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ABSTRACT

In a workshop held by the National Research Council through their Board on Telecommunications and Computer Applications, the participants determined that the earlier vision of affordable telephone service for all, already fundamentally achieved in the United States, can be extended to a new national policy of affordable information for all. This new policy can be achieved through networking the systems of business, education, and knowledge. The anticipated benefits of an information communications infrastructure linking people with information, services, and knowledge in any place at any time are enormous as are the challenges of developing and managing such a system. The authors of these papers discuss the benefits, disadvantages, and issues of this topic. Following the "Foreword" (Roy Merrills) and "Introduction" (Oscar H. Gandy, Jr.), the following papers are included: "What the Coming Telecommunications Infrastructure Could Mean to Our Family" (Francis D. Fisher); "Investing in the Telecommunications Infrastructure: Economics and Policy Considerations" (Bruce L. Egan and Steven S. Wildman); "Telecommunications Infrastructure and U.S. International Competitiveness" (Jonathan Aronson); "Educational Telecommunications Infrastructure: Ferment, Flux, and Fragmentation" (Donald J. Stedman and Louis A. Bransford); "Realizing the Business Value of National Communications Infrastructure" (Robert J. Benson); and "Telecommunications Technology and Infrastructure" (Marvin A. Sirbu). (JLB)

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A NATIONAL INFORMATION NETWORK

Changing Our Lives in the 21st Century

1992

Annual Review of the
Institute for Information Studies

A Joint Program of Northern Telecom Inc.
and The Aspen Institute

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The Institute for Information Studies was established in 1987 by Northern Telecom in association with The Aspen Institute, a prestigious international center for the study of the humanities and public policy alternatives. IIS programs recognize the increasingly significant role and responsibility of senior executives in leveraging the information assets, as well as formulating the strategic direction of the enterprise. Through discussions and workshops on vision and change within an organization, the program focuses on the importance of information communication in business, and addresses the impact of business principles on the individual, community, and society.

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FOREWORD

In the book *2020 Vision*, Stan Davis and Bill Davidson state that "Infrastructures in any economy are the elementary networks that are put in first, and upon which all subsequent economic activity depend." Examples are often given of power and transportation infrastructures built to support the industrial economy that grew so rapidly in the 20th century. As we prepare for the 21st century and the rapid growth and maturing of the information economy in which we find ourselves, what about the "information infrastructure"?

In a workshop held by the National Research Council through their Board on Telecommunications and Computer Applications, the participants determined that the earlier vision of affordable telephone service for all, already fundamentally achieved in the United States, can be extended to a new national policy of "affordable information for all." This new policy can be achieved through networking our systems of business, education, and knowledge. They believe that "a strong information infrastructure within the United States is absolutely essential to our continued success as an advanced industrialized nation," and to attain it, "a compelling vision of what we want to achieve, embracing all aspects of computers and communication, is sorely needed."

It seems to be a simple rally cry—the need for a National Information Communications Infrastructure—with which everyone can agree. The benefits described by the proponents are broad and desirable. Availability of an enhanced information infrastructure could help address the education and health care crises. It could simplify access to global networks and open the worldwide marketplace. American businesses of any size could be in a position to compete in any market through the strategic use of information and knowledge made available via the networks. The impact of easily accessible advanced information services through an enhanced information infrastructure would undoubtedly reach people on a personal individual basis, on a community basis, and on a professional, global business basis.

Of course, goals of this magnitude are never easily attained. There are many questions that must be thought through at varying levels of detail. One of the overall challenges is raised by the participants in the National Research Council's workshop: "A high-level architecture and system plan for achieving a unifying vision is absolutely essential, and there is no entity or process in place for its development." Developing such a system plan is no simple task. What technologies should be incorporated in an infrastructure? Who will implement it? Who will manage its complexities? Who will pay for it? It will certainly benefit all who access information throughout the world. Shall other countries assist in its funding? How?

Defining the specifications of a national information infrastructure is tremendously challenging. Can there be an overall universal governance of such a network; or indeed, does each state have unique requirements in serving its own populace in urban and rural communities? Developers of infrastructure must perhaps "think nationally and act locally" since many health care and education issues define local needs. Does one attempt to define applications first and meet those requirements; or can an infrastructure be built flexible enough to evolve to meet the requirements of applications yet unknown? Will the population shifting away from the urban metropolis follow the path of the infrastructure and move to where the capabilities are available; or will the population moving out create the demand randomly for a national information infrastructure?

The anticipated benefits of an information communications infrastructure linking people with information, services, and knowledge in any place at any time are enormous. The challenges of developing and managing such an infrastructure are equally huge. The knowledgeable, thoughtful authors who have contributed to this volume discuss the many benefits, potential disadvantages and issues in a provocative way. Questions are raised and opinions offered in order to inspire insightful consideration regarding one of the major challenges facing all of us as leaders in our communities and in our country, as we progress through this information economy.

The Institute for Information Studies is pleased to sponsor the research presented here. The goal of the Institute—a combined effort of Northern Telecom Inc. and The Aspen Institute—has never been to offer pat solutions. Rather it is to explore the larger all-encompassing issues that face people, in all aspects of their lives, as new technologies are discovered with their applications and their implications in this Information Age. A key benefit of the Information Age is that it gives rise to a new type of transaction as the scholar Harlan Cleveland has said: a sharing transaction. Information given is shared, not lost. This volume strives to share information so that others may develop knowledge.

