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LIVING COMFORTABLY WITH NETWORK GROWTH*

BY

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Providing a communications network in a rapidly expanding environment opens an opportunity for enhancing operations, even though, if improperly managed, it also carries with it the potential for spiraling costs and gross inefficiencies. At Stanford Linear Accelerator Center (SLAC), when uncoordinated growth threatened to make the latter possibility a reality, we took the opportunity to regroup, streamline our terminal network, and provide better control and monitoring of its operation at the same time.

The key step, taken in 1981, was to configure the network around an expandable, intelligent data PABX with extensive control and statistical reporting capabilities. Along with the flexibility to accommodate a variety of functions, this system controls and coordinates use of the terminal network at the same time that it provides orderly, easy-to-use, interactive access to the network for a large variety of users.

Today, more than 700 terminals, 24 Digital Equipment VAX Corporation computers, and the IBM 3081 mainframe at SLAC are interconnected via a MICOM Micro600 data PABX. Researchers from the U.S. and other nations, including Switzerland, Germany, and England, can connect their terminals to the SLAC data PABX computer network via the dial-up phone system and via Tymnet. Also, on-site SLAC researchers regularly connect their terminals, via a data PABX dial-out facility, to computers located elsewhere in the U.S. and in Europe. Further, we are in the process of expansion to tie in directly with computer networks in Europe, with additional networks in the U.S., more facilities at SLAC, and with other high-energy

physics labs to keep pace with the growing demands that bigger and more complex investigations continue to place on our facilities.

THE PROBLEM

Just as successful businesses tend to expand, successful research almost inevitably results in pressure for further research -- the deeper we delve into the universe, the more we find there is to learn. Typically, when the Voyagers flew by Saturn, rather than provide an explanation of the rings, they showed us that these fascinating structures are more complex than anyone had ever imagined.

Similarly, in our own subatomic world of high energy physics at SLAC, each breakthrough tends to bring with it a multitude of new questions. And just as new questions about extra-terrestrial conditions require more sophisticated space probes to find answers, new questions about subatomic particles necessitate bigger, more complex experiments to gather the data that is needed to bring us closer to a true understanding of the basic building blocks of the universe.

Because of this, the pressure for new research tools at a national lab like the Stanford Linear Accelerator Center is enormous. And that includes pressure to add or expand computer systems and networks.

THE FACILITY

The Stanford Linear Accelerator Center is operated by Stanford University for the U.S. Department of Energy and it

is devoted to experimental and theoretical research in elementary particle physics, and to the development of new techniques in high-energy accelerators and elementary particle detectors. SLAC is located on 480 acres of the Stanford University campus south of San Francisco.

The two-mile long linear electron accelerator is the major experimental facility at the center. It generates the highest energy electron beams available in the world. It was experiments with this machine, which may be thought of as a very powerful microscope, which showed us that the heart of the atomic nucleus, the proton, is itself composed of still smaller particles.

Following this discovery, an electron beam storage ring was constructed in which particles from the linear accelerator could be made to collide. These collisions resulted in bundles of energy from which new particles emerged. This in turn led to the award of a Nobel Prize to SLAC's Burton Richter for the discovery of the psi particle, and after that to the construction of an even larger colliding-beam storage ring, one which provides collision energies four times those attained with the original ring. Today, it has become obvious that the future of this field of basic scientific research depends on machines that will produce colliding beams of ever high energy and SLAC is currently constructing a \$114 million linear collider to enable it to stay in the forefront of high-energy research.

For all of this rate of investment in physical research, as late as 1974, our communications capability centered around 60 IBM Selectric® typewriter terminals and a few CRTs in pool areas for the physicists. Until 1979, terminals still were located only

in pools. But as SLAC's terminal use expanded, this arrangement increasingly hindered people's ability to work efficiently and nowadays many terminals are located in individual offices.

However, many terminal users needed access to more than one computer. Initially, this was solved by the simple expedient of placing one terminal for each computer in the users' offices. This required extra cabling, extra terminals, and extra ports. Eventually, we found ourselves running out of computer ports at the same time that the demand for additional terminals was outstripping our resources for acquisition and installation.

