Implementing a large office automation system—how to make it work

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ABSTRACT

This paper discusses the implementation of a large office automation system to be used by nondata processing as well as data processing staff, i.e., the knowledge worker. At its completion the system will encompass more than 1,000 terminals (one terminal per office). The paper covers the nature of the basic system, IBM's Professional Office System (PROFS), what it does, how it functions, the extent of use, and how to encourage potential users to use it. The paper reviews training procedures from one-on-one to higher ratios and the reasoning behind them, and goes over in detail the nature of the “innovation” curve. Also reviewed are the computer performance and the Local Area Network (broadband with Sytek bus interface units). We currently serve more than 500 users with around 300 terminals already distributed.
INTRODUCTION

We discuss here the implementation of a large office automation (OA) system and how we made it work. By and large, we’re talking about one terminal per office, or a total of 1,000 terminals, covering nine buildings within a two-mile radius.

Our discussion will go over the nature of the corporation, a nonprofit organization that does business primarily with the federal government. We will review our office automation architecture and design goals, our implementation strategy in terms of our basic system, the pilot group used in developing the system, and how we controlled additions to the group.

And most importantly, we'll cover what actually happened in terms of acceptance of OA concepts by the pilot group, communications problems, and wide-implementation problems.

Corporation Background

The MITRE Corporation is a not-for-profit systems engineering company chartered in the public interest. MITRE was established in 1958 to assist the Air Force, but today assists most federal civilian agencies, as well as other DoD agencies in the areas of command and control systems, information systems, as well as the energy/environmental area. The major product of the corporation is information, utilizing the media of reports, specifications, memos, briefings, etc.—paper in general.

We cover here office automation activities supporting the 1,500 or so staff at the Washington center. We will allude to other systems used throughout the rest of the corporation and how we interface with them. Additionally, we wish to stress the implementation problems and solutions, not the specific hardware or software components of the system.

OA at MITRE

MITRE entered the office automation area in 1972 when we developed a centralized word processing support facility with an administration support center. During this period we had two shifts (eight operators each shift, working six days per week at its high point). In 1976 we migrated to the decentralized word processing concept (approximately 40 word processing terminals off cluster controllers). From 1976 until 1980, word processing and computer usage was growing at a rapid rate.

In 1981, the Corporate management decided it was time to develop an integrated plan for the spread of information services to our professionals, secretaries, and administrative staff. An internal study group, consisting of four senior managers, was chartered to review the computer and telecommunication support needs of the company. The committee’s work was completed in the fall of 1981 with corporate management’s acceptance of a “target system,” a four-phase implementation plan, and authorization and funding for the plan’s first two phases.

The system was designed to account for the heterogeneous user population in terms of data processing skills, typing skills, the nature of work being performed, and the level of each person in the company. The design encompassed hundreds of terminals and tens of computers with multiple vendors making up the system.

The target system networked computer resources, allowing the users to share data, programs, and special-purpose peripherals. We also strongly wanted to have a local area network that would support video in terms of both security (e.g., badge readers from remote buildings) and instructional TV (e.g., the lunch-time seminars).

Based on the 1981 recommendations of the committee, our 1983 architecture evolved to a fully connected system. We are basically utilizing a Sytek LocalNet 20 bus interface unit in our broadband data distribution system. We now have connectivity and information transfer among all of our major segments, internally in the Washington Center and with the outside world.

Implementing a Large-Scale OA System

We would now like to discuss how our implementation strategy obtained a workable office automation system.

There are four major components that make the system work:

- the computer system
- the local area network
- user acceptance
- applications software

Our implementation strategy was as follows. In late 1981 we evaluated the available software options in the office automation area. Our primary concern, beyond the normal OA functions, was that the software reside on our IBM mainframe. The Professional Office System (PROFS) was chosen because of cost, maturity of the product, breadth of applications, and relative ease of use. 1982 was spent debugging, customizing, testing the product, and implementing a prototype system. By mid-1983 we were ready for corporate-wide implementation.

PROFS is a menu-driven system; that is, the capabilities are
accessed through menus (or lists). There are three main menus and numerous submenus. The display terminal's Program Function Keys (PF Keys) are used to move between menus and to invoke specific functions. The system was customized over time to offer the various user segments different levels of information. These included (what we deemed important) management needs, and staff needs.

As was stated, the PROFs architecture allows for the ready access of information not provided by the basic software. The basic software offers general OA tools such as electronic mail, calendar functions, electronic filing/retrieving, reminder functions, and document preparation.

