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Computer and Information Networks

The movement in research and education toward national resource sharing via networks is accelerating.

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A medical researcher sits at an online terminal in Honolulu searching an index to the world's medical literature stored on a computer in Bethesda, Maryland, over 5000 miles away. His request passes across a radio network of the University of Hawaii; the telephone network of the Hawaiian telephone company; the Pacific Ocean via an international satellite; a nationwide research network in the continental United States; and, finally, a commercial time-sharing network, before reaching the medical information system in Bethesda. By mail the request would have taken several days. By computer-communication networks it takes less than 5 seconds. The response to the request, a set of literature citations, starts printing out at the terminal back in Honolulu within 15 seconds from the time the request was dispatched. Numerous other remote users of the medical information system receive service simultaneously.

This example of what is happening now may seem dramatized, but it does illustrate the daily use of a variety of communication networks that are currently providing efficient interconnection between computer systems for their users. Domestic usage of the online medical information system through the commercial time-sharing network has been doubling every 6 months. This fact plus countless other important uses of networks in many areas proclaim the growing significance of information and computer networks. The possibilities they offer in research and education point to new and better computing and information services, greater efficiency in operations, broader markets, widespread access to facilities, and extensive resource sharing.

Responding to the heightened interest in the possibilities of networks, and reflecting its own continuing interest in improving the use of new technologies in research and education (*1*), the National Science Foundation (NSF) in 1972 announced the mounting of "an expanded research program . . . to explore . . . the resource-sharing potential of a national network in support of research and education" (*2*). An NSF grant under this program permitted EDUCOM to bring together interested users and administrators with those possessing shareable resources and relevant experience in a series of three 2-day working seminars. The seminars, held in late 1972 and early 1973, were designed to help identify the central organizational, political, and economic issues in building and operating networks on a national basis.

EDUCOM has been concerned since its founding in 1964 with fostering the collaboration of colleges and universities in the use of computer and communication technologies. It has given the subject of networks special emphasis, beginning with its July 1966 summer study in Boulder, Colorado (*3*), and continuing with the open conferences that it recently has been holding twice each year (*4*). In these working seminars, highly expert technologists joined in discussion with social scientists, physical scientists, decision-makers, and others from many fields (*5*). This article is based on the results of their deliberations (*6*).

This article is adapted from the book *Networks for Research and Education—Sharing Computer and Information Resources Nationwide* (MIT Press, Cambridge, Mass., in press). It reports on a series of working seminars conducted by the authors for EDUCOM with National Science Foundation support. Dr. Greenberger, director of the seminars, is professor of mathematical sciences and senior staff associate of the Center for Metropolitan Planning and Research at Johns Hopkins University, Baltimore, Maryland. Dr. Aronofsky is professor of management science and computing at Southern Methodist University, Dallas, Texas. Dr. McKenney is professor of business administration at Harvard University, Cambridge, Massachusetts. Dr. Massy is vice provost for research and professor of business administration at Stanford University, Stanford, California.

Current Setup

Today there are, by estimate, 7000 computers in the United States whose primary business is processing information for research and education. Their combined annual operating budget runs into billions of dollars, of which more than $600 million is associated with higher education alone (*7*). The programs they run and the information they use are similar in general character and, often, in specific detail. These computers represent a national asset of considerable importance by virtue of the magnitude and nature of the work they perform and the missions to which their work contributes. One might expect their operation to be concentrated in relatively few places or at the very least to be well integrated. Yet the overriding pattern is quite the opposite. The 7000 computers are distributed in a large number of autonomous centers and laboratories that are separately staffed and managed. Autonomy and separateness are the rule, not the exception.

To understand the reasons, one must review the 30-year-old history of information processing in research and education and study how computers were introduced, developed, and marketed (*8*). Roles were played by computer manufacturers through their sales strategies and discount policies; by the federal government through its funding programs and restrictive rules; by research and educational organizations through their rivalries and proprietary instincts; and by technological advances, especially in minicomputers in increasing computer performance at dramatically lower costs.

Given the commonality in the work performed by the many autonomous centers, one might expect them to engage in a great deal of sharing of data, programs, and other computing resources. While some sharing does take place, its range is limited and it is beset by problems, not the least of which are the basic incompatibilities that persist in equipment, data formats, programs, and operating systems, owing to the lack of industry standards. Except for some cooperative groups of computer users and the customer support initiative of computer manufacturers, few organized sharing arrangements of any magnitude have prospered and grown; many have failed (*9*).