THE SOLUTION

To bring the situation under control, a Micro600 Data PABX was installed in the computer facility as the hub of the terminal network. All cabling extends from this unit to terminals, computers, and other services so we have a central point from which we can provide some control and monitoring of network operation.

With the Micro600 in place, we have, in essence, a state-of-the-art private telephone network for data. Instead of a telephone set at each extension, we have either a terminal or a computer port. The data PABX makes connections between terminals and ports in response to requests entered at the keyboard; then once a connection is established, the data PABX becomes transparent to data until it recognizes a terminal's request to disconnect.

The data PABX provides features similar to those found in today's newer voice exchanges, but adapted to the data-only environment. A basic example of this adaptation is how the user specifies the destination when asking for a connection: where the

voice user can most easily enter a series of digits (because telephones have numeric keypads), the terminal user can easily request a resource by name, such as SYSTEMA. And we get the effect of a telephone rotary -- where one number selects the first available extension among several -- because a name can refer to any number of computer ports. Our Micro600 also provides features akin to "camp-on-busy" and "call forwarding."

For controlling the network, the Micro600 has a command port. Via a terminal connected to the command port we can redefine the "Class" names (like SYSTEMA) that refer to ports, we can enter new security restrictions, take entire classes of ports out of service for preventive maintenance, etc. In short, the command port lets us react to our changing environment.

However, we soon saw the need to have an external computer take over the connection to the command port. The computer, a PDP-11/60 running SLAC-developed programs, allows more than one person to share the Micro600's command port and eases the tedious task of reconfiguring the Micro600 in several predictable situations, such as preventive maintenance to a host. (The role of the 11/60 is described in more detail later.)

Any asynchronous terminal can be connected to the data PABX, allowing a major cost savings where terminal population growth is involved. It is not even necessary for terminal speed to be known in advance -- the Micro600's autobaud feature provides automatic terminal speed detection up to 9,600 bits per second.

Terminals are connected to the PABX in a variety of ways. They can be directly cabled or connected by line drivers if the

distances are short. For longer distanes, terminals can be connected via modems and dial-up lines. Each incoming interface is monitored by the Micro600 just as a local interface would be, and its access to port classes can be restricted for security purposes by entering commands via the command port.

To control the Micro600 and thus the network, SLAC connected a DEC PDP-11/60 computer to the data PABX's command port. This provides for automated management of the Micro600 at the same time that the computer accumulates usage data via the data PABX's Statistics Log Output. The statistics log provides time- and date- stamped records of the switch's operation, including all connections, disconnections, and failures to connect (along with the reasons for failures).

For a user, the Micro600 makes accessing the network simplicity itself -- he or she simply depresses the RETURN key on the terminal. The data PABX responds with a message requesting the class of service the user desires and the user replies by typing in the class name. (The class designations can specify a certain computer, specific ports on a particular computer, or other services that the network offers.) Once the user enters the class designation, the data PABX makes the required connection and displays a GO message on the terminal. Or if the connection cannot be completed, the data PABX displays a message on the user's terminal that indicates the reason. If all of the ports in the requested class are in use, the Micro600 responds with a BUSY message and tells the user how many others are waiting for connection to the class. Then, the user can opt to get into the queue and

be connected automatically when a port becomes available or to disconnect and try again later.

This puts contention for available services on an orderly basis, and the interactive communication with the data PABX makes the system "friendly" to work with.

CONTROL

The main reason that we have been able to comfortably handle rapid network growth and keep pace with SLAC's operations is that the Micro600 provides comprehensive control and statistical reporting capabilities. Thus, we are able to monitor and manage use of the network to provide users with maximum capability.

The PDP-11/60 computer connected to the command and statistics ports on the Micro600 is programmed to provide instructions for the Micro600 in response to commands from the terminals. Knowledgeable network technicians can access the PDP-11/60 through the Micro600, get help, and find out the states of designated lines and ports. In fact, multiple terminals can interrogate the data PABX simultaneously.

Even more important, however, is the fact that those of us responsible for the network not only can interrogate the network, but under password control we also can change configurations to put individual or groups of terminals or ports into or out of service. For predictable situations, such as scheduled maintenance or testing of a front-end terminal control unit, we have programmed the PDP-11/60 with reconfiguration commands and

appropriate messages for display on user terminals. The PDP-11/60 also automatically can monitor the Micro600 and, for example, make simple adjustments to terminal inactivity timeouts based on usage and/or time of day.