From March to August 1983 we undertook several studies. These included a system evaluation, communication options between buildings (statistical multiplexing, microwave option, etc.), a definition of our FY84 configuration, a definition of an adequate support structure, a finalized training mechanism, and, of course, a study of the role of the personal computer in our environment.

Starting in August 1983 and extending to August 1984, we have been installing an additional 180 terminals (which translates to an additional 270 or so users to the system). This is Phase 1 of across-the-company implementation. FY85 will be an additional 180 terminals, and so on until there will be one terminal per office.

### The Local Area Network

For our local area network we used a broadband CATV system utilizing Sytek LocalNet 20 system. LocalNet is a packet-switched local area data communications network providing communication functions and standard broadband CATV coaxial cables. The properties of a broadband system permit LocalNet to construct independent subnetworks—terminal channels. Each of those subnetworks provides data communications for hundreds of users. In the summer of 1982, we initiated a limited test of the system within one building to ensure functional compatibility of all components. In 1983 we extended the network to cover our five remote buildings, all within a two-mile radius. Our problems arose when we could not physically connect the buildings with a cable. We experimented with a host of alternatives; these included telephone lines at 9,600 bits per second, microwave transmission at a very high effective data rate, laser transmission, and the use of statistical multiplexors. We are currently utilizing all of these for one reason or another.

The LocalNet medium provides the high band with 300 to 400 MHZ proven reliability and multidrop capability required for growing data communications requirements. Analog video or voice applications can share the same cable using dedicated frequency channels. A single channel can accommodate approximately 100 simultaneous virtual circuits.

### Getting The System “Used”

We would now like to discuss how one goes about generating productive use of the system. Nothing is more important than having senior management commitment; however, 100% commitment is really not needed to have successful implementation. Management should not be negative. Once this commitment is in place, the road to success can then be followed.

Aside from the typical notes and messages on any office automation system, it is important to have tools on the system that would be helpful to the knowledge worker or the professional. We chose to have project financial information as the first application on the system for management use. This financial planning and analysis tool proved to be most useful inasmuch as the system was used immediately (in other words, users took the time to become familiar with the system because they were getting something useful out of it). People will not take the time to learn a system that does not have useful information: if all they have are the note and message functions, its utility is small, (although these functions are important and some OA systems are designed just around notes).

We suggest that the system population be enriched as soon as possible. We added approximately 15 terminals per month (25 users per month), but doubling this number would have been more productive. Additionally, the service divisions or entities of the corporation should be made part of the system as soon as possible. This allows the support people to become productive almost instantaneously. The message here is to not be discouraged by the lack of enthusiasm among the users. At the beginning, having a sparse population is like having a telephone with no one to call.

In an early, sparse system, the financial systems and other individual productivity aids predominate. As the system becomes richer and the conductivity fuller, mail and documents become the most popular features.

We would now like to discuss the implications of having a “rich” vs. “sparse” network in terms of individual use of the system. From observation, the typical nonda ta processing user can be thought of as going through five phases. We call the first phase tinkering or learning. Depending on the number of people on the system, this can last anywhere from one to six months, with the average around three months. During this time the unsophisticated user (not data processing oriented) learns how to use the machine, not that it actually takes three months to learn, but rather that the user is “too busy” to read the manual or ask questions. After the initial tinkering stage, there is a two- to three-month getting acquainted period. The user starts to generate mail, type a few documents, and use some of the applications on the system. No (real) productivity is gained during this time, just an awareness of what can be done. We call the next phase the suggestions phase. During this phase the user realizes the potential of the computer and becomes an instant expert on how to do things better. Suggestions come pouring in on what to put on the system and how to make it more productive. Overlapping this suggestion phase is the commitment phase. At this point in the user profile, he will not move to another office when office moving time comes around unless there is a terminal in his office (similar to a telephone). The next phase is the most important, the synergistic phase. It is at this time that individual users help and compliment one another on the system, and we finally see corporate productivity increases rather than just individual productivity gains. From
beginning to end this cycle can take anywhere from 6 to 18 months depending on the background of the individuals involved. This is why we previously stated, “Don’t get discouraged during the early life of the system or when suggestions come pouring in.”

Initially, we spent about three months (one person) in developing the training manual and procedures. For the first 50 users, we trained on a one-to-one basis; for the next 100 users, we trained on a one-to-three ratio, with one-to-seven for the remainder of the early population, (the first 250 users). Our philosophy was that we should build a strong foundation during the first 50 users, so that they could be called upon to answer questions from their coworkers (the next generation of users). This philosophy works out very well.

