLOGY CENTER SITE PROJECT MANAGER, SAYS THE PC SERVER (RIGHT) GIVES PCs USING DOS A DIRECT LINK TO ANDREW's UNIX ENVIRONMENT. THE PC SERVER WAS DEVISED BY IBM SYSTEM DESIGNER LARRY K. RAPER.

The PC Server

For machines like the IBM RT PC, which are designed to run the Berkeley UNIX operating systems, connection to Andrew was a relatively simple chore. But Carnegie Mellon has over 3,000 IBM PCs and other microcomputers owned by students, faculty, and staff that never were intended to run UNIX.

"To give those machines access to Andrew," says John H. Howard, IBM ITC Site Project Manager, "we took an IBM RT PC that connects to VICE as a regular workstation, and wrote a piece of code that allows the IBM PC to connect in through the IBM RT PC. So you can go from an IBM PC to the IBM RT PC, and through this to files anywhere in the file tree. The PC Server application, according to Howard, accounts for half of the IBM Token-Ring Network connections.

PC Server Block Diagram



The Andrew Cabling System

Robert Cape, Carnegie Mellon Director of Telecommunications, has overseen a massive wiring project that not only links every building on campus, but has forged extensive links to the outside world. "When we're done," he claims, "we will have the world's largest local area network, with 7,000 nodes—a node being defined as an intelligent workstation or greater.

"As a ballpark estimate, we're talking about 50 buildings, 11,000 outlets, and 300 miles of IBM Type 2 Media Specification cabling. If it isn't the largest installation of the IBM Cabling System, it's certainly the most significant retrofit to a set of existing buildings."

Selecting a cabling system was no trivial task. Cape's office first began grappling with the question of what wiring strategy to employ some two years ago.

"The turning point came when we found ways to run Ethernet on the twisted pairs of the IBM Cabling System. This gave us the confidence we needed, knowing that IBM's system had the flexibility needed for our complex installation."

