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# MACHINE SPACE AND THE COMPUTER NETWORK: A NEW TECHNOLOGY IN THE CALIFORNIA LANDSCAPE

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Machine space is a topic that first received attention in the geographic literature in the works of Horvath and Bunge.[1] Like earlier divisions of the world into the inorganic, organic, and superorganic realms, Bunge categorized things into mankind, machinekind, and nature. He then discussed the kinds of space occupied by various species within these taxonomic kingdoms. Such things as streets and railways were identified as examples of machine space.[2] Horvath also wrote of machine space and introduced the notion of automobile territory. In East Lansing and Detroit he provided an example of how this kind of space expands and eventually comes to dominate the landscape.[3]

Another form of machine space, which is very much like automobile space and railroad space, is computer space. Bunge alluded to this kind of space when he described missiles and computerized bombs being safely buried beneath our cities while we leave our children exposed to danger at the surface.[4] Bunge's image is not without basis. For example, at one time banks and insurance companies were fond of displaying newly acquired computer equipment in their front windows. Then, after a few were destroyed during urban riots, they were hastily removed to basement locations, deep within the earth, safe from harm.

In his discussion of machine space, Horvath pointed out that although this space, exemplified by such things as rails and asphalt, may be occupied only occasionally, it is clearly allocated for full-time use by machines.[5] The same description might apply to computer space as well, except that human beings cannot occupy computer space in quite the same way. Instead, elements of culture (messages and ideas) occupy it for infinitessimal units of time.

Until recently, computers existed in small, discrete, geographically insignificant parcels of territory. At this scale computer space was beneath the notice of geographers, although it did occupy the attention of industrial engineers and scholars interested in such things as crowding and the proximate environment.[6] Today these isolated units of machine space are increasingly being

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joined together into unified grids called computer networks. What used to be a geography of minuscule points is rapidly becoming a geography of routeways visible at the continental scale.

*Computer Networks*

There are three levels of computer organization. These include individual computer systems, distributed computer systems, and computer networks. An individual system consists of a central computer, called a mainframe or host processor, connected to a number of interactive terminals by telephone or by permanent lines. These terminals, which do nothing more than communicate with the host processor, are called "dumb" terminals. A distributed computer system also contains a single mainframe processor and a number of interactive terminals. Unlike an individual system, however, it also contains a number of interactive terminals that are small autonomous computers themselves. These machines, which are called "smart" terminals, can perform many small processing functions alone without having to engage the mainframe system. This is a great advantage in many instances because it frees the main computer for more important tasks. Autonomy is what separates a distributed system from an individual system. For a computer system to be truly distributed its component devices must be autonomous and must be capable of operating independently.[7] At various times a number of peripheral units may interact with each other or with a more powerful host processor, but they must perform at least some of their processing functions alone. Although these peripheral units augment the host processor, they do not replace it, and a single host computer remains the most important part of a distributed system. Today, distributed computing is rapidly growing in popularity and about 10% of all newly installed systems fall in this category.[8]

A computer network is a collection of computers and computer terminals connected together by a communications system.[9] Within the network are central mainframe computers and smaller peripheral computers located at remote sites. Computer networks are larger than distributed systems and they usually contain more than one mainframe processor. These large computers are connected to interactive terminals, small autonomous computers, and other mainframe processors devoted to network control. All the machines of the network constantly interact with one another and thus form a spatially distributed electronic entity.

Computer networks are sometimes referred to as distributed data processing systems, although it is often argued that networks and distributed systems are completely different technologies. For example, it is sometimes held that networks are less specialized in function and have fewer processing capabilities at remote sites than distributed systems.[10] At the same time, there are many instances where a single central processing unit connected to dozens of interactive terminals is called a network.[11] As a general rule, however, a network is anything that links up different mainframe processors and operates over great distances.