Technological Trends

Four significant technological trends are beginning to alter the organization of computing services in research and education.

1) Minicomputers selling for as little as $20,000 (and less) are becoming ever more powerful and popular, allowing computer users who were formerly customers of large computer centers to purchase and operate their own equipment.

2) The use of computers remotely, either in a time-sharing or remote job entry mode, is gaining in acceptance. This development frees users to look to outside suppliers (whether industry or other institutions) for the best service and price for their purposes.

3) Improvements in computer communications technology and in data transmission and switching procedures are making it easier and less costly to have connections between unlike computers running under unlike operating systems across great distances. The resulting networks are spreading and are beginning to provide what could become an important new mode, called *networking* (*10*), for sharing the resources and linking the otherwise incompatible procedures and formats of different systems and organizations.

4) Large, cheap memories make the amassing of ever bigger information banks feasible and dependent primarily on the cost of developing and maintaining the bank, thus tending to favor a single, centralized information storage and retrieval operation over numerous dispersed operations.

Many people regard the minicomputer trend as running counter to the remote computing and network trends. Users who acquire their own computers seem less likely to require the services of a remote computer or computer network. In a different sense, however, the trends are complementary and mutually reinforcing. They work to reduce the dependency of the user on the local center, they accord the user more options, and they increase the responsibility and freedom of the user to locate the best deal available. In addition, the use of minicomputers as message processors enhances the technical performance of computer networks.

These trends do not necessarily spell the doom of the local center, but they do suggest that the traditional autonomy of the center is shifting toward the user and that more and more the function of the center may be to help the user plan, compare, and choose among a variety of service alternatives. Not all users may want as much autonomy and responsibility as the new situation permits, and they may look to an altered kind of center for advice, brokerage services, and general assistance.

Current financial strains are causing many institutions of research and education to pay particularly close attention to the opportunities for importing and exporting services afforded by the technological advances. Some institutions have closed down their central computer operations, or important peripheral activities. Harvard University has removed the shingle from its central facility and returned its large computer to IBM. In taking this action Harvard at first planned to develop a joint computer center with Massachusetts Institute of Technology, but this plan gave way to an arrangement wherein Harvard essentially became a customer of MIT. Most recently, Harvard has set out to shop nationally for the best service available for each application. Other institutions may follow its example.

Ongoing Network Operations

As an experiment, one of the routes Harvard is taking in its shopping tour is through the national computer network known as ARPANET, developed by the Advanced Research Projects Agency of the Department of Defense (*11*). ARPANET interconnects several dozen heterogeneous and independent computer centers from coast to coast, through the use of broad bandwidth lines and an innovative communication procedure referred to by its developers as "packet switching." Two of the large university computer centers on the ARPANET in California were reported to be receiving as much as 20 to 25 percent of their total revenue from customers on the network within their first year of accepting such business. A major research institute at the University of Illinois is said to have given up its large Burroughs computer in order to use a similar computer at one of these network centers in San Diego.

ARPANET is just one illustration of networking. The NSF over the past few years has supported the development of about 30 regional networks among colleges and universities. Here the using institutions are often smaller schools with minimal computing facilities of their own. The better known of this class of networks includes those of Dartmouth College, the University of Iowa, the University of Texas, and Oregon State University.

Another form of network is the Triangle Universities Computation Center (TUCC) which provides computing services to the University of North Carolina, North Carolina State University, Duke University, and other educational institutions throughout the state. The MERIT network is a resource-sharing facility run by the University of Michigan, Michigan State University, and Wayne State University. UNI-COLL is an organization of the University City Science Center of Philadelphia that operates a combined computation center for a number of colleges and universities in the Delaware Valley by building on the University of Pennsylvania's computing system. A number of states—including California, Missouri, Illinois, New Jersey, New York, Minnesota, Oregon, and Florida—either already have or are developing statewide computer networks.

Networks are also being developed to widen the availability of science information services. The NSF is funding at the University of Georgia the construction of an information system with primary focus in chemistry and biology that will provide services to about 30 colleges and universities by means of the NSF-supported Georgia regional computing network. An information system under development at the University of California, Los Angeles (UCLA), will eventually service the nine campuses of the University of California. Remote television terminals at Lehigh University permit on-line users to query current articles and abstracts in a natural language, a service that Lehigh also makes available remotely to six other academic institutions in the NSF-supported Lehigh Valley regional computing network.