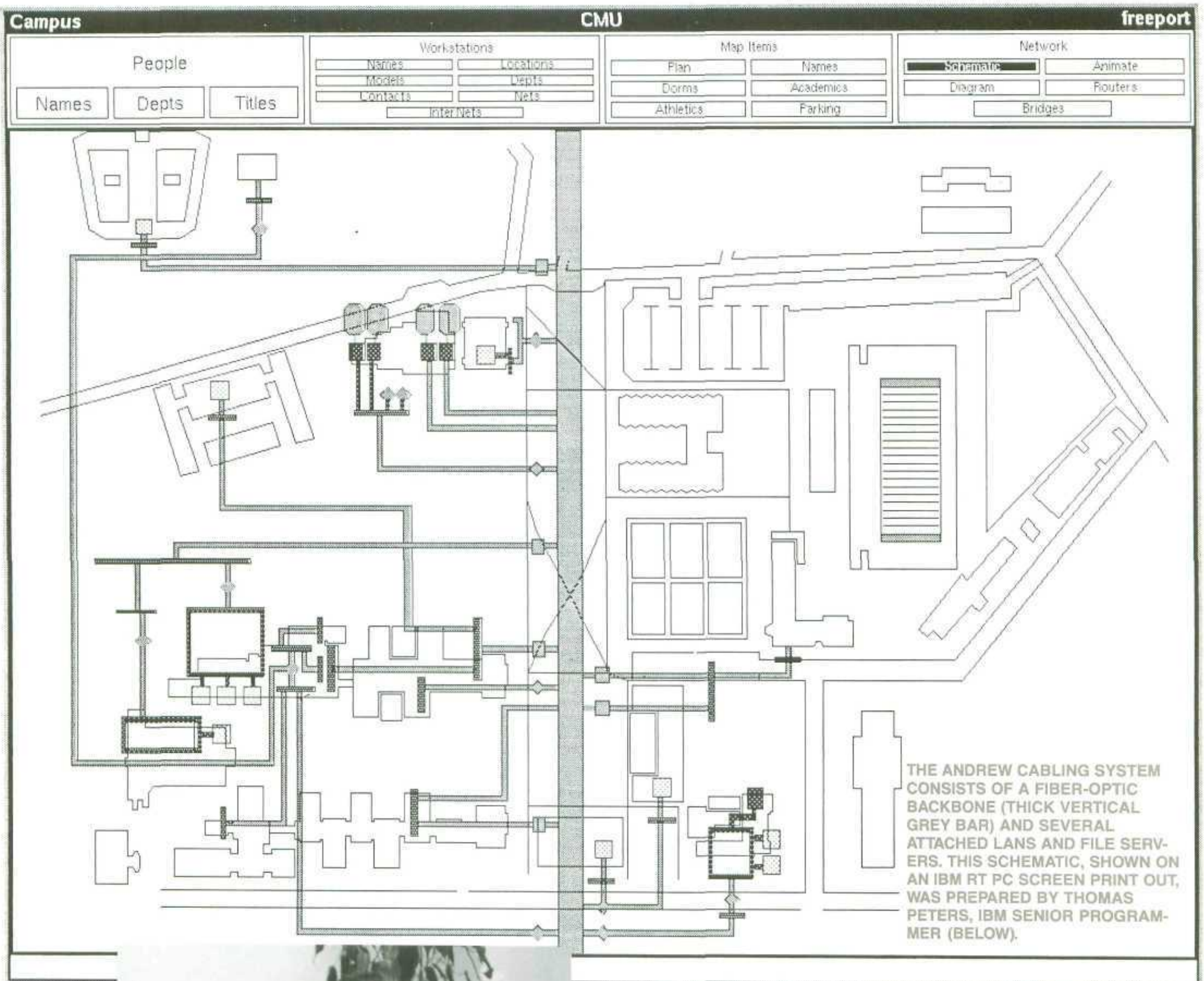
The IBM Cabling System at Carnegie Mellon provides, within a single sheath, two pairs of shielded wires for data, and four pairs of unshielded wire for voice. This single cable substitutes for the multiple coaxial, twinaxial, and telephone wiring installations traditionally used for institutional communications networking.

"Concurrently with the IBM cabling, we installed extensive inter-building fiber-optic cabling to complete the connectivity of the campus," Cape adds. "Our main off-campus, fiber-optic links run to the Mellon Institute. We also have fiber into the Bell of Pennsylvania central office in Oakland, and use it to extend 64 KB service to workstations in neighboring homes and apartments over their existing loops. This service is part of a project called the Metropolitan Campus Network."

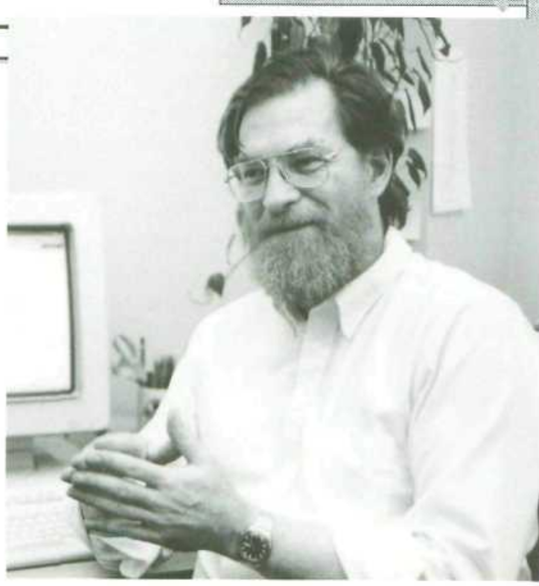
ROBERT CAPE, CARNEGIE MELLON DIRECTOR OF TELECOMMUNICATIONS, HAS OVERSEEN A MASSIVE WIRING PROJECT THAT, WHEN COMPLETED, WILL BE THE WORLD's LARGEST LOCAL AREA NETWORK.