Computer networking got its start in the mid-1950's when programmers began transmitting digital data from one computer to another over telephone lines.[12] The early 1960's saw the rise of several small data processing networks but it wasn't until the early 1970's that this new technology began to have much of an impact on the nation's business and research communities.[13]

Networks grew in importance as they provided solutions to two major problems encountered by the computer using community. The first involved access to and control of information necessary for the running of a business. Originally, corporations tended to maintain single mainframe processors at central locations. These monolithic, remote, and frequently overburdened setups were often denounced by their users as being unresponsive to their needs.[14] The introduction of networks overcame this problem and gave many users direct access to data that had previously been denied them. Although many data processing managers strongly opposed the decentralization that resulted, field managers in remote locations welcomed it since it provided them with better information about business operations in less time.[15] Networks thus enabled corporations and other operational concerns to decentralize and move many of their operations from a central office out to remote field locations where business is actually being transacted.[16]

The second problem involved the transfer of information over great distances. Before the advent of computer network technology, whenever it was necessary to transfer digital data between different metropolitan areas it had to be recorded on magnetic tape or cassettes and either shipped through the mail or hand carried from one city to another.[17] This process took a great deal of time and was highly inefficient. Later, such transfers could be made instantaneously via the computer network.

## *Machine Space Networks*

Computer networks are large extended regions of machine space but they are not unique. There are other kinds of machine space that exhibit network properties and their geometric form is similar if not identical to that of computer networks. Through the years geographers have described and analyzed many such machine space networks. Among these are railroad networks, airline networks, highway networks, pipeline networks, power transmission networks, and television networks.[18]

Although the literature on these other forms of machine space is extensive, there is nothing in the geographic literature on computer networks. They are apparently so new that no one has yet considered them as spatial phenomena. It is also rare to find computers in general treated as legitimate objects of geographic study.[19] There are, however, a great number of articles dealing with the use of the computer as a tool. For example, many papers and monographs deal with the use of computers in cartography and drafting.[20] There are also many publications that deal with computers as aids in teaching. These works describe various sorts of computer games and simulations of geographic processes.[21] There is also a great amount of material dealing with the use of computers in data manipulation and statistics.

The lack of material on computer networks is unfortunate. Computer networks are economic tools and major elements in the rapidly expanding information industry. This industry is not only becoming one of the most important sectors in our economy, but it also has the particular ability to shrink and eliminate space. For this reason, as well as the fact that computer networks form spatial patterns in the landscape, computer networks should be of special interest to geographers. As Leighly might have put it, computers and the transmission lines that link them together are examples of cultural immobilia in the landscape and are thus worthy of geographic study.[22]

Like other geographic phenomena, machine space can be approached in several different ways. It can be treated descriptively, it can be treated ideologically, or it can be treated analytically. Analytical approaches can take three different forms: the genetic, the mathematical, or the functional. In genetic, or historical, explanations, the evolution and the diffusion pattern of a network is usually described and various factors pertaining to why it spread in some directions and not others are discussed.

Machine space networks have also been subjected to geometric analysis. This has been very popular in the past and it will continue to be in the future. Most geographers have at least a passing interest in the geometric regularities that these networks possess and in most cases networks are useful in revealing the geometric form of a nation's urban hierarchy. In this country the urban hierarchy has manifested itself through such evolving phenomena as highways and canals, railroads, telegraph and telephone lines, and finally airlines and television networks. All of these systems share a family resemblance. In all of them, things move between cities and the pathways are marked by lines on a map. Computer networks are extending this evolutionary trend. New linkages are being formed between cities and these connections are bringing cities together in different ways than before. Places that heretofore had little importance in the nation's hierarchy are assuming higher positions by virtue of their newly forged information links with other places. As Pred has pointed out, these between-place information links are highly important in the formation and growth of urban systems.[23] Attempts to measure hierarchical relationships among cities on the basis of computer networking is premature, however. At present the networks are simply changing too rapidly for such relationships to have any meaning. Nevertheless, several places are beginning to stand out as centers of activity within the networks of many different companies. In the west, the Los Angeles and San Francisco areas have become prominent as have Chicago and Dallas in the midwest. Out east, important network nodes include Atlanta, Washington, New York, and Boston. Several new places have also emerged with names that were unfamiliar only a decade ago. Just as places like Ypsilanti, Idlewild, and Inglewood acquired prominence during the air age, so also do we now find places like Silicon Valley and Research Triangle entering into the lexicon on the computer age landscape.