The Ohio College Library Center is operating an on-line shared cataloging service for 48 college and university libraries. This network has been extended to university libraries in New England, New York, and Pennsylvania, and it is about to be replicated in other regions of the country. The National Library of Medicine has established on-line search facilities to its medical library through the nationwide MEDLINE service, using the TYMNET communication network of the TYMSHARE Corporation (*12*). Massachusetts General Hospital and the Systems Development Corporation also provide national services via TYMNET.

Other commercial firms, including the General Electric Company, University Computing Company, and Computer Sciences Corporation, operate national and international general-purpose computer networks. Several companies, such as Keydata Corporation, Data Resources, Inc., and Interactive Data Corporation, use communications to furnish highly specialized on-line services and information resources to clients across the country. The over-the-counter securities market has an on-line national network for prices and quotations (NASDAQ). And the list goes on.

Possibilities and Requirements

The networking advocate sees in the trend toward greater networking profound possibilities for improving the organization of information processing and for expanding the sharing of information and program resources. The benefits envisioned include:

- Greater variety and richness of available resources and more flexible intermingling of information with computing services.
- Widened availability of resources to all institutions regardless of size, location, or financial status.
- Decreasing cost per unit of information stored or processed because of increasing economies of scale and expanded sharing.
- Payment for information processing as it is obtained, with virtual elimination of the capital costs and budgetary uncertainties currently characteristic of autonomous information and computer center operations.

Thus, the advocate sees networking as leading to increased integration, resource sharing, and availability and thereby to more and better services and higher efficiency.

If the advocacy of networking is indeed sound, obstacles that stand in the way of further network development must be recognized and overcome. The new problems that networking may introduce must be anticipated and, where possible, treated in advance. The resources really worth sharing must be located, new shareable resources must be developed, and the best ways for maintaining and distributing them must be determined. Special attention needs to be paid to support requirements, with multiple vendors and many different using and supplying institutions involved. The people who would benefit most from networking need to be identified and, where desirable, encouraged to organize themselves in ways appropriate to their fields. Suppliers must be made financially liable and accountable. Ways need to be found to phase out localized centers displaced by the networks, without causing major dislocation to users or trauma to operating institutions.

Concept of a Network

Before attending more closely to some of these issues, it is instructive to examine the meaning of "network." It is not preordained what properties a network must have to earn that designation. Some consider any time-sharing system a network. A time-sharing system connects multiple users (who may be geographically dispersed) to a remote source of computer and information services. It employs a communications network to effect this connection. It depends on strict compliance to rules and conventions for its successful operation. These are properties of computer networks. But a time-sharing system customarily involves only one central computing apparatus, manufactured by one vendor, operating under one program executive, and managed by and accountable to one organization. In short, it is a single supplier. For this reason, except as a limiting case, many observers probably would not regard a time-sharing system by itself as an interesting example of a computer network. It is, of course, a fundamental component of computer networks.

For present purposes, it is useful to distinguish between a single-access computer (SAC), a time-sharing system (TSS), and a computer network (NET). A TSS with its one supplier and many simultaneous users stands midway between a SAC with its one supplier and one user and a NET with its many suppliers and many users.

Just as a fundamental goal in time sharing has been to give each TSS user the illusion of having his own SAC (*13*), an ultimate goal in networking may be to give the average user the impression that he is dealing with only one supplier no matter how many or whose services he uses.

A related objective, as with a TSS, is to make a NET transparent or invisible to the user. An ultimate performance measure for a NET could be defined in terms of the NET's transparency and its apparent consistency across suppliers, as well as its stability, reliability, efficiency, and ability to support its users and explain its services. The better a NET, the less the user will know he is on it, the more it will seem to him like the operation of one supplier, and the less he will be aware that he is sharing its resources with other simultaneous users.

The complexity of the operation can go up geometrically as one moves from a SAC to a TSS to a NET. A NET presents special problems because of the involvement of many vendors, systems, and supplying organizations. Not everyone is convinced that it is worth the trouble (*14*). If everything offered by a NET could be provided as well by one TSS developed and operated under a single management roof, it would be difficult to understand the reason for wanting the NET. The same could be (and was) said of a SAC in relation to a TSS. But although some still grumble about the additional overhead or burden that they believe time sharing imposes on their operation as compared to batch processing, time sharing has become an accepted mode of continuing importance. Whether a similar verdict is to come down in the matter of networking as compared to time sharing remains to be seen.