The IBM cabling project posed quite a different challenge of going back to existing buildings and trying to make a $7-million capital improvement without anyone noticing. "Another of the complexities we faced," says Cape, "is a varied assortment of buildings. They're of all different kinds. The classic view of cable trays running down a hall, with drops coming off each side, just couldn't work here. The architecture wouldn't support it."

One alternative proved particularly effective—the distributed riser, whereby cabling was fanned out in the basement or the attic, and then distributed vertically—

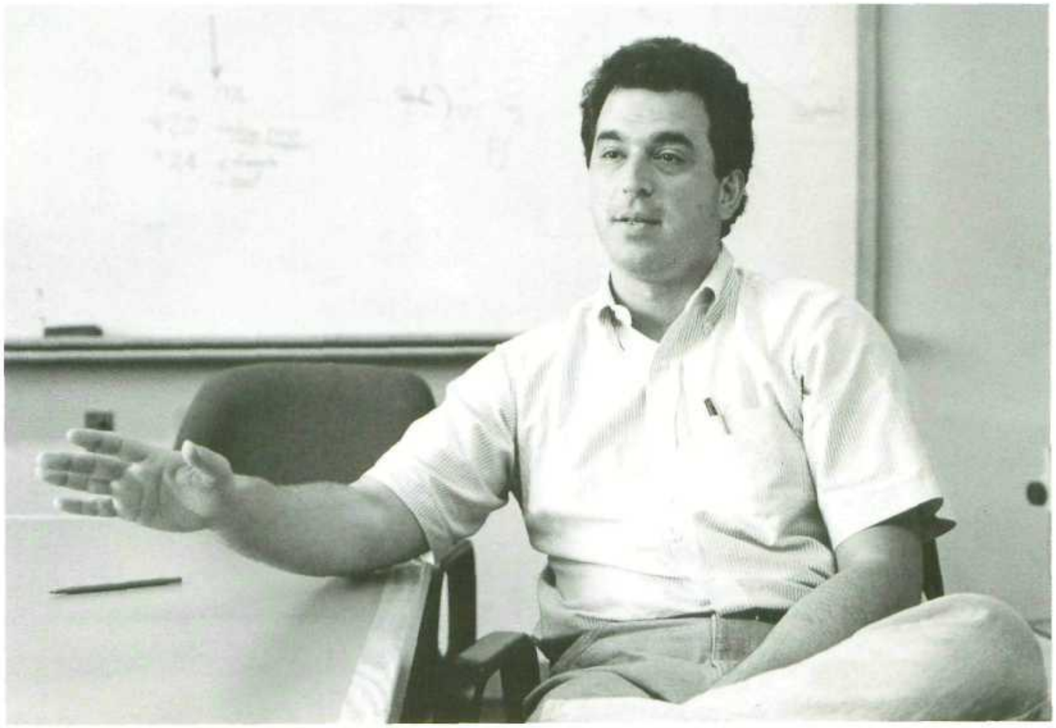


THE ANDREW CABLING SYSTEM CONSISTS OF A FIBER-OPTIC BACKBONE (THICK VERTICAL GREY BAR) AND SEVERAL ATTACHED LANS AND FILE SERVERS. THIS SCHEMATIC, SHOWN ON AN IBM RT PC SCREEN PRINT OUT, WAS PREPARED BY THOMAS PETERS, IBM SENIOR PROGRAMMER (BELOW).



with wiremold raceways coming off into rooms. This has been particularly effective in residence halls, where no one wanted conduits running horizontally through the bedrooms.

"I had thought that the hardest problem would be to find wiring closets, which in reality are small rooms," he explains. "I had visions of going to deans and department chairmen asking which junior faculty offices they were going to give up. But it has turned out not to be a problem, though we have had to be very creative with janitors' closets, landings on stairwells, and other crazy places."



JONATHAN ROSENBERG, CARNEGIE MELLON MANAGER OF THE MESSAGE SYSTEMS GROUP, IS RESPONSIBLE FOR DEVELOPING AND DELIVERING BULLETIN BOARD, ELECTRONIC MAIL, AND DATABASE SERVICES TO THE ANDREW NETWORK.