Machine space networks have also been analyzed functionally, that is to say, how do they work and how are they used by human beings? Technical descriptions of a phenomenon are part of this approach. There are several reasons why geographers should be interested in functional explanations of how computer networks operate. In the future, more and more geographers will be getting jobs in the computer field and it will be important for them to understand how computer networks function. Similarly, geographers in business and in planning agencies will find an increasing need to use computer networks in their work. Academic geographers as well will find access to this new technology opening up new research opportunities. Many functional aspects of the computer network industry will be of interest to individuals wishing to use them and to teach about them just as some of the technical aspects of the airline and travel industry have been of interest to the geographer-layman wishing to use this information in teaching and in personal travel.[24] Other examples of how geographic phenomena have been functionally treated are endless.[25]

*How Computer Networks Operate*

There are many terms that describe the different kinds of networks currently in existence. Some describe ownership, some describe services that the network provides, and some describe how the network functions electronically.[26] All networks can be divided into two types: resident and external. A resident network is composed of a number of interconnected computers of the same make (such as IBM, Hewlett Packard, or Burroughs). Machines made by the same company can communicate with each other without any software modifications. Machines made by different companies cannot. An external network is programmed to accept and pass on information between computers made by different manufacturers. An external network contains within it special processors called nodes. These processors concentrate entirely on operating the network. A node receives a message from a user's computer and translates it into the language of the network using a coding procedure called a protocal. The message is then sent to another node which translates it into the language of the receiving computer. An external network is, therefore, more flexible than a resident network since it is independent of the kind of computer attached to it.

In both resident and external networks there are five primary components. The first of these is a central computer. Most networks have readily identifiable central site processors called host nodes.[27] These host nodes are mainframe systems (like an IBM 370, a DEC 10, or a UNIVAC 1106) used for such things as network control, the management of data, and large-volume batch processing. All computer networks have at least one of these mainframe computers and many have more than one. When they are available to all users they are called dedicated central processing units.[28]

The second, third, and fourth components include devices that control the communication lines between the elements of the system, devices that supervise the terminals operated by the users, and the terminals themselves.[29] These relatively low cost remote terminals are placed at many different geographical locations throughout the system. These remote terminals are often small computers themselves (called micro-processors and mini-computers) and they process many transactions independently of the mainframe computers. Many of them are as powerful today as host processors were fifteen years ago.[30] Remote terminals also transmit information to the mainframe conputers over a communication network. In most networks remote terminals have access to the entire range of devices existing within the system.

The fifth component of the computer network is the linkage pattern. This is the most visible part of the network and the one that interests geographers the most. The linkage pattern of the computer network shows how data is transmitted between the different places in the system. The most universally used medium of transmitting data is the telephone line, but information is also being transmitted through communication satellites like Western Union's WESTAR I.[31] Other forms of transmission include microwave radio, undersea cable, television cable, and the still experimental optical fiber.

In most cases the companies that own the means of transmission are not the ones operating computer networks. There is a separation between computer networks and electronic communication networks, although outwardly they appear to be the same thing. Companies like Bell Telephone, General Telephone, Western Union, and Southern Pacific, which own public service transmission lines, are called common carriers. Common carriers can lease their electronic communication lines directly to customers wishing to transmit data between their own computers. Common carriers can also lease lines to large customers who in turn sell space on these lines to small customers. These customers can interface their own computers with the common carrier network either through dial-up phone lines or through permanently wired connections.

An individual business can build its own private computer network by purchasing node processors from a manufacturer and permanently leasing telephone lines. These networks are often called single purpose networks and include such things as airline reservation systems and the electronic funds transfer systems of the banking industry.[32] Private networks are often economical when there is a large volume of traffic.[33] However, if a company has many offices and its volume of traffic is low, a private system can be prohibitively expensive.