For management, the PDP-11/60 continuously monitors the statistics port, and every time a terminal accesses the Micro600, it creates a session record, complete with such information as start and end times, class, line port, number of ports of that class currently in use, etc., and adds it to a log on disk. Each day, the log is transmitted to the IBM 3081 where it is used to generate detailed summaries showing the time each line was used, along with other information that aids us in pinpointing potential trouble spots in order to take remedial action before they develop into real problems, and to plan for future growth.

For users in central areas of SLAC, we developed an additional, inexpensive aid for working with the network. The 11/60 accumulates key information from the session records, on the fly, to arrive at totals for lines in use, ports in use, number of people waiting in queue, and so on. The totals are transmitted to an IBM PC where they are used to periodically update usage statistics and merged with other data, such as listings of units that are out of service. This information is passed to a Commodore VIC-20 computer which formats it for graphics and transmits it to other VIC-20s in more populated locations. The latter VIC-20s display the information on large, easy-to-read color monitors so users can check on the network at a glance.

SPECIAL FEATURES

With the data PABX forming an intelligent hub for our network, it is easy to provide customized functions that suit our particular requirements. A few examples illustrate the scope of this capability:

LOOP: A port on the Micro600 is wired to loop back to the sending terminal. Thus, if users experience difficulty, they can quickly check their terminals by connecting to this port and seeing if their input comes back.

TRACE: This connects to a port on the PDP-11/60 which has been set up to tell users the MICOM address of the line they are using. Thus, if they have problems, they can supply information to aid in troubleshooting.

HELP: When users request the HELP class after they connect to the data PABX, they are provided with a listing of the classes of service available, important phone numbers, and instructions for using the network. (The HELP function is implemented on the PDP-11/60.)

DIAL-UP ACCESS: Users at remote locations can dial into the network via several modems that connect to the Micro600.

DIAL-OUT SERVICE: Outgoing traffic is handled through the Micro600's dial-out option, allowing access to off-site systems without having to equip each terminal with its own external telephone line.

PROTOTYPING: When we consider the addition of new types of networking gear, we usually can configure a small-scale prototype working version, connect it to the main terminal

network via the data PABX, and test it in actual operation. For example, at one point we were considering a major investment in another type of network technology for a specific application. By purchasing a small amount of the equipment involved and connecting it to the PABX, we were able to simulate the proposed network's operation on a small scale. When we worked with it on a daily basis, it turned out that the service was not suitable to support a general-purpose, SLAC-wide terminal network. Thus we were saved from making a costly mistake.

SPECIAL CONNECTIONS: Lawrence Berkeley Laboratory does a great deal of work involving use of SLAC facilities. Since these two locations are in line of sight, microwave communications proved to be advantageous. Also, since LBL's network is built around digital switch too, we were able to make switch-to-switch connections that provide virtually universal access within the two locations.

LOOKING AHEAD

For the future, we expect to see the number of terminals at SLAC growing at 30% to 40% per year and the demands on the network will surely multiply. Even today there are about 200 visitors from about 40 nations stationed here, major experiments often are ongoing and can involve more than 100 physicists from all over the world plus additional technical people, so there is no alternative to data communications to coordinate their efforts. In the same vein, SLAC collaborates in experiments at other labs. In some cases SLAC scientists work at other

facilities, such as the Deutsche Electron Synchrotron in Germany and CERN in Geneva, Switzerland, and then need a means of communicating with the resources here.

However, our present network has accommodated our requirements economically and efficiently because:

1. A central, expandable data PABX allows for easy network growth.
2. Complete, internal system redundancy makes it relatively easy for us to switch the entire logic, etc., in order to more quickly recover from a failure.
3. Inexpensive, dumb terminals can be used with the network.
4. The data PABX provides the control and flexibility that are necessary for maintaining efficient service and adding needed features as the network grows.
5. And last but certainly not least, the ease and straightforward manner in which the data PABX is used means that users need only minimal training in the use of the Micro600.

