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ABSTRACT

This report intended for officials responsible for solving metropolitan problems identifies ways that telecommunications could improve the delivery of public services to metropolitan communities during the 1980's. Areas included in this study are delivery of public services to the home, operation of mobile public services, personal security networks, and energy conservation and management. Major recommendations include the establishment of a pilot program to demonstrate the ways in which telecommunications can help deliver public services to the home and the nationwide implementation of 911 service, by legislation if necessary. Because the uses of mobile radio for delivering public services are many and varied, it is deemed unlikely that any single mobile system approach will provide a universally appropriate solution; however, it is recommended that some preliminary experiments with community security telecommunications networks be carried out. Several peripheral but potentially significant applications of telecommunications in energy conservation and management are indicated: substitution for travel, transmitting demand and providing information between consumers and utilities, and facilitating the marketing and transfer of bulk power. A list of references is included. (Author/RAO)

Telecommunications for Metropolitan Areas:

Opportunities for the 1980's

A Report by the
Steering Committee for the
Metropolitan Communications Systems Study
of the
Board on Telecommunications-Computer Applications
Assembly of Engineering
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1978

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

This report examines the application of telecommunications technologies to the delivery of public services in metropolitan communities during the 1980's. The study on which this report is based was undertaken at the request of the Departments of Commerce; Energy; Health, Education, and Welfare; Justice; Transportation; Housing and Urban Development, and the U. S. Postal Service. To conduct the study, the Board on Telecommunications-Computer Applications of the National Research Council formed the Steering Committee for the Metropolitan Communications Systems Study. The Steering Committee's previous report, Telecommunications for Metropolitan Areas: Near Term Needs and Opportunities (1977), identified the telecommunications technologies that could provide useful services for homes, businesses, and governments up to the year 1980. While the focus of these reports is primarily on metropolitan areas, many of the technologies and applications examined here may be of benefit to small communities and rural areas as well.

The Committee wishes to acknowledge the assistance provided by the following contributors to the preparation of Chapter III (Access to Public Services from the Home): John V. Bowser, United Telecommunications, Incorporated; R. Gary Burke, IBM Corporation; and James E. Goell, International Telephone and Telegraph Corporation.

The Committee also acknowledges the assistance of the following contributors to the preparation of Chapter IV on mobile telecommunications: Lee Blachowicz of Harris R. F. Communications; William Borman, Martin Cooper, and Albert Leitich of Motorola Corporation; Robert L. Casselberry of General Electric Company; George Cooper of Purdue University; Robert E. Kahn of the Defense Advanced Research Projects Agency; Peter M. Kelly of Kelly Scientific Corporation; George F. McClure of Martin Marietta Aerospace; Terrence McGarty of Communications Satellite Corporation; Jack Neubauer of Urban Sciences, Inc.; Arthur C. Stocker, retired from RCA, and W. Rae Young of Bell Laboratories.

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IN MEMORIAM

The members of the Steering Committee were saddened by the death in December 1977 of a most distinguished colleague, Peter C. Goldmark. In addition to his many contributions to the engineering and scientific communities, he was celebrated for his remarkable innovations for the betterment of society. Dr. Goldmark was a member of the National Academy of Sciences and the National Academy of Engineering and had been an active and effective member of the Committee.

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CHAPTER I

Introduction and Summary

This is the second of two reports about the application of telecommunications technologies to selected problems confronting metropolitan areas. Both reports are summarized in this chapter. The purpose of these reports is to inform officials responsible for solving metropolitan problems about the ways in which existing or advanced telecommunications might be applied for the benefit of the community.

The first report, issued in 1977, identified applications available immediately and through 1980. This second report identifies ways that telecommunications could improve the delivery of public services to metropolitan communities during the 1980's. The term "public services" is used in a broad sense to include services for which governments have at least partial responsibility--such as health care, education, welfare programs, law enforcement, citizen safety, energy management and conservation, electromagnetic spectrum management, fire protection, transportation, housing, and postal service.

In consultation with its federal sponsors, the Steering Committee decided to concentrate on the following four areas:

- Delivery of Public Services to the Home
- Operation of Mobile Public Services
- Personal Security Networks
- Energy Conservation and Management

A chapter is devoted to each, with the initial section of each chapter serving as an introduction and summary.

As its major recommendation, the Committee urges establishment of a pilot program to demonstrate the ways in which telecommunications can help deliver public services to the home. The Committee concludes that the elements of a home telecommunications center already exist, with the potential for making dramatic improvements in the way that communications contributes to the quality of urban life. A major demonstration is considered necessary to test the potential for improved service.
The Committee believes that a bold step must be taken. Disjointed, disaggregated experiments will not converge in any reasonable time. A framework must be established so that opportunities can be pursued by industry and government with each sharing both technological and financial risks.

The Committee also recommends that nationwide implementation of 911 service be encouraged--by legislation, if necessary.

In mobile communications, the Committee finds that because the uses of mobile radio for delivering public services are many and varied, no single mobile system approach is likely to provide a universally appropriate solution. Several new developments in technology will permit more efficient use of the frequency spectrum, but such improvements result in systems of increased sophistication, and should not be expected to yield any dramatic reductions in cost.

For high-capacity mobile telephone service in the early 1980's, cellular systems appear to be the most promising. With cellular systems, more vehicles can be integrated into the national telephone network, with essentially the same quality of transmission and grade of service as now experienced in the telephone network.

To enhance the individual's sense of personal security, and as a contribution to a more systematic study of crime and its prevention, the Committee recommends some preliminary experiments of community security telecommunications networks, using simple equipment and operated by the community members themselves.

In energy conservation and management, the Committee concludes that telecommunications can be applied in several peripheral but potentially significant ways: substituting for travel, transmitting demand and pricing information between consumers and utilities, and facilitating the marketing and transfer of bulk power. Telecommunications technologies are available, but other obstacles must be overcome, including the widespread preference for personal, face-to-face encounters, the uncertainties about utility-rate design and extent of cooperation between utilities, and the arguments against increased bulk power transfers. The Committee recommends a number of studies that would assist in clarifying the potential of telecommunications in energy conservation.

Because such applications differ markedly in character and scope, it was not possible to analyze them in an identical manner. Yet, where possible, the Committee has sought to:

- identify approaches for upgrading telecommunications that could be implemented during the 1980's;
- evaluate the feasibility of this upgrading and to describe approaches for minimizing any perceived barriers;
- describe the associated social, economic, and energy costs and benefits;
- estimate the likelihood of utilization, and
- suggest, where appropriate, trial projects and demonstrations.

The Committee's earlier report, <u>Telecommunications for Metropolitan Areas: Near-Term Needs and Opportunities</u>, was a review and evaluation of present and evolving telecommunications technologies as applied to near-term metropolitan needs and opportunities (until 1980). The Committee found that while telecommunications already provides significant services to support both private and public functions in metropolitan areas, opportunities remain. Planners of urban services need to recognize such opportunities in a more analytical manner by aggregating urban needs and bringing them into sharper focus. To achieve greater awareness of the potential of telecommunications to support the delivery of public services, urban administrations should engage individuals trained in the disciplines necessary to make computer-communications systems work effectively. Yet, seeking ways to apply existing and new technologies supplements rather than substitutes for the hard systems analysis of the public service functions to be performed.

A second objective of the previous study was to investigate whether the integration of telecommunications facilities and services would result in greater effectiveness. On that issue, the Committee concluded that although the integration of facilities and services should be considered, it may not be the most cost-effective response to metropolitan needs and telecommunications opportunities. So many dissimilar requirements exist that each situation needs to be studied separately and on its own merits.

In these reports, the Committee has sought to provide the urban-service planner and the urban administrator with a better understanding of the potential of state-of-the-art telecommunications technology to improve the delivery of public services. We urge public officials to use the best technology available on a practical, economical basis, and not to put off action in the expectation that tomorrow's technology will be better. Because of the rapidly changing nature of technology, urban administrators are urged to keep up with new developments and possibilities for implementation to be able to evaluate prospective service benefits and reduced system costs.

Effective utilization of technology requires the ability to match an opportunity to adopt the technology with a need for more efficient achievement of service objectives. Making such matches requires both a clear statement of public service objectives (defined largely in terms of desired capabilities), and an understanding of the technology (characterized largely in terms of service features rather than hardware). In some cases, the realignment, consolidation, and integration of public service activities themselves may facilitate the use of new technology or may so change the cost/benefit ratio as to make its early application economically feasible.

Telecommunications is but one element in public service systems, whose improvement depends more on large-scale rationalization and change than on attempts to correct deficiencies by modifying a single component. While it is possible to generalize about how telecommunications can best serve public needs in metropolitan areas, the most practical and useful strategies can be derived from measured evaluations of realistic demonstrations, and from studies focused on specific metropolitan communities.

CHAPTER II

Technological Projections

Improving the delivery of public services through telecommunications does not necessarily require the use of the very latest technologies. As this report will make clear, the delivery of public services can in some cases be enhanced by more systematic use of mature technologies. Nevertheless, important advances in telecommunications technologies will be available for implementation during the 1980's. To establish the technical background for the report's proposals, some of these advances are briefly summarized here.

Telecommunications systems are composed of three major subsystems: terminals, transmission, and switching and control. Specific advances in technology usually improve only one or two of the subsystems, but with each major improvement, the system as a whole must be rebalanced for maximum system service at minimum system cost. The technologies expected to induce major changes in telecommunications systems during the 1980's are integrated circuits, digital techniques, and optical transmission systems.

Integrated circuits, an outgrowth of transistor development and sophisticated solid-state electronics, are approaching levels of reliability, cost, and capability likely to hasten their application in local-service terminals. As microprocessors, they perform digital computer functions in matchbook-size packages. The trend to greater capability and reliability at even lower cost is expected to continue for many more years. The application of scientific techniques already known could support such a strong prediction even in the unlikely event that no more scientific breakthroughs occurred. A desk-size computer of the early 1960's that cost $30,000 had a computing capacity now matched by a microprocessor the size of a postage stamp that costs only $15. Local telephone service will make increasing use of such devices in accepting, switching, and transmitting calls, and in operating terminals in homes and offices.

Digital technology owes its existence in large part to developments in solid-state integrated circuits for the computer industry. Digital signals--very short electrical pulses--are used in two distinct ways: as the language of the digital computers controlling the switching in telecommunications systems, and as representations of both data and voice for more economical transmission between telephone exchanges in high-density areas. The voice signals are reconstituted at the receiving end with such fidelity that users are unaware of the digitizing process. As an example, the pulses representing the speech of several callers are actually interleaved into one continuous bit stream, and then sent to the destination switching center on two wires originally installed to carry only one conversation. Swift and orderly conversion of all voice signals to digital pulses for transmission through the network is taking place today. The economies of digitizing voice communications are so great that most observers believe the telephone network may be almost entirely digital by the year 2000.

Optical transmission is just beginning to emerge from the laboratory, and is already showing great promise for reducing costs and making possible new communications services. Ultra-transparent glass fibers, a natural transmission medium for pulsed light signals easily produced from lasers or light-emitting diodes, reinforce the trend toward digitized telecommunications networks. Their first application in the telephone network will be for carrying digitized voice signals on the trunks between telephone exchanges, where they are expected to be cost-competitive with copper cables by the early 1980's. An especially attractive feature of glass fibers is their ability to carry a large volume of traffic in less space than coaxial or multiconductor copper cables, and to do so without causing or being sensitive to electrical interference. Fiber optics will probably be used first on new routes and on underground routes now built to physical capacity. Full conversion, particularly of local loops to residences, may not take place for many years unless demand develops for new wideband services to the home.

Although it may take some time before optical fiber technology proves economical, such fibers may some day provide connections to every home and office--the same fiber carrying voice, data, video, and other signals simultaneously. At the customer's terminal, integrated circuits would separate the several signals from one another instantly. This vast information-carrying capacity could greatly increase the versatility and utility of telecommunications services.

New technologies pass three tests on their way to the marketplace. Initially, the technological theories need to be confirmed by actual experiment; then, systems employing the new technologies must be engineered and found operationally reliable, and finally, a system incorporating the new technology must be viewed as cost-effective by potential users. In order to be useful in the 1980's, new technologies must now be at least in the engineering stage. In this report, the Committee uses the term "technical feasibility" to reflect high confidence that a reliable system can be engineered, but not necessarily that users will find such a system cost-effective.

CHAPTER III
Access to Public Services from the Home

Enormous resources are being spent for such public services as medical care, remedial education, and emergency services. Delivery of such services by government and the private sector takes many and varied forms. Our question, then, is how can telecommunications technology improve service delivery and reduce costs? Furthermore, can the technology be applied in a way that permits its use by the urban public, especially by the unemployed, the sick, the handicapped, and the elderly?

The potential of modern telecommunications to provide services to the home has been described by several committees and individuals (Baer, 1971; National Academy of Engineering, 1971; Sloan Commission on Cable Television, 1971). On the basis of this work, some limited projects demonstrating such services were initiated with government support, primarily, though not exclusively, based on two-way cable (Mrozinski, 1975). But the promise of expanded services that could become available to a "wired city" have not been realized, in part because of the single-thread or one-service nature of the projects and the limitation of objectives in order to conserve funds, in part because of the almost exclusive use of a single telecommunications medium and the heavy emphasis on the technological aspects of the projects.

Today's telephone, radio, television and cable technologies, together with new developments that can confidently be predicted for the next few years, are more than equal to the task of providing innovative telecommunications services for use by the average citizen. What is needed is a concerted effort to provide a variety of services over an integrated communications-information system so that the feasibility of sharing facilities and operating costs can be firmly established. Such an effort will require a consortium of government and industry and the cooperation of the public. Some of the services are likely to be those that are now provided by the private sector, such as entertainment, while others will be those now provided by government, such as emergency and information services. Without including both public and private services, such a project is doomed to failure: public services by themselves cannot support a wired city. Furthermore, industry, with no experience on which to base an expectation of future profits, and with no single organization able to provide a full complement of telecommunications services (telephone, radio, television and cable), is unable to proceed. In this situation, government can, and should, help to generate some momentum.

With current technology, opportunities already exist for innovative communications services to the home, as illustrated by the rapid progress being made in other parts of the world. In the United Kingdom, trials of Teletext (Ceefax, Oracle and Viewdata)* are underway (Willson, 1977). In Japan, government and industry have begun field trials of a wide variety of services using cable systems (LVISDA, 1977) and fiber optics (LVISDA, 1976). In West Germany, plans have been reported for trials of both Teletext and services using fiber optics (Pascher, 1977; Wireless World, 1977). Interest has been expressed in a Viewdata system in Sweden, the Federal Republic of Germany, France, and Italy. Nowhere in the United States are such developments being pursued as broadly. It is not idle speculation to suggest that advanced telecommunications will be demonstrated first in Japan, Europe, or the Middle East, and then imported to America. Who can tell what effect this would have on our domestic communications industry?

The Committee believes that a bold step must be taken. The present paths of today's disjointed, disaggregated experiments will not converge in any reasonable time. A framework must be established within which these opportunities can be pursued by industry and government sharing financial risk and technology for the public good. A multi-year, multiphase demonstration project should be undertaken to determine the best way to use a combination of telephone, radio, television, and cable to provide innovative communications services to the public.

An outline of such a project is given in Section 8 of this chapter. Prior to that, Section 1 briefly discusses the households of the future, Sections 2 through 6 give examples of services that might be delivered to the home by telecommunications, and Section 7 outlines the possible ways that home communications-information centers might develop.

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*TELETEXT is a specific text and graphics presentation intended for display on standard television receivers. It was designed by engineers at British Broadcasting Corporation (BBC), and presents (in the U. K.) a "page" of 24 lines of 40 characters per line, in up to seven colors (including white).
CEEFAX is the BBC service that provides Teletext information to the public by including data on unused scan lines in the TV signal.
ORACLE is a similar service provided by Britain's IBA (Independent Broadcasting Authority).
VIEWDATA is a system developed by the British Post Office to provide a wide variety of information in Teletext format to the public over the telephone network. The service is offered under the name PRESTEL.

Section 1 The Future Home Environment

The metropolitan household depends on the real-time communications media--radio, television, and the telephone--for information, assistance, social contact, and entertainment.

Integrating existing technologies with those now in development, we can look forward to new combinations that provide greater communications capability for families in the '80's, creating increased opportunities within the home to gain access to a broad spectrum of public services to the benefit of both the citizen and his government.

Any forecast of future applications must take into account America's changing lifestyles.

Projecting the trends that have developed in metropolitan living over the last few years (p.34, National Research Council, 1977a), we conclude that by 1985, there will be approximately 60 million households in the metropolitan areas of the United States. Of these, approximately 60 percent will be headed by a man and a woman (with or without children), another 10 percent will be headed by one person (usually a woman with children), and the remaining 30 percent will be units maintained by individuals living alone. During the day, when schools are in session, perhaps only 30 percent of the family dwellings will be inhabited. There will be about as many units occupied by elderly persons living alone as are occupied by non-working wives with children. If present trends continue into the '90's, there will be a shift toward more units occupied by the elderly as the number of elderly people continues to increase and the number of children stabilizes or decreases.

For the households headed by one person, for households maintained by individuals living alone, and for the 70 percent of dwelling units unoccupied during the working day, there will be an increasing demand for security monitoring and for preprogrammed and remotely controlled household services. The working head of a household will find it economically advantageous to turn off air conditioners while the dwelling is unoccupied, and to have them turned on either automatically or by a device that is called remotely to turn on air conditioners, ovens, or heating units.

In households of the elderly particularly, there will be rising concern for personal security, for emergency services (especially if disabling household accidents occur), for social welfare, for socialization, and for other services.

In Sections 2 through 6, we discuss examples of possible public services that could be provided in the home (or immediate community) as they relate to:

- Information Services
- Education Services
- Health Services
- Emergency Services
- Household Management Services

The applications we describe are not new. The concepts date from the late 1960's, but their implementation will be easier with the technology of the 1980's.

Section 2 Information Services

Public service agencies now provide information about jobs, medical and insurance benefits, Social Security, consumer guidance, and tax assistance. To gain access to such information, a citizen usually appears in person at the appropriate government office. Searching out the right office can be frustrating and time-consuming. Many government facilities now contain information centers to answer general questions and guide the citizen to the proper office. For example, the federal government, through the General Services Administration, opened its first pilot Federal Information Center in 1965, and subsequently expanded this service to 37 centers throughout the country. The centers use toll-free tie-lines to an additional 40 cities and now cover about 55 percent of the country's population on a local-call basis. Last year, Federal Information Centers handled more than 7 million requests, of which 65 percent were made by telephone.

Making information available directly to the home in an easily understood form is a natural extension of traditional government information services. Since most households in the United States have both telephone and television services, the means exist for providing such information directly, without substantial additional cost to the householder.

The Social Security Administration operates teleservice centers to provide information by telephone to the general public about its system, to initiate post-entitlement actions for beneficiaries, and to refer calls about pending issues to appropriate offices. About 20 million calls are received annually. The Internal Revenue Service allows any taxpayer in the United States to make a toll-free call for assistance, information, or clarification of bills and notices. Of the 40 million requests received annually by the IRS, 70 percent are by telephone. For the hearing-impaired, the IRS accepts calls by TV-PHONE, a standard typewriter-style keyboard that connects to the phone system through an acoustic coupler and uses a home television for display. The same type of service for the hearing-impaired is also available at some hospitals and libraries, and from local governments.

Three broad levels of information services can be distinguished. The first is a simple data-base query that requires only an automated response. Examples in the public sector include job listings, public transportation information, public building hours; in the private sector, restaurant services, entertainment information, stock prices, and so on. Several countries in Western Europe are developing an innovative service known as Viewdata, in which data requests and responses are transmitted over the switched telephone network for display on television receivers through supplementary electronics. A variation of Viewdata being examined in the Federal Republic of Germany would use a broadband cable network for interactive data transmission.

The second level of information services that could be provided directly to the home is characterized by the requirement for personalized information from the government agency. For example, a citizen could call a phone center for information about his or her unemployment benefits, Social Security status, or veterans benefits. In the private sector, typical second-level services include insurance claims and credit card applications. Some government agencies are already experimenting with the concept of providing personal services by telecommunications. For example, the Social Security Administration has set up pilot centers to process requests for information and changes in status.

The third level of information services that could be provided directly to the home involves interactive personal services such as counselling, response to crisis situations, or medical advice for specific classes of citizens. An information system for such services could provide a point of contact for isolated citizens, and could be designed to help the caller analyze the problem.

At all three levels, some computer support is essential for rapid information handling and response. Indeed, in the first (data query) level, the interaction is only with a computer. The trend in public information services seems to be away from the personal one-to-one service and toward computer-assisted response. As the costs of providing personal response go up, more information will be made accessible at office sites through computer information terminals without personal assistance from an agency employee. (At this time, it is unclear to what extent the human intermediary will, or should, eventually disappear.)

The next step may be to permit remote access to such information from terminals in local centers or in the home. Indeed, home retrieval may be encouraged by private sector enterprises. In the future, messages could be delivered to the home over telephone wires to the television set, as in Viewdata, or mixed with broadcast television signals, as in Ceefax and Oracle. Some private sector organizations can be expected to support such systems, thereby providing a base on which public services can be overlaid. The overriding need for a seller of goods or services to give notice of their availability is strong incentive to support a flexible home information system.

Feasibility

The widespread availability of computer time-sharing services and the existence in the United Kingdom of such experimental services as Viewdata, Ceefax, and Oracle leave no doubt that it is technically feasible to provide interactive information services in the home. Acceptance by the public will depend on the cost of the service, the degree of difficulty in operating the terminals, the degree of literacy required, and reaction to the loss of human contacts.

Barriers to Implementation

The creation of data bases containing general information on benefits and their prerequisites, or highly specific information about the status of a citizen's claim or payment, is a task of no small difficulty. Nevertheless, the technical problems can be solved. Of far greater concern is the question of whether citizens would be satisfied with automatic public information and services. Would they consider it sufficiently reliable to form the basis for significant personal decisions? Would a system without personal contact foster a bureaucracy insensitive to the needs of the individual? Would operation be simple enough for the majority of citizens to use it satisfactorily? How frustrated would users become if unable to obtain certain information? Anyone who has used a time-sharing terminal knows the feeling of utter helplessness when the machine responds "IMPROPER SYNTAX--REENTER: ...." Worse, would users become disillusioned because they received wrong information as a result of not asking the right question?