When the computer traffic of an individual company is not great enough to warrant the expense of leasing a transmission line from a common carrier it is usually cheaper to connect its computers together through a previously established public network. Public data networks cater to such companies by offering both temporary and permanently leased circuits between branch offices. These public data networks themselves lease lines directly from the common carriers. They then sell time on their permanently leased lines to customers wishing temporary or limited access to network facilities. In addition to data transmission, many of these companies make available specialized computer related services like image transmission, electronic mail, and computer related consulting services. Such companies are called value-added networks, or VANs.[34] Most customers of value-added networks use them to get inexpensive services in areas where their own inhouse networks don't reach. This is a great advantage for a small company that needs to utilize a nation-wide computer network but lacks the financial resources to build its own system. VANs are particularly useful when data volumes are low.

*Computer Network Applications*

Computer networks have many current and future applications and are presently being utilized in such widely diverse fields as the insurance industry, government, health care delivery, banking, manufacturing, and retailing. Organizations and businesses often link computers together in order to share workloads. This is one solution to the problem of owning or having access to a number of different computers that are not in the same location.[35] It also solves the problem of inadequate capacities at individual sites.[36] Linking many different kinds of computers together is expensive and difficult. However, there are many advantages to such a strategy. Linking many small systems together creates a giant that has great economic and technical advantages over all of the smaller systems operating alone. For example, each computer in a system might specialize in some specific function that no other computer in the system can do quite as well by itself. One machine may contain a specialized data base such as a computerized planning library. Another may have a large storage bank of unique computational routines or a compiler for a highly specialized or powerful computer language. Another may have an enormous memory capacity or an unusual input-output device.

The reliability of a network is also higher than its components are individually. If a given machine is down, for example, programmers at that location need not wait until it begins working again. Instead, they can feed their programs into the network and run them at other locations. Similarly, during network failures, satellite processors can continue to work independently. Networks also allow workloads to be shared. If the work at one location is too much for its machine to handle, the excess can be sent to another location where the activity is not as great. This advantage is highest when a network spans many different time zones.[37] In California, for example, programmers are still busy running programs three hours after their counterparts on the east coast have gone home. Other advantages include faster turn around time for certain problems and lower costs to the members of the system.