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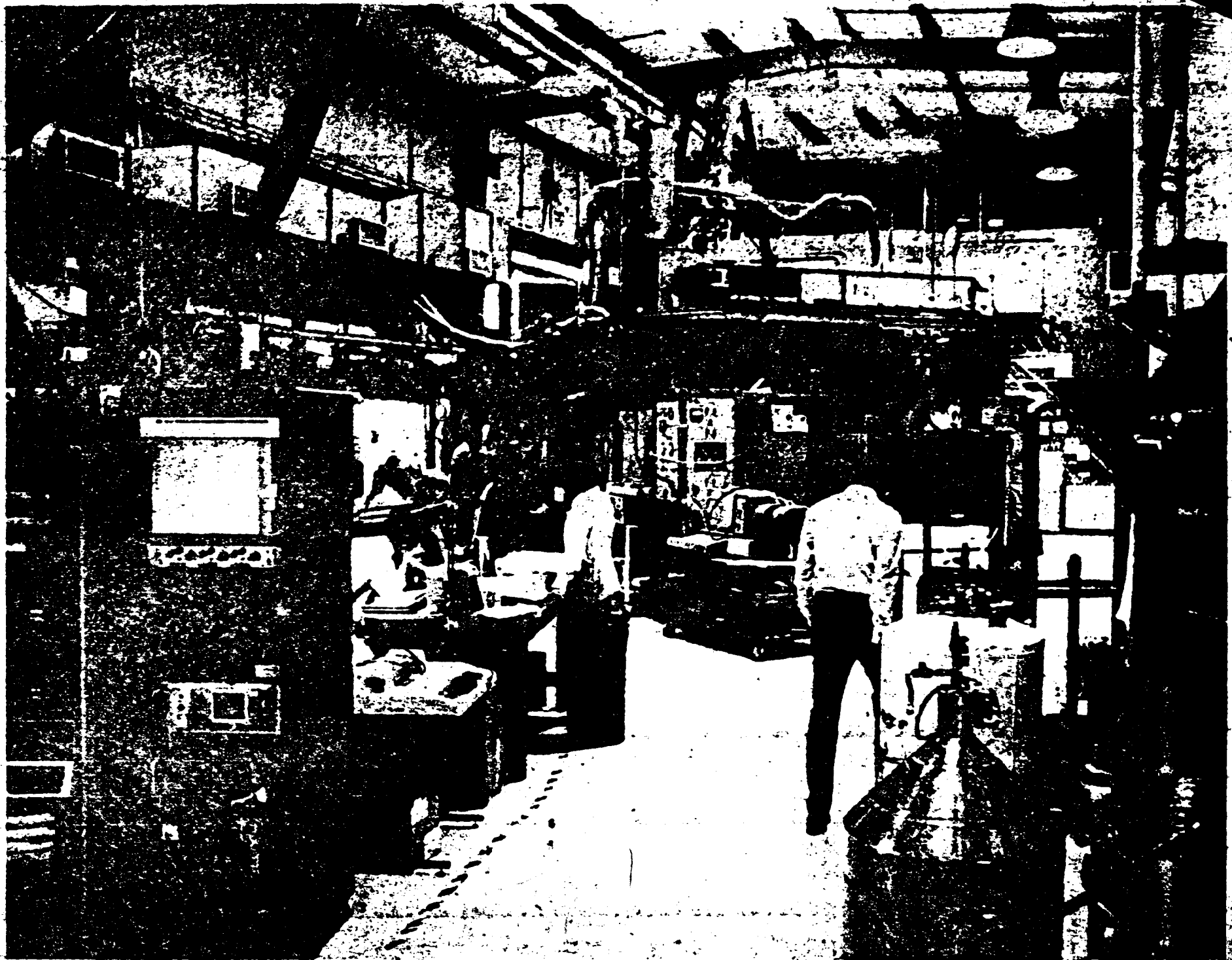
PICTURE CAPTIONS

1. At Stanford Linear Accelerator Center, terminals and computers in experimental areas like the one pictured, along with mainframes, computers at other universities, additional terminals, remote work stations, and several outside networks are interconnected in the facility's network.
2. The key to living with network growth, according to Dr. R. L. A. Cottrell (right), seen here with Charlie Class who heads the Network Operations Group, has been to install an expandable, intelligent data PABX like Stanford Linear Accelerator Center's MICOM Micro600.
3. In central areas of Stanford Linear Accelerator Center, a continuously updated series of inexpensive color displays, two of which are shown here, keeps users up to date on network conditions.
4. As experiments become increasingly complex and more individuals at widespread locations become involved, a streamlined data communications network is the only plausible way to provide access to resources, such as the IBM 3081 computer center at Stanford Linear Accelerator Center.