Another important issue concerns privacy. Will it be possible to protect personal information from unauthorized acquisition and use? Can a data base that contains many millions of confidential records be simple enough for the average individual to use remotely, yet secure enough to prevent penetration by unauthorized people skilled in computer technology? What are the added system costs to provide privacy?

Finally, as with any technical development that replaces people, there is the issue of support within the bureaucracy. Will a department head support the development of a system that reduces the department's staff and may transfer a substantial portion of its budget to data-processing?

Likely Extent of Utilization

Many citizens are not in frequent touch with government agencies; for them, income tax time is the only period when they consider requesting information or asking advice. Others require fairly frequent communication--the unemployed, the poor, the handicapped, and the elderly--as they seek information about requirements and benefits. As a group, they make up close to one-quarter of the population. Because many of them may also require counselling or the assurance of human contact, they may well be motivated to use inquiry stations located in government information centers, community centers, and other central points. Initial implementation of new information service at such centers has the advantages of introducing new technology in a familiar environment, continuing the element of human involvement, and providing a natural vehicle for feedback to the designer prior to implementation in homes.

If the private sector develops commercial information services that send data over telephone wires for display on television sets, certain public services could do likewise. It seems unlikely, however, that specific personal information would be included. Information would be of more general interest, such as schedules, news, and registration reminders that many people may wish to obtain from time to time.

Benefits and Costs

An accessible information system could make essential public information readily available on demand at convenient points, thereby reducing unnecessary travel and frustrating delays. Both the government and the public should benefit. Only important matters would require the citizen to visit a government office; in turn, government employees would have more time to devote to substantive problems.

Because much of the information dispensed is already stored in a computer for easy manipulation, creating data files for an information system would not appear to be an overwhelmingly costly task. Local information-center terminals might cost several thousand dollars each (the range of today's time-sharing terminals) and a terminal to be used at home would cost several hundred dollars (the range of today's television receiver).

Recommendation

As a first step, it is recommended that federal government departments and agencies undertake a study of the actions necessary to establish a pilot data base containing government information frequently requested by the public in order to investigate the usefulness and public acceptance of making such information available electronically at government information centers.

Section 3 Education Services

We seem to be on the threshold of a "learning society" in which learning is regarded as essential not only for the survival of man, but also as a route to social and individual maturation (Bronowski, 1974), the key to personal development and adaptation to the social changes wrought by new knowledge and technology. Technology, which itself requires more independent and self-directed learning, can at the same time improve access to learning opportunities (Wedemeyer, 1976).

Educational services of the future should not only serve the full range of learners in society, but should also be concerned with the residual effects of less effective education. Not all children and youth received an adequate education in the past, and as they have grown into adulthood, they have carried with them the learning deficits of their school years. Since World War II, such learning deficits have become impediments to steady employment, job satisfaction, successful parenting, and effective participation in the affairs of a rapidly changing society.

Persons with learning deficits may have suffered some degree of learning trauma during school attendance, and therefore find it difficult to turn to standard schooling, which they expect to be ineffective in helping them.

Supplementary education services that are mere extensions of regular schooling at fixed places and times do little to improve access and opportunity for those who most need to overcome learning deficits, and tend to perpetuate barriers to their continuing education. Delivery of educational services to the home by telecommunications could overcome some of these problems as well as expand educational opportunities for a whole range of citizens: pre-schoolers, elementary and secondary pupils, employed adults, the home-bound, the handicapped, and the elderly. In view of the population trends projected earlier, evening hours could be used to supplement the education of those who attend school, or who work during the day, while services during the day might be directed to preschool children, mothers occupied in the home, the handicapped, and people in institutions.

A demonstration program has recently been reported whose aim is to provide educational services through telecommunications for the handicapped (Upton, 1977). Similar services could be provided for preschoolers in metropolitan areas. The communications technology exists to allow each preschooler to have regular interactive sessions with an electronic tutor. Starting at day-care and community centers in metropolitan areas, the program could be expanded into homes as the cost of terminal equipment decreases. If implemented on a national scale, cable-TV and satellite networks could be used to distribute program material. The same basic communications system could be adapted for use by the elderly, the handicapped, the homebound and people in institutions.

Children and youth could be served by preschool programs, by programs for exceptional pupils, dropouts and advanced learners, by compensatory and preparatory programs, and by programs that reach parents, children, and youth learning together. Adults could be served by courses and materials that lead to certification or accreditation at the high school, vocational-technical, and university levels; by materials for persons with personal, economic, vocational, and social or developmental needs; by post-experience courses that would provide adults the opportunity to retrain for new careers or at new levels or to re-enter advanced and degree programs.

Instruction could be diffused through an interactive communications system. Access to services could be provided in the home, workplace, office, community center, library, museum, or other institutions as available and appropriate.

Feasibility

Hundreds of experiments and demonstrations on the use of technology in instruction have consistently confirmed the feasibility, efficiency, and cost-effectiveness (for volume use) of using the telecommunications media for instruction of distant, independent learners (Dubin and Taveggia, 1969; Advisory Committee on Issues in Educational Technology, 1974; National Academy of Engineering, 1973; Carnegie Commission on Higher Education, 1971). Surveys of learners indicate readiness and willingness to learn through technology (Wedemeyer *et al.*, 1971). The Committee's earlier report (National Research Council, 1977b) examined a number of promising applications. Non-traditional, independent programs for learners distant from schools and teachers have successfully served millions of youth and adults through various formats and technologies for nearly a century. Universities, university extensions, community colleges, specialized institutions such as the University of Mid-America, and many private institutions, as well as business, industry, and government have created programs that could be models for education services in metropolitan areas. The technical and educational feasibility has been well established (Wedemeyer and Najem, 1969).

Barriers to Implementation

There are several barriers to the creation of a system of education services that employs telecommunications and computer technology for delivery to the home:

1) *Software development*. The difficulty and expense of good software development has discouraged or prohibited many educators from work in this area. Part of the difficulty in software development has been the persistence of the old classroom learning model, which has to be abandoned in the development of appropriate software for new systems learning.

2) Teacher education and development of learning theory. Some teachers have had no preparation for conducting education outside the school. They are subject-matter centered by professional preparation, and they feel incapable of acquiring the necessary skills to contribute effectively to non-traditional education, even if they wanted to. Theory about learning outside schools, by adults and self-directed learners, is only now receiving general attention.

3) Demand vs. need. The two-way home video experiment at Spartanburg, South Carolina (Lucas and Quick, 1977) has shown that need does not necessarily translate into demand. Although 62 percent of the adults there had not completed high school, participation in the high school equivalency program was not as great as expected. The anomalous differences between that experiment and other studies reported below need to be better understood.

4) Attitudes about learning. Barriers may also exist because of the importance that some teachers, parents, and students attach to the classroom and the teacher-learner relationship. It is almost impossible for some people to think about learning without assuming that it is synonymous with schooling. The self-concept of educators (among the most successful products of schooling) often encourages them to follow the models by which they were taught and which they now profess. We do not dispute that a vital part of education is the human relationship between learner and teacher. Technology cannot substitute for human relationships, but such relationships can be sustained over distance by electronics where the communications medium itself is perceived to be responsive--a perception dependent on the quality of software, not on the medium itself. Building a "wall of electronics" is no way to develop social skills in a pre-schooler, provide assurance to the elderly, and assist the handicapped any more than it is a way to run a business (Carne, 1972). Nevertheless, a combination of communications and electronics should be able to provide a tireless facility that can stimulate the learning of facts, skills, and good learning habits.

Likely Extent of Utilization

In 1974, the "learning force" in the United States consisted of 100 to 120 million people, of which about 60 million were formally enrolled in public and private institutional programs (elementary to university level), and another 40 to 60 million were involved in vocational, technical, informal, and independent learning programs. It appears that enrollments of part-time learners in all types of post-secondary and independent study will continue to increase.

It is estimated that in the United States, 40 percent of the adults over age 25 have not completed high school, 22.5 million adults have not completed elementary school, and 11.5 million adults are functionally illiterate. Learning deficits in a complex and changing technological society are among the cruelest of all deprivations.

But what proportion of people with needs will actually make use of education services of the kind proposed? This question cannot be answered without specific studies in targeted areas, when program content and format are known. However, there have been consistent general responses to surveys in various parts of the country that provide a broad picture of interest and intent. From one such survey (Wedemeyer et al., 1971):

- 23 percent of adults are interested in non-degree continuing education;
- 27 percent of adults are interested in education leading to a degree;
- 64 percent think they could successfully complete more education;
- 46 percent wish they had acquired more education;
- 38 percent want more education for job or career advancement;
- 32 percent want more education for self development;
- 66 percent want to continue learning;
- 80 percent think media and technology could be used to improve access to education.

In Section 1, we pointed out that in the 1980's, the majority of adult women will participate in the labor force. For those with preschool children, this implies the use of babysitters or daycare centers. The installation of interactive terminals in day care centers would make them available to many of the nation's children. As the cost of terminal equipment decreases, installations could be made in the more affluent homes and eventually in all homes with small children.

A similar pattern might be established for the elderly, the handicapped, and those seeking remedial and vocational education. Initial installations could be in community centers, or other central locations, with later dissemination to homes.

Benefits and Costs

The telecommunications-based services we have described could benefit the public by instilling early learning skills and attitudes in preschoolers, providing remedial and vocational education, and opening a window on the world for the elderly and the handicapped. A large initial and continuing cost would be incurred by the development of program material--a cost that should be recovered by the reduced expense of providing remedial education later in life.

In time, the cost of terminal equipment should approach the cost of a television set. There would be other initial costs for the data-base hardware and computer-based management system (centralized or distributed). The preparation of program material and the use of distribution facilities would create continuing costs. In a large system, the per-subscriber cost might eventually be equivalent to typical monthly rental fees now charged for cable-TV service.

Experience at the Open University of the United Kingdom confirms predictions of reduced costs per unit of instruction when the telecommunications media are used in a large system of instruction. When high volumes are aggregated across numerous metropolitan communities, the per-unit costs of education services to learners at home are likely to decline.

The economic advantages to society of a better educated populace can be compared to the cost to society of learning deficits--in terms of institutional care, welfare payments, community unrest, and unused human talent and potential.

Recommendation

It is recommended that the Department of Health, Education, and Welfare support and encourage the experimental development of a variety of media-assisted education programs in homes for the purpose of creating attractive education opportunities for all.

Section 4 Health Services

Under certain conditions, many medical problems can be dealt with at the periphery of the medical care system with a very high degree of safety. Because decentralization of patient care involves the substitution of personnel with less medical skills than physicians, and may reduce the number of trips patients make from their homes to a hospital or clinic, it may be in the national interest from the viewpoints of containing medical costs and of reducing energy used in transportation. Efforts in this field using telecommunications-aided paramedics at a medical care site have made credible such decentralization (Bashshur _et al._, 1975).

In its previous report (National Research Council, 1977b), the Committee reviewed potential telecommunications applications in the delivery of health care generally. This report discusses two examples of decentralized care involving the use of telecommunications.

One example is the treatment of a patient who has already been diagnosed to have uncomplicated hypertension (high blood pressure of unknown cause but without other interacting disease) and has been given medication to keep blood pressure within well-defined limits. The patient is under the care of a physician equipped with a computer programmed for the management of hypertension, and for the identification of patients who have not visited the physician within well-established intervisit intervals. Non-physician providers obtain information, evaluate results, and ask for physician intervention when necessary. Through the use of automatic instruments and a terminal in the home, the patient could transmit information about his physical condition to the non-physician health provider and answer a set of questions presented on a terminal to establish whether the hypertension is within the desired range, whether complications have arisen, and whether undesirable side-effects of medication have occurred. If there are no unusual findings, the patient will have saved a visit to the health care facility. If there are unusual findings, the patient will arrive at the facility with a specific reason for the visit, which should make the visit more efficient.

As a second example of the potential of telecommunications to improve the delivery of health services, consider the patient hospitalized with acute myocardial infarction (heart muscle damage from localized interruption of blood supply). At present, treatment normally involves hospitalization for 14 to 21 days. A number of trials (Hayes _et al._, 1974; Hutter et al., 1973; Bloch et al., 1974; Abraham et al., 1975; Harpur et al., 1971) have demonstrated that early walking and discharge is not detrimental and may, in fact, be beneficial to the patient. The reluctance of both physician and patient to consider early discharge might be overcome by the assurance that the patient could be systematically monitored after discharge for a period at least as long as he would have stayed in the hospital. Such monitoring could be achieved by telecommunications if automatic instruments were used to transmit an electrocardiogram on request and to monitor pulse rate and regularity. Even supplemented by a daily visit from a trained nurse, the total cost would be substantially below a day's hospital stay. A baseline check on the patient's condition would be made upon his arrival home. A home measurement of cardiac rhythm, which can be monitored by telecommunications, will indicate the existence of premonitory arrhythmias calling for transfer to the hospital or for medication at home. Should unusual symptoms develop, the monitoring equipment could automatically call the medical center, relaying data to enable an informed decision whether to counsel the patient by telephone, to dispatch a physican's aide, or to bring the patient to the hospital by ambulance--again, with a specific reason for further hospitalization.

We recognize that the most pressing concern in monitoring a patient with acute myocardial infarction is the possibility of a sudden electrical failure of cardiac rhythm. This kind of emergency must be responded to in minutes, which is the classic justification for the coronary care unit. If the patient should experience such an event at home, there may be insufficient time to reach the hospital. Two points must be made in this connection. The first is that work by Mather et al. (1976) in Great Britain has shown these events to be rare among patients with uncomplicated acute myocardial infarction or even to be induced inadvertently by treatment, particularly by the stress of being transported to coronary care units. The second is that anti-arrhythmic agents are now under widespread development and testing as oral medication and are likely to be routinely available within the next five years. Increasingly, the burden is falling on hospital coronary care units to demonstrate that they are significantly better than alternative forms of care for acute myocardial infarction. With that shift, the monitoring of such patients by telecommunications will become of increasing interest.

Feasibility

Both applications are technically feasible. The medical feasibility of hypertension management and the monitoring of uncomplicated acute myocardial infarction (AMI) is based on experience in Britain and elsewhere that did not have the advantages of the technological aids proposed here. The central issue is one of trade-off between the presumed level of medical safety provided by in-hospital AMI care and that which might be achieved at home. Based on available data, out-of-hospital care of uncomplicated myocardial infarction, as measured by randomized clinical trials involving several hundred patients, shows no statistically significant difference in outcomes (Mather et al., 1976).

Barriers to Implementation

The significant economic, social, and psychological barriers have been generalized in the Phase I report of this Committee (National Research Council, 1977b): incentives for using telecommunications for economic or energy conservation reasons are lacking in the present health care system.

There are actually some disincentives. A visit saved by care at home generally means one less office fee. Nearly 75 percent of all office visits are made to physicians who are recompensed by third-party payers only if a personal service is rendered (National Center for Health Statistics, 1975). Patient care by telephone, the use of non-physicians for patient care, the added cost of equipment to permit follow-up and audit of non-physician care are not reimbursed by many third-party payers, including Medicare. Home visits (as for acute myocardial infarction) are financially inefficient for providers. The provider's time is more efficiently expended by asking the patient to come to the hospital emergency ward. The decision can now be rationalized by the availability of more sophisticated equipment and better follow-up care for those patients who require it. The patient sees little financial advantage in eschewing such care. Even if the "save" rate were found to increase by only 1 or 2 percent despite the added expense, the patient effectively does not expend the money personally, so there is no economic incentive to turn down such care. With many insurance policies, it is to the patient's financial benefit to be admitted to the hospital because insurance will not pay for ambulatory care.

With the exception of prepaid Health Maintenance Organizations, hospitals have no incentive and many disincentives to make the capital investments to reduce hospital stays by such techniques. The average occupancy in hospitals across the country is around 75 percent. Why should hospitals reduce it further? There is no easy mechanism for getting trained personnel to use this equipment, no assurance that individual providers or even small groups of physicians can aggregate enough patients to use the equipment economically.

The first step toward minimizing such barriers would be to ensure that providers do not lose any income by providing more economical care. This implies a system in which the providers are reimbursed for providing telecommunications-mediated health care and for supervising and auditing non-physicians. In a demonstration application there should be little difficulty arranging this, provided there are concomitant arrangements to ensure the quality of the care delivered. One might wish to go further and allow the provider to share in the savings that may result.

Another step would be to encourage institutions to support such innovations by allowing the capital investment to be made, and by securing reimbursement for out-of-hospital care. Hospitals are the most likely institutions to aggregate the numbers of patients required to make the use of the capital investment cost-effective. Since out-patient departments now account for about 25 percent of ambulatory visits, the task is not insuperable. With further restrictions on in-hospital costs, the hospitals may be eager to open new sources of revenue production.

The most likely providers to accept such innovation are organized provider groups. The hospital may act as a surrogate organization for the more conventional group practice or pre-paid health plan by providing managerial and aggregating abilities to make the system economic.

Likely Extent of Utilization

If the health care system remains substantially unchanged structurally, and if the increases in health care costs are contained by budget "caps" with no attempt made to rationalize the system, then utilization will approach zero. But if one assumes that the system will be rationalized in the oncoming debate on national health insurance, then utilization will depend on whether the options are available for consideration. If medically safe, cost-effective ways of delivering care at home can be demonstrated, a rational health care system will be forced to consider using them.

The applications discussed have been based on a great deal of experimental work to demonstrate the fundamental feasibility that makes them worth considering. In order to make optimal use of telecommunications in health care, a great deal of added experimental work is needed.

The average American makes between 4 to 5 visits a year to a health care provider--about 1 billion outpatient visits per year. Home terminals and equipment might play a role in half of these visits, and perhaps deal with half of these again without requiring the patient to visit the provider (both figures are conjectures). Based on experience with face-to-face care provided by non-physicians, this might result in saving one visit per year per capita or four visits per year in a household of four. The figure might be higher for the households that contain elderly people and very young children, both of whom have visit rates very much higher than the average. High-risk patients--hypertensives, diabetics, cardiacs --could make use of such equipment for potentially higher-quality care at lower cost--a partially tested conjecture (Komaroff et al., 1976).

Economic Benefits and Costs

A small but significant part of the cost of an out-patient visit is the overhead of maintaining a medical records room. The computer used for interrogation and storage of information about hypertension patients could be used to displace some records room costs and some part of the billing costs through computer-generated bills (or their equivalents for management information in an insurance system).

A mass-produced sphygmomanometer might be made very cheaply. For example, a strain gauge transducer could be used to measure blood pressure with calibration at the upper end through a pressure relief at 300 mm Hg. This could save the aneroid gauge. The addition of pulse-counting circuits and power through the cathode-ray tube interface might also minimize instrumental costs. Even with an aneroid gauge, such instruments are now being sold for $50. If one visit in four could be eliminated, the instrument should pay for itself, even discounting for the capital investment, in two or three years.

Instruments proposed for monitoring patients with acute uncomplicated myocardial infarction are substantially more expensive, but the hospital care eliminated by their use is also very expensive.

An episode of uncomplicated myocardial infarction may cost $3,150 in the hospital. Care in the home is an attractive alternative. As shown in Table A, the cost of one episode of uncomplicated myocardial infarction treated in the home is estimated to be $1,600, or one-half the hospital costs. While the projections for hospital costs in five years are expected to be significantly higher, the cost of electronic equipment for monitoring at home is expected to grow much less rapidly than hospital and personal service costs.

TABLE A: HOSPITAL vs. HOME CARE MEDICAL EXPENSES
Example: One episode of uncomplicated myocardial infarction

HOSPITAL EXPENSES	
Assume:	
3 days of coronary care @ $250 per day	$ 750
16 days of hospitalization @ $150 per day	2,400
Total (not including physician fees)	$3,150
HOME CARE EXPENSES	
Assume:	
3 home visits by nurse (1 initial visit; 2 follow-up visits) @ $50 per home visit	$ 150
46 computer interactions of 1 hour each (24 the first day; 6 for each of the next 2 days; 2 per day for the next 5 days) @ $1.50 per hour	69
46 nurse interactions by telephone for 1/2 hour each interaction to supplement computer @ $12 per hour (including overhead)	276
Hospitalization for complications (average 1 in 10)	315
Amortization, rental, installation, removal and maintenance of monitoring equipment*	790
Total (not including physician fees)	$1,600

Recommendation

It is recommended that the Department of Health, Education, and Welfare encourage the study of these and other uncomplicated medical situations in which patients can be tested at home by a combination of paramedical personnel and telecommunications in the interest of reducing medical care costs.

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*Capital investment $23,700 using a 20 percent utilization rate to avoid queues when several patients simultaneously have myocardial infarctions.

Section 5 Emergency Services

Confronted with a sudden or unexpected situation that threatens life or property, the average citizen's immediate reaction is to seek the assistance of fire, police, or emergency medical services. For the responding agency to provide prompt assistance, the dispatcher must receive information about the location and extent of the emergency, plus supplementary information that may aid in the dispatch of appropriate personnel and equipment. Virtually every home in the United States has telephone service, and the overwhelming majority of citizens now rely on the telephone to gain access to emergency services. In 1968, a three-digit telephone number, 911, was set aside for emergency use nationwide.

Most 911 systems connect the caller dialing the digits 911 to an emergency answering center. The caller gives the emergency message to the public safety dispatcher, who then initiates the response or relays it to the appropriate response agency. Because telephone exchange boundaries and the boundaries of police, fire, and ambulance jurisdictions are usually not identical, planning for 911 services is often difficult. In metropolitan areas, these overlaps can be so complex that a central dispatching point is often established to receive calls from all exchanges and relay them to the appropriate responding agencies. This relay function can be manual or automatic. Additional automation can provide the emergency answering center with the caller's telephone number and location to speed the emergency response, but providing these capabilities is expensive and might pose a threat to privacy (Hovey, 1974).