Now that the Carnegie Mellon Andrew network is in place and working, how is it being used?

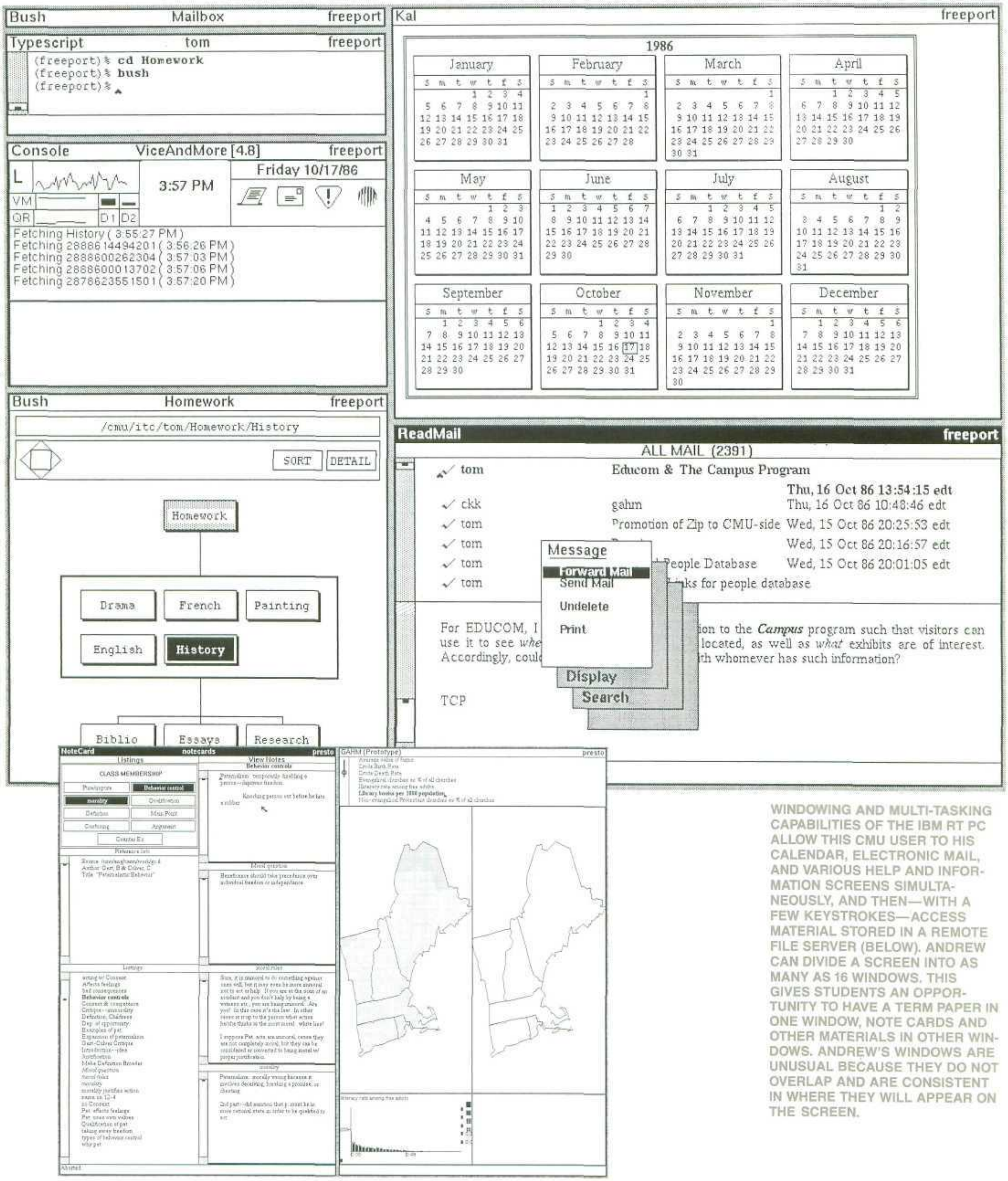
The answers are many, but can be broken down into the three general areas: messaging, teaching, and research. The first of these responsibilities resides with Johathan Rosenberg, Carnegie Mellon Manager of the Message Systems Group, who is responsible for developing and delivering bulletin board, electronic mail, and database services to the Andrew network.