5. The two-mile long linear electron accelerator is the major experimental facility at Stanford Linear Accelerator Center. It can be thought of as a very powerful microscope used in studying the basic structure of matter.

(diagram)

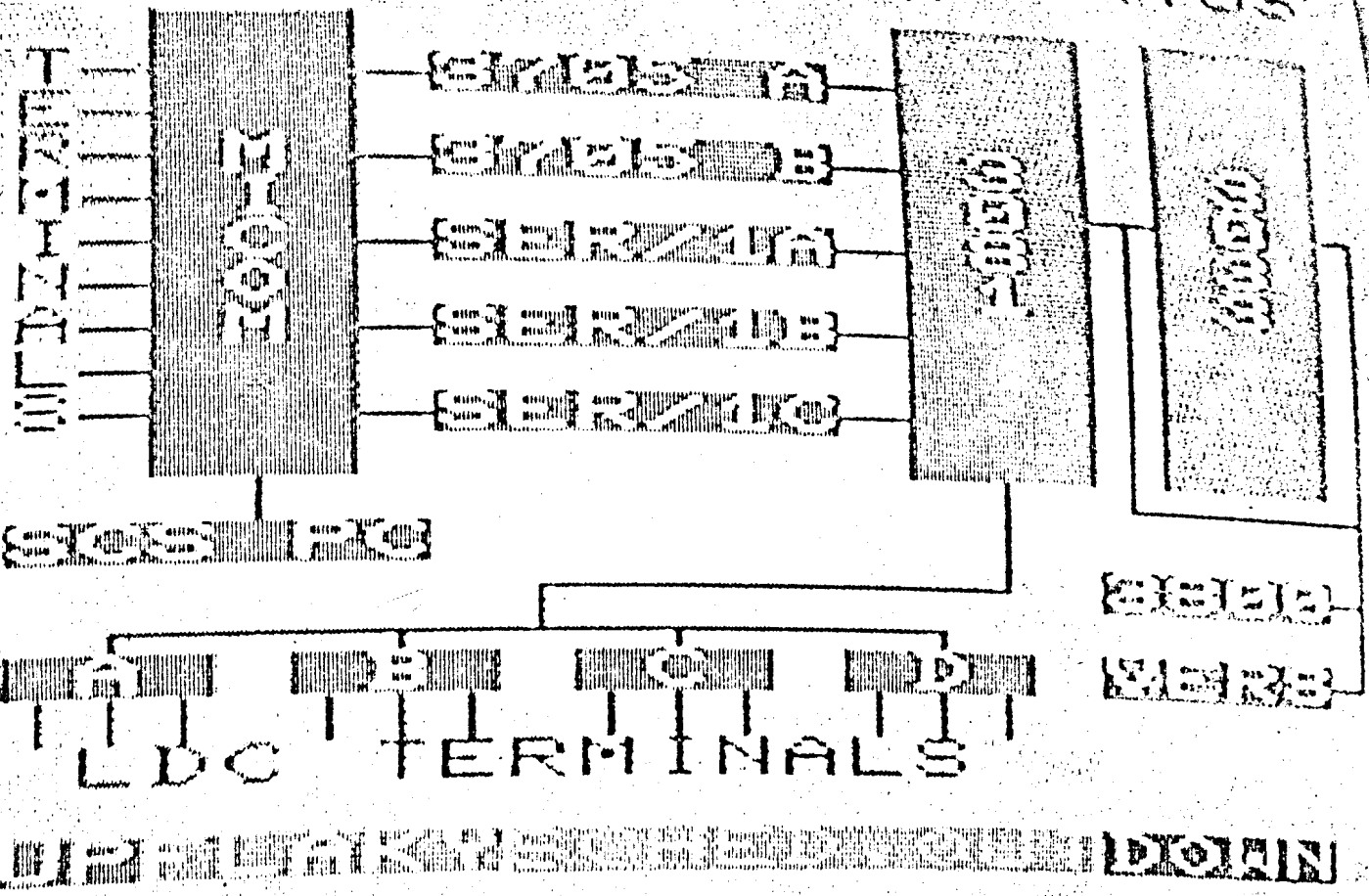
6. The Stanford Linear Accelerator Center Network.