After ten years' experience with 911, only about 25 percent of the population of the United States is served by about 750 systems. At this rate, it may be 1990 before most of the country will be covered by 911 service. By contrast, a similar service is available nationwide today in some Western European countries, notably Sweden, Belgium, and the United Kingdom. The Committee recommends that nationwide implementation of 911 service be encouraged.

About 80 percent of emergency calls are for the police (National Academy of Engineering, 1971). For this reason, most answering points are manned by law enforcement personnel and are usually located at or near a major police or sheriff's facility. Fire calls are usually relayed to a fire service dispatcher immediately, although this procedure may result in some delay. Direct access to the fire department, without an intermediate answering point, might assume life-saving importance under certain circumstances. However, from a practical point of view, locating the 911 answering point at fire headquarters would require the transfer of four out of five calls to the police. Integrating the communications and management of the two departments (as well as emergency medical teams) is an alternative, although it is sometimes considered unworkable by the people directly involved. In any case, 911 service provides a more rapid response to a fire call than is achieved if the caller must look up, then dial, a 7-digit number (Illinois Commerce Commission, 1976).

Alternatively, sensors that detect fire, or unexpected entry, can be installed in the home to provide an audible local alarm or to alert fire, police, or private security services over the telephone network, CATV cable, or private connections (usually leased from the telephone company). Sensors connected to the telephone network use an automatic dialer and recorded location information (taped message or data) to inform the responding service of the location and nature of the emergency. Understandably, the reliability of some automatic systems (particularly fire alarm systems) is in question because the lack of discrimination in the sensors may lead to false alarms (smoke from burned toast may trigger the system). Thus, the first response by a security service to an automatic alarm may be to telephone the subscriber to determine whether an emergency exists. For sensors that use CATV cable, or private connections, information about the location and nature of the emergency are intrinsic to the connection and the equipment. Use of facilities of this sort in the home is not widespread because of the initial cost of the station equipment and the continuing cost of private communications channels.

A microprocessor used as an information storage and retrieval device in the home could incorporate specific emergency features for requesting help by dialing the appropriate emergency center upon activation of an automatic alarm, or when the request for help was dialed manually, for providing location information automatically to the emergency answering center. Subscribers could then choose to have as much, or as little, emergency communication as they wish.

Elderly people living alone fear a disabling accident that would prevent calling for help. Various social means are employed to combat their fear, including daily home visits or telephone calls by neighbors and friends. But between visits and calls there may remain long unmonitored periods. An urgent requirement, then, is some means of signalling for help in the event of a disabling accident. A possible solution might be a wireless device with a slow-acting switch activated when the wearer is horizontal, that causes a telephone to dial an emergency number. Devices of this kind are discussed in Chapter V.

Feasibility

As 911 systems are now available to a quarter of the population of the United States, the feasibility of providing such service is well established.

Barriers to Implementation

Until crimes or natural disasters actually occur, people may not be too concerned about their ability to summon assistance, nor about the ability of local emergency services to respond. This natural apathy, coupled with the fact that the operation of a 911 system requires the expenditure of local taxes, results in little overt public support for implementation of a universal emergency service.

A 911 service, *per se*, cannot distinguish between fire, police, and ambulance calls. Fire calls may be delayed up to 30 seconds or more by the need for the dispatcher to relay the information to the fire service (Illinois Commerce Commission, 1976). The alternatives are to route all calls through the fire station first (not a very sensible solution when four out of five calls require police assistance), or to dispatch all emergency vehicles from the same answering point.

Automated systems that supply the dispatching officer with the calling number (ANI, automatic number identification) and calling location (ALI, automatic location information) have the potential for abuse. Specifically, the information supplied could include an unlisted number, whose use by unauthorized persons could be an invasion of privacy. Should this be of sufficient concern, the caller has the option to dial the 7-digit numbers for emergency services, thereby protecting his number. An automated system with ANI and ALI will contain a file that includes the addresses associated with unlisted telephone numbers, and these might be obtained by unscrupulous persons. Nevertheless, this information is already available in telephone company computers.

Likely Extent of Utilization

If 911 were available nationwide, we believe the public would rely on it almost exclusively to summon emergency services.

Benefits and Costs

The use of a universal number to summon emergency services means faster emergency assistance, because the number 911 is easy for a citizen in trouble to remember, and because the individual emergency services are better coordinated. Furthermore, the use of the same emergency number nationwide would help visitors and travellers get help quickly. Emergency service operating costs are not significantly greater than those incurred without 911 (Illinois Commerce Commission, 1976).

Recommendation

It is recommended that state legislatures be encouraged to enact legislation establishing statewide universal emergency calling service. Several states, including New York and California, have already done this.

Section 6 Household Management Services

There is no doubt that energy conservation will assume greater importance in the future. Telecommunications can be used to help people manage appliances and environmental controls in the home. For example, during periods of high demand (anticipated or unanticipated), the energy supplier could transmit a signal that would activate a warning light in the home (and perhaps increase the rate being charged). Upon receipt of this alert, the consumer could turn off high-use appliances or elect to pay substantially more for the privilege of continuing to use them. If away, the consumer may wish to call home and regulate such major appliances as air conditioning, central heating, dryer, or hot water unit. This subject is explored in more detail in Chapter VI.

Other services could have more personal significance--a customized accounting and family data base, for instance. Financial information could be stored and used for computing income taxes, medical histories (vaccinations, medication, etc.) could be preserved conveniently, and other important information could be held for future use. While these are not public services, they employ some of the same technology and connections as public services, and could provide a broader base over which to spread the cost.

Feasibility

Utility companies, searching for ways to control consumer load, have used radio to turn off water heaters (Hastings, 1975), and have demonstrated that the power network itself can be used for communications. Several companies offer home computers that make it possible for consumers to dial special telephone numbers to switch equipment on and off (Hawkins, 1977). There can be no doubt that the services described here will be technically feasible in the early 1980's.

Barriers to Implementation

Much of what has been discussed is discretionary; there are no obvious barriers to implementation.

Likely Extent of Utilization

With two-thirds of all homes likely to be empty during the working day, remote control of appliances could be a widespread supplement to timing devices. Customized accounting and record keeping, however, are likely to be confined to a small percentage of relatively affluent homes.

Benefits and Costs

As a supplement to timing devices, remote control of appliances could be very useful in the conservation of fuel or electricity during the day. The cost of the necessary equipment might be a few hundred dollars, depending on the number and type of controls desired.

Section 7 The Home as a Communications and Information Center

Today, almost every home in the United States is supplied with electricity and equipped with a telephone, radio, and television receiver. Information is received and transmitted by wire and over the air. These instruments make it possible for the occupant to talk to almost anyone in the world, hear and often see a variety of music, news, sports events, movies, discussions, and other forms of public affairs, education, and entertainment of their choice. A relatively small number of homes have security alarms attached to coaxial cable (2-way CATV) or special telephone lines, and an even smaller number have some level of interactive cable television.*

Recently, special-purpose, computer-like attachments have become available that extend the capability of a television receiver for playing games. Video games are now a very active segment of the consumer electronics market. General-purpose microprocessor-based computers have appeared for the home hobbyist. Costing less than $1000, current models have a computing capability greater than ENIAC (the first electronic computer, completed in 1946) and can be programmed in BASIC (a high-level programming language). Rapid market growth and decreasing costs will continue in these terminal technologies. Printers and facsimile devices will become particularly important in the development of home communications; so too will a full alpha-numeric keyboard. Today's commercial versions will be superseded by less expensive, more convenient models for home use.

In addition, new transmission media may be introduced. Optical fibers are attractive because they are interference-free, can be installed in a small space, will not cause fires, and have a large communications capacity. The cost of optical fiber cable as well as associated electronics is declining, but whether it will be economically competitive for short-distance applications is still uncertain.

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*In Reading, Pa., for instance, elderly subscribers to Berks Community Television use a telephone to respond to one-way cable programs from neighborhood centers which are themselves interconnected by two-way cable. In Columbus, Ohio, subscribers to Warner Television have a narrowband return channel over the cable. Similar systems exist in Spartansburg, S.C., Woodlands, Texas, and Arlington, Texas.

It is also possible that geostationary broadcasting satellites will provide direct transmission to the home. Reception may be feasible with a dish antenna one meter or even smaller in diameter.

The provision of emergency, health, education, and information services described here requires "smart" terminals and communications devices. The demand for any particular service will probably vary by age-group and location. To achieve economies of scale, it is essential that a flexible, multi-purpose distribution system be employed so that the cost of service can be spread over a number of applications. This suggests an integrated communications and information system. As illustrated in Figure 1, one or more microprocessors operating four subsystems could provide a combination of public and private services. Some of the functions likely to be performed in the homes of the 1980's by each subsystem are:

- ENERGY MANAGEMENT, SECURITY, AND ENVIRONMENTAL CONTROL SUBSYSTEM

  Adjust electrical consumption by time-of-day, rate structure, or remote command
  Read meters
  Activate intrusion, fire, and hazard alarms
  Adjust temperature and humidity
  Control lighting
  Minimize resource consumption

- EDUCATION, INFORMATION, AND ENTERTAINMENT SUBSYSTEM

  Receive educational and entertainment TV
  Support interactive education
  Receive, display, and print information
  Support interactive information services
  Record education and entertainment for later replay
  Send, receive, and print personal messages
  Support video games and other activities

- ACCOUNTING AND RECORD KEEPING SUBSYSTEM

  Maintain family accounts
  Pay bills by electronic funds transfer
  Compute taxes
  Maintain family records
  Store addresses, recipes, telephone numbers, etc.

- COMMUNICATIONS SUBSYSTEM

  Interface with transmission media
  Distribute signals appropriately
  Provide automatic emergency calling

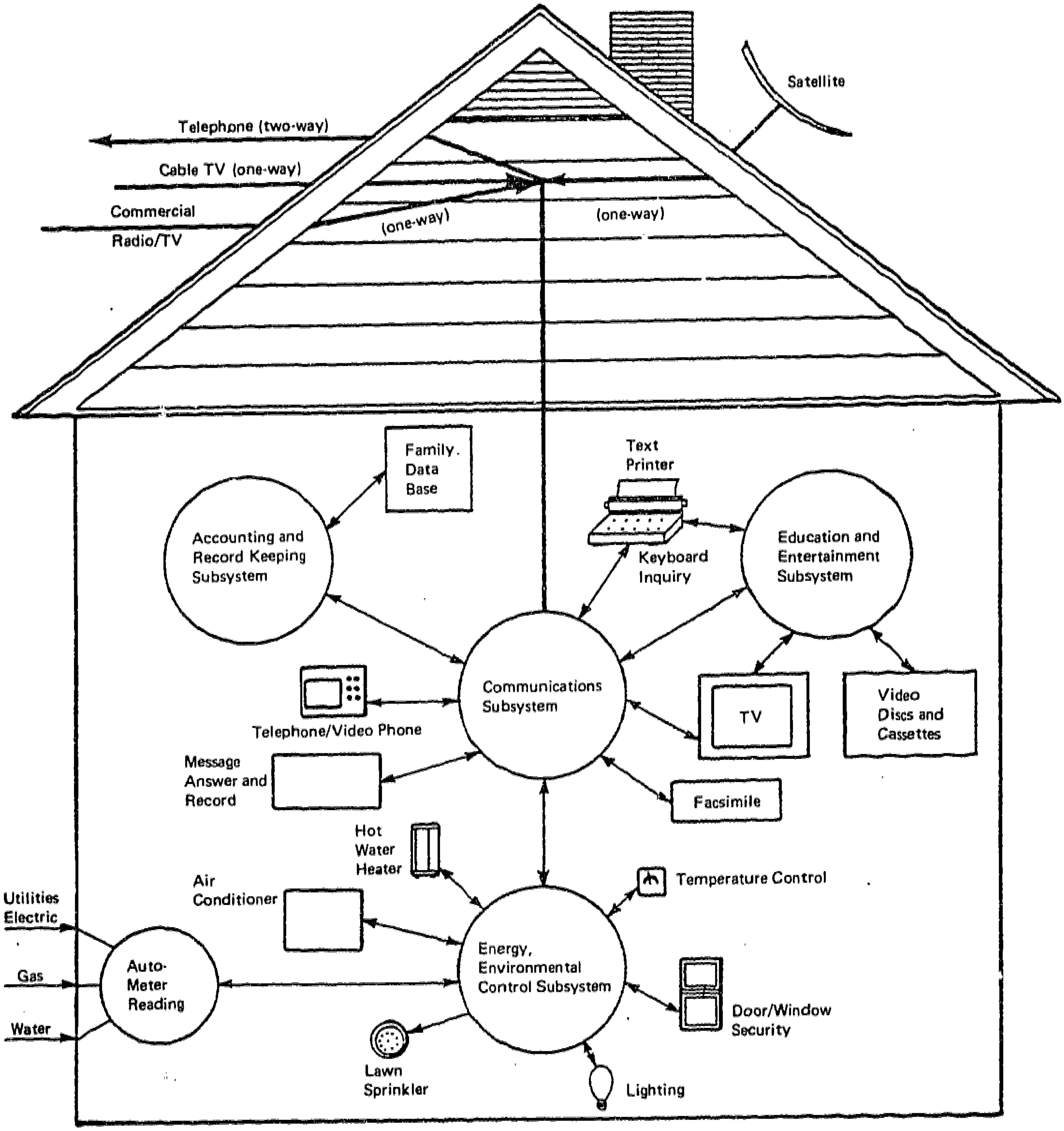

FIGURE 1: HOME INTEGRATED COMMUNICATIONS AND INFORMATION SYSTEM

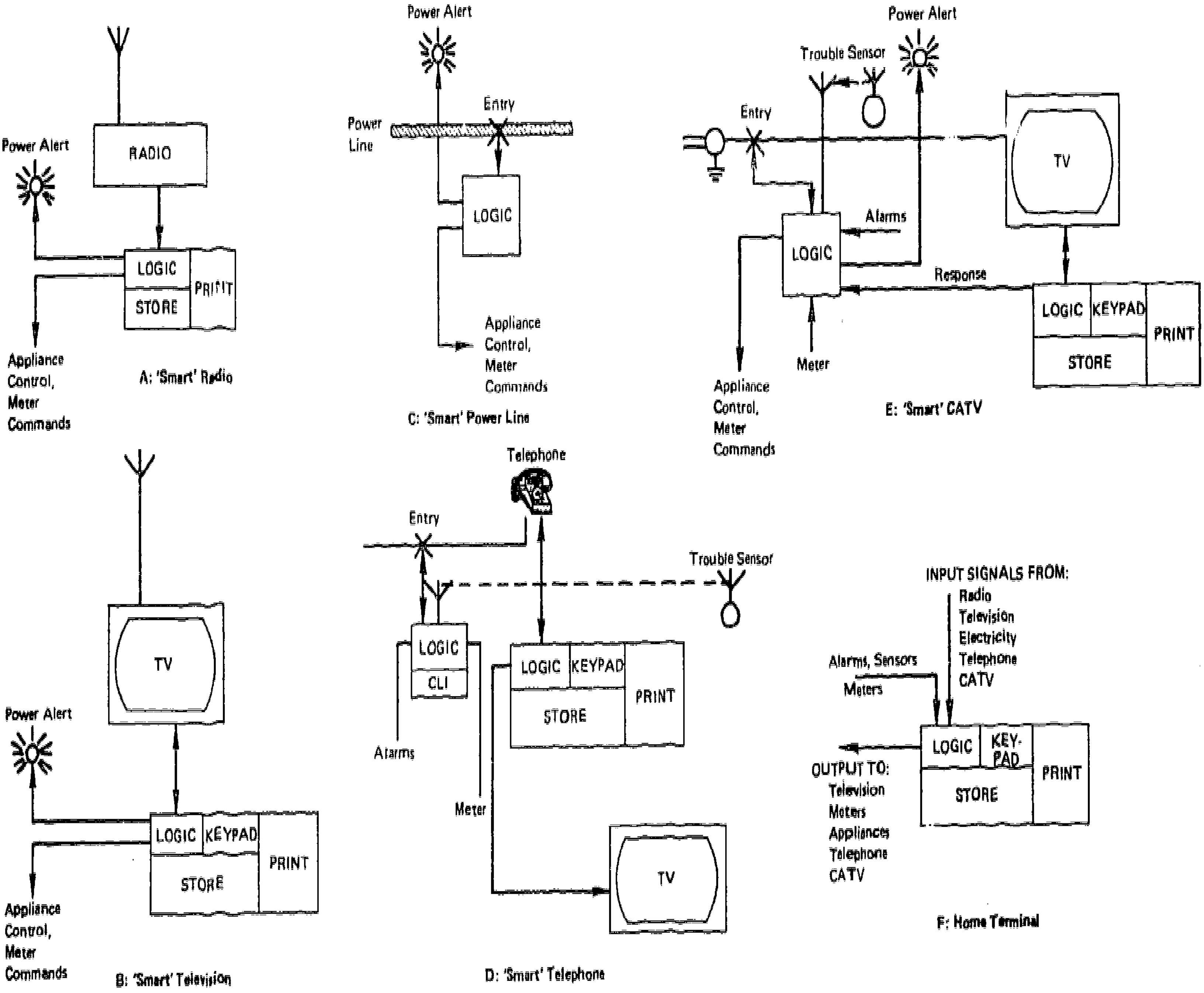

FIGURE 2: POSSIBLE CONFIGURATIONS OF HOME COMMUNICATIONS-INFORMATION SYSTEMS

With a complex of terminal equipment, supported by appropriate information sources and transmission media, virtually any home in the 1980's could have access to the full range of public services described in Sections 2 through 6, receive commercial entertainment and information, manage household energy consumption, and perform many other functions. The components of home communications systems are already developed or in development, and will become available in the 1980's.

Even so, we do not expect such a fully integrated home communications and information center to be installed in American homes of the 1980's.

Why not?

First, change in man-made systems does not occur suddenly, nor in a top-down fashion. Change occurs continuously in relatively small increments from the bottom, building on what already exists. A unique, single design for a home communications-information system is therefore unlikely. Instead, extended versions of current equipment will be introduced continually until many of the functions we have described are implemented on an evolutionary basis. The process of change will then proceed further, with the implementation of even more functions, reflecting the ingenuity of users to see opportunities that equipment designers had not anticipated.

Second, innovative commercial development is not the prerogative of any single organization. Many corporations manufacture equipment or provide services that could support the functions of a communications-information center. Each manufacturer can be expected to initiate developments that appear in its best interest.

Figure 2 shows a few of the directions in which development can be expected to proceed. Besides their intended functions, "smart" devices could be made to provide the following functions for an integrated home communications-information center:

- "SMART" RADIO
  Receive and record information
  Print bulletins, schedules, news, etc.
  Receive load-shedding commands

- "SMART" TELEVISION
  Receive and record information
  Print bulletins, schedules, news, etc.
  Receive load-shedding commands
  Support video games
  Display local messages

- "SMART" POWER LINE
  Receive load-shedding commands

- "SMART" CATV
  Receive information for display on TV
  Support interactive information retrieval
  Support interactive education
  Provide emergency alarms
  Execute load-shedding commands
  Support video games
  Transmit, receive, and print local messages

- HOME TERMINAL
  Household management
  Coordinate reception and transmission
  Store, print, and display information

A prerequisite for many of these functions is the adoption of the Viewdata and Ceefax type of information distribution systems.

Feasibility

Feasibility is often judged by the availability of necessary technology. The availability of technology that promises increased efficiency--measured in terms of saving time and money--would normally be adequate justification for a commercial product or service. But we are not dealing in a closed business environment. Entering the home expands the set of values that need to be considered. Business judgments are made on the basis of increased benefits (savings of time and money) to the providers of services. Yet if products or services are to be used willingly, they must also be perceived as beneficial to users. What does it benefit the users to save time, if it weighs on their hands, or to save money, if the service is paid for by local government or medical insurance?

While we do not pretend to know all the values that lead to public acceptance, we do know that products and services that reinforce a sense of community, enhance self-respect, and raise mutual esteem are likely to be successful (Burns, 1978). None of these is necessarily created by the cost-effective application of technology.

The availability of technology is but one requirement for a communications system that people will accept and welcome into their homes. It must be perceived as improving the human condition and preserving the social context. Because human needs are never fully articulated and change with time, a rigid communications structure should not be erected. A framework that encourages independent flights of fancy may result in applications and benefits that are not anticipated. What is more, human values always need to be uppermost in the development of such a system.

Barriers to Implementation

In discussing individual services, we have noted many barriers to implementation. Who can tell what the response might be when people are faced with a new communications medium? Operating new telecommunications equipment might be many times more complicated than using a telephone or television receiver, and understanding the services might require substantial education. Unfortunately, as we noted earlier, a significant fraction of the metropolitan population suffers from illiteracy and learning deficits. Others are victims of anomie, the state of emotional depression and feeling of meaninglessness that may increase as mass-produced machines take over many previously individualized decisions and actions. It is an open question whether residents of the metropolitan areas (or residents anywhere, for that matter) want such complex devices, even though they provide virtually instantaneous access to public services. Is there sufficient motivation to master their operation? Will it be more convenient, and perhaps more socially rewarding, to continue to seek out face-to-face assistance at government offices, say, or hospitals and schools? These questions cannot be answered by abstract study: they must be approached through trials and demonstrations of the new technology.

Achievement of the home communications-information center that has been described here will require cooperation among many units of local, state, and federal governments and the resolution of sticky administrative problems. The cooperation of many industrial groups will be needed to set standards and define points of commonality. Without such cooperation and agreement, orderly development will be impossible since there is no obvious market leader.

What is more, the organization of a basic data base containing information about essential services available to the citizen could be a long and difficult task. Expanding the data base to include data from schools, colleges, hospitals, and other institutions would greatly increase its complexity and cost. The alternative to a central data base is to have many different data bases, provided they use compatible formats and a common language.