Concurrent with training, we established a user services group (three staff); one telephone number was established by which all questions could be handled. We also instituted monthly user meetings where innovations and particular questions could be discussed and guest lecturers presented. We are now starting to use computer-aided instruction.

Although we feel that our initial training mode worked out well, we recommend a slightly different approach. More effort should be spent in the development of training material, and several skill-level/position-level materials should definitely be prepared. A training ratio of one-to-five with a large-screen terminal projection, followed by a 30-minute one-to-one follow-up is recommended.

Once the network is enriched, users tend to help each other; so, the task of training should actually decrease as users are added to the system. Although there are more individuals to train, there are more training aids around.

We keep an accurate record of all questions and comments that come into our user services group as an example of the problems and questions that arise. The format is as follows:

- General PROFS (five categories)
- General “other” software
- Hardware (when system is down)
- Administrative (training requests (other than PROFS); documentation)
- software
- Word Processing (Wang or NBI questions)
- UNIX
- Cable Plant
- Personal Computer
- Miscellaneous
- Consulting (more than 15 minutes on the phone)

Once a significant number of users have been added to the network, system reliability is a major issue. Therefore, it is prudent to have accurate records of why the system, or any component, is down and what the “fix” or resolution is. This is important, since you will often hear, “the system is always down,” when actually it may have been down for only five minutes during a given week.

In regard to our local area network (LAN), we found that there is plenty to choose from. But remember, a LAN may not be for you. In our installation the cost for the backbone cable ran from $5 to $10 per liner foot, depending on the building layout size (e.g., needing amplifiers). This averages $300 to $1,000 per drop or tap, depending on the building configuration. For comparison, point-to-point averages $500 per terminal.

One important item is new skills; the type of person needed to run this type of activity is usually not within the organization. And, of course, the LAN facilitates office moves.

One is always asked, What are your productivity gains? How many people have you let go?, etc. The answer to the first is, “don’t know and probably won’t,” and the answer to the second is, “none...but you can be sure, things get done faster, more efficient, and with better results.” We usually don’t get rid of people, but redefine their roles.

We make no attempt to get a productivity figure, but we do make an attempt to evaluate the system. This is done in several ways: first, we get user feedback on a daily basis; then meetings and our PROFS Answer Line (PAL) provide additional feedback. We also investigate the usefulness of the system by means of questionnaires, telephone interviews, and usage data.

Most importantly, we get feedback on how the system has changed the way we do business, both as individuals and as a group. As individuals, we see uses other than OA functions being used, e.g., spreadsheet. As a group, we see reports going electronically to our sponsors, remote sites sending their documents for review back to the main office, and more dialog among and between groups. We see the service organizations modernizing in large ways.

Health Effects

When the potential health effects of using VDTs came up, we performed a literature review in the area of terminal effect on operator fatigue. The study covered optical, musculoskeletal, morale, and radiation issues. The medical literature revealed little risk in all areas. We realize that the specific area of radiation is not satisfactorily documented and is still an area of volatile discussion. Additionally, VDT use and eye strain are still being investigated.

The Computer

In this section, we describe the facilities we employ to deliver the office automation service to our customers.

The overriding goal in an office automation environment is excellent response. The most important aspect of excellent response is choosing the correct definition of excellent. At the MITRE Washington Computer Center (MWCC), we aim for a general consensus that our response is excellent. Customers are encouraged to send notes or mail to the computing center management whenever they see a response problem. Regular presentations are made to the community describing our response measurement techniques, and as a consulting company, we have an internal interest in both the techniques and the results.

Office automation makes everyone neighbors and removes (at least in its initial phases) the traditional management lines of filtering. Everyone becomes a performance expert, every-
one wants a hand in running the computing center; and everyone has instant access to everyone else. Thus, the systems team must be selected and trained to be customer-oriented; and although we have a user services section, each member of the systems team and operations staff must always be aware, and willing, to work with any user or customer who is having a problem with the delivered system.

Our present configuration is an IBM 4341 with 16 million characters of main storage. Please note that this is a historical accident and not an endorsement of either IBM or the 4341 product line. While this device serves our needs very well, MITRE is in no way suggesting this as a recommended device, nor are we in the position to comment on the strength of this compared with other, similar configurations proposed by other vendors.