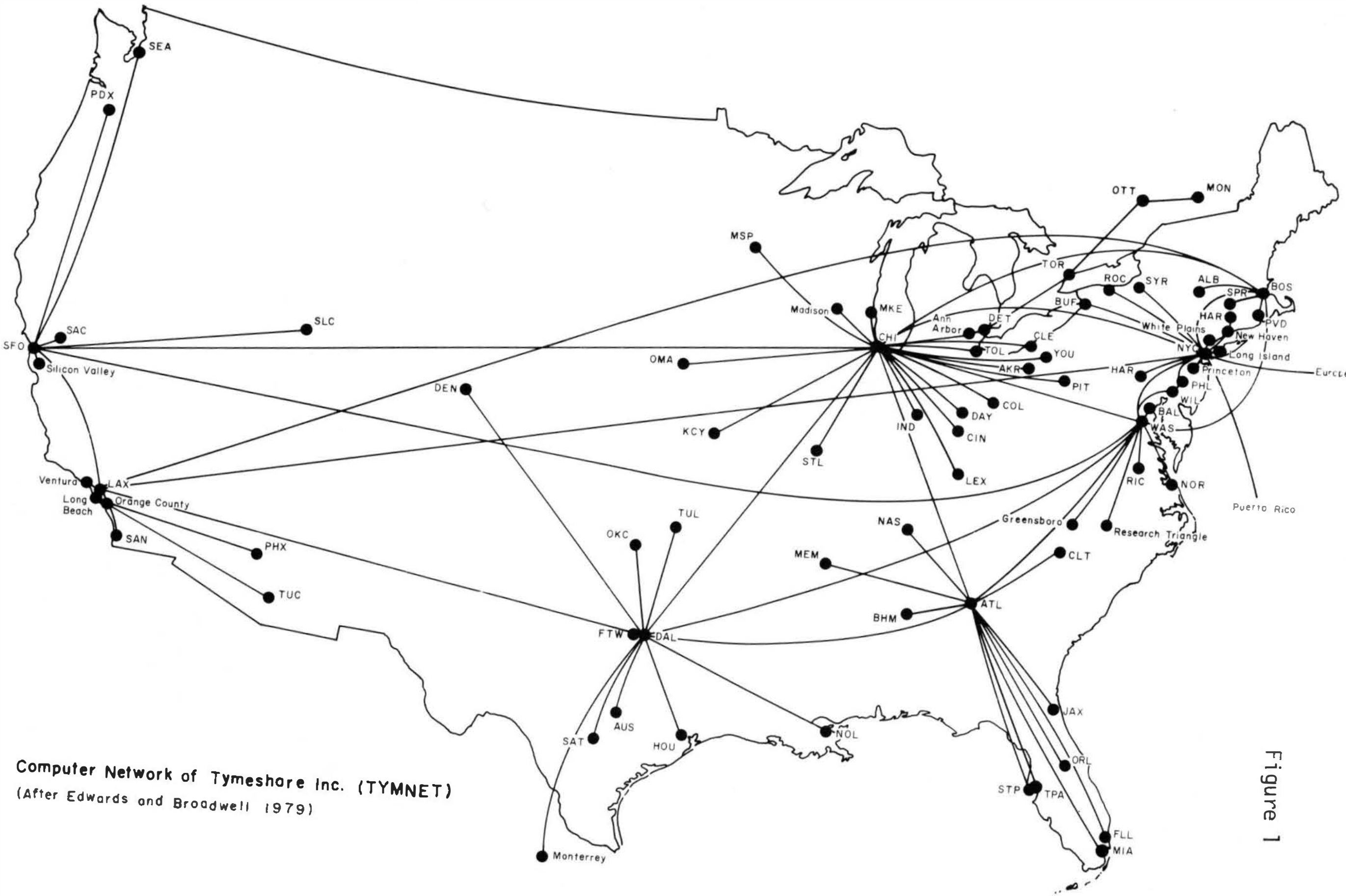
In recent years the cost of computer hardware has been falling more rapidly than the cost of communication services. For this reason it has become cheaper for a business to locate small computers at remote sites where they can handle some of the less complex chores than to transmit all its raw data over expensive phone lines to a central site for processing.[38] This has led to increasing amounts of within-network autonomy throughout the industry. Line costs and direct satellite communication with city centers may in fact eventually eliminate the need for land lines altogether and computer networking will undergo yet another technological revolution.[39]

*Some Representative Networks*

During the past decade many new public data networks have appeared throughout much of the industrialized world. At present there are several hundred of them with names like CYBERNET, ARPANET, SWIFT, DATAPAC, INFOSWITCH, TRANSPAC, EURONET, TYMNET, and INFONET. Their network configurations change quite rapidly as new links are added and as the connections between nodes are altered or discontinued. It is often difficult even for people in the industry itself to keep track of the spatial transformations they undergo from one month to the next.

Today, the computer network field is exactly like the airline industry during the late 1920's and early 1930's. It is expanding rapidly and new companies are entering the field every few months. The networks of several of the larger companies now in existence are shown in Figures 1-3. These maps constitute a partial record of this industry as it looked during its infancy, much as a similar record of the airline industry during its adolescence appeared in an article by Robert Platt over thirty years ago.[40]