To make the venture successful, each institution must share its knowledge willingly and be prepared to discover that its present way of doing business does not transfer easily to the electronic media. There will be problems of a proprietary nature. Who will own the data placed in a data base by several agencies and institutions? Who will have a right to access? Only the citizen? Or could each agency and institution have access to all the information in the data base? Is invasion of privacy a real issue here? Who has legal responsibility when the information provided is wrong--or when information is wrongly given? Could this lead to a proliferation of lawsuits? And what would be the attitude of lawyers and doctors or other professionals to a data base that lists their qualifications and fee information?

Throughout this chapter we have discussed the technological opportunities for adding information to broadcast signals, using electronic systems to substitute for some of the functions of daily newspapers and the mails, and increasing the reliance on cable systems for some community services, but we have not confronted the issues raised by the fact that both regulated and non-regulated facilities are involved. The Committee has not examined how such considerations will affect existing services, but the impact is likely to be great. The thorniest problems of all may well be those associated with regulation.

Likely Extent of Utilization

Eventually, every home in the country could have some form of communications-information system providing access to public services. Within metropolitan communities the potential exists for organizing services among government, academic and medical institutions, and citizens. Elderly citizens in particular might obtain great advantages from such systems. According to our projections, people aged 65 or older will occupy 15 percent of all households in the mid-1980's. A similar proportion of households may contain non-employed mothers with dependent children. Both groups could take advantage of many of the services offered, particularly health and education services. Universal utilization could follow, and some forms of communications-information systems could become as pervasive as the television receiver and telephone set are today. Whatever is achieved in providing public services in urban homes can be applied to homes in rural areas as well.

Benefits and Costs

The availability of a home communications-information system, providing some or all of the services that have been described, could substantially affect metropolitan life. There are promising opportunities to expand, enrich, and simplify life through the new telecommunications, and to replace tasks that are boring, routine, and time-consuming. Life could become safer, more productive and more fun. It could be healthier and better organized. Travel could be reduced and energy conserved. While it is unrealistic to believe that all this can be calculated in dollars and cents, some benefits can be measured. By providing specialized medical monitoring, hospital stays can be shortened and hospital costs may be lessened. By providing faster response to emergency calls, fires may be prevented or contained, criminals may be apprehended, and lives and dollars may be saved.

By providing ready access to information and assistance of all kinds, the home communications-information system could improve the quality of life for a majority of citizens; but it could just as easily become a force leading to the break-up of society. Will so versatile a device cause citizens to isolate themselves behind a wall of electronics, reducing yet further their opportunities to develop those human contacts that are so essential to a balanced existence? For many people, a visit to the doctor, the welfare office or the library has a social and psychological significance that far exceeds the satisfactory resolution of the specific situation that prompted the visit. And what use will be made of the time saved? Will it be used to take advantage of the new educational opportunities offered, or will it lead to further frustration and loneliness? Only time, and well-designed pilot projects can provide some answers.

Section 8 Recommendations

No laboratory exists for testing the virtues and defects, the benefits and the costs, the social effects and the economic consequences of the technological revolution in communications and information that promises to alter the way Americans live, learn, work, and play. A pilot program is therefore needed to demonstrate the delivery of such important community services as health care, education, police and fire protection, and information, along with such private services as household management and entertainment, to homes equipped with several forms of communications-information systems. Such a demonstration should call on the combined resources of communications and electronics companies, academic institutions, and local, state, and federal governments.

The test sites, number of participants, specific services, and duration of the demonstrations should be selected to allow firm conclusions to be drawn about the demand for advanced telecommunications services. This will require careful planning, organizing, and financing. Such an elaborate and complex program will require a coordinated national effort involving many parts of government (both legislative and executive), private industry, institutions, and the people, possibly under the leadership of a specific federal agency. The organization that manages this program must be able to deal with regulatory, social, and economic issues, while accomplishing the objectives of providing new and different services to a diverse urban population. A multi-year program is proposed as follows:

DEFINITION PHASE (approximately 12 months): An objective study would be undertaken to assess the technical tradeoffs and draw up a detailed design. Of equal importance, the social context and point-of-view of potential users must be examined in detail. Accordingly, specific attention should be given to:

> Existing Work: A thorough review should be made of all previous and ongoing demonstration projects to determine the strengths and weaknesses, and to ensure that the demonstration takes advantage of all available experience both here and abroad. It will be important to learn whether any specific failure was due to a lack of need, to poor concept and design, to inadequate implementation, or to inept management.

Site Selection: A major urban center should be selected for the demonstration. The basis for selecting the metropolitan area should include the availability of institutions and specialized users to support special services and interests of citizens. A maximum of citizen participation is necessary. It is mandatory that the needs of the elderly, handicapped, unemployed, and poor be considered. Many of the applications already described are aimed at different audiences. The elderly are likely to benefit most from a medical care subsystem, while preschool education will appeal to different households. Thus, the choice of site involves competing requirements. The period of the experiment is related in part to the site and scale of the demonstration program. Many health and educational effects are measurable only over long time intervals. To some extent, time may be traded against numbers of participants.

Human Factors: It is most important that the demonstration be acceptable to the test community: it must be designed and implemented with the needs, objectives, and aspirations of the citizens in mind. Citizen groups should be encouraged and their views on critical areas fully explored. The needs of the elderly, the handicapped, the unemployed, and the disadvantaged of all sorts should be considered. An understanding and concern for the goals of users is essential. This phase should include a planned measurement of social effects, complemented by sensitive observation.

Services Offered: A list of services would be prepared to include both public- and private-sector activities. Selection would be made on the basis of site and citizen preferences.

System Design: The demonstration system must include power lines, radio, television, cable TV, and telephone facilities, augmented by computer capability, inquiry terminals, and teletext processing centers. The system ought to serve several thousand subscribers, arranged in clusters of specialized users, as well as a distributed set of general users. It should be designed to furnish a combination of public and private services.

Legal Constraints: An early determination must be made of possible legal and regulatory constraints, and steps to be taken to overcome them (during the demonstration period).

Financing: The demonstration could be operated by a quasi-public corporation with equity provided by government and industry.

Criteria: The criteria to measure success must be firmly established before demonstrations begin. Provision should be made for independent observers to seek out the unexpected consequences of the technology.

PROCUREMENT PHASE (18 months): All necessary signal generation, distribution, interface, and reception equipment would be procured and installed to provide a combination of integrated communications services to participating citizens and institutions in the urban site. The procurement phase may overlap the definition and demonstration phases. This phase should include pre-trial social measurement and observations, as well as preparations for measurements during the trial.

DEMONSTRATION PHASE (3 years): A communications-information system, providing a combination of emergency, medical, education, information, household management, and other community services, would be operated. The demonstrations should ensure that the maximum amount of useful information is obtained. Depending on the results of the definition phase and the list of services selected, demonstrations could proceed in stages, such as:

- Delivery of several single-thread services to specialized clusters of users, mostly in local centers;
- Partial integration of single-thread services and their extension to homes;
- Addition of commercial services, and
- Operation of an integrated system to both local centers and homes.

The proposed 3-year duration should be substantiated by the study in the definition phase.

REPORT PHASE (6 months): An analysis would be made of operating data to arrive at the best estimates of demand, costs, and long-term acceptance and effectiveness.

CHAPTER IV

Telecommunications for Mobile Public Services

Section 1 Introduction

Radio systems are used widely in the delivery of mobile public services. In recent years, greater use of radio has been hampered by insufficient frequencies to meet the demand for such communications. The Federal Communications Commission has recently allocated a new frequency band in the 800-900 megahertz (MHz) region, and new technologies are being developed that promise more efficient use of the radio frequency spectrum. As a result, there is likely to be even greater use of mobile communications by public service agencies.

This chapter examines the system requirements for public services, the emerging alternative architectures for mobile systems, and some of the useful features such systems might provide. We have considered communications systems that aid in the delivery of a public service, as in the case of dispatching, and communications systems that are themselves the service, as in mobile telephone. The presentation is aimed primarily at the administrator, not the technical specialist.

The radio frequency spectrum is used more efficiently when radio channels are assigned to users only for the duration of a call than when they are dedicated to users without regard to the degree of utilization. Systems that provide user access on demand to any free channel of a group of channels are called "trunked" systems. In this way, use is made of the spectrum with significantly greater efficiency than in non-trunked systems, because the possibility is reduced that a channel will remain idle while some user has a need to communicate.

Still greater spectral efficiency is offered by systems that combine trunking with repeated reuse of the same frequencies in non-adjacent coverage areas or cells. When the cells are small, say 1 mile in radius, capacity of a given number of frequencies is typically increased by a factor of 10 or so for a realistic distribution of traffic.* Such "cellular" systems require a greater investment in fixed base station equipment and are best suited to metropolitan areas having high user densities.

Spread spectrum and packet radio techniques offer alternatives to discrete frequency channels. Such techniques remove the fixed ratio of

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*In a theoretical situation in which high traffic is offered uniformly throughout the service area, the factor of increase can be on the order of 100.

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capacity to bandwidth at the cost of an increase in interference levels as the number of simultaneous users increases. However, the techniques are untried for commercial applications in a concentrated urban environment.

Time-division multiplex systems with a large radius of coverage have been proposed. Such systems can provide the equivalent of trunking, but because of their large-area coverage they do not permit the frequency reuse opportunity of a small cell. What is more, they are digital systems that have yet to be tried in urban environments.

Mobile communications systems using a satellite relay greatly extend the area of coverage to regions the size of states or larger. Trunking can be used, but the advantage of frequency reuse is lost throughout the extensive coverage of the satellite antenna beam. For the 1980's at least, it does not appear feasible to consider beam sizes of several miles in diameter, the cell size anticipated for purely terrestrial systems.

In addition to the growing demand for standard services, requirements exist for tailoring communications along organizational or command lines in such applications as police and fire operations, and for providing such new services as automatic vehicle location and monitoring electrocardiogram and data transmissions, and, when security is a necessity, the transmission of secure voice messages.

Automatic vehicle location systems, developing as an adjunct to mobile communications systems, hold promise for more efficient control and utilization of mobile units. Ideally, such systems should be sparing in the demands for additional bandwidth to be used for the location function alone.

Transmission security for voice is receiving increased emphasis, particularly among law enforcement agencies. Techniques are available for providing a useful level of privacy/security in either analog or digital communications.

Paging services provide a means of delivering a one-way signal code or a voice signal or both to a person on the move. A paging receiver reacts only to a uniquely coded signal from the base station. Response is usually by land-line telephone.

With the exception of paging systems, the systems and techniques described here are discussed in greater detail in subsequent sections of this report.

Section 2 Summary

Mobile Radio Systems

The decade of the 1980's will see the introduction of the high-capacity cellular system to allow an order-of-magnitude increase in subscribers using the mobile telephone service (MTS)--from roughly 100,000 to more than 1,000,000. This will be a start toward integrating a significant part of the nation's motor vehicles into the national telephone network, achieving the same quality of transmission and grade of service as for the fixed network. This will facilitate mobile communications not only within cities but on a national and even international basis.

Differences in user requirements result in three mobile communications configurations, each used where it is best suited. Thus, we expect that conventional dispatch systems will still be needed for some public service and commercial operations; trunked systems will provide spectrum efficiency for larger users, and the cellular system will be best suited for the high-density urban mobile telephone system. It may be desirable for many urban services to have the ability to switch between, say, dispatch and cellular, and common equipment should permit such flexibility.

Several new techniques, radically different from the present system in which each channel is assigned a separate frequency band and transmission is by frequency modulation (FM), have recently been considered for mobile communications. The new methods differ in type of modulation and in system configuration. They include a time-division multiplex system, use of spread spectrum modulation in place of FM in a cellular configuration, and application of the packet concept to a mobile radio system.

The first two techniques have been considered only from a theoretical viewpoint, and experts differ about the appropriate assumptions. If the theoretical differences can be reconciled and the findings are positive, field tests should be conducted to confirm the theoretical assumptions and uncover any operational problems that might have been overlooked or underestimated. Construction of field-test equipment should provide a more realistic estimate of production costs. The final decision on the new systems will depend on their relative efficiency of frequency use, operational comparisons, and cost, matters best determined by field tests.

The packet system--a data system designed for military use--is in an early test phase. Application of the packet technique to a commercial urban voice system would require a different set of system parameters, and its relative advantages and disadvantages are not yet clear.

Based on our knowledge of such systems, and considering the progress needed between initial concept and large-scale operational use of equipment, the Committee concludes that the United States should proceed with the cellular system using conventional FM for the mobile telephone service, and continue to study (and possibly test) other systems.

Satellite-to-mobile transmission has been tested with several NASA satellites, and its transmission performance in open country can be calculated with a high degree of confidence. Transmission into the urban area from elevation angles of, say, 10 to 40 degrees is not well known, but rough estimates of performance and equipment costs show no advantage to such a system for urban use. However, such a system would offer the capability of communicating with a conventional mobile radio anywhere in the country at locations not readily accessible by present mobile systems.

An important regulatory problem arises with the use of satellites for mobile communications: how to obtain frequencies for such use that are part of, or adjacent to, present mobile bands to permit the eventual use of conventional terrestrial equipment for communications by satellite.

Voice Privacy

The increasing use of mobile radio will bring with it an increased demand for privacy of voice communications. We believe this can best be achieved with a digital method. Regulatory action may be needed to allow such methods. Production of privacy equipment in the United States will raise the possibility of export. The Department of Commerce and Department of Defense need to consider the question of permission to export such equipment.

Automatic Vehicle Location (AVL)

Experiments on AVL have been conducted for a number of years, but there appear to be no clearcut technical or economic advantages for any single technique. The economic benefits obtained are not yet sufficient for prospective users to choose an operational system. The Committee concludes that efforts sponsored by the Department of Transportation should continue and that results should receive close attention.

Section 3 Mobile Public Service Requirements

The development of mobile radio services has long been stimulated by applications in the public-service sector, particularly for police and transportation systems. In the future, automatic vehicle location, alarm, and monitoring systems will be added to the mobile radio systems now in widespread use. This section discusses some fundamental issues that should be considered in developing mobile radio systems, and outlines requirements from the perspectives of the users, the operations supported, and the equipment used. Subsequent sections examine some of the major alternatives that merit consideration for the 1980's.

Before investing in any new capability, a public service organization must decide whether the benefits to be derived justify the costs. Benefits such as time that might be saved or more positive control that might be achieved may be difficult to quantify; nevertheless, they should enter into any judgment of the system's effectiveness. In addition to cost, the options available for upgrading mobile radio systems are constrained by available frequency spectrum, and the need for different systems to be capable of operating together.

Three factors--cost-effectiveness, spectral efficiency, and system considerations--affect one another. For example, the effectiveness of mobile radio systems declines when congestion increases, most likely in metropolitan areas, yet measures to improve spectral efficiency have their own costs and might prevent interconnection between an existing system and an improved one. Decisions to acquire mobile radio equipment will be based on the cost-effectiveness of a specific system, while the system's spectral efficiency or inefficiency will be of greater concern to regulatory agencies and systems planners than to its purchasers. In the interest of spectral efficiency, a system may be required to have features that make it compatible with other systems sharing the same part of the radio frequency spectrum.

User Requirements

The variations in user requirements that influence the design of a mobile radio system include:

Mode of operation --mobile-to-mobile, dispatcher-to-single mobile dispatcher-to-many mobiles, or mobile-to-telephone system.

Voice quality --ranging from intelligible to trained listener, through recognition of speaker, to telephone (toll) quality (for examples, see Lane, 1973).

Area of coverage --from local through regional to nationwide.

Type of communication--from short emergency transmissions to one or to many mobiles, to long and routine transmissions.

Network discipline --varies from no discipline (e.g. Citizens' Band) to complete control by a central processor.

Type of access --single shared channel; dedicated channel (per call or full-period); multichannel trunked; trunked plus priority channel to provide speed of access and restrict blocking. (A channel may be a discrete frequency assigned to the call or to the user, or it may be a frequency-time pattern that rapidly changes the radio frequency in use many times during a single call.)

Information forms --analog voice, digital voice, paging alerts or alarms, vehicle location, monitoring or status reporting and other types of digital data.

Privacy or security --the range of privacy extends from shielding the transmission from the casual listener to absolute security, depending on the complexity chosen.

Operational Requirements

Police and fire services have been plagued by inadequate channel capacity. These users will want guaranteed channel availability in any new system. To circumvent possible blocking within a trunked system, dispatchers sometimes hold a channel in the "off-hook" condition even when it is not in use, thus defeating the trunking advantage. If one channel is always kept available for the use of police and fire services, it can be used when required, and this may avoid unnecessary standby holding of the channel. In either a trunked or cellular system, reservation of a police or fire channel may be done by the control processor.

A communication channel suited for small operations tends to become overloaded during major catastrophes, such as fires, riots, floods, and earthquakes. In any new system, a communications hierarchy should be established to limit the number of units that report to one officer over one channel. As each additional unit comes on-scene, it should have its own communication channels for reporting. All the units would have to be coordinated by the commander at the scene.

To avoid service disruption by sabotage, emergency control of all public safety services should be possible without reliance on centralized facilities.

Both vehicular and personal portable radios are required for fire departments. While trucks of selected fire companies are en route, for example, the dispatcher can advise them of road and traffic conditions. The first officer at the fire can radio an assessment to the dispatcher who may respond by calling out additional equipment or diverting some trucks. When two chiefs respond to a fire, taking position on opposite sides and communicating via personal radios, the driver of the senior fire official can serve as a relay to the dispatcher at headquarters.

In police operations, officers need to be able to communicate to the dispatcher and should be able to receive replies, even when on foot or inside buildings. Police cars are dispatched now with a voice call from the dispatcher. For urgent calls, several cars may be dispatched; coordination of these units requires group-calling capability.

While any public-service communication system must provide for coverage of a specific area such as a city, county, state, or region, several levels of call-addressing should be provided to match the organizational requirements of the user group: individual calls, area calls, group calls, sub-group calls, and perhaps an all-call capability.

Emergency medical-service vehicles such as ambulances require direct communication with hospital emergency rooms to enable life-sustaining procedures to be directed by the doctor to the paramedic, and telemetric data channels to enable vital life processes to be monitored en route.

In handling a large disturbance, reinforcements or special units may be needed for new units to take up the group calls used in temporary assignments. In the case of mobile units in a cellular system, this requires changes in the setting of the address decoder for group calls.

Additional requirements apply to public safety communications in the event that a link in the command chain fails, a cell station or dispatching office, for example:

- Each shift commander of police must be able to talk directly to the group under his command;
- On-scene commanders (police or fire) must be able to talk to other commanders at their own level of command, or to a senior commander or marshal in charge at a major emergency;
- Senior commanders or fire marshals must be able to talk directly to officers under their command and to headquarters.

Equipment Requirements

The following requirements apply to public safety service applications:

- The system should provide for operation of both vehicle-mounted and personally carried mobile equipment;
- The probability that there will be no channel available to police or fire dispatchers should be near zero;

- Dispatchers should be able to talk to groups or individual patrols, on foot or in vehicles;
- Dispatchers should be able to control lateral communications (car-to-car or person-to-person radio transmissions);
- In the case of hot pursuit, the fixed portion of the mobile communications should track the group of pursuing cars closely enough to maintain communications;
- Single-button calling of frequently called numbers is very desirable;
- Automatic identification of the calling party by the system should be provided;
- The time required to connect to the called unit(s) must be held to a minimum;
- The address of a vehicular or personal radio should be easily changeable when the radio is assigned to another user or group, but should be safeguarded to prevent unauthorized tampering. The user should have control of his own single-button calling repertoire;
- The system should handle ancillary signals required for electrocardiograms or other diagnostic indicators, mobile printers, status monitors, call-back indicators, etc., and
- A loudspeaker should be provided to permit hands-off operation of mobile radios.

Spectral Efficiency

Spectral efficiency must be considered, even though it may not be stated as a user requirement. The measure taken in the past to increase the number of channels available was to reduce the spacing between channels, as better filters and more stable radio designs were developed. A number of mobile users generally share each channel, perhaps using a number of separated base stations. This is single-channel access.

The next higher level of spectral efficiency is achieved by pooling a number of frequencies, and assigning these whenever required. Because service demand fluctuates, a number of pooled channels can provide more service capacity than an equal number of independent channels. The degree of improvement depends on the number of channels pooled, and the blocking probability that can be tolerated in gaining access. The added cost of pooling is that all mobile sets must be rapidly and remotely tunable over a number of frequency channels. This arrangement results in a trunked system, often used for mobile telephone service, but seldom used for other mobile radio systems.

Still greater spectral efficiency is possible by dividing the coverage area into cells, each with its own base station and family of frequencies. Frequency families are used over and over again in a number of non-adjacent cells. Several such cellular systems have been proposed. The added cost of cellular systems comes mainly from the increased number of base stations and interconnections required, with some increase in costs for control of the mobile sets.

Section 4 Alternative Mobile Radio System Technologies

New technologies are becoming available to satisfy the requirements just outlined. In reviewing the technologies, it is important to note such considerations as methods of modulation, techniques for access, strategies for radio spectrum use, and provision (if any) for privacy or security.

Existing systems and related services use FM in channels assigned uniquely in the frequency spectrum (frequency division) in bands below 500 megahertz. Aside from such systems as Citizens' Band and coastal harbor radio, which are not discussed here, two basic system configurations are now available to the public for two-way voice communication with mobile units:

- Private conventional systems provide two-way communications (voice and data) between land-based stations and mobile units, and from mobile-to-mobile over a channel dedicated to the users. There is no attempt to achieve privacy. All mobiles receive base station signals, and mobile-to-mobile interaction is limited only by propagation considerations. Such service is referred to as "dispatch service" and is not ordinarily connected to the public switched telephone network.

- Public trunked systems, including the Bell System's Improved Mobile Telephone Service (IMTS) and some radio common carrier (RCC) systems, provide mobile telephone voice service that can be connected to the public switched telephone network. In such systems, each mobile unit may have access to any of several radio channels (trunking), but none will tune to a channel in use by any other.

Although the quality of voice and data on an uncrowded channel is excellent in conventional public and private systems, the demand for channels has been so great, and the solution to the problem of frequency spectrum allocation by the FCC was so long delayed that "service quality" (which includes waiting time, messages garbled by interference, and repeats) has become marginal in many instances, particularly in urban areas.