The local area network has substantial performance impact since it presents each terminal image to the central computer as though it were locally attached to the CPU, thus yielding substantial (over one second) performance improvements. The customer on the remote end of the local network sees these performance improvements directly.

The path between the central computer and the remote terminal is operated at 9,600 bits per second, roughly 1,000 characters per second. In a normal IBM remote terminal environment, the screen of a remote terminal remains blank until the full image is transmitted (1,920 characters plus overhead). Thus, in a normal multibuilding campus environment such as MITRE, the fastest response that can be delivered is a woeful two seconds per screen (assuming zero CPU).

Performance in a growth environment requires an understanding of both the growth effects and the prediction of added load to be placed on the system. As we described earlier, we have a clear understanding of our expected load growth. We are adding 15 terminals per month for the next three years (approximately). The main effect is in the increase in logged-on-users. We are growing at the rate of approximately five users per month (about one peak logged-on user per each three new terminals).

The number of active users is a better indication of the load on the central facility. It is well known that a CPU will support a large number of terminals if they are not used. In our office automation environment, logged-on terminals tend to be active because of a strange anomaly of our office automation software: it keeps a clock on the screen up to date by refreshing the screen once each minute. Thus, the active user count is also growing by about one user for each three terminals added to the network.

Capacity comes in chunks; a machine is typically either upgraded or replaced whenever there is insufficient capacity to support the required workload. Given this fact, we can expect response to degrade slowly as the user load grows until the response goals are no longer being met consistently. At that point (or ideally, just before), a capacity upgrade is required. This, in turn, causes an improvement in response and the cycle starts again.

There are many elaborate tools for capacity planning on the market. Each attempts to predict, based on past performance, when the present hardware will become saturated and require upgrade. If you are fortunate to locate a measure of performance that correlates well with response, you may save a lot of money and time. In our case, interactive response time is reported by the system. The reported figure is the inboard response and does not include communication software, line, and terminal delay. The time the user sees is not as good as this number, but it is a constant ratio.

We have determined from previous experiments that interactive response time below 200 milliseconds is excellent. We are not claiming that the end user sees response within 200 milliseconds of the pressing of a function key. While we believe it is close, we have not measured this number and can make no such claims. We prefer, however, to state that the response delivered is well correlated to the number presented, and the majority of our users feel that response is excellent when numbers below 200 milliseconds are reported by the system reporting software.

During a typical day, six to seven seconds per minute are devoted automatically by the computer scheduling software to the interactive OA users. This low percentage of the CPU resource (10%-12%) is sufficient to provide a repeatedly measured response time of less than two-tenths of a second for all interactive transactions of a short duration. Those interactive functions of a longer duration, such as database queries and massive report generations, are detected by the computer scheduler and scheduled over a one- or two-second period by the remaining 80% to 90% of the CPU resource.

Modern disk subsystems provide a large amount of data per disk. We have found that our disk access mechanism will serve between 15 and 30 simultaneous office automation users, providing for their storage and systems support needs in an efficient and timely manner. Currently disks yield about 10 million characters of storage per user by just providing sufficient disk drives to meet the needs of system responsiveness.

This leads to a very well balanced condition in a modern operating system environment that permits the mixing of system and user data. Each increment of user growth requires more storage for private data and more access arms to ensure excellent system response time. Both are delivered in a balanced package with modern disk subsystems.

Real memory is the critical factor in delivering excellent performance in a central support office automation configuration. Each vendor’s scheme for mapping virtual storage into real memory differs in its implementation detail; however, all must be provided with sufficient real storage to ensure that most of a user’s program is in real storage whenever required.

In our environment, we feel that a program portion, or page, once referenced should remain in real memory for a minimum of 10 seconds before being replaced by another user’s pages. Our current 16 million bytes of real memory constantly better this goal for a peak of 180 simultaneous users.

Bottlenecks always exist in meeting the stated performance goals for any computing center. In an office automation environment, they extend beyond the traditional CPU and DISK SPACE numbers normally considered in a batch environment. The nontraditional bottlenecks extend to printers, communication ports, and terminals. High-quality printers are a must in an office automation environment. It is a myth that electronic mail replaces paper. Try to read a 500-line message
on a video terminal. A hundred or so lines into it, you automatically reach for a magic marker and circle something to go back to for further study. The result, in our case, is needing a cloth and a spray bottle to clean the screen several times per day.