The first of these networks, TYMNET (Figure 1), was founded in 1969 and has its corporate offices in Cupertino, California, right in the heart of Silicon Valley. Its main regional headquarters are in Santa Clara, California and Vienna, Virginia. TYMNET currently supports over 500 network nodes and is expanding at a rate of more than 20 nodes per month. It has 50,000 geographically dispersed users and over 300 customer host computers. Its network includes nearly 534 lines representing over 86,000 circuit miles. Users can connect to the network with a simple inexpensive local telephone call in nearly 250 domestic and international metropolitan areas.[41] TYMNET's customers include oil companies, banks, hospitals, libraries, research firms, and universities. The network provides such services as timesharing, credit card processing, inventory control, accounting, statistical analysis, data base management, computer aided instruction, word processing, geological research, and electronic mail. TYMNET allows its customers to interconnect fully terminals, computers, and even entire




Computer Network of Tymeshare Inc. (TYMNET)
(After Edwards and Broadwell 1979)

Figure 1

networks. A local phone call will connect a customer's computer outlet with a local TYMNET node. If a customer is located outside of a major metropolitan area, services to the nearest TYMNET node can be provided with a WATS line.

The second network shown is INFONET, the computer network of the Computer Sciences Corporation (Figure 2). The company is headquartered in El Segundo, California and has other major facilities in Chicago, Washington, Houston, Cape Canaveral, Huntsville, Sacramento, and Moorestown, New Jersey. The company was founded in 1959 and its Information Network Division, which is responsible for INFONET, was formed ten years later.

INFONET serves users throughout the world with communication lines extending over 150,000 circuit miles. The network currently consists of leased circuits interconnected by processors in North and South America, Europe, and Australia. Access from other points is provided through links with other systems. INFONET's host processors, located in the United States, are accessed by customers located in more than 50 different countries.

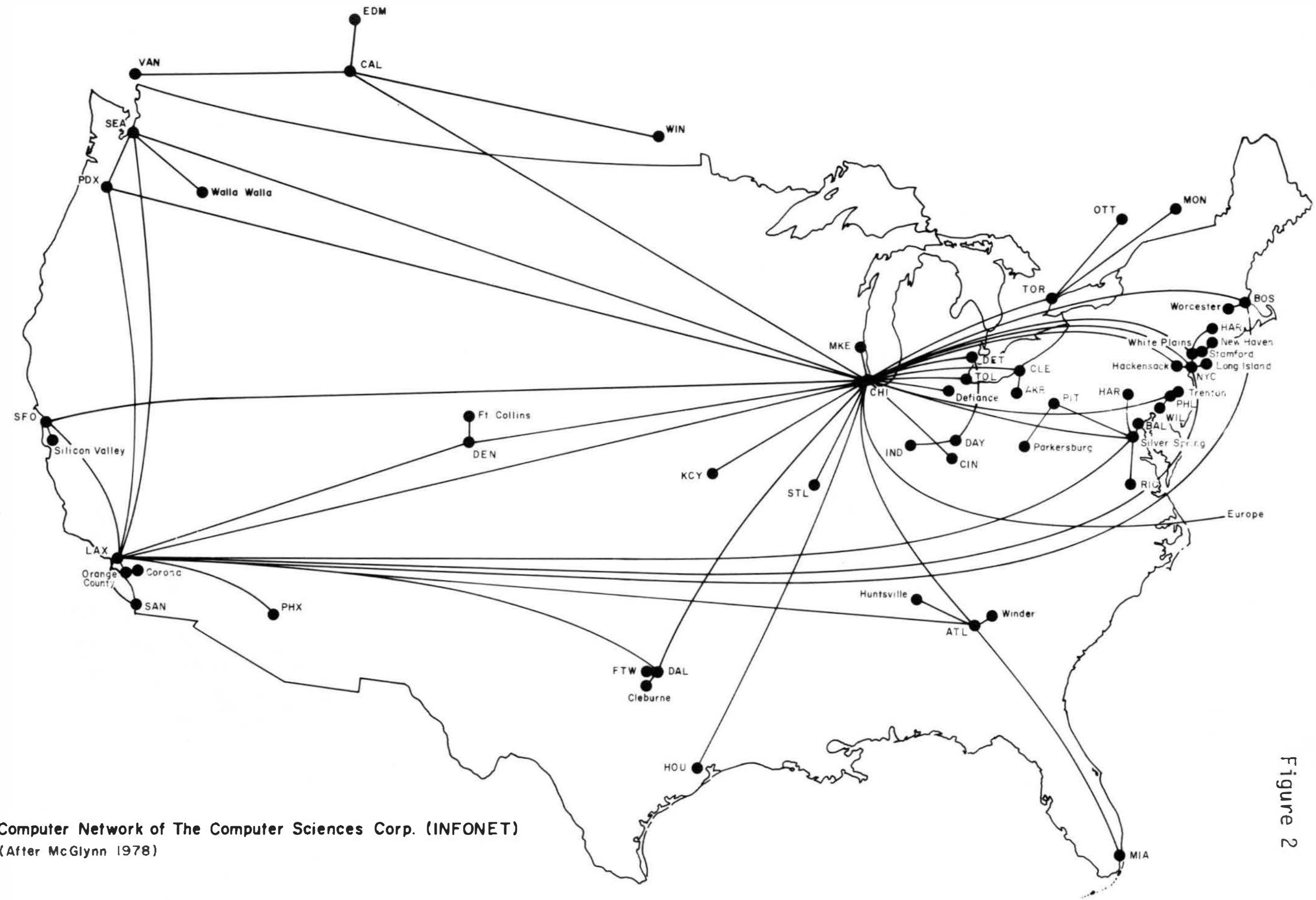
INFONET clients range from large corporations to small businesses and include many government agencies at the federal, state, and local levels. In addition to networking facilities the company provides its customers with many computer related services. These include data storage, pre-developed computer programs, the preparation of tax returns and payrolls, and a number of other general accounting services.[42] The company also provides consulting services in the fields of environmental science, oceanography, and physics.