Options for improving this situation are: 1) allocation of more of the frequency spectrum for land mobile radio, and 2) adoption of new equipment and systems that make more efficient use of the frequency spectrum.

FCC Docket 18262 initially appeared to have resolved the frequency allocation issue. In this decision (made in 1975), the FCC allocated 40 MHz to a high-capacity nationally compatible mobile telephone system, allocated 30 MHz for dispatch use, employing either conventional or trunked systems, and held 45 MHz in reserve.

Making use of the newly assigned spectrum at 800 MHz has been delayed by uncertainties in administrative procedures and by debates about the relative merits of emerging technologies. Both problems will be overcome eventually, but for many, the delay is considered frustrating in view of the demand backlog.

Technologies that are more efficient in their use of the spectrum do exist. In our view, the components, circuits, and equipment that have been demonstrated or that appear promising in principle can contribute to a continuous flow of evolutionary improvements in mobile equipment, improvements that can be directed to achieving lower costs per function or to providing functions not previously available.

Configurations differ in their use of such resources as the electromagnetic spectrum and dollars. Spectrum is a resource characterized by frequency, space, and time. The economics of mobile systems are generally expressed in terms of cost per mobile per month, and include the operational and administrative costs of the entire system, as well as equipment cost amortization and maintenance.

Alternative system concepts also differ in feasibility for commercial application. Some are based on technology that has been explored and developed for many years; others employ principles that appear to have great potential, but little is known about their performance in the metropolitan environment.

The next few pages take up the basic concepts, special features, and technical feasibility of the following technologies:

- Conventional FM Systems
- Trunking
- Cellular Systems
- Time Division Multiplex Systems
- Satellite Mobile Communications
- Spread Spectrum Techniques
- Packet Radio
- Speech Privacy.

Conventional FM Systems

System Concept

In FM, the frequency of the radio signal is varied from an assigned carrier frequency by an amount proportional to the amplitude of the modulating voice signal, and at a rate that represents the instantaneous frequency of the voice signal.

FM has been widely accepted since its invention by E. H. Armstrong in the early 1930's. In broadcasting, it provides the high audio quality of FM radio, and the sound portion of television. In communications, it is used for mobile telephone, radio common carrier, and for dispatching trucks, cabs, and the safety services--fire, ambulance, and police.

In mobile phone and common carrier services, and in some dispatching services, two frequencies are used, one for transmission by the base station and the other for transmission by mobile stations. In many dispatching services one frequency is used for all transmissions on a sequential push-to-talk basis.

Special Features

FM provides greater freedom from static and noise than amplitude modulation (AM) systems. When stations operate on the same frequency, they are vulnerable to cochannel interference. Such interference can be avoided when the desired station is not transmitting, either by separating stations far enough that undesired signals are not heard or by having each station include an inaudible signal that tells receivers to open the squelch or silencing circuit. When the desired station is transmitting, audible interference is avoided through "capture." The capture effect is a property of frequency modulation: a signal that is stronger by a small ratio, called the capture ratio, effectively suppresses all weaker signals.

Through the assignment of frequencies, it is possible to segregate groups of channels for different services. By merely changing frequency, any station can participate in any service. By combining the capture effect with the ability to use different power levels on different frequencies, the communications manager can achieve great flexibility of choice, limited by permissible secondary interference.

Technical Considerations

In nearly half a century of development, FM has accumulated extensive propagation data. In the entertainment field, stereo and quadraphonic sound can be transmitted in the original width of a single channel. In communications, greater capacity within a given spectrum allocation has been obtained by reducing the channel width through better filtering and more stable oscillators. These evolutionary improvements have resulted from better materials, components, and engineering, as well as long experience. (There were almost 9-1/2 million licensed mobile transmitters in 1977.)

Improvements continue. Through large-scale integration, it is now possible to include complex controls in a mobile radio at a cost of a few dollars, using the manufacturing techniques that produced the pocket calculator. Moreover, a frequency synthesizer for 660 precise and stable frequencies now costs about the same as an older unit with six crystal-controlled frequency pairs.

Trunking

System Concept

In a trunked system, users have access to many shared channels or lines instead of a single dedicated channel. Trunking is a well-known and accepted practice in land-line telephone and public radiotelephone systems. Improved service results from the random nature of use by both calling and called parties.

Automatic trunking is used on Improved Mobile Telephone Service (IMTS) public radiotelephone systems, and its use is inherently necessary for the cellular systems described below. In the past, it has not been used for dispatch services, except on a manually switched basis, but it will now be required for all systems using five or more channels in the 806-821 MHz, 851-866 MHz portion of the spectrum allocated to the use of private systems.

Special Features

The presence of a computer in a trunked system allows the performance of functions that, in other systems, are either not available at all or available only through some action of the dispatcher. These include selective calling, priority handling for the calls of some users (if that is considered desirable), call waiting, automatic identification of calling mobile, recording such information as identification of called party and length of call, reliability through redundancy, and billing for services.

Trunking should be viewed as a technique for employing the radio frequency spectrum rather than as a separate system configuration.

Technical Considerations

Multiple channel transmission and automatic channel selection are state-of-the-art today. System design is simplified and cost is minimized if the multiple channels in the trunk system are adjacent in the frequency spectrum, but this is not a fundamental requirement. It is quite possible within the state-of-the-art to design systems for selecting channels from different parts of the same band or, indeed, from more than one frequency band.

Cellular Systems

System Concept

In today's conventional mobile radio services (either private or public trunked systems), communications with mobile stations can extend to about 25 miles under normal conditions. To avoid interference, a single frequency is not shared in the same metropolitan area. Instead, base stations operating at the same frequency are located up to 100 miles apart.

In a cellular system, base-station radiated power is intentionally limited to reduce geographic coverage and to allow frequencies to be reused by nearby base stations. With properly designed cellular arrangements, a given frequency can be reused many times for many conversations in a single city.

Special Features

Because mobile stations on the move cannot be limited to the coverage of a single cell, even during a single conversation, systems based on the cellular concept must incorporate automatic features to detect movement of the mobile and to transfer the mobile station circuit from base station to base station as the mobile moves through the array of cells. Such a system plan obviously requires far more sophisticated equipment and system integration than a simple, private, conventional system, or today's public trunked system.

By allocating 40 MHz in the 800 MHz band for high-capacity mobile radiotelephone services, the FCC has created the opportunity to serve a very large number of mobile radiotelephone users. A cellular system with trunking and a base station network covering cells of a mile in radius, could carry more than 50,000 simultaneous conversations in a service area 25 miles in radius with uniform traffic distribution. Even if radiotelephone traffic were heavily concentrated in the city center, the capacity would be more than ten times as great as that of existing systems. Only the cellular system concept offers such efficient use of the spectrum.

A cellular radiotelephone service operating under computer control offers all the features previously noted for a trunked system.

In order to route conversations via different cells as a mobile moves through the array of base stations serving a cellular system, far more equipment, interconnecting transmission lines, and network control are required for the array than for a single base station of a conventional trunked system. Thus, a configuration of small cells is economically attractive only if there is a large number of users to share the cell network costs. Systems can be designed to operate initially with large cells, serving a modest community of users. As demand grows, the system can be reconfigured to operate with small cells. The base station array and network would be adapted to satisfy the demand for service, while the mobile stations would remain unchanged.

Technical Considerations

The FM cellular system concepts proposed by Bell and Motorola are based on well-developed technology, but differ in detail. Bell and others have been conducting extensive measurements of radio propagation using FM techniques in metropolitan environments at 800 MHz frequencies. The effects of fading and multipath are well understood, the effects of shadowing and short-range transmission are being examined, and the effects of the urban environment on pulse transmission are coming under study. The challenges in FM cellular system design are to achieve automatic control of the switched base station network and to develop equipment to meet the requirements of the market. These are systems engineering and development tasks employing well-known methods, not requiring any technological advances.

The cellular system concept is not restricted to any single type of modulation, but because the relative interfering effects of transmission from a station in one cell to a receiver on the same frequency in a nearby cell will depend on the type of modulation, acceptable cell spacing may vary with the type of modulation.

Time-Division Multiplex Systems

System Concept

In a time-division multiplex system (TDM), speech signals from a user are sampled, and individual samples transmitted at pre-established times (time-slots). The interval between sample transmissions can be long compared to the time to send a single sample, and can be filled with transmission of samples of speech from other users. The sample may be represented by a signal proportional to the content of the speech sample (pulse amplitude modulation, PAM) or the sample may be coded into a binary signal with each individual binary signal (bit) sent separately (pulse code modulation, PCM).

Special Features

Sampled speech systems offer opportunities to achieve privacy and security unavailable in conventional FM systems without scramblers. Samples can be scrambled before transmission and rearranged after reception, and the binary signals can be encrypted by addition--and subsequent subtraction--of an arbitrary sequence of pulses known to both transmitter and receiver. Security can be improved if sampling, coding, and encryption are performed at the point of origin, rather than at the base stations.

Technical Considerations

Technically, TDM systems with any form of pulse modulation differ from conventional FM systems in two respects. First, the pulses in each speech channel require greater bandwidth than the original speech. Second, the urban environment causes multiple reflections and transmission path delays that culminate in a blurring or spreading of the transmitted pulses before reception and detection. Schemes to mitigate these effects must be built into specific system configurations. Either the pulse rate must be kept so low that pulses do not overlap, or the system must be designed to operate with occasional pulse interference.

Digital radio methods for mobile services have been employed in military systems, particularly air-ground systems. In land mobile applications, experience has been limited, and the extensive body of experimental results needed to validate the application of TDM concepts to high-capacity mobile services in the urban environment has not been amassed.

While theoretical calculations suggest that the potential exists, tests of propagation in the uncertain urban environment are incomplete.

Satellite-Mobile Communications

System Concept

Satellite technology has advanced to the stage where communications between shore stations and ships at sea (using antennas 4 feet in diameter) are being carried out in routine commercial operations today, via relay satellites (MARISAT system). This concept can be extended to transmissions between fixed base stations and autos or trucks on roads. Transmission of signals can be predicted accurately for a vehicle in open country, but propagation from a satellite to a vehicle in the urban area has not yet been studied. It would be useful for NASA to conduct such tests using its 860 MHz transmitter in the ATS-6 satellite (Brown, 1977).

Special Features

Because a typical urban mobile system is designed to cover a radius of about 25 miles, it would seem uneconomical to consider a satellite for this purpose. A major advantage of a satellite repeater is that it is in line of sight of stations located anywhere in its footprint. Satellite repeaters are well suited for communication to mobile terminals located in areas not readily accessible by terrestrial communications systems. Today, no single group of mobile users appears to have sufficient traffic to justify a dedicated satellite, but aggregations of such users appear to offer an attractive market. Alternatively, part of a satellite might be allocated for this service, thus greatly decreasing the required investment. One possible use is in law enforcement (Parness *et al.*, 1977).

Another possible application would be the use of a multi-beam satellite, each beam providing coverage for a state the size of California, Texas, or Pennsylvania, to replace the network of repeater stations now used for police mobile communications. Satellites could be useful for communication with long-haul trucks bearing dangerous or expensive cargoes, and for communications during emergencies and disasters.

Technical Considerations

For a satellite-mobile system, three kinds of terminals could be considered for the terrestrial station:

- An unmodified, commercial, mobile terminal operating in the 800 MHz band; typically, the same mobile terminal now planned for terrestrial use in this band.

- A modified mobile terminal with, for example, a steerable parabolic reflector two feet in diameter that would provide about a twentyfold advantage over the typical small, car-mounted whip antenna, but would require a relatively expensive steering mechanism. A more expensive low-noise amplifier could also be added to improve system performance.

- Fixed land repeaters could be used with a larger antenna (say, 8 feet in diameter), giving a power gain several hundred times over a car whip. This would permit a corresponding reduction in satellite power. The land repeater would likely be in a different frequency band than 800 MHz and would rebroadcast the signal from the satellite through a conventional 800 MHz base station transmitter to completely conventional mobile terminals.

The first type of terminal would minimize the mobile cost, but at the expense of relatively high satellite-radiated power. The second type would reduce the satellite power by an order of magnitude, but would increase the cost of every mobile station. The third would minimize the cost of the mobile terminal, but would require fixed repeater stations, equal in cost to a conventional mobile base station, plus a small satellite earth terminal, located within a few tens of miles of all possible mobile terminals.

In a system with a great many mobile terminals, the use of unmodified commercial units would appear to be preferable. The optimum choice of terminals for a given system must take into account the number of mobile terminals, extent of use, geographical distribution, circuit performance, grade of service, cost of mobile equipment and land-based repeaters, and satellite costs for a range of radiated power. As satellites become available that have antennas 100 feet in diameter or even larger, the trend will be toward the direct approach.

One barrier to the implementation of satellite-mobile systems is the lack of any frequency band allocated to their use for commercial service. Before existing mobile radio sets could be used in satellite-mobile systems, part of a mobile band would have to be allocated to that service. The present mobile users have fought long and hard for the 800 MHz band and, understandably, are not enthusiastic about still another competitor for part of that band. Furthermore it would be premature to set aside adjacent frequency bands, if these could be made available, for a service that might not materialize for a number of years. But if the potential of this unique system is to be realized, frequency space must be available. We recommend that the FCC make a suitable allowance to this end in the consideration of frequency allocations during the World Administrative Radio Conference in 1979 (WARC-79).

Spread Spectrum Techniques

System Concept

The spread spectrum technique enables many users to share a common, wide frequency band, within which separation is effected by unique codes. Spread spectrum modulation was originally developed for the military because it provides anti-jam capability and is well suited for privacy coding. The necessary equipment is considerably more complicated and expensive than today's FM equipment.

The spread spectrum technique is a particular way of transmitting binary coded pulses. Before a voice signal can be transmitted, its normal analog wave form must first be converted to a bit stream. Each bit of the binary coded stream is transmitted by a signal that has a bandwidth far greater than that of the binary pulse--that is, the representation of a single pulse is a signal that is spread across the spectrum allocated for the service. There are many ways of spreading out signals in frequency. For example, each bit could be represented by the transmission of a series of short pulses of different frequencies ("chips") in each of several time slots. The time-frequency pattern would be unique to a given mobile receiver, and the base station would encode each outgoing bit into the pattern appropriate for the called mobile unit. The information would be carried by the phase modulation of the signal in each "chip"--one phase representing a "0" in the signal bit, the other phase a "1."

The mobiles would transmit to the base station, using their unique address code. Because the base station receiver must receive the signals simultaneously from all mobiles in its service area, the usual concept of automatic gain control cannot be used. To avoid receiver overload at the base station, each mobile would have to reduce its radiated power as it nears the base station.

Special Features

The spread spectrum technique is inherently private because of its encoding. It is resistant to narrowband interference because the power of the transmitted signal is spread across a wide bandwidth and interference at specific frequencies would have negligible effect. The theoretical studies for its use in urban cellular systems have indicated promise, but have not yet been verified by experiment.

Spread spectrum modulation is a particular example of the time division multiplex concept which, as noted above, has not yet been investigated thoroughly in urban centers, nor considered for application to a commercial dispatch or mobile telephone service, with predominantly voice communications.

Technical Considerations

Theoretical studies are underway on the performance of cellular systems using spread spectrum modulation instead of FM. Studies have suggested that the number of possible subscribers using the spread spectrum system might be several times to several tens of times greater than the number using FM, depending on the assumptions made (Cooper and Nettleton, 1977). Nevertheless, many workers in the field believe it would be foolhardy to discard a system as well developed as FM to adopt an untried technique. Yet they also feel that the spread spectrum technique shows sufficient theoretical promise that it should not be discarded without a fair trial in a field test. We completely agree.

Opinions differ about the validity of the assumptions used to date in the analysis of spread spectrum modulation for cellular systems. We understand that the various approaches now under study will soon be published. These differences may then be compared. Two studies have been recently undertaken for the Federal Communications Commission by the Institute for Telecommunication Sciences in the Department of Commerce on the possibility of operating spread spectrum modulated mobile radios in a TV channel, and on the extent to which spread spectrum mobile radios can co-exist with conventional FM mobiles.

If such studies show positive results, field tests should be conducted to prove the assumptions and to reveal any practical side-effects not covered by the theoretical analysis, as well as to provide a more realistic measure of equipment costs. The information will guide a final determination of the system's utility. In the meantime, work should proceed on known methods of improving spectrum utilization, such as the FM trunked and cellular systems.

Packet Radio

System Concept

Packet transmission of data is now available to the continental United States via the terrestrial network and to Hawaii and Western Europe via satellite. To time-share the transmission medium efficiently, computer processing centers temporarily store data messages received from local subscribers, arrange these in a queue, and transmit them sequentially using spread spectrum modulation in packets of about 1,000 to 2,000 bits each. The computer adds extra bits for error detection and selects the best of several paths for transmission. Transmission efficiency is obtained at the expense of a very slight delay (typically a fraction of a second) and additional complexity in the processing centers.

Use of similar technology has been proposed for a military radio network. An experimental system is being tested by Stanford Research Institute under contract to the Defense Advanced Research Projects Agency (ARPA). This system is designed to interconnect mobile terminals and fixed stations dispersed over a relatively wide area that communicate with one another by radio. A number of repeater stations are located throughout the area to effect this interchange.

Special Features

Messages from a mobile terminal are routed from one repeater to another by one of several control stations. When the mobile approaches the limit of one repeater's coverage, the control station alerts the mobile to address the next repeater. This latter procedure is similar to the proposed cellular concept. Because the system is designed for military use, provision is made for alternate routings that may be needed if some repeaters fail or suffer damage. In the particular system being tested, system parameters are selected for data transmission; voice is used only as supplement. If the concept were adapted to commercial, urban mobile service the parameters would have to be reconsidered. The differences in statistical use between a dispatch service and mobile telephone service--an average message burst of 10-15 seconds in the former and 180-240 seconds in the latter--may require different system designs.

It should be pointed out that efficient use of the transmission channel obtained by queueing in the packet system is achieved in large part in the push-to-talk dispatch service, in that a number of users share a given channel and each talks as soon as he hears the preceding speaker stop. Thus, the storage is in the user's head rather than in a digital storage register. Another point to be made on the applicability of this system to commercial, urban use is that a given message in the packet system may be relayed sequentially through a number of separate repeaters before reaching its final destination. This increases use of the spectrum by the number of relays. In the commercial cellular system, the mobile's message is relayed by the base station (equivalent to a repeater in the packet system) via a wireline so that the spectrum is used only once rather than a number of times. For military purposes, the wireline interconnect of the commercial cellular system would not be practical.

The packet concept of using all the available channel time (including all pauses) for interleaving messages from various sources has been used in undersea cables for 20 years in Time Assignment Speech Interpolation (TASI), and is now being applied to commercial satellite time-division terminals ("digital speech interpolation" or DSI). It has not been used in the mobile telephone system, where the listening channel lies idle as the subscriber talks (a full-duplex system).

Technical Considerations

The effects of urban multipath transmission on narrow pulses of 0.05 to 0.1 microsecond, used by the spread spectrum modulation method in the ARPA system, must be evaluated by suitable propagation tests. Some tests have already taken place (Nielson, 1977). Testing of this experimental ARPA system will continue for the next few years and should be evaluated for possible commercial use.

Speech Privacy Equipments

Basic Concept

With the greatly increased use of personal and mobile radios, there is likely to be an increase in unauthorized interception of radio transmissions by the idly curious, criminals, or industrial spies. While most of the millions of mobile users do not require equipment that ensures privacy, the few that do create a significant need that justifies serious examination.

Technical Considerations

Heretofore, scramblers for mobile application have been of the analog type, in which the 3 kHz voice signal is processed in the frequency or time domains or a combination of both. Digital scramblers have recently been made available. Both of these are discussed briefly.

- Analog Scramblers

The earliest speech scramblers started with a simple frequency inversion in which the high speech frequencies were made low and vice versa. There is only one "code" and even this could be simply decoded. In a more complex system, the voice spectrum is divided into five bands with filters, then either transposed directly or inverted. Only a very small percentage of the possible codes can be used.

Time-domain scramblers continuously record the voice on a magnetic tape, and transmit voice segments in transposed time order. Here as well, only a very small fraction of possible codes are useful. Combinations of time- and frequency-scrambling provide significant improvement over either used separately. While these would be effective against the casual listener or one with a similar machine but no knowledge of the exact code, they could be broken by a professional with the proper equipment.

- Digital Scramblers

With the invention of pulse code and delta modulation, it is possible to represent speech by a digital sequence and, accordingly, use can be made of the scrambling techniques already used to encipher digital telegraph signals. A key generator producing over a billion billion possible digital sequences, which are combined with the digital speech signal to produce an enciphered output, has been built on a single chip less than a quarter-inch square. The total scrambler, including the key generator chip, the analog-to-digital coder (and the corresponding decoder), and the synchronizing circuits occupy less than 1.5 cubic inches, weigh under 3 ounces, and draw only a fraction of a watt of electric power.

When such devices are used with standard mobile FM equipment, the digital voice signals are typically restricted to about 12 kilobits per second (kbps). The resulting pulses then frequency modulate the carrier, remaining within the 20 kHz receiver bandwidth. The 12 kbps signal is intelligible, but the speech quality is clearly inferior to present telephone quality. Work is underway to improve the quality of such lower bit-rate codes by using more powerful algorithms. The processing equipment will be more complex, but with digital techniques, the physical increase in size and weight should be relatively minor.

Special Features

Small speech privacy devices of a digital type, now being offered by at least two manufacturers, could readily be incorporated into mobile radio sets--and provide a high degree of privacy. We do not know how they would stand up to the efforts of professional cryptanalysts using computers and specialized equipment, but they appear to provide a period of privacy for most mobile users requiring this feature.

For most mobile applications, privacy equipment is not needed at all. A relatively few users consider privacy to be essential, even if the cost were equal to that of the radio set--meaning several thousand dollars. Substantially more users would buy such units if the cost were perhaps a tenth that of the radio--a few hundred dollars. With the declining trend in digital component costs as a result of large-scale production, the lower price may be realistic in the 1980's.