Functions of Networks

A major computer network includes the following three important functions:

1) "Task-centered" operation, or the provision of services and facilities to accomplish specific jobs for users of the network.

2) "Signal transport," or the transmission of data from one place to another across the distances spanned by the network.

3) "Communication facilitation," or arrangements for making possible the reliable, versatile, efficient distribution of services to users from suppliers.

To delineate these functional categories, it helps to define three different types of networks or network organizations that may or may not be separated in network operations of the future: a *user-services* network, a *transmission* network, and a *facilitating* network.

The user-services network includes the users and suppliers of services, along with the resources from which the services derive. The users and suppliers are joined not necessarily by physical links but by their mutual desire, commitment, and capability to share resources. To achieve a user-services network may require considerable change in attitudes, training, development of interpersonal contacts, and refinement of resources. The user-services network is fundamentally people-directed and task-oriented.

In contrast, the transmission network consists of a set of communication facilities by which machines can pass data to each other. The facilities are generally automated message processors and high-capacity cable, microwave, and satellite telecommunication channels, but in fact may also be ordinary dial-up telephone lines or even the U.S. mail. Recent changes in technology and regulatory attitudes are changing the picture for data transmission. The development of packet switching and other new transmission and switching technologies seems likely to decrease significantly the costs of high-capacity telecommunications, and a number of private companies may become common carriers to exploit the new technologies.

Mediating between the transmission and user-services networks are facilitating networks that may be likened to the broadcasting systems of radio and television. The functions they provide might include any or all of the following:

- Creating and enforcing standards, as for transmission codes.
- Establishing and implementing basic user protocols.
- Performing centralized accounting and billing.
- Furnishing documentation and general user support.
- Making a market for computing services.
- Supplying interface hardware and software among network computers and message processors.
- Providing communication services from the facilities of one or more transmission networks to the user-services networks, as communication services are provided by the broadcasting systems to the radio and television stations that are their affiliates.

While the lines between these types of network organizations cannot always be cleanly drawn, the three-way classification into user-services, transmission, and facilitating networks has proved useful in focusing discussion on key issues in what is inevitably a very complicated subject.

Nature of Network Development

Although many feel that there is an immediate need for the organization of user-services networks, creation of a facilitating network could be essential to other developments. The facilitating network has the capacity to reduce dramatically the problem of distance in computing and to bring the goal of effective sharing within reach of many kinds of geographically dispersed and organizationally dissimilar institutions. Once an effective facilitating network is established, it might permit without major modification the addition or trial of various user-services networks. If the same facilitating network accommodates both general computing services and science information services, for example, it could be useful to several different communities of interest.

Although a few facilitating networks at most might be entirely adequate for the needs of national networking, a similarly small number of user-services networks would not suffice for all institutions of research and education. Higher education alone seems much too diverse in its requirements and much too heterogeneous in its political structure for all its institutions to get under the same tent. More likely is a variety of discipline-oriented and mission-oriented user-services networks. The concept of widespread pluralism in the development of user-services networks is not forbidding so long as there is at least one large-scale facilitating network for them to associate with. Market forces should encourage discipline-oriented networks to rely on a central facilitating network for their procedural and communication needs. The facilitating network would provide the glue to hold the user-services networks together.

A trend toward discipline-oriented

networks could have a disruptive effect on the organization of computing in universities, if discipline-oriented networks with economical telecommunication facilities tended to draw away computing sponsored by outside agencies. If this were the most efficient part of the university's computing load, as it might be, the university could find itself suffering doubly from a loss of sponsored revenue compounded by a comparatively more expensive and difficult residual computing load. It is costly for a university to provide good user support. Deprived of an adequate revenue base for covering this cost, the university could be the victim of a kind of "cream skimming" unless countermeasures were developed through careful planning and possibly restricting regulations.

A university might respond to a drain of computing dollars by eliminating its large-scale central computing system, as Harvard has done. The remaining load might be taken care of by less expensive machines, including minicomputers. Or, if there were at least one stable, reliable set of general-purpose computing services available from a large facilitating network, much of this load could be delegated to external sources. In this case, the university might be expected to convert its computing center into a user-services center which would contract through the facilitating network for information and computing services at the best price. This possibility suggests a wholesaler-retailer type of arrangement in the marketing and distribution of user services.