"What makes my job fun," Rosenberg says, "is this giant time-sharing file system that looks like one big server. We have about 12 file servers either online or soon to be online, with about 120 gigabytes of storage. So, essentially, we have unlimited storage. But the nicest thing is that we can all share this common system.

"The problem you usually run into with electronic mail and bulletin boards is trying to deal with physically separate machines. Getting timely information to machines and updating them is difficult, because you have to go into the file system of each to post to the bulletin board, for example. With Andrew, they all share the same virtual file and have immediate access to information or messages when they're posted. Without the system, we would have to worry about updates and synchronization and locking—but Andrew does it all for us."

At Carnegie Mellon as at most universities, Rosenberg points out, many departments have their own mail systems, which they insist on retaining because they serve unique informational purposes. Rosenberg resolved the issue by leaving the existing message networks intact. He concentrated instead on making it easy for them to incorporate Andrew services into their own systems. Individual groups may now have two distinct hierarchies of messaging service; one which meets their specific internal needs, and one which connects them to the broader community.

"The definition of a message here is interesting," Rosenberg continues. "In general, it constitutes ASCII-based (American Standard Code for Information Interchange) mail. But, in fact, a message might include pictures, graphs, or even spoken text. We have recently received an award from the National Science Foundation to study the editing and transmission of multi-media documents, and we are looking at those needs."



WINDOWING AND MULTI-TASKING CAPABILITIES OF THE IBM RT PC ALLOW THIS CMU USER TO HIS CALENDAR, ELECTRONIC MAIL, AND VARIOUS HELP AND INFORMATION SCREENS SIMULTANEOUSLY, AND THEN—WITH A FEW KEYSTROKES—ACCESS MATERIAL STORED IN A REMOTE FILE SERVER (BELOW). ANDREW CAN DIVIDE A SCREEN INTO AS MANY AS 16 WINDOWS. THIS GIVES STUDENTS AN OPPORTUNITY TO HAVE A TERM PAPER IN ONE WINDOW, NOTE CARDS AND OTHER MATERIALS IN OTHER WINDOWS. ANDREW'S WINDOWS ARE UNUSUAL BECAUSE THEY DO NOT OVERLAP AND ARE CONSISTENT IN WHERE THEY WILL APPEAR ON THE SCREEN.

Data security is another issue, says Rosenberg. "To help resolve the problem, a three-phase authentication technique has been developed to ensure that encrypted messages go to the right people once the packets have been handed from VICE to VIRTUE. The technique involves a combination of passwords and machine-to-machine double handshakes."

Rosenberg believes that bulletin boards are not trivial, fulfilling a vital role as a "giant information utility" that should be generally available. The Carnegie Mellon network currently provides access to some 500 bulletin boards, many of which are received via ARPANET. Andrew subscribers can also create and sustain their own bulletin boards.

"One of the nice things about our system," Rosenberg concludes, "is that it's hierarchical. When a new bulletin board is generated, subscribers to older bulletin boards are notified of it."