The third network shown is the MARK III system operated by General Electric (Figure 3). This network is available from local telephones in over 600 cities in 24 different countries. It provides both interactive and batch processing as well as computer support services like customer training, access to program libraries, and consulting services in programming and system design.[43]

The system's domestic host computers are located in Cleveland and in Rockville, Maryland. In Europe there is another host computer located in Amsterdam. Tying the host computers and their peripheral subsystems together is a set of network lines operated by the General Electric Company. These are not voice lines and they are maintained separately from conventional Bell System lines since they are owned by General Electric.[44]

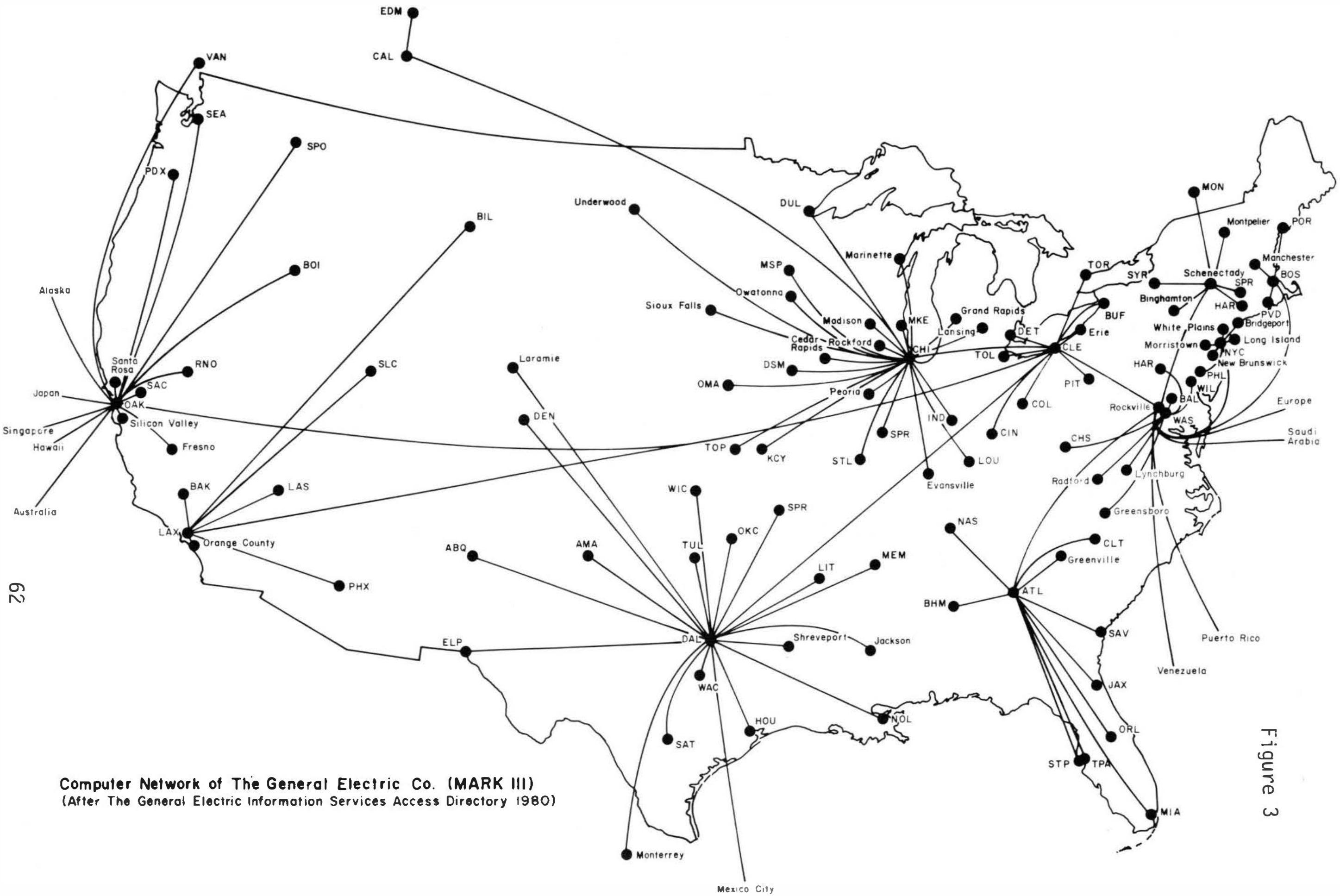
### *Prospects*

As computer networks expand, the realm of machine space also expands. This can be viewed in several different ways. Horvath and Bunge have taken an




**Computer Network of The Computer Sciences Corp. (INFONET)**
(After McGlynn 1978)

Figure 2




Computer Network of The General Electric Co. (MARK III)
(After The General Electric Information Services Access Directory 1980)

Figure 3

alarmist view. Bunge, for example, recoils in horror from "radioactive computer bombs" that threaten to destroy mankind and advocates the dismantling of various forms of machine space.[45] Horvath, on the other hand, simply advocates the "moniterng" of certain kinds of machine space.[46] Bunge also calls for such things as the "separation" of machine space and children space, the "protection" of children from machine space, and the "conversion" of machine space to people space.[47] Both Bunge and Horvath specifically advocate the mapping of machine space as a preliminary to any other discussion, as if to say that when the true extent of machine space is exposed, there will be a reaction. In this paper three examples of a new kind of machine space have been mapped. However, a more sanguine view will be taken as regards its future. The expansion of machine space is value neutral. It is neither good nor bad. It simply is. Just as domestic corn cannot survive and reproduce itself without the aid of man, so also has man domesticated himself to the point where he can no longer survive without the aid of his machines. In this and the next century machine space will continue to expand. Computer networks will increasingly be used by the nation's colleges and universities. Today, research libraries are being linked via networks to hundreds of data bases. Eventually, entire libraries will be tied together into one large data retrieval system. Each college, no matter how isolated, will then have immediate access to all the resources available in say, the Library of Congress. It may then come to pass that another form of space called Academic Siberia will gradually disappear.

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47. Bunge, "Geography of Human Survival", op. cit., pp. 295, 292; Bunge, "Perspectives on Theoretical Geography", op. cit., p. 173.

48. Bunge, "Geography of Human Survival", op. cit., p. 291; Horvath, op. cit., p. 188.