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ANALOGOUS COMPUTER SYSTEMS



(a)

FINANCIAL RECORDS AND REPORTS

BATCH JOB BOOK LOG
LEAD HOURS

LEFT JOVER
JOB USER

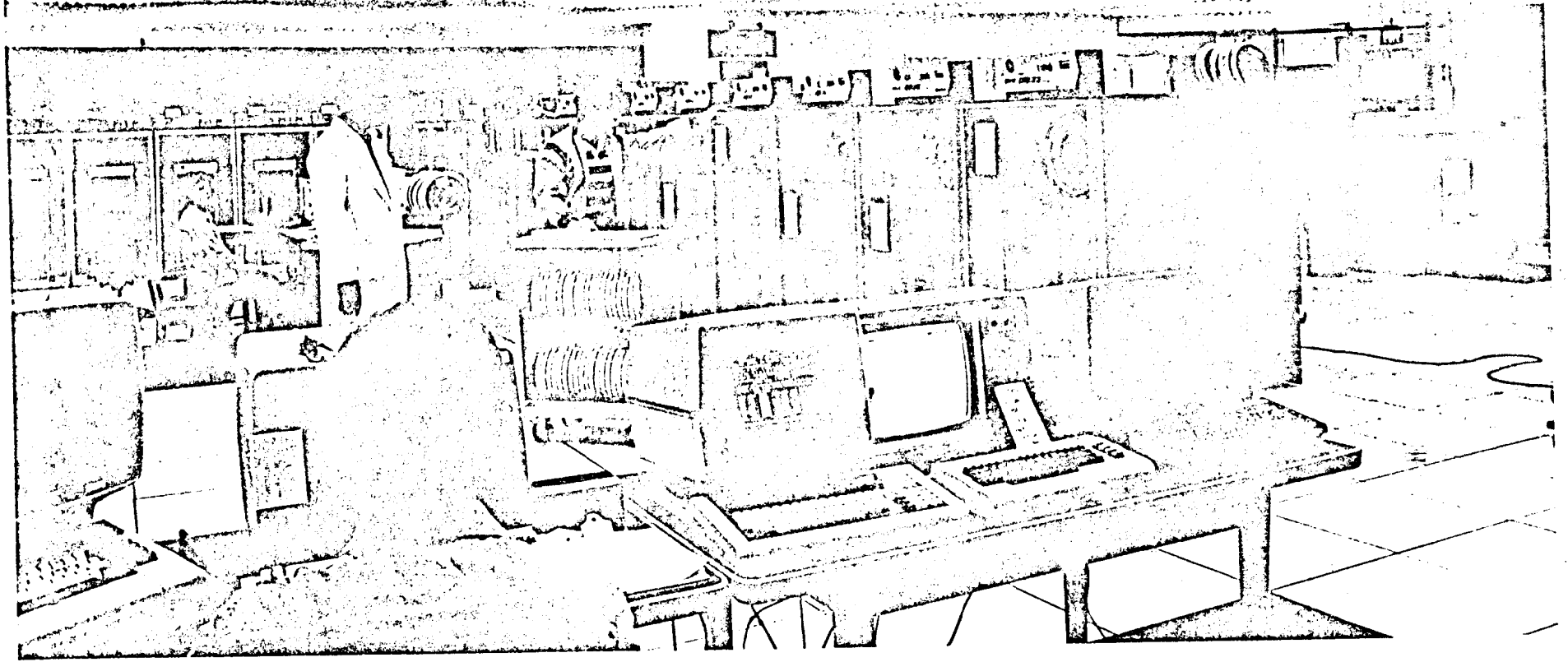
USERS
OFFICE

EXPANSION FACTOR

RESPONSE TIME
JOB USER

PRINT JOB LINES

DOWN JOB LINES



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