From a regulatory viewpoint, the present allowable spectral envelope is based on a frequency modulated analog voice signal. This should be re-examined for validity in light of the increasing use of digital signals. Another regulatory matter that now affects the United States' balance of payments is the restriction on exporting such equipment. This, too, should be studied.

Section 5 Vehicle Locating and Monitoring Systems

The subject of automatic vehicle location (AVL) is included in this study of mobile communications for several reasons. Telecommunication, or communication at a distance, is defined internationally as including radio position-finding by passive means (radar) and by active means (beacon) as well as radio station location by direction-finding methods. Telemetry, or measurement at a distance, is also considered within the telecommunications family. In a narrower sense, most AVL systems involve transmission of radio signals from the mobile station back to the base station to inform the latter of the mobile's position, thus requiring a radio circuit separate from that used to measure position. The techniques and equipment used to determine position are mainly those already used in the telecommunications field. From a practical viewpoint, these are best treated as part of that field. Finally, AVL systems use the radiofrequency spectrum and should be considered part of frequency spectrum management.

Automatic means for locating a fleet of vehicles and for monitoring their condition could be useful for a number of public services. Such systems can assist in schedule keeping and can uncover improper routing or shirking. With equipment sensors, they can reveal improper functions before these result in major damage. They could provide signals on holdups, terrorism, or vandalism, and some might track stolen vehicles.

In any such system, there must be a means to establish the location of vehicles, and sensors to detect the speed and direction of movement from that location (or to re-establish location frequently). There may be sensors to report the condition of equipment and load, and there must be means for transmitting the data to some common point for computation, storage, and use.

Systems

Systems may be designed for vehicles that repeat a fixed route--buses, for example--or for vehicles that have unpredictable routes, such as police patrol cars. In view of the array of needs and the large number of techniques that could be applied, this section will describe several representative systems.

SYSTEM A--A vehicle repeatedly issues a weak radio signal coded with an identifying number and any other information that may be required. The signal is picked up by receivers mounted at intervals ("signposts") along the route and sent to the computer via ordinary telephone lines. This gives the computer a periodic location and time. The computer can calculate later approximate positions--based on average speed of the vehicle--until another position signal is received.

SYSTEM B--Each signpost along the route transmits a low-power signal coded with the identity of that location. Equipment in the vehicle picks up the signal, stores the location identity, and starts an odometer and clock. A central computer facility polls the vehicles using the regular FM communication radio. When a vehicle is called, it responds with the data it holds in store, the identity of the last signpost, the time elapsed, and the distance travelled. With such data, the computer determines the vehicle's present position. Situation data may also be included. In a variation of this system, the radio transmitter of the signpost is replaced by magnetic nails driven into the pavement in a recognizable pattern.

SYSTEM C--A central station transmits the identity of each vehicle in turn, followed by a timing pulse. The identified vehicle waits a fixed time, then transmits a radio pulse. Three receiving stations pick up the pulse and send it to a central computing facility. From the differences in reception times at the three receivers, the vehicle's position can be triangulated. In a variation of this system, the communication channel is replaced with very precise clocks at the receiver locations. Each receiver determines the precise time of arrival of each pulse and sends this information to the central computer. Status information can be sent as an addition to each voice transmission or as independent short messages at unrelated times so that any interference does not long persist.

SYSTEM D--It is possible for vehicles to intercept signals from the Loran navigational system. Each vehicle must have an automatic Loran receiver and must store its output and other information for transmission to the computer. Condition information can be included in a message.

SYSTEM E--A system can be based entirely on dead reckoning. This requires higher sensor accuracy, but avoids the cost of signposts and their power supplies.

Any of the systems that do not require a fixed route can track a stolen vehicle. In all the systems described, sensors for such conditions as engine temperature, oil and air-brake pressures, can be standard mechanical devices with electrical indication of limiting values. Loads can be read by spring compression or by passenger counters. Fire or smoke can be detected by standard means. Vandalism, holdups, and terrorism can be signalled by the operator.

Results

Tests using different techniques have been carried out in Chicago, St. Louis, Philadelphia, Dallas, and Orlando. A second round of tests has recently been completed in Philadelphia, and the results were used to select a system for a large scale experiment in Los Angeles. The tests are sponsored by the Department of Transportation's Urban Mass Transit Administration, which has established a research and development specification for accuracy of 300 feet, 95 percent of the time.

More important are the operational results (some from experience, some from simulation, and some based on study data):

- One city found it could reduce the number of roving supervisors and cut the time required to resolve a scheduling problem from 30 minutes to less than 5 minutes.
- One study simulating patrol car runs showed that a vehicle locator, when combined with a computer to indicate one-way streets and other impediments to the chase, could increase the probability of arrest by 15 percent.
- Orlando reported that it could reduce the number of patrol cars by 5 percent using a locator. While this seems small, the annual cost of a car and the three police shifts that use each car runs to nearly $250,000.
- Hamburg reported the ability to reduce the reserve fleet of buses by 4 percent and to reduce deviations from schedule by 50 percent.

Problems

While such examples bring out advantages achieved with the AVL system, the lack of standardization inhibits large-scale production of equipment and the corresponding price reductions. Despite the tests, the cost-effectiveness of AVL systems has yet to be demonstrated.

Radio transmission problems in AVL are the usual ones of noise (especially in industrial areas), multipath, shadowing, and occasional anomalous long-distance propagation. Wire problems are also the usual ones of imbalance, induced noise, ground currents, and distortion. Corrective measures and their limitations are well known.

A major problem is system design and standardization to achieve cost reduction. There is a wide range of techniques for both sensing and data transmission, and it is necessary to select the combination that offers the best ratio of performance to cost for each application or group of applications. The variations among cities in vehicle distribution, population density, geographic size, probable rate and direction of growth, and radio propagation conditions, make for uncertainty that a standard, single approach will be possible, yet the use of different systems impedes movement toward lower costs with standardized systems. It is therefore an open question whether a reasonable compromise can be found to realize the operational savings possible at a cost consistent with such savings. The forthcoming Los Angeles experiment will be important in answering this question.

Section 6: Mobile System Alternatives

This section deals with two-way mobile radio systems. Neither paging systems nor CB radio is discussed.

Technical Feasibility

The technical feasibility of FM mobile radio service is beyond question. Commercial systems for both private and public service have been in operation for years at frequencies below 500 MHz. Difficulties have been encountered only because of channel crowding.

In Docket. 18262, the FCC allocated frequencies above 800 MHz for land mobile radio services. Bell Laboratories and others have conducted extensive studies of narrowband radio propagation in an urban environment at such frequencies (Jakes, 1974). The Bell System is conducting a trial of its high-capacity cellular concept in Chicago. The trial is expected to continue through 1978, but Bell reports that preliminary results confirm the validity of the design concept.

Time-division multiplexing (TDM) of voice signals has been employed in commercial wireline carrier systems for more than 15 years. It is the preferred technology for short-haul applications and holds the potential for long-haul guided wave systems using coaxial cable, millimeter waveguide, or optical waveguides (fiber) as the transmission medium. The electronics for sampling, encoding, and multiplexing are well understood, reliable, and economical. In addition, fixed location microwave radio relay systems are transmitting digital signals with time-division multiplex. Thus, transmission and reception of high-speed pulse-coded radio signals can be considered state-of-the-art technology.

Finally, TDM radio systems have military applications in mobile use, and information has been gathered on field propagation. Such experience is of value in assessing the potential of TDM for high-capacity mobile services in the urban environment, but the evaluation is not conclusive. Military grade-of-service requirements may be similar to those for some public safety services, but do not meet the expectations of users of the public switched telephone service. Futher, the interference, multipath, fading, and delay effects of radio propagation in the urban environment are unique. Such effects on the reception of digital radio signals by moving vehicles in cities have not been investigated in adequate depth to assure the applicability of TDM for mobile radio service. In our judgment, basic propagation studies should precede system design and feasibility trials.

Satellite relay between fixed base stations is of unquestioned feasibility and is being used commercially to ships at sea. There are few measurements of radio propagation between satellites and vehicles moving in the urban environment. Here again, propagation tests must be made before the system concepts are implemented.

Ability to Meet User Needs

Public Radio Telephone Service

The cellular concept appears suitable to meet the need for high-capacity public switched services in metropolitan areas with efficient use of the spectrum. This conclusion is independent of the modulation technique used, whether FM or any of the various TDM techniques.

Theoretical calculations have been made of the number of separate mobile units that can be handled with spread spectrum techniques (Eckert and Kelly, 1977). There is no experimental verification of a spread spectrum system's ability to carry the large number of simultaneous conversations expected in public radio services in urban areas. Military applications are promising, but do not provide a sound base for extrapolation to high-capacity metropolitan systems.

Among the characteristics to be considered in comparisons between systems is speech quality. An objective of the proposed 800 MHz telephone cellular system is to provide speech quality comparable to that of our terrestrial telephone network, so that it can interconnect without loss of quality. When digital systems are considered as replacements for FM systems, the voice quality should be equivalent.

To augment public mobile radio service in metropolitan areas in the most timely manner, FM systems operating with cellular arrangements above 800 MHz appear to be most promising.

Where a smaller user community exists, as in cities with relatively low populations, a single higher-powered base station operating in a trunked system arrangement might meet initial demands. This is equivalent to a cellular system of one cell. With a single large cell, use of the spectrum may not be as efficient as with a number of small cells in a large metropolitan area, but it would be consonant with demand. This assessment is independent of whether FM or TDM techniques are used.

In principle, either an integrated network of terrestrial stations or a satellite relay station could meet the needs of complete coverage of the highway system for mobile services. The former is known to be technically feasible, and the latter has great potential.

Private Radio Services

Private radio services are used in such public safety services as fire, police, and first aid squads, and in much commercial dispatching of trucks, taxis, buses, and other road vehicles.

The operational requirements for radio services vary. Public safety services are tightly organized, operate with disciplined protocols, and may be more tolerant of grade-of-service variations, provided immediacy of communication is given prominence. Radio services for taxicabs and trucks typically operate with shorter message-holding times than public telephone users, so on a per-message basis may be more efficient users of the spectrum.

A high-capacity trunked or cellular system could be engineered to meet the needs of both public safety and commercial vehicles. However, particular requirements--for example, voice privacy in public safety services--may be sufficiently different from the needs of the public user community that separate channels should be dedicated for their use. Even when channels are dedicated to private users, implementation of a hybrid arrangement would provide an alternate communication path in the event of failure or overload of the dedicated channels.

Economic Considerations

All of the new technologies under consideration are intended to provide more efficient use of the spectrum or new service opportunities, and none should be expected to yield a dramatic reduction in costs over systems available today.

Where the technology is well established, as in FM, there are years of experience in cost reduction. Alternately, if a receiver is tuned to a fixed frequency band, as is the case for a spread spectrum receiver, no need exists for the automatic channel-selection equipment of a trunked system. However, with integrated circuits for complex logic and data manipulation, and solid state radio frequency devices, sophisticated signal processing and access to a wide range of frequencies will be available at costs comparable to those of the electronic components in contemporary mobile units. Furthermore, mobile unit costs consist largely of structures, power supplies, handsets (or microphones and speakers), antennas, and other non-electronic apparatus, so the costs of mobile equipment for the new techniques should not differ widely from current costs.

Base complex costs are another matter. Base stations to serve a few channels at 800 MHz should cost about the same as those operating at lower frequencies and serving the same number of subscribers, but the base complex for high-capacity mobile systems will be more expensive. In the TDM concept, for example, each base station would require equipment for up to 96 simultaneous conversations and a broadband transmitter for distribution of the signals. In any cellular system, high capacity and frequency reuse would be attained with many small base transmitters distributed around the metropolitan area. Fixed equipment could be separated by as little as 2 miles. To maintain communications with a mobile moving through the cellular complex, it is necessary to provide a centrally controlled, fixed communications network linking the base stations. The ground network might consist of a separate array of microwave radio links or a wireline network. A satellite system dedicated for land mobile radio use would require a very high initial investment of the order of $100 million to $200 million.

The cost of a large base complex is reasonable only if it can be shared by a large number of users. Cost estimates are not available for each of the alternatives. We caution that care must be taken in implementation and introduction planning to ensure that the base station investment can be recovered with tariffs low enough to satisfy the market.

With proper planning, the cellular concept can be introduced economically. An initial installation should have the smallest number of cells and radio equipment to meet the coverage and volume requirements of the subscribers. The first installation could be a single cell that covers, say, a 25-mile radius. As service is extended outside the initial area, more cells can be added around the periphery to increase coverage. As traffic density grows, more radios can be added to the loaded cells until a maximum number is in use. To meet further service demands, it will be necessary to add cell sites to create smaller cells within the initial group. In implementing this strategy with optimum reuse of frequencies, it is necessary to allocate frequencies in initial large cell configurations, with the expectation of future cell subdivision and frequency reuse.

To obtain modest nationwide mobile coverage, one transponder in an appropriate frequency band might be piggybacked on a geostationary satellite whose major capacity would serve other domestic communications purposes. Initial market studies are promising and should be pursued.

Several attempts have been made to assess the national economic benefits and costs associated with the use of land mobile radio. It is generally accepted that the use of mobile radios results in a cost improvement of 20 percent for performance of an appropriate function (Federal Communications Commission, 1967), but by 1980 the reduction may be as much as 25 percent because of increased costs of equipment and labor.

Spectrum Efficiency

In current mobile radio services, individual radio channels are separated by 25 or 30 kHz. In some cases, it may be possible to cut the separation in half. Thus for discussion of spectrum utilization, we take a baseline figure of 5 to 10 radio channels occupying a band 150 kHz wide, with the frequencies reusable only for services separated by, say, 100 miles.

Dispatch services commonly use a single channel for both directions of transmission with a push-to-talk protocol. In mobile radio telephone service, separate frequencies are used for transmission and reception.

In a typical TDM concept, up to 96 channels of base-to-mobile transmission would be time-multiplexed in a 1 MHz bandwidth, giving approximately 15 channels per each 150 kHz, with the frequencies reusable at spacings approaching 100 miles. Mobile-to-base transmission could be over separate FM channels.

The proposed FM cellular system at 800 MHz has frequency separations comparable to those used today. In the design strategy it is expected that the high capacity of the cellular system for urban services will be realized by configuring the system so that frequencies can be reused at separations of less than 5 miles, using cells of 1-mile radius. Such a configuration will permit a frequency use on the order of 10 times greater than that with current system configurations, assuming typical traffic-density patterns, and even greater frequency use if traffic is uniformly spread.

Spread spectrum techniques also offer an opportunity for efficient use of the spectrum. Theoretical computations (Eckert and Kelly, 1977) suggests a capacity greater than that of the FM cellular system. Some of the assumptions in this particular calculation have been challenged as inconsistent with existing measurements (Jakes, 1974). We hold that the efficiency of spectrum use is at least comparable to that of FM cellular systems, and that continued investigation is justified.

Satellite systems, with FM system designs, would have the spectrum efficiency of systems currently operating: 5-10 channels in 150 kHz. If TDM techniques are feasible, the effective channels per megahertz could be doubled. Inherently, satellite systems do not offer the spectrum efficiency of small cellular systems. The advantage of satellites lies in their broad coverage.

Section 7 Conclusions and Recommendations

As a result of this study, the Committee offers the following conclusions and recommendations.

Conclusions

Public Radio Telephone Service

The demand for high-capacity public radio telephone service in the urban environment should be met with a newly designed system that will allow efficient use of the spectrum. In major urban areas, such a system would use the "cellular concept" in which computer-controlled, interconnected base stations communicate with mobile units on the road. Smaller cities may be served by a single cell with automatic trunking.

Private Communication Services

A mobile radio system using the cellular concept could provide basic communications for both public safety and commercial dispatch services, but the operational needs of these two services, and such communication traffic characteristics as holding times, may be so disparate that separate channels would have to be dedicated to each service.

Technologies

Two fundamentally different technologies have been proposed for high-capacity mobile radio service:

- Transmission of voice signals with frequency modulation over radio channels that are separated in frequency (FDM), and
- Transmission of samples of the voice signal in radio frequency pulses that are separated in time. Several variants of this scheme have been proposed, including pulse amplitude modulation, spread spectrum modulation, and packet radio. All have in common the notion of time-division multiplexing (TDM).

FDM and TDM technologies are fundamentally incompatible: a radio system built for one cannot communicate with a system built for the other.

Radio propagation of FM signals to and from mobile units in the urban environment is well understood. This technology is now in use, and can readily be adapted to the 800 MHz frequency band.

Radio propagation of pulses to and from mobiles in the metropolitan area has not been extensively studied, particularly at the high pulse rates needed for a spectrally efficient, high-capacity system. Initial tests have recently been reported by Stanford Research Institute, working for the Defense Advanced Research Projects Agency on packet radio (Nielson, 1977). Enough is known about interference, fades, and multipath in radio propagation in cities to question the feasibility of ultra-high-speed pulse transmission, and to emphasize the need for propagation measurements prior to system design. Even if plans for basic propagation tests of high-speed pulse transmission in metropolitan areas were started now, it would be several years before the measurement program could be completed, a system engineered on the basis of measurements, and field tests undertaken.

Satellite relay between mobile units is technically feasible, but the cellular concept is more economical than satellite relay within a given metropolitan area. The principal advantages of a satellite relay between mobiles would be the opportunity to alert a mobile anywhere in the nation that a call is being directed to it, and to provide service to remote areas not served by a terrestrial system. The costs of a satellite relay are great, and it is not known whether there are enough users to justify its expense. Frequencies allocated to satellite relay must be different from those allocated to the cellular system to allow multiple reuse of the same frequency in many cells within the coverage region of a single satellite beam. It would be desirable, however, to make frequency allocations for satellite-to-mobile service adjacent to the present mobile bands to permit use of conventional terrestrial mobile radio equipment.

We conclude that for high-capacity mobile radio telephone service in urban areas an FM cellular system is the most promising technology for large-scale production in the early 1980's. Although this conclusion does not differ significantly from premises already being acted on, it was reached only after full consideration of some more dramatic alternatives that were finally judged to be technically unsupportable at present.

Recommendations

To implement high-capacity public radio telephone service for the metropolitan area in the near future, appropriate government agencies should:

- Identify the FM cellular concept as the technology to be used in the 800 MHz band;
- Initiate processes for standardization of all parts of the system, including mobiles, base stations, access protocols, and network arrangements, and

- Plan frequency assignments for initial large cells with a view toward growth into small cells and frequency reuse.

Any plans for the dedication of channels in the 800 MHz band to such specific user groups as police, fire, emergency units, or to dispatch services should include opportunities to:

- Achieve reduced costs for all mobile services, either public or private, through high-volume manufacturing of equipment common to all, and
- Allow private-channel mobile units to have access to the public network either initially, or if the experience is favorable, at some future time.

To achieve these goals, system designs for use of the 800 MHz band should:

- Follow the same FM mobile unit radio standards for both private and public use channels, and
- Include the same protocols for access to private trunked and public cellular systems.

To provide the basic knowledge for development of future complementary mobile radio systems, appropriate government agencies should encourage:

- Propagation tests of high-speed pulse transmission to and from mobile units in the urban environment;
- Propagation tests of spread spectrum techniques in the urban environment. In such tests, potential interference among closely-packed user codes should be investigated;
- Propagation tests of mobile-satellite communications in the urban area using both frequency division and time division techniques, and
- Study of the demand for a nationwide satellite mobile communication system.

For those systems where the findings of the propagation tests and demand studies are positive, appropriate government agencies should encourage feasibility tests of exploratory systems using time-division multiplex, spread spectrum, packet radio, and satellite-mobile communication techniques so that informed system choices can be made in the future.

In preparing frequency allocation plans for the World Administrative Radio Conference in 1979, the federal government should take into serious consideration the future use of satellite-to-mobile transmission in a band in or adjacent to a present mobile band.

CHAPTER V

Telecommunications and Community Security

In addition to examining the problems of access to public services from the home and delivery of mobile public services, the Committee studied the special case of access to public services (particularly emergency services) by people who are themselves mobile. Some form of radio communications could be necessary for such people under certain circumstances.

A communication network could be created to overcome two concerns often expressed by the elderly, particularly those living in inner-city areas. They express concern that an in-home accident or episode will leave them helpless and out of touch with anyone who can provide assistance, and they worry about their ability to summon help if their personal safety is threatened inside or outside their dwellings.

For many people in urban centers, the threat to personal safety and property is a serious social and psychological concern. The application of a systems approach to the problem of community security involves, among many factors, the use of current telecommunications and sensor technologies.

This Committee addressed a few narrow aspects of crime prevention with the objective of identifying some experiments that could gather data useful for a larger system study, and might have some palliative effects in the short run. Our proposals are not the result of deep study; they are examples of applications of telecommunications technology in a comprehensive anti-crime program. A more intensive and extensive study might perhaps identify as targets for improvement through telecommunications other elements of an anti-crime program such as employment, job satisfaction, or education.

The Committee, nevertheless, considers it worthwhile to test the thesis that personal security might be enhanced by telecommunication techniques through a personal security network* that would provide quick and reliable assistance to individuals under threat or actual attack.

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*In this analysis, the term "network" is used in the larger sense of interpersonal communications made possible by electrical transmission.

The Committee considered several examples in which technology shows promise:

- Placing an urban dweller in nearly instantaneous voice or signal contact with police forces whenever danger threatens.

- Making it possible for an urban dweller to transmit an alarm to police or neighbors, and receive an instantaneous response that help is on the way.

The central purpose would be the physical and psychological security of defenseless citizens, particularly the aged, the young, the handicapped, and people living alone. The use of telecommunications to re-establish a sense of belonging and trust in a neighborhood may have an effect on urban life similar to the effects of architecture observed by Jane Jacobs (1961).

Federal support should be used to encourage demonstration projects that would be observed and evaluated to determine the effects of the network on the community, and to determine the technical developments that could improve network performance or overcome obstacles to full utilization. In the Committee's opinion, funds necessary for experiments leading to the development, maintenance, and evaluation of personal security networks would be comparatively small.