Our customers depend on the timeliness of the printing facility to meet their production schedules. Several very high quality printers must be utilized to ensure sufficient capacity and redundancy for any expected action. For example, this briefing was prepared electronically on an IBM 6670 LASER printer using software developed at the MWCC. The final charts were previewed on the terminal and only a single, camera-ready copy was produced on the printer.

You might think this would reduce the printing demands. Actually, the opposite has proven to be true. Our customers were expecting several-day turnaround for the production of high-quality VUGRAPHS by the reprographics department. We have shortened that time to 15 minutes. Unfortunately, the customer has also shortened the time before the briefing to work on the presentation by a like amount. Thus, the computing center must be able to deliver very rapid turnaround with extreme reliability whenever the VUGRAPH software is invoked.

CPU BUSY is the first number everyone wants to know when looking at response. It is not an important number in an OA environment since BUSY is normally a measure of batch rather than interactive workload. A better number is the number of seconds per minute the CPU spends servicing the interactive workload.

A channel is a path from memory to a direct access device, tape, or communications controller. In our environment, no more than six disk drives share a single channel. You may be able to support more or fewer disks per channel depending on the speed of the pack and the size of the disks.

There is no single value that can be determined for all hardware and software configurations; however, any one configuration should work for a balanced configuration, acquiring hardware and relocating data to meet this need.

In the environment shown, we began an aggressive balancing program in January and are now running a balanced I/O configuration.

Real memory is the critical determination of response in office automation or any other environment employing IBM equipment. We suspect real memory is the critical response factor in any environment. Real memory usage is a difficult item to measure precisely. We have examined many different reports to try and identify a single number of sets of numbers that characterize the utilization of real storage in our environment.

In doing this, we examined the dynamics of paging in our computing center. Our system operates in a demand paging environment. This means that a user’s program does not require storage sufficient to hold the entire program before it can begin operating. The result, in a memory-constrained environment, is frequent suspension of the program while additional portions of the code or data are brought into memory from a backing storage device such as a disk.

When a user’s program finishes executing, the code and data remain in storage for some time until that area of memory must be reused by other users for their code or data. Ideally, an active user will always have all code and data in storage for each execution of a program. Since OA customers tend to perform the same functions over and over, there is generally little or no paging or other I/O activity required; thus, excellent response is possible without exotic system tuning.

In our environment there is a table, called the CORE-TABLE (historical interest in core memory), that is scanned to find free pages. The system reports the rate of scanning of this table (SCAN RATE) in one of its regular performance charts. The change in SCAN RATE took place when we added an additional eight million characters of real memory to our overloaded computer.

SCAN TIME, the reciprocal of the SCAN RATE, is a derived number that IBM does not directly report in their performance software. A portion of a user program will remain in real memory for 10 seconds if it is not utilized. For example, if an OA customer uses a program section more often than once per 10 seconds, no I/O will result when the SCAN TIME is longer than 10 seconds.

There is a tendency to understimate the costs of implementing an OA program throughout the company. Management is prone to forget the second-order costs and focus on the cost of the terminal and the terminal support cable plant.

Often there is a CPU replacement or upgrade required. There is always more printout, and printout of a more urgent nature. In our environment, much of the new printout can be of a sensitive nature (performance reviews, interview reports) and must be specially handled and retained for the users in a dispatch area.

The training demands jump. Prior to OA, our systems programmers conducted classes informally, as our user community was small and stable. Now, we have a very large percentage of nondata processing users with urgent training demands. Frequently, these training demands are placed on us by high executives who are satisfied only with, “Yes” or “Yes, sir,” as answers to our schedule conflicts.

Documentation must often be written (or rewritten) to address customers who have never used a central computer before. Have you ever pondered how many different ways to spell ENTER as you survey the range of terminals that use RETURN or various graphic symbols rather than one consistent symbol?

Everyone wants to manage the computing staff. Systems team members suddenly get messages from vice presidents and are expected to be at their beck and call. Substantial interpersonal training is required of the systems team. Members who were accustomed to hiding are suddenly connected electronically with everyone in the company.

Operations and system members must become diplomats! We have replaced nearly our entire systems team since the office automation project began. New systems programmers are selected as much for tact as for technical skills—it is a myth that systems people are hard to deal with and each systems programmer tries to cultivate that myth. There is a large group of professional systems programmers who understand they are responsible for many millions of dollars and long for the respect and responsibility that such investments
demand. Our staff has an excellent attitude toward our customers and recognizes that each of them directly contributes to support our mortgage, hobbies, growth, and professional aspirations.