Wholesaler-Retailer Marketplace

In the wholesaler-retailer concept, a number of large suppliers provide information and computing services to a greater number of smaller nodes on the network that serve as retail outlets for users in their districts. A major research center at the University of Illinois operates such a retail outlet with a small computer called a "minihost." The minihost provides a general-purpose port to the ARPANET, with printer, reader, punch, disk, tape, and graphic output device, in addition to providing line concentration for interactive terminals. The computer center of the University of California, San Diego, provides what amounts to wholesale service to the Illinois group through the minihost. Its large computer substitutes for a similar machine that the Illinois group formerly operated itself. The Illinois group is said to make extensive use of several such wholesaler's computers on the ARPANET, which it views as a marketplace for user services. Purchase costs of the Illinois minihost and network hardware are reported to be less than half of the bill for a year's computing; communication charges are an amount less than 2 percent of the sum paid to wholesalers; and the total costs for computing services are less now than when Illinois operated its own large computer.

In a wholesale-retail system, the retailer provides local aid and information to customers and charges a markup to cover the costs of this support. Present-day computer centers operate as combined wholesale-retail outlets. When joined with a facilitating network they can provide retail outlets to local users for distant network wholesalers and can at the same time serve as wholesalers to the network. But the economics of these two functions are different, and there may be an evolution toward a more clear-cut distinction between wholesaling and retailing in the future. Some high-volume users with little need for user support may not be willing to pay the overhead burden currently charged for support services at many computing centers and may prefer to deal directly with specialized wholesale facilities. The much larger group of users is likely to continue to require good retailer support services, similar in certain respects to services provided by an air-freight forwarding company. The retailer would help the user obtain access to the wholesale service most appropriate to his needs. The retailer's fee might be separated into a local component (for example, a lines-printed charge) and a general component, calculated as a percentage of the wholesaler's fee according to a volume discount schedule.

Central Management and Regulation

In view of the fact that wholesalers may include university, federal, and privately owned centers, some form of regulation may be necessary to protect users and their organizations. One form of regulation is by means of admission rules and operating standards administered by either a network governing board or a strong trade association of network participants, somewhat in the style of the stock exchanges. Items for regulatory attention might include:

- The relation between aggregate cost and aggregate revenue for wholesalers, and whether full cost recovery should be the basis for setting prices.
- Nondiscrimination clauses and length of service assurances for network users to prevent the kind of situation wherein a low-priced wholesaler creates havoc by supplying network service for a year or two, then withdraws that service because of increased load at home or to accommodate favored clientele.
- Requirements for sufficient advance notice in the introduction of new resources or the addition of a network traffic load so great as to impact existing services, so that appropriate steps can be taken to alleviate expected insufficiencies and perturbations.

With respect to managing the network, there are two approaches. One is "participatory management," such as a consortium governing operation of a centrally run market. Here the institution participates directly in network management under an agreement that calls for an appropriate balance in influence among members of the consortium and ensures that each institution gets its fair allocation of system resources.

The alternative is the "open market." If a facilitating network is available to it, an institution can seek to protect its interests by contracting with multiple suppliers and threatening to shift its "business" to a competitive supplier if service becomes unsatisfactory. Contracts can be short-term or long-term in character and can reflect the bargaining power and volume of the buying institution. The protection offered by this approach depends on whether the facilitating network has achieved critical mass in terms of the number of alternative suppliers it makes available to users, on whether basic user protocols and programming systems have achieved adequate standardization across the network, and on whether data files can be transferred from machine to machine at reasonable cost and convenience. If current difficulties in switching from one system to another are not overcome, this possibility will be of more academic than practical interest.

Computing in Higher Education

Colleges and universities have traditionally developed computing and information services primarily for their own internal purposes. They have on occasion sold off their excess computing capacity to other schools and even to industrial customers, especially in periods of financial stress; but this has normally been considered a temporary measure that would be put aside as soon as local demand was restored or new funds were secured. In other words, the interests of the outside customer have come second to those of the institution, and stability of service for the outside customer has constantly been in jeopardy.