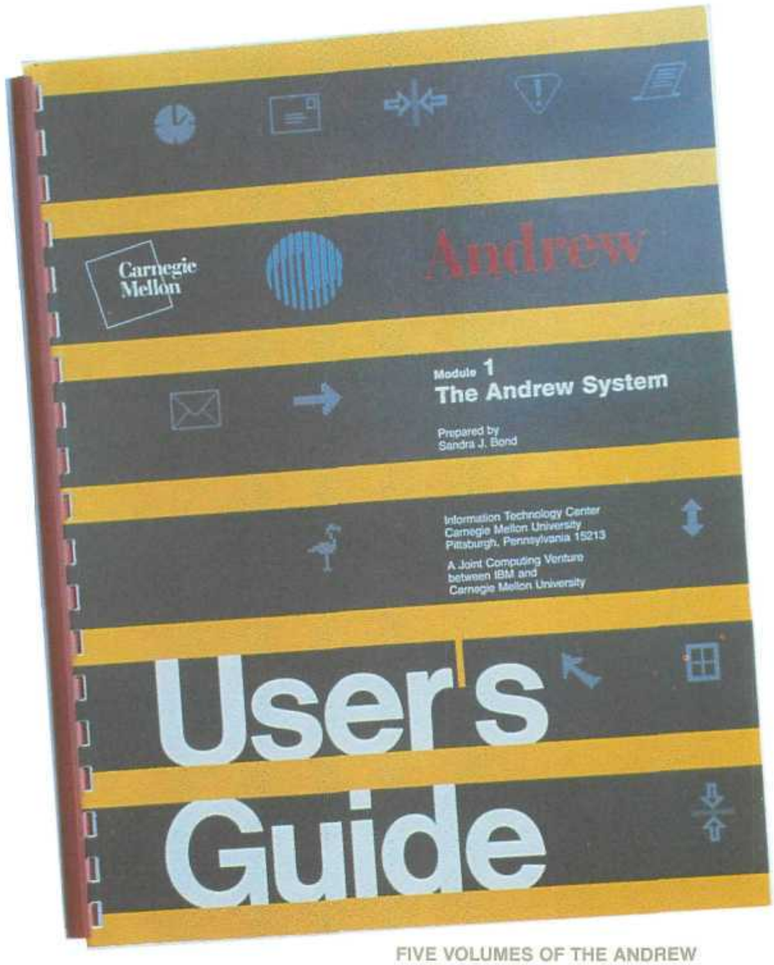
Teaching with Andrew

The primary expertise in courseware development at Carnegie Mellon resides with the Center for the Design of Educational Computing (CDEC). CDEC and ITC staffs work closely to support faculty members who develop courseware.

"The ultimate producers of educational software must be faculty members," says ITC Director James Morris. "We and CDEC diffuse technology and tools to them. Our job is to make it exciting enough and easy enough that there are no impediments to courseware development."

Courseware developed at Carnegie Mellon is published by CDEC in a 264-page catalog which lists dozens of course offerings in architecture, art, design, music, civil engineering, electrical engineering, engineering and public policy, mechanical engineering, English, history, modern languages, philosophy, psychology, social science, biology, chemistry, mathematics, physics, and computer science.

Much of the advance in Carnegie Mellon-developed courseware has been made possible by a project called CMU Tutor. Developed by Bruce and Judith Sherwood, CMU Tutor is an authoring language that allows non-expert programmers to write educational software on