Much of the malaise of the cities has fundamental social origins. Telecommunications can at best act only as a Band-Aid when major social intervention is really needed. But, for a change, telecommunications might help overcome rather than contribute to the sense of anomie. The growth of Citizens' Band radio testifies to that effect.

A network could most easily be established where the elderly population has both a physical site at which it gathers and a visible organization. Measurements could be made on the social effects of telecommunications support--enhanced sense of security, reduction of actual crime, detection and action on crimes in progress, lives saved by timely medical intervention, etc.

The general goal would be to enable community members to communicate with one another for mutual support, and with the community center for calling in public services (police, ambulance, fire fighting). To be economical, the experimental network should be operated by the elderly, and should consist of relatively cheap and simple telecommunications terminal apparatus. Such a network could be organized around state-of-the-art equipment, but several different types of terminals should be tested.

The communications center, run by the elderly community on a 24-hour basis, would be in contact with police, fire, and emergency health services on a direct or rapid dial-up mode. Radio links (CB, common-carrier cellular, low-power telemetry, etc.) would link mobile users to the center. Land-line telephone--used imaginatively in modes from broadcast and party line conference to anonymous alerts--would connect the users to the center from fixed locations (homes, apartment hallways, garages, meeting places, alarm boxes) to the center. It is also possible to impose a carrier on a telephone line at a higher frequency to carry alarm signals or to obviate the need to dial. This service is called Added Main Line (AML).

Participants in such a community network would be given (for the demonstration) transceivers of several types. At least one type should be sufficiently small to be attached to the body or clothing. If th has insufficient power to make direct contact with the communicatio center, a second type could be supplied to provide automatic relay from an apartment to an outside window antenna.

The community should organize the network to meet the priorities the community sets for itself. Examples of procedures might include:

- Checking periodically on each member of the community during the day, and at specified times during the night. Between checks, individuals would be encouraged to use the communication network for social support of one another (late-night conversations, organization of group shopping trips, requests to shoppers to buy materials for others, etc.)

- Notifying members of the community's planned activities--the proposed times of departure and arrival, expected route, and desired check interval during the route. The communications center could track the individuals, and might even alert police patrol cars not otherwise engaged to monitor the route.

- Adapting transceivers to signal when wearers fall. A body transceiver could include a slow-leak mercury switch that activates the transceiver to transmit an identifying signal when the wearer goes from a vertical to a horizontal position. One problem would be the incidence of false alarms triggered by forgetting to take off the transceiver when going to bed, or accidentally dropping it. The community would learn to deal with false alarms by social pressures, and by action at the communications center to sort out false alarms--following up a non-vertical signal with a telephone call to the apartment, asking neighbors to check out non-vertical signals, and calling for police investigation if necessary.

- Controlling transceivers from the communications center when necessary. When an intruder is encountered and the body transceiver sends a signal, the communications center could take control of the transceiver and switch it to a mode in which a person at the center could speak directly to the intruder through a voice amplifier on the victim. The character of certain acts might become very different if the aggressor knew that outsiders were aware of a crime in progress.

- Developing add-on devices that would enhance the community security system, such as an individual locator mode to identify the position of any transmissions, and multiple networks on the same radio channels to allow overlapping use (through more sophisticated modulation techniques).

For demonstration purposes, the federal government is urged to support several networks and the development of several types of add-on equipment. Ultimately, equipment will become commercially available for purchase by individuals. The trade-offs of costs and benefits would be made by the members of the network. The role of the government would be to gather data on the effects of such systems on crime rates and on citizen satisfaction, to encourage demonstration, and to help generate a market through support of initial development.

A number of problems may arise concerning control of the network when non-members interfere with operation of the network. These could be alleviated if members had a reserved channel (through modulation techniques). The noise level might rise, but some communication would be possible. Existence of such a network might also encourage criminals to become more highly organized, to use the network to determine whether the crime has been detected, or to jam the network to discourage intervention when a crime is in progress.

The demonstrations could help define the characteristics of the network: whether the radio portion could be used for indiscriminate chit-chat (in view of security and of congestion of the radio band), range (5 miles?), number of users (a few hundred?), duty factor per user (0.1 percent?), time of day (mostly early evening?), propagation environment (2 to 20 story buildings in a grid layout?), traffic pattern (Main Street with half a dozen dangerous side streets?), and psychological imperatives (signal type, acknowledgement requirements, reliability, control of use, cost per user, etc.). For some of the mobile equipment to be low cost (say, under $100), it will have to use low power and narrow bandwidth--providing less than toll-quality voice. Some functions are best handled by the ubiquitous telephone network and others by the radio net.

There are economic questions: who is the beneficiary, who is the supplier, who pays? Telephone rates to and from the center should be made low, but a special tariff, similar to "lifeline" rates, might be required.

By itself, a government demonstration, without any plans for transfer to a community organization, would be almost pointless. It is important to have a total plan for such a demonstration, from concept through continuing, self-sustaining operation of the network.

One of the components of any study would be to determine the relationships between community security networks and both the 911 system and automatic vehicle location systems. Clearly, a generally applicable personal alarm system has to be devised that is not compromised by sharing with other community or social services, or with the already overcrowded Citizens' Bands.

The community security network is a new concept in which a wholly different social need is being addressed--one that may require esoteric technologies, ingenious equipment designs, and a specialized network architecture. The community security network is critically dependent on the mobile part, whereas other networks can treat the mobile access as only a desired option.

It may be premature to improvise expensive partial solutions in terms of specific hardware and communications networks, outside the content of other efforts being made to reduce crime. It is not advisable to proceed in haste with some "quick fixes" that are insufficiently tested. Improvizations that backfire discourage the formation of major, meaningful projects. It would be better to experiment with components and systems in a social laboratory that yields data for a more complete system study. The efforts and resources involved in such a social laboratory need not be formidable.

CHAPTER VI

Telecommunications in Energy Conservation and Management

At the request of federal agencies supporting this study, the Committee examined the role of telecommunications in national energy policy. We find that telecommunications has a peripheral but potentially significant role in energy conservation and management. This chapter examines the use of telecommunications:

- To substitute for transportation;
- To transmit real-time demand and pricing information between customers and utilities;
- To facilitate load management, to promote the maximum use of efficient generating plants, and to reduce peak demand, and
- To support a growing bulk power market.

Existing telecommunications technology is largely capable of supporting such applications, even though certain terminal equipment needs to be designed for some specialized purposes.

In assessing the degree to which telecommunications could reduce the use of energy for personal travel, the key issue is whether telecommunications is an acceptable substitute. The combination of telephone communications (both teleconferencing and one-to-one communications) and face-to-face meetings, appears to be more effective [illegible] either alone. It would be oversimplification to assume that a long-distance telephone conversation exactly replaces X miles of travel [illegible] saves Y gallons of oil. Furthermore, studies indicate that telecommunications offers a greater potential for reduction of intra-city travel and commuting than for reduction of inter-city travel. Several experiments and prototype systems have sought to demonstrate and evaluate how fuel may be saved by replacing travel with telecommunications. The total savings in petroleum by additional substitution cannot be predicted easily, but estimates have been made in the range of a few percent.

Additionally, automatic meter reading enables establishment of time-variable, demand-dependent rate structures, providing incentives to customers to manage their own load distribution and providing improved data on consumer use to utility companies. Potentially, automatic meter reading can save the expense of meter-reading personnel and reduce electrical theft. Furthermore, if electricity, gas, and water services were all read automatically, savings in fuel might be considerable. (Some aspects of energy conservation in the home have already been discussed in Section 6 of Chapter III.)

In the area of load management related to the retail use of electricity, telecommunications could provide the consumer a broader range of options and permit better planning of energy use. More detailed data on consumer use would enable the power company to improve the quality of its market demand estimates and the assessment of such influences as weather, public events, seasonal and diurnal variations on the demand for power.

At the wholesale level, greater use of telecommunications systems could create opportunities for a substantial expansion of the bulk power market.

Section 1 Telecommunications-Travel Substitution

The energy crisis has stimulated a prodigious number of studies of techniques for energy conservation. One approach to conservation seeks to achieve more efficient utilization of energy resources to perform the same functions; another approach seeks to extract more power from the same amount of fuel.1/ With either approach--simple conservation of energy resources or more efficient conversion of energy resources into work--there is a growing awareness of the promise of significant energy savings from the use of telecommunications in place of transportation. There is already a significant body of literature examining the possibilities for substitution, but a great deal of it is reiterative and highly speculative.

One of the most comprehensive surveys of the subject (Harkness _et al._, 1976) reports on a variety of means for substituting informatio transfer for intercity travel. This survey identifies as most promisi the use of teleconferencing, from voice-only transmission to full audi visual and graphic transmission. A number of studies confirm the report's conclusion that the _potential_ energy savings are substantial. The studies are summarized briefly in Appendix A; some prototype systems are summarized in Appendix B.

The central issue, however, is not whether a significant amount of energy can be saved by substituting telecommunications for travel, but whether it is likely that substitution will be made to a significant degree. Estimates of the potential for substitution are summarized in Appendix A. Studies indicate that a significant amount of business-related travel is highly susceptible to substitution by telecommunications, depending on the type of communication services available. On the other hand, the indicators are not in one direction only. For example, one study suggests that communications and transportation are, in general, mutually reinforcing (Cowan, 1973). Thus, travel may stimulate telecommunications, and telecommunications may stimulate travel, creating occasions for travel by speeding up the pace of economic activity.2/ There is, however, no reliable empirical evidence on this issue.

The potential for energy conservation in substituting telecommunications for intercity travel, though significant, is a fraction of the potential that is offered by the substitution of telecommunications for intracity travel and commuting. In particular, telecommuting--the use of telecommunications to reduce or eliminate routine travel to and from jobs--holds promise for large savings (see Appendix A for estimates). This might take the form of geographic decentralization through neighborhood office centers. The potential savings need to be qualified. It is possible that neighborhood office locations could consume more energy than longer-distance commuting. It does not automatically follow that dispersal of work centers to suburban locations would result in shorter commuting distances (Harkness et al., 1976). Decentralization could produce a shift from a more efficient mode of travel to a less efficient form where decentralization results in a shift from public transit to automobiles. Mass transit is typically designed along hub-and-spoke lines, so the availability of mass transit between and within suburban areas is much more restricted than it is between suburbia and the core city.

It is uncertain whether intracity substitution will take place on a scale large enough to produce significant energy savings. In contrast to intercity business travel, there does not appear to be much empirical data that would shed light on the question. Business travel usually takes place for reasonably specific purposes which are at least centered on, even though not necessarily occupied solely with, the exchange of information. However, daily work routines are more complicated. It is theoretically possible, of course, to perform office work with the mere exchange of information. However, the social reality is quite a bit different--the actual exchange of information being inseparable from the social contacts possible only in an environment of at least occasional face-to-face encounter. Of course, in neighborhood offices some such aggregation of workers would still take place, but such face-to-face encounters would not be among the same range of people.

This last point raises another more general concern--the social effects of neighborhood work centers. Although neighborhood work centers offer attractive features--alleviating the strain of commuting long distances, saving time, reducing problems that are thought to attend concentration, such as crime, congestion, and pollution--some aspects of neighborhood work centers are disturbing. They could lead to reduced social interchange, particularly between socioeconomic and racial groups, because in the long term workers would be sorted out by neighborhood. Neighborhood work centers could exacerbate the problems arising from the flight of the middle classes to the suburbs, and the consequent drain of financial support and social concern for cities and their problems. The idea of decentralizing work locations warrants further pursuit, at least experimentally, but the many social and economic consequences of neighborhood work centers must be considered in conjunction with the more immediate concern of energy conservation.

Above all, there is the need for some reliable information about the quality and effectiveness of the work performed. There is no significant experience with this concept, nor have the more suitable industries been identified or the effects of size and density of metropolitan areas been estimated. Without empirical data, we can only speculate about the potential savings or the broader social effects.

With respect to intercity travel, there have been some studies of attitudes expressed by business and government, but much remains that can be learned only from experiments. There have been a few experiments 3/ on a very limited scale, but there has been no systematic study.

It is possible, of course, that the situation will take care of itself. If telecommunications substitution is found to be cost effective, we might expect it to be adopted without government intervention. The difficulty with this assumption is that the energy costs of travel may be a very small part of the individual firm's budget--too small to induce the firm to search for cost-saving alternatives (bearing in mind that the search itself is not without costs). In addition, a number of external costs associated with travel (congestion, pollution, the costs to future generations from long-term energy scarcity, etc.) may not be adequately internalized in the cost function of the individual firm. In the former instance, the case can be made for government intervention by disseminating information about telecommunications alternatives; in the latter instance, government economic support for telecommunications alternatives may be warranted. In either case, however, there is a need for better information about the efficiency of telecommunications substitutes and about other social and economic effects.

While scholarly convention demands a plea for more study and research, it is appropriate to add the caution that what is needed is some concrete empirical information on travel and telecommunications patterns, on substitution, and on effects. A set of detailed proposals for further research is set out in a study by Harkness, Tyler, and Pye (1976), including proposals for analysis of changes in travel costs after the introduction of teleconference facilities. A few general comments may be appropriate.

There is little to be gained from further work that merely calculates the amount of energy savings to be gained from particular substitutions. While the evidence on energy savings is not by any means complete, it is enough to justify the presumption that savings are potentially significant, depending on the degree of substitution. For example, the National Aeronautics and Space Administration, where a conferencing system has been in operation for nine years, estimated for 1976 that teleconferencing replaced travel that would have cost $3.3 million, or about 21 percent of NASA's travel budget. The annual cost of the NASA teleconferencing network was about $500,000 (Data Communications, 1977). Indeed, at some level of generality it is intuitively obvious to this Committee that any net substitution of telecommunications for travel (after discounting possible travel-generating effects) will yield energy savings. The hard question is whether, and under what circumstances, and to what degree such substitution can be induced. Reports of surveys conducted in Canada and the United Kingdom (cited in Appendix A), suggestive of attitudes concerning telecommunications travel substitution, contain estimates that telecommunications might effectively substitute for 20 to 50 percent of business meetings. But there is very little empirical data about actual substitution.

One might expect the rate of travel substitution to vary with the relative costs and convenience of travel and telecommunications. Nearly all the half-billion phone calls made daily in the United States are one-to-one. It may be that conference systems enabling multi-point connections and many-to-many conversations will offer new opportunities to conserve energy. Some of the conferencing systems now in use are structured for point-to-point conferencing, and do not take advantage of multi-point connections. Video systems are usually found only in conferencing systems with just two connected sites. Multi-point audio conferencing is available from telephone companies, but requires operator assistance.

Some conference systems combine audio, facsimile, and video capabilities in varying degrees of sophistication and cost, yet there is some indication (Chapanis, 1976) that simple audio systems may be equally effective.

One obvious question remains: if telecommunications can be an effective substitute for travel, why is it not taking place on a greater scale? There is certainly considerable substitution now, but we need to know how more might be induced.4/

In this respect it is important to investigate the following:

- Under what circumstances can telecommunications be an effective substitute for travel?
- What travel purposes and work functions can most effectively be performed by telecommunications?
- To what extent does the size and density of a metropolitan area affect the substitutability of telecommunications?
- Are there significant market imperfections that impede the adoption of economically efficient substitution?
- If telecommunications facilities are available, why are they not being used more intensively?
- Is information about both the technical and economic aspects of substitution adequately disseminated?
- What travel needs cannot be fulfilled by telecommunications?

In approaching the investigation of these questions, new field experiments to analyze the substitutability of telecommunications should be emphasized over efforts to analyze cost trade-offs. Care must be taken in these investigations not to force the results by directing the level of substitution or otherwise skewing the results in favor of a particular outcome simply to test the amount of energy savings that can be realized under artificial conditions.5/

Communications can also be used to conserve energy indirectly by improving the efficiency of travel. Perhaps the greatest opportunity is in the remote operation and monitoring of mobile fleets. Studies indicate that radio contact can reduce energy consumption 20 to 25 percent by more efficient assignment (Federal Commmunications Commission, 1967).

Remote monitoring and control of traffic lights can also conserve energy, but it is not clear whether energy savings alone would justify this application.

It would require heroic imagination to insist that telecommunications offers a major opportunity for travel reduction in the foreseeable future. Despite the technological potential for significant substitution of telecommunications for travel, the social preference for personal, face-to-face interactions among individuals is unlikely to be voluntarily set aside on a large scale in the absence of compelling economic and time advantages for telecommunications over travel. No such advantages are evident now, nor are they predictable for the near future. At the margin, however, increased substitution of telecommunications for travel is quite possible, and as an energy-conserving measure, desirable. Such a marginal increase in substitution for marginal energy savings does not warrant a prominent place on the energy conservation policy agenda, but it deserves some attention.

Section 2 Telecommunications and the Metering of Consumption

For more than 70 years, the price per unit of electricity declined. This decline stemmed from the interaction of new technology, economies of scale, and market growth. By 1969, however, it became clear that a number of pressures would reverse this long-term trend: the rapid rise in the cost of new construction, escalating fuel prices, and the cost of compliance with environmental standards. Between 1970 and 1975, the price of electricity increased by 60 percent (Council of State Governments, 1977). Some industry sources now project average annual price increases of 7.5 to 10 percent. The rising price of electricity during the 1970's has drawn attention to the need to assure efficiency in electric utility systems.

To respond to the broad needs of industrial and residential demands, utilities frequently use several types of generating units: highly efficient base-load units, units of intermediate efficiency, and less-efficient units for peak loads. Base-load units must be operated near maximum capacity to recover their high initial cost. Intermediate-load units are frequently older base-load units. Peaking units generally incur lower capital costs. They are intended to operate for short periods when the load is at its maximum. Telecommunications can promote greater efficiency in the supply and distribution of electricity in applications:

-- between consumers and utilities;

-- within the utility distribution system, and

-- between utilities.

Metering of Consumption

A number of utilities in the United States have tried automatic meter reading over the past 8 to 10 years, but the practice has been exploited much more extensively throughout Europe. Automatic meter reading reduces costs by eliminating meter readers, and by reducing opportunities for consumers to steal electricity by altering meters. Large industrial customers have previously been supplied with meters that register maximum demand and energy consumed. Automatic meter readers cost $175 to $250 per unit, not including the support hardware and software.

Meter-Reading Technologies

With microprocessor technology, meter-reading systems can be developed whose total costs (equipment installation, data collection, and communications) are expected to provide a net over-all savings to the utilities when compared to the costs of the manual system now in use, particularly if several utilities in the same geographic region cooperate in the development and use of automatic meter-reading systems.

Transmission Technologies

A variety of transmission technologies have been investigated, ranging from the standard telephone line used on a single-direction basis to cable television circuits used on a bi-directional basis. The American Telephone and Telegraph Company has carried out a fairly extensive experiment to test the communication portion of a total meter-reading system for electric, gas, and water utilities in several cities. The field trials of this experiment have demonstrated the technical feasibility of using telephone circuits as communication links in a remote utility meter-reading system and have provided experience useful in the design of meter-reading equipment. It is encouraging to note that utilities of several types were willing to cooperate with one another in the development of automatic meter-reading equipment for this experiment, even though such cooperation is rare in manual meter-reading systems. Whether such cooperation is a necessary condition for cost-effective automatic meter reading should be examined.

Other technologies that are being explored and used in several relatively small experiments throughout the United States range from one-way ripple control systems using power line or radio communications to two-way digital systems using television cable. Effective information transfer rates range from 30 bits per second for the power line to 300 bits per second for the telephone line and approximately 2,400 bits per second for cable TV. The information transfer rate will be important in multifunction control and meter reading systems in large metropolitan areas, particularly if time-of-day pricing is incorporated, and customers are given the ability to override the utility's control of their consumption of electrical energy. Many of the experiments have relied on radio communication or older electronics technology, but several recent experiments have incorporated microprocessor technology both at the consumers' end and at the interface between the data collection system and the computer for processing bills.

Meter-Reading Systems

One manufacturer has developed a combined telephone/power line system for automatic meter reading that begins at a reading/control center and communicates downstream through telephone or microwave trunk lines to section control units that communicate via power line to meter terminal units. Each meter terminal unit can accommodate up to four readings and three separate load-management devices.

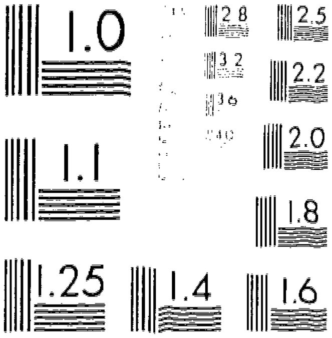
Another company has developed an automatic meter-reading system that communicates exclusively via telephone trunk lines. This system incorporates a computer-based master terminal that initiates and controls the interrogation of meters at consumer sites by dialing a special number for the access unit located at the telephone company switching office. The access unit makes the connection to each subscriber's telephone line without ringing the telephone equipment. The control equipment at the customer site reads and stores meter readings, and when interrogated by the access unit, converts the data for transmission back to the master terminal. Such a system can accommodate readings from several meters per customer, but has no load-management capabilities.

Another quite similar system incorporates a microprocessor unit at each customer site to carry out load-management commands in addition to accumulating data from several utility meters in a manner similar to one described in Chapter III.

One manufacturer has developed a prototype automatic meter-reading system that communicates either by coaxial cable or microwaves. In this system, each utility meter is modified to include a switch linked to the meter register and connected through cable to a data collection unit called the data accumulator. The data accumulator can scan and sample up to 16 meters. It stores the data, generates the meter addresses, and sends the information via cable to a radio transponder. A data acquisition truck drives through the area and continuously transmits a low-power carrier signal illuminating the transponder. As soon as the transponder is illuminated, it generates the second harmonic of the illumination frequency and retransmits the meter data. The truck demodulates the second harmonic signal and its data are processed and recorded on computer-compatible tape. This system is not able to accommodate time-of-day meter reading.