One of the good (and bad) side effects of a centralized office automation configuration is that everyone in the company becomes a performance expert. Terms such as Q1TIME, SRM, RMF, PAGE RATE, and such are not the measure of excellence in performance. Use terms such as excellent, good, fair, and poor; and encourage complaints when response is other than excellent.

Measure everything easily available in your environment and look for items that correlate well. Hunt for those numbers that change sharply with a small change in response. Consider yourself, or your performance expert, as a detective. Request regular reports and expect presentations on trends and bottle-necks on a frequent basis.

Excellent performance is mandatory for office automation. Our software performance measurement tools report the introduce response time, excluding network delays, as 200 milliseconds maximum. This number is not an absolute measurement, but an indication of excellence. Users are consistently satisfied when the number is two-tenths of a second or below and begin to grumble when it rises above three-tenths of a second.

You must rethink and understand your goals in a large OA environment. Batch production must take second place on the machine dedicated to supporting the office automation customer.

The growth of the computing terminal network will be a byproduct of OA. The decision to introduce OA carries the decision to provide a very large number of terminals for use by professionals and support staff. It is MITRE’s goal to install a terminal in every office occupied by professional or support staff. You cannot expect people to walk down the hall to use the telephone or read their morning mail.

User support is absolutely required in an OA environment. We select a portion of our user support team from the secretarial staff to ensure a minimum of jargon and ensure a good relationship between the customers and the support people.
Computer hardware and architectures

Faye Briggs, Track Chair

Achieving high performance in computer systems depends not only on using faster and more reliable hardware devices but also on major improvements in computer architecture and processing techniques. The Computer Hardware and Architecture track focuses on these issues. The track is composed of nine sessions that address the new generation of high-performance computers. The topics of these sessions are

1. Trends in Supercomputer Systems
2. The Fifth Generation
3. VLSI Design
4. 32-Bit Microprocessors
5. Attached Numerical Processors
6. New Microprocessor-Based Computer Architectures
7. Multiprocessor Systems
8. Distributed Processors
9. System Reliability

"Trends in Supercomputer Systems: Design and Use," a panel session, discusses five major issues: new system organizations, design trends, application software, the implications in operating systems and languages, and the Japanese effort in these areas. Another panel, "The Fifth Generation Revisited," follows the very successful panel on the same subject last year. The objective of this year's panel is to present an updated report on the status of the various worldwide programs that are fifth-generation computer research and development efforts.

"VLSI Systems" is a paper session investigating the impact of VLSI designs and structures on computer architecture and hardware. The session starts with a tutorial paper on the status of VLSI. A design automation system and a sample design and application of a VLSI co-processor will be presented.

The new generation of "32-Bit Microprocessors" and microcomputers is organized as a paper session. This session looks at the organization of these new high-performance microprocessors and the new challenge for integrating them into systems. They display advanced architectural features often found in minicomputers and mainframes. Examples of features presented are pipelining, prefetching schemes, larger virtual and physical address spaces, and data buffering schemes. "New Microprocessor-Based Computer Architectures" takes a look at complete computer systems based on these newer microprocessors.

The next paper session, "Attached Numerical Processors," looks at the software and hardware approaches to implementing floating- and fixed-point arithmetics for use in the new generation of powerful microprocessors. The goals and design tradeoffs for one specific system are presented, and a new approach to designing a fast numerical workbench is also discussed. The latter scheme uses a set of replicated functional processors for fine and coarse granules of numerical processing.

Two sessions are devoted to multiprocessing systems. The previously mentioned session, "New Microprocessor-Based Computer Architectures," focuses on how to exploit these new microprocessors in multiprocessing and other distributed applications. A paper session on multiprocessing investigates general multiprocessing concepts. The first paper illustrates the design of a high-performance multiprocessor using off-the-shelf microprocessors. The other two papers discuss new data-sharing techniques and models to estimate the throughput of multiprocessor systems.

The "Distributed Processors" session consists of papers looking at new techniques for network control. The first paper investigates a new bus arbitration scheme when VLSI func-
tional units are distributed on the network. An innovative concurrency control mechanism and a practical implementation of a network operating system are also presented.

Finally, we have a paper session, "System Reliability." This session investigates innovative methods for diagnosing a multiprocessor system and methods for incorporating fault tolerance in system-level designs.

In summary, the Computer Architecture and Hardware track presents exciting continuity in the quest for reliable high-performance computing structures that are needed for the exploding computing needs of the late eighties and nineties.