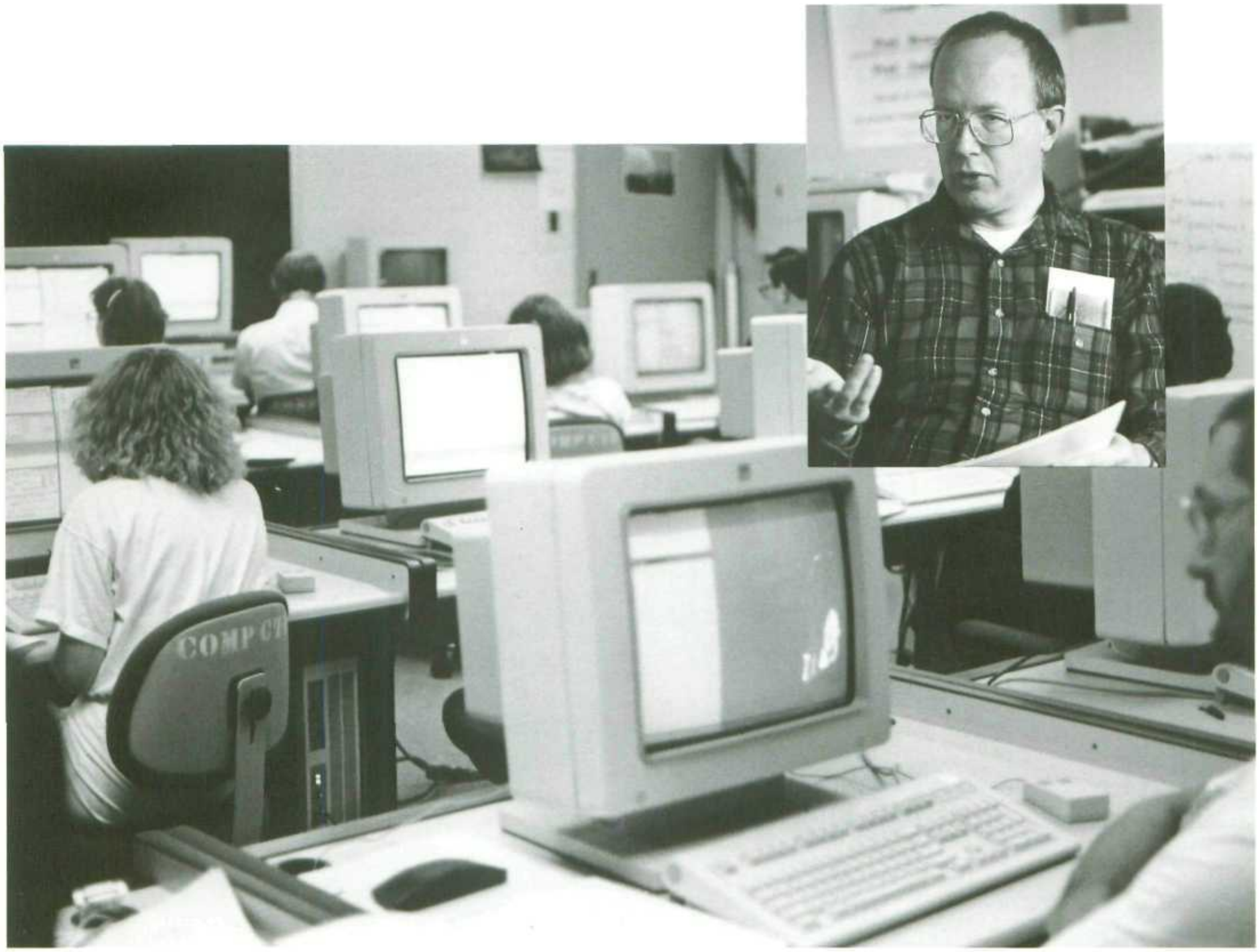


FIVE VOLUMES OF THE ANDREW USER's GUIDE HELP STUDENTS AND FACULTY TAKE ADVANTAGE OF THE SYSTEM's CAPABILITIES. FEEDBACK PROVIDED BY A SOCIAL SCIENCE DEPARTMENT STUDY IS BEING USED TO MAKE THE USER's GUIDE A MODEL DOCUMENT OF ITS TYPE.

Andrew workstations. It has been adapted to Andrew from the MicroTutor language developed at the University of Illinois.

CMU Tutor gives full access to the powerful bit-mapped workstation graphics capabilities of Andrew, including labeled graphs, rotatable displays, pattern-filled polygons and disks, and animation of icons. Rescaling of programs to window size is significantly simplified, and pop-up menus are easily created and managed. Standard calculational structures are provided, and it handles input from both keyboard and mouse. CMU Tutor also provides an extensive on-line reference manual.

Regular classes in using CMU Tutor on IBM RT PC workstations are held for Carnegie Mellon faculty and students, as well as for faculty and researchers from other universities.