This attitude may be starting to change with the advent of regional computing networks, but most colleges and universities would not want to put themselves in the permanent position of having to give assurances or be accountable to sister institutions for the quality and reliability of their computing and information services. Whatever their present feelings, it is questionable whether the California universities with ARPANET users would welcome a substantial increase in this outside business if it required additional systems and personnel and threatened to compromise the interests of inside users. For these reasons, colleges and universities seem unlikely contenders for roles as serious suppliers of services in networks of the future. Perhaps their roles as suppliers will be of a specialty nature, and commercial firms will be the routine suppliers.

Among the potentially most difficult problems posed by networking to universities are the implications of possible new patterns of funding. Network users tend to be aligned by disciplinary and other groupings that are orthogonal to their institutional affiliations. By virtue of the type of use he makes of a network, a professor of chemistry is primarily a crystallographer or theoretical chemist, not a member of the faculty of university X or a resident of state Y. In view of this fact, it is not clear how a chemistry-services or any other user-services network is best funded. Facilitating networks also cross institutional and state lines, so that their development poses a similar problem. In general, the appropriate role for present-day institutions of research and education in relation to future networking developments requires thoughtful study. User groups, consortia, and the participation of private firms are among the several organizational approaches that may help to solve the problem, but there are no pat answers. Satisfactory resolution of these people-oriented problems may be critical to the future success of national networking.

Conclusions

The most basic conclusion coming out of the EDUCOM seminars is that computer networking must be acknowledged as an important new mode for obtaining information and computation (*15*). It is a real alternative that needs to be given serious attention in current planning and decision-making. Yet the fact is that many institutions are not taking account of networks when they confer on whether or how to replace their main computer.

Articulation of the possibilities of computer networks goes back to the early 1960's and before, and working networks have been in evidence for several years now, both commercially and in universities. What is new, however, is the unmistakable recognition—bordering on a sense of the inevitable—that networks are finally practical and here to stay. The visionary and promotional phases of computer networks are over. It is time for hard-nosed comparative analysis (*16*).

Another conclusion of the seminars has to do with the factors that hinder the fuller development of networking. The major problems to be overcome in applying networks to research and education are political, organizational, and economic in nature rather than technological. This is not to say that the hardware and software problems of linking computers and information systems are completely solved, but they are not the big bottlenecks at present. Research and educational institutions must find ways to organize themselves as well as their computers to work together for greater resource sharing.

The coming of age of networks takes on special significance as a result of widespread dissatisfactions expressed with the present computing situation. There is a feeling that the current mode of autonomous, self-sufficient operation in the provision of computing and information services is frequently wasteful, deficient, and unresponsive to users' needs because of duplication of effort from one installation to another, incompatibilities, and inadequate documentation, program support, and user assistance. Complaints about the relative lack of uniform standards and the paucity of information on what programs and data are available and how to get and use them are commonplace.

The human tendency, when beset by problems such as these, is to seek a savior in the next new technology—networks in this case. But networking does not in and of itself offer a solution to current deficiencies. What it does offer is a promising vehicle with which to bring about important changes in user practices, institutional procedures, and government policy that can lead to effective solutions.

Thus more critical than whether networking is developed and applied is how it is developed and applied. For example, networking emphasizes the need for standards and good documentation. Unless effective mechanisms are developed and strong measures taken in networking to ensure that suitable standards and documentation are developed, present inadequacies could get worse, not better.

Recommendations

The general feeling expressed in the seminars is that additional research and discussion are required before deciding whether and how to launch a major national networking effort, but that this should not be taken as reason for delaying other activities that could help to illuminate the prospects and problems of large-scale national networking. Efforts should be mounted to collect data, analyze existing networks, and perform highly targeted experiments designed to investigate important issues and areas of uncertainty. Organizational activities, market research, and business planning also need not and should not be deferred. To the contrary, this is the right time for top-level decision-makers to meet and begin thinking about how large-scale networks might look and work. Officials must question how well computing and information services are currently supplied, how well users are served, how networks and other fast-advancing technologies might improve the present mode of operation, and what changes in government policy and institutional attitudes would be either required or helpful in bringing about this improvement.

Institutions of research and education should commit themselves to a comprehensive reexamination of how they supply and receive computing and information services, and they should consider possibilities for networking to correct present-day problems and deficiencies. Sound planning could be the basis for the formulation of programs funded by government and private foundations designed to assist the institutions' move to more effective computing and information services in the years ahead.