The power line communication system, known as ripple control, was developed for use in Europe. It provides extremely slow data-transmission rates. In this one-way system, a coded message is superimposed on the power line network and is interpreted at command-receiver relay devices located with each utility meter register. The receiver relay reacts only to certain codes, and such discrimination allows the relay to control the register selection (for dual rates), load-delayable items, and other industrial and residential switching devices. Because of the extremely slow data-transmission rates characteristic of this one-way system, substantial effort has been made in the United States to develop a two-way power line system. The major difference between the two-way system and the one-way system is the transmission frequency. Because of the higher data-transmission rates required in the two-way system, a wider bandwidth and higher frequency (up to 100 kHz) are employed. The power line distribution system is inherently designed for low-frequency operation, and transmission difficulties have been encountered when such high frequencies are used. Other problems have arisen because on-line utility transformers act as filters to the higher frequencies. Such problems raise questions about the system's reliability that are as yet unanswered.

As noted earlier in this report, radio control systems or radio communication systems have been in use for a number of years, primarily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for consumer load control and meter switching. These are generally one-way systems: the customer cannot override the utility's control. One manufacturer has recently developed a radio-controlled meter-reading system that uses cables to connect groups of consumers to microwave units. This radio control system uses the radio frequency spectrum, which must be allocated by the FCC. Interference from other radio services affects the reliability of this system.

In a cooperative project between Michigan State University and Rockford Cable Vision, Inc., a broadband TV cable system has been investigated in a preliminary way with interesting results (Michigan State University, 1977). Because of the large bandwidth of cable television, communications for automatic meter reading and consumer load management can be accomplished more efficiently than with either power line or standard telephone line communications systems. The expanded bandwidth allows data transmission at significantly higher speeds than power or telephone lines currently accommodate. It has been estimated that a broadband cable system is capable of providing a sampling rate of up to 5,000 consumers per second per channel--considerably more than a telephone system, which can handle approximately 2,000 consumer readings per hour.

The three major advantages of cable-based communications systems for automatic meter reading have been summarized (Eldridge, 1972):

- Wide bandwidth cable systems can be used to significantly reduce the complexity and cost of meter-reading and encoder equipment by eliminating the need for an account storage unit at each terminal;
- Required cable communication channels in the subscriber's data terminal can be time-shared with a number of other services;
- Simplified and shared terminals in time-shared communications channels result in low installation, maintenance, and depreciation expenses for the cable system as well as lower communications costs per individual served.

The wide bandwidth of cable systems would not be fully occupied with automatic meter reading as currently conceived, but would remain available for a variety of additional applications in the future. The fundamental limitation of cable meter-reading systems is that their availability depends on the expansion of broadband TV facilities, while telephone lines and power lines are already well established.

It is projected that cable TV systems will reach only 40 percent of all TV homes by 1985. But it is likely that the implementation of automatic meter reading will proceed very rapidly during the next decade, because microprocessor technology is advancing rapidly and the cost per customer unit is estimated to be $200 or less. For meter-reading systems that use power and telephone lines, the added cost is primarily associated with the addition of microprocessor control units at customer sites and at data collection and processing sites.

The basic communications and electronics technology, particularly microprocessor technology, needed to implement automatic meter-reading systems in the next decade is available today. Current costs per terminal unit (ranging from $175 to $250) restrict implementation of AMR systems, but large-scale production may reduce costs to $100 to $200. Non-technical barriers to implementation of AMR include uncertainty about rate design, time-of-day pricing, and cooperation between different kinds of utilities in a geographic area.

The justification for automatic meter reading has been given here in terms of savings to the utility and better energy management by the consumer. Perhaps of greater significance would be the improvement in operation and control of the utility system made possible by more detailed, real-time information about energy consumption patterns that automatic meter reading would provide. This is discussed in the following section.

Section 3 Telecommunications in Load Management

The concept of load management for electric utilities is based on the fundamental assumption that a smoothing out of the system load from industrial and residential consumers will improve efficiency in the production and distribution of electricity.

Since 1967, annual load factors* for the electric utility industry have declined, reflecting the growing dominance of summer peaking associated with air conditioning (Federal Energy Administration, undated). The nation's regional reliability councils project an average annual rate of growth in summer peak demand of 6.3 percent through the period 1976-1985, a growth in capacity of 5.5 percent and a growth in total energy consumption of 6.15 percent (Federal Power Commission, 1976). Fossil fuels accounted for 75 percent of the electric power generated in this country in 1975, and according to an FPC forecast, would account for 73 percent in 1980 (Federal Power Commission, 1976). Attention to conservation and optimization will remain an integral part of power planning.

An improvement in the load factor may help conserve primary energy resources and a more nearly optimal use of generation plant. The conservation of primary energy resources would result from shifting more of the system load to the more fuel-efficient base-load units. Since the load factor and fixed unit costs are inversely related, a more nearly optimal load factor would reduce fixed unit costs in the short term. Over the long term, the new capital investment otherwise needed to satisfy growth in total demand could be avoided or accommodated by a proportionally smaller expansion of plant, since growth would take place primarily during off-peak periods.

The utilities have improved their ability to respond to variations in load requirements by pooling arrangements. Local sharing of generating capacity does not necessarily offer relief from peaks, however, because when peak demand is high in one area, it is apt to be high in an adjacent area.

To induce consumers to shift their loads to off-peak periods, the electric utilities and state regulatory commissions appear to place

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*Load factor is the ratio of the average demand to the maximum demand during a specified period.

primary reliance on rate structure reform and more sophisticated metering. Both measures apply primarily to retail sales of electricity (sales to ultimate customers). Pricing or rate structure reforms have been ordered by several state commissions, such as those of Wisconsin, Michigan, and New York. Other pricing reforms have been tested in pilot projects financed by the Federal Energy Administration. A broad investigation --the Electric Utility Rate Design Study--has also been undertaken under the joint sponsorship of the Electric Power Research Institute, the Edison Electric Institute, the American Public Power Association, the National Rural Electric Cooperatives Association, and the National Association of Regulatory Utility Commissioners. A central feature of peak-load pricing is the establishment of peak/off-peak differentials that will discourage peak growth and promote off-peak growth. The unanswered question is how consumers will react to a variation in price between peak and off-peak periods.

In another approach to load management, the utility controls certain non-essential appliances if customers agree to accept interruptible service. The Detroit Edison Company system, for example, employs a radio control to turn off electric water heaters when load reduction is needed. In most cases, customers are unable to override such utility control, and are given a lower rate for this interruptible service. Control by utilities will probably be practiced more extensively in the future to adjust load demand at the peak, to increase use of base generating systems rather than peak generating systems, and to reduce reserve requirements.

Communications can also be used to automate, monitor, and control a utility's electrical distribution system. Communications now exist between the utility control center and the distribution system, but the use of remote automation techniques holds promise for improving system reliability by enabling distribution facilities to be reconfigured in response to changing load patterns.

Conclusions (Load Management and Metering of Consumption)

The technologies required to implement control and communications systems for load control and automatic meter reading are well developed, particularly the semiconductor technology supporting the widespread use of microprocessors in control and communications systems.

A significant number of experiments are being carried out in the United States to test various utility and consumer load control techniques. Experiments with automatic metering systems--ranging from power line control, the use of standard telephone lines, radio communication, and cable television 6/--are yielding valuable information that can be used during the next several years to assess the over-all effectiveness and acceptance of load control and meter-reading techniques, likely to be installed in the near future on a widespread basis.

Load management at the retail level suffers from two major infirmities. First, it is by no means clear that current proposals for rate structure reform and new metering techniques will afford the consumer an adequate range of choice. The ultimate mix of peak-load pricing, metering and associated control mechanisms must give all classes of consumers a reasonable basis for choice between different levels of service quality reflected in different levels of prices. Too often, peak and off-peak use are defined in such broad, inflexible terms that residential, commercial, and industrial users have too little latitude for altering consumption patterns. A peak period that extends from 7:00 a.m. to 7:00 p.m. each day, for example, provides little incentive for customer selectivity, and may lead to considerable user antagonism.[7] In contrast, a greater reliance on telecommunications technology and microprocessing would seem to hold the potential for greatly expanding the range of options available to the consumer. Such technology could provide terminals that show daily and seasonal peak periods based on the actual experience of the utility, and that indicate price during peak, intermediate, and off-peak periods, as well as projected charges on an incremental and cumulative basis, depending on the pattern of use selected. The information collected by a communications network would permit the utility to engage in more effective load planning and to refine, on a continual basis, the cost-of-service characteristics for each class of customer. The latter, in turn, would allow successive refinements in the design of rates based on actual experience.

The second problem in load management at the retail level is that the markets served by a given electric utility may be too limited for any combination of metering and pricing to achieve a high load factor. The market area and scale of operations must be sufficient to achieve the objectives of load management. If the extensive and intensive markets are too restrictive, the results of pricing and metering efforts are certain to be minimal. In effect, the firm may be a suboptimal unit for such planning. A more comprehensive view, which may need encouragement from the federal government, would include wholesale as well as retail sales, and could open a new dimension for achieving a high level of conservation and efficient use of aggregate plant and facilities. A wholesale market is discussed in the next section.

From this brief study of the use of communications in load control and automatic meter-reading, it is clear that the following actions should be encouraged by the Department of Energy:

- Continued experimentation with schemes for load control and automatic meter reading that accommodate peak pricing and broaden customer choice;

- Studies of rate-making policies that would exploit the opportunities to modify patterns of energy use afforded by the increased flow of information between consumers and utilities made possible by remote meter systems, and

- Experiments of cooperative efforts by dissimilar utilities to form consortia to install automatic meter-reading systems.

Section 4: Telecommunications in the Bulk Power Market

Two types of transactions characterize the wholesale or bulk power market: sales for resale and power exchanges. Large electric systems that sell power at wholesale to small distribution systems for resale is the typical sale for resale. Power exchanges are typically between large utility systems that buy and sell generating capacity on a short, intermediate, or long-term basis.

Most of the bulk power transactions are effected through pooling and interconnecting arrangements that link large, privately owned electric companies in a particular region--arrangements that vary from loose coordination to tightly integrated pools with centralized load dispatch.

The more tightly integrated pools make extensive use of communications in administration and management. Telecommunications is used to monitor reliability and emergency conditions, for scheduling, protective relaying, and automatic operations. Dial telephone, leased circuits, private microwave, and two-way radio are employed for voice, high- and low-speed data, facsimile and video transmissions.8/

In the 1960's and early 1970's, the growth of the bulk power market exceeded the rate of growth of retail power sales.9/ This rate of growth reflected the substantial gains to be made by bulk transactions in reducing reserve requirements, permitting the sale of excess capacity from new generating units, and balancing diverse regional loads.

A major unresolved issue is whether the bulk power market has realized its full potential. Critics of expanded government involvement in bulk power planning argue that the gains from matching diverse load characteristics between systems and regions have been attained, and that any residual gains are not sufficient to justify investment in a national power grid (U. S. Congress, Senate, 1976).

Without becoming involved in debate over the extent and nature of federal involvement in the bulk power market, a number of factors suggest that significant gains remain to be realized.

First, reserve margins of generating capacity vary significantly between different electric utilities. There may be excess capacity that could be exchanged in the bulk power market.

Second, gains from balancing regional load diversities are largely a function of the speed and accuracy with which such diversities can be measured. Greater diversity may exist than is now measured.

Third, power transmission losses are inversely related to voltage. Unit costs over distance could fall with higher voltages, thereby encouraging the bulk market to expand.

Any significant expansion of the bulk power market will depend on the ability of buyers and sellers in that market to quantify the scope and magnitude of these potential benefits. Estimates of the public benefits and costs associated with expanding the market depend on the same type of information. Improved gathering and distribution of information may well be the key to further growth of the bulk power market.

Responsibility for gathering information and data pertaining to the bulk power market is fragmented. The Federal Power Commission has general responsibility for fixing interstate electric power rates. Accordingly, the Commission collects a great deal of information pertinent to rate-base regulation, sales, and various types of transactions, but the data are neither complete nor organized for ready use by prospective participants in the bulk power market. It is reasonable to assume that power pools and individual electric utilities also collect a great deal of data useful for the bulk power market. Such information is usually considered proprietary and is not often made accessible to the general public. Further, the interests of the power pool and the individual firm usually extend only to the immediate or adjacent service area, which is not a sufficiently broad frame of reference for analysis of the emergent bulk power market. The nine regional electric reliability councils and the National Reliability Council also collect data. These are voluntary organizations, formed at the instigation of the FPC, and the membership does not necessarily represent all the interests with a stake in the bulk power market. In addition, the Nuclear Regulatory Commission, the Federal Energy Administration, and the Department of Energy have a partial involvement in power generation and transmission matters, but their concerns are selective and often fragmentary. The state commissions exercise some form of authority over the electric utilities within their jurisdictions, but transactions in the bulk power market tend to cross state borders.

The future development of the bulk power market will depend upon the perception by utility companies of benefits to be derived from power exchanges on a regional and interregional basis. A broadened, readily accessible information-data base would help buyers and sellers in this market make effective decisions. Telecommunications could help make ample information available instantaneously. The lack of clear responsibility in any single organization or agency of government for collecting and disseminating such information will impede efforts to create the information data base.

Section 5 Conclusions and Recommendations

Telecommunications can improve the basis for real-time decision making by both buyers and sellers in the retail and bulk power markets. To the extent that communications enhances the effectiveness of decisions in these markets, improved conservation of energy is likely to follow.

In retail markets, communications holds the promise of providing immediate and accurate information on the price of electricity during peak, shoulder peak, and off-peak periods to all classes of consumers. For electric utilities, such information could establish the basis for integrating demand patterns and attendant cost-of-service characteristics. For regulators, more precise information would be useful in evaluating rate structures and the adequacy of existing services.

In bulk power markets, communications offers rapid exchange of much more information between buyers and sellers on the benefits and costs of power transactions between regions, systems, and firms. Although the transactions are complex, ranging from short-term 24-hour sales of emergency and economy power to 3-4 year sales of unit power, the communications engineering involved is not a significant technological barrier. The barriers appear to be organizational, political, and institutional.

All phases of the electric utility industry are under considerable pressure to come to grips with inflation, environmental constraints, and the energy shortage, and may be unable to give full consideration to all the options for improving load management. Perceptions of the bulk power market are too often circumscribed by the normal utility boundaries and political jurisdictions. Although it is unlikely that examination of telecommunications opportunities will be undertaken before the results of the current series of pilot studies and experimental rates are evaluated, a thorough assessment at that time might point toward the greater use of telecommunications.

To determine more precisely the potential contribution of telecommunications to energy conservation and management, we recommend that the Department of Energy:

1) Evaluate consumer response to time-variable, demand-dependent peak pricing periods made possible by remote meter-reading systems. FEA pilot studies will provide some insight into the elements of demand

elasticity, but neither these nor the EPRI-EEI studies will produce data needed to judge consumer response to much more flexible definitions of peak and off-peak periods and the use of floating peaks.

2) Analyze the effect on utility operating practices of more effective communications between consumers and electric utilities. Studies of consumer reaction as recommended above should be matched by an equally extensive inquiry into the results of refined peak-load pricing and metering, including two-way communications on the operating practices and planning capabilities of the utilities, giving special attention to the benefits for management from forecasting loads, scheduling the maintenance of generating equipment, and planning new investments.

3) Investigate the role of telecommunications in establishing marketing mechanisms to bring together buyers and sellers in a bulk power market. Because a bulk power market may be viewed as a form of commodity market in which power is bought and sold between electric utilities for varying time periods, it is important to determine how telecommunications can bring together these buyers and sellers, reflect all demand and supply characteristics, assess transmission capacity instantaneously, monitor and record all transactions, and facilitate a system of controls to bring all interconnected systems into parallel operation.

4) Determine what can be done to increase the substitution of telecommunications for travel. To make realistic estimates about how much more substitution is possible, concrete empirical information is needed on the substitutability of telecommunications for travel.

5) Determine which industries and which jobs can best be adapted to neighborhood work centers. There is no significant experience with this concept, nor have the more suitable industries been identified. More information is needed on the economic and social effects of work decentralization.

6) Determine the feasibility of cooperation among dissimilar utilities to implement remote meter-reading systems. Utilities cooperate in a number of areas--in the multi-utility use of poles for example, and rights-of-way, but a number of factors may impede cooperative efforts for automatic meter reading, such as jurisdictional mismatches and different billing periods.

APPENDIX A

Estimates of the Substitutability of Telecommunications for Travel

Intra-urban Transportation

A study by the National Academy of Engineering (1969) reviewed by Polishuk (1975) and Friedman (1977) indicates a total of 85 percent of urban travel is for the purpose of exchange of ideas or information, and is therefore susceptible to substitution by telecommunications. However, this figure includes recreation, social visits, etc., for which telecommunications is a limited substitute. When this is accounted for, the potential for substitution is given as 15 percent. In 1974, this would have represented 7 percent of total daily petroleum consumption.

Nilles et al. (1976) estimate that even a 1 percent replacement of urban commuting would yield annual savings of more than 5 million barrels of gasoline.

Harkness et al. (1976) offer estimates of energy savings on the basis of alternative scenarios. By 1985, a 20 percent substitution of telecommunications for business auto travel (presumed to be partly intra-urban) would save about 110,000 barrels of petroleum a day. Commuting to and from work accounts for more than one third of all travel by automobile in the United States. The development of neighborhood work centers to reduce commuting would yield savings of more than four and one-half times this amount. Work at home would save six times as much.

Intercity Transportation

Harkness et al. (1976) estimate that substituting telecommunications for 20 percent of business travel by air (about 50 percent of all intercity air travel) could reduce daily petroleum consumption in the United States by about 80,000 barrels per day by 1985--about 0.3 percent of total consumption, assuming flights were reduced proportionately. As noted above, a 20 percent substitution for business travel by automobile would yield savings of 110,000 barrels--0.5 percent of total consumption. Tyler et al. (1976) and Katsoulis (1976) estimate comparable savings for the United Kingdom and Canada, respectively.

With respect to substitutibility, surveys of business in the United Kingdom indicate that 45 percent of business meetings might be replaced by teleconferences using audio facilities alone, and 53 percent might be replaced if video facilities were added (Tyler et al., 1976). A similar survey of civil servants indicates that roughly two-thirds of their face-to-face meetings could have been transferred to telecommunications, and that narrowband telecommunications would be satisfactory for 43 percent, with 23 percent requiring broadband capability (Communications Study Group, 1975).

A survey in Canada indicates that approximately 20 percent of business travelers would have been willing to substitute telecommunications for their trips (Kollen and Garwood, 1975).

APPENDIX B

Experimental or Prototype Systems for the Substitution of Telecommunications for Travel

Polishuk (1975) reviews several prototypes or experiments involving travel substitution:

1) The NASA-Apollo Teleconferencing System has been in operation since 1968. NASA estimates average annual travel expenses have been cut nearly in half through teleconferencing--from $2.52 million before 1968 to $1.38 million since.

2) GSA Teleconferencing Service is a nationwide system of eleven interlinked conference centers equipped with teleconferencing facilities for use by federal government employees.

3) Metropolitan Regional Council Television System is an audio-video teleconferencing network linking state and local governments in New York, New Jersey, and Connecticut. It is apparently in an early stage of development. Polishuk reports that the costs compare favorably to those for travel.

4) Bell Labs Video Conferencing System links two Bell facilities in New Jersey (about 35 miles apart).

5) Institute for the Future FORUM System is a commercially available computer conferencing system. The Aspen Institute is one of a variety of organizations using or experimenting with the system.

6) Telemedicine systems have been established in various locations to link hospitals with peripheral health care sites.

7) Educational telecommunications link campuses in several states.

8) New York-Boston Banking Video Teleconferencing System is an audio-visual system connecting two banks in New York and one in Boston. (From Polishuk's description it appears that each bank has its own system, used for internal purposes, to facilitate emergency communications. It does not appear to be used as a substitute for travel.)

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Notes

1/ For an interesting discussion of the different approaches, see B. Commoner, The Poverty of Power, New York: Alfred A. Knopf, Inc., 1976.

2/ Recent telecommunications developments in mobile radio may lead to a net increase in transportation and the energy it consumes, even though these developments might increase the efficiency of transportation as well.

3/ Appendix B summarizes some limited experiments with systems that substitute telecommunications for inter-city travel.

4/ "Induced" is used advisedly. We are presumably interested in additional inducements for substitution beyond those inherent in market economics; however, one inducement might simply be better dissemination of information about the economic advantages of substitution.

5/ Some proposals have been made for experiments in which individuals would be directed to use telecommunications in lieu of travel wherever feasible. Such directives invalidate one of the principal objects of the study--to learn more about the factors governing voluntary substitution under different circumstances. We do not need a special study to test whether people will follow orders.

6/ EPRI/DOE feasibility tests of bi-directional communications are currently being carried out with San Diego Gas and Electric, Omaha Public Power District, Detroit Edison, Carolina Power and Light and Long Island Lighting.

7/ Efforts to further refine the peak period, such as those set forth by the New York Public Service Commission, do not seem to constitute a significant improvement in expanding the range of consumer choice. For example, the New York Public Service Commission used the following rating periods in Case 26887--Long Island Lighting Co.--Electric Rates--SCZ-MRP, Opinion No. 76-26. Issued: Dec. 16, 1976, p.7:

Peak: 10:00 a.m.-10:00 p.m.: June - Sept.; except Sundays.
Intermediate: 10:00 a.m.-10:00 p.m.: Jan. - May, and Oct. - Dec.;
7:00 a.m.-10:00 a.m.: All Months;
10:00 p.m.- Midnight : All Months.
Off Peak: Midnight - 7:00 a.m.: All Months.

8/ Information on the use of communications by Potomac Electric Power Co., as part of its participation in the highly integrated PJM pool, was supplied by staff members at PEPCO's Consolidated Control Center.

9/ Between 1963 and 1973, retail sales (i.e., sales to ultimate consumers) of privately owned electrics increased by 113 percent while bulk power sales increased by 223 percent. See: W. W. Lindsay, "Pricing Intersystem Power Transfers in the United States," *New Dimensions in Public Utility Pricing*, edited by H. M. Trebing, East Lansing: Michigan State University Bureau of Business, 1976, p.498.

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