Roy Merrills
President
Northern Telecom Inc.

INTRODUCTION

INFRASTRUCTURE: A CHAOTIC DISTURBANCE IN THE POLICY DISCOURSE

Infrastructure Defined

When I was invited to develop an introduction to this volume, it was suggested that I make it clear that there was no universally accepted definition of a "national telecommunications infrastructure." Thus, part of the contribution of this volume and my introduction to it might be the sharpening of the debate surrounding the meaning of the term. This sharpening might be accomplished paradoxically, by actually expanding the scope of the definitions already in common use. As you will see, in my frequently perverse way, I have not only expanded the definition, but I have raised questions about the processes through which such a term actually comes into use, and rises to prominence within the policy sphere.

The U.S. Office of Technology Assessment (OTA) is explicit and fairly consistent in its definition of what it means by the communications infrastructure. "The communications infrastructure is the underlying structure of technical facilities and institutional arrangements that supports communication via telecommunication, broadcasting, film, audio, and video recording, cable, print and mail."[1] In a later publication, OTA locates this infrastructure within the social system rather than in some concrete physical space. Its identification within this conceptual space is one which emphasizes its critical nature and vital importance. "The communications infrastructure is both nested in and sustains the larger social system of which it is a part. For communication is the basis for all human interaction and one of the means of establishing and organizing society. Communication is the process by which all social activity is conducted; without it a society could not survive."[2] By implication, flaws in the infrastructure must be reflected in flaws and failings in the social system.

A somewhat more expansive definition, and one that is reflected in this volume in the definition proffered by Bruce Egan and Steven Wildman, casts a net wide enough to include not only technical facilities, but also "the collection of people and skills required to utilize them." From their perspective, infrastructure means not only the tangible capital assets, but the human capital necessary to realize the potential of any technical system. This is a definition which includes users as well as providers of telecommunications services, and helps to draw our attention to those aspects of an information system which may serve to reduce or exacerbate distributional inequalities.

What is missing in most of the available definitions is an explicit recognition of the critical importance of the moral and ethical aspects of supply and demand where standards of appropriateness include more than assessments of technical efficiency and competitive advantage, but also include the deontological notions of right and wrong.[3] While Marxist scholars may still debate over the relative autonomy of the economic base and the superstructure,[4] the general consensus within this camp and in the emerging school of socioeconomics is that the realm of values and ideals plays a powerful role in determining the uses to which any technological resource may be put.[5] This influence is felt not only through the more formal influence of laws and regulations, but more diffusely in the day-to-day decisions of producers and consumers who consider what is right and just as well as what is instrumentally beneficial.

For example, we may see that the skips and starts that have characterized the introduction and deployment of calling number identification services (Caller-ID) can be understood to have been caused by widespread uncertainty about the rights and responsibilities of calling and called parties in comparison with those of the service providers and others who might utilize the data generated by the use of the service. Continuing debates about competing claims regarding this and other telephone transaction-generated information (TTGI),[6] and even concerns about the threats to civil liberties inherent in the development of an information environment referred to as cyberspace,[7] will be reflected in routine practice as well as regulatory constraints. Problems regarding security and the protection of strategic information, as well as the control over access to and use of intellectual property, are not only problems of encryption, authentication, and audit trails, but they are also problems of continually evolving notions about whether information is a resource, a public good, a joint product of a communicative interaction, or private property available for sale in markets.[8]

Because these notions of appropriateness are so inextricably linked to the development and use of information technologies, it seems only logical that they be included in our expanded definition of infrastructure. Thus if we must have a working definition of infrastructure, then it should be a definition that identifies three critical components or spheres, and the uncertain and evolving relations between them. The three spheres are the technical, the economic, and the cultural.[9] The technical includes the hardware, the software, and the current state and distribution of technical knowledge which governs their efficient use. The technical would also include the organizational forms and managerial practices which make the realization of technical efficiencies possible.

The second sphere, which we refer to as the economic, includes the market, its structure, and the conduct of key players within these markets. The market is both status and relations. As is becoming increasingly clear, the specification of the boundaries of the relevant market, even the markets for telecommunications equipment, facilities, and services, is a problem of some substance. Identifying key players in these markets, both suppliers and consumers, in terms of their relative power, is a necessary aspect of its specification.

The third sphere includes the values and expectations which govern the acquisition and use of technical resources both within and outside of formal markets. Although we have traditionally focused on the formal expression of those values as reflected in laws, in the interpretation of those laws through judicial reasoning, and in the threats and sanctions of regulatory authorities, I suggest that it is also necessary for us to include the normative thinking of individuals reflected in day-to-day practice and expressed through public opinion and political action.

The relations between these three spheres are multileveled, multidirectional, contradictory, and difficult to describe independently of the competing theories which make claims about their importance, and the means of their exact measurement. It is clear that changes in technology disturb markets and challenge relations of power at the same time that changes in cultural norms widen the limits of reasonableness in our expectations about what can and should be accomplished through technical means. Critical theory identifies these relations as being involved in a process of overdetermination.

This expanded notion of infrastructure describes a reality which is incredibly complex and dynamic. By defining it in this way, we are not suggesting that one should, even if one could, attempt to capture all of this complexity in a single glance. Indeed, I take from Steven Resnick and Richard Wolff the notion of an analytical entry point, a purposefully selected beginning from which