As a means for getting started, a planning and organizing council on computing and information services in research and education should be formed to provide educational and research institutions with an organizational locus for continuing the study of networking possibilities, identifying and discussing current problems, dealing with funding sources, handling internal relations, and negotiating with one another. The council should be a working group rather than an associational organization of representatives. Its membership should include people from institutions of higher education, research centers, information service groups, libraries (including those of profit-making corporations), selected on the basis of their experience, expertise, and ability to contribute not only to the deliberations and mission of the council but also to the national networking arrangements to which the activities of the council might lead. Since there should be no a priori presumption that national networking is the correct course of action, it would be desirable to have some members of the council who question the desirability of networking.

The council should not be set up or operated in a way that blocks or discourages separate or prior organizational efforts. Neighboring institutions that wish to enter into an agreement to work together and share facilities before the council is formed should not be put off or dissuaded. To be successful, the council must act as a stimulant and guiding force, and not as a depressant or inhibitor.

With respect to organizing user-services networks, organizational efforts to locate and bring together disciplinary, mission-oriented, and other appropriate groupings of similarly interested or motivated individuals whom networking can potentially benefit should get under way without delay. These groupings, already formed or forming in certain fields, can provide a basic element of user-services networks. The other major elements are the suppliers and their resources. Suppliers and resources potentially useful for networking should be identified. Where the desired resources do not now exist, incentives and development funds should be provided to stimulate their production and adaption to networking.

The council should help but not control the organizing of user-services networks. It might draft an organizing plan and make it generally available and visible, but it should not set itself up as a clearing agency for network formation. A modular structure and noncompulsory, nonexclusive membership policy should be adopted to allow institutions and their faculty members to consider the advantages and disadvantages of joining each user-services network individually and independently of their joining or not joining other networks.

The strategy of adding user-services networks one at a time and permitting institutions and their members to pick and choose according to interests, benefits, and costs will give users maximum flexibility while it affords system designers a graduated schedule of development that lends itself to continued checking and evaluation. This gradual approach will permit the greatest number of parties to participate.

References and Notes

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3. G. W. Brown, J. G. Miller, T. A. Keenan, Eds., *EDUNET—Report of the Summer Study on Information Networks* (Wiley, New York, 1967).
4. See, for example, *Networks for Higher Education* (Proceedings of the EDUCOM Spring 1972 Conference) (EDUCOM, Princeton, N.J., 1972); and *Networks and Disciplines* (Proceedings of the EDUCOM Fall 1972 Conference) (EDUCOM, Princeton, N.J., 1972).
5. A similar mixture of people was assembled in a 1969–1970 series of symposiums in Washington, D.C., sponsored jointly by the Brookings Institution and the Johns Hopkins University [M. Greenberger, Ed., *Computers, Communications, and the Public Interest* (Johns Hopkins Press, Baltimore, 1971)].
6. The full report is contained in M. Greenberger, J. Aronofsky, J. L. McKenney, W. F. Massy, Eds., *Networks for Research and Education—Sharing Computer and Information Resources Nationwide* (MIT Press, Cambridge, Mass., in press).
7. Based on figures given by J. Hamblen [*Inventory of Computers in Higher Education: 1969–70, Utilization and Related Degree Programs,* NSF Report 72-9 (Government Printing Office, Washington, D.C., 1972).
8. M. Greenberger, in *The Financing and Organization of Computing in Higher Education: 1971* (Proceedings of the EDUCOM Spring 1971 Conference) (EDUCOM, Princeton, N.J., 1971), pp. 6–9.
9. See, for example, J. Legates, "The lessons of EIN," *EDUCOM Bull.* **7** (No. 2), 18 (1972).
10. We used the term *networking* in the seminars to designate the general set of activities and arrangements whereby computers and communications are used for extensive resource sharing by a large number of separate, independent organizations.
11. L. Roberts, *EDUCOM Bull.* **6** (No. 3), 4 (1971).
12. D. B. McCarn and J. Letter, *Science* **181**, 318 (1973).
13. J. McCarthy, in *Computers and the World of the Future,* M. Greenberger, Ed. (MIT Press, Cambridge, Mass., 1964).
14. J. Kemeny, *EDUCOM Bull.* **8** (No. 2) (1973).
15. Greater treatment of these and the other conclusions and recommendations coming out of the seminars is given in (*6*).
16. M. Greenberger, *EDUCOM Bull.* **8** (No. 1), 2 (1973).

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