IN THIS IBM RT PC LABORATORY, FACULTY AND STUDENTS ATTEND CLASSES IN USING CMU TUTOR, AN AUTHORING LANGUAGE THAT ALLOWS NON-EXPERT PROGRAMMERS TO WRITE EDUCATIONAL SOFTWARE. BRUCE A. SHERWOOD, ASSOCIATE DIRECTOR, CDEC, AND PROFESSOR, DEPARTMENT OF PHYSICS (INSERT, TOP), DEVELOPED CMU TUTOR WITH JUDITH SHERWOOD (FAR LEFT). SHERWOOD GIVES UNIVERSITY OF PENNSYLVANIA FACULTY MEMBER ELIZABETH PALAZZI SOME ONE-ON-ONE HELP.

Also driving the revolution are developments like the intelligent tutor that John Anderson of Carnegie Mellon's Psychology Department built for teaching LISP. He believes he has evidence that it takes only half the time to reach the same level of proficiency in LISP as it takes in traditional lecture classes. He has another tutor for teaching geometry to high school students in local schools. The preliminary evidence is that it raised grade averages by one full grade.

Other Implications of Andrew

The Committee on Social Science Research in Computing (CSSRC) is headed by Sara Kiesler and Lee Sproull, Professors in the Department of Social and Decision Sciences. Sponsored in part by IBM, the committee was formed to study the social aspects of computing, as well as the social, organizational, and educational effects of Andrew. "We are trying to assess the impact of creating electronic communities," says Kiesler.

"We have two goals. One is to do research on fundamental processes. By this, I mean research independent of the particular application you might be using. For example, how do people communicate using a computer network? We are looking beyond surface differences to try and find out what's really important in creating social effects. Is it the linking up of many people, or the reduced social context that matters?"

The other goal is to provide feedback for systems and applications under development, Kiesler explains. The designers of these systems can use what has been learned from studying people at Carnegie Mellon and elsewhere. Considerable feedback has already been forthcoming in setting up the mail system, and in helping to devise policies for managing the development and implementation of projects.

"We looked at how people really use a system. We have investigated electronic systems used in classrooms," she says. "We've done empirical research of all kinds, from experimental research on how groups use computer mail for decision making to studies of business and government organizations."

Facts gained from this research help guide system managers and designers in their modifications or additions to the Andrew network. "The distributed network will allow new kinds of work and group interactions," Kiesler adds. "Therefore, understanding these potentials can influence both technical and policy choices."

SARA KIESLER, PROFESSOR IN THE DEPARTMENT OF SOCIAL AND DECISION SCIENCES, HEADS A COMMITTEE STUDYING THE SOCIAL, ORGANIZATIONAL, AND EDUCATIONAL EFFECTS OF ANDREW.

Although Carnegie Mellon University has built what may be the world's most extensive local area communications network, further enhancements are already being planned.

"On a practical level," says President Cyert, "we still have a long way to go in terms of pulling all computing resources on campus into one commonly shared, compatible system. So our development work will continue."

To help achieve this, the university is building a strong Andrew Systems Group totally separate from the ITC for developing, installing, and maintaining system components as Andrew evolves from a development system into a production system.

Continues Cyert, "On the academic side, we will increase our efforts to implement the university-as-information-utility idea. We also will push harder for inter-university cooperation on standardizing systems and software for academia. We must get to the point where educational software is as portable and usable as text books. Work done at any university should be readily available to all of academia."

Progress in this latter arena, according to Cyert, is being made through the Inter-University Consortium for Educational Computing (ICEC), which represents some 20 universities and colleges dedicated to developing high-quality educational applications software for workstation environments. ICEC is considering a proposal that will take the best software from the Andrew Project and projects at other universities to create a standard system for academic computing.

"The subject of standardization will also certainly be taken up by EDUCOM, which holds membership in ICEC," says Cyert. "We look to IBM and other vendors to support these emerging standards in their future products, so that the broader academic community can benefit from our efforts and we in turn from theirs. We think the choice of Pittsburgh as the 1986 EDUCOM Conference site reflects our growing leadership in this work," Cyert concludes, "How better could we serve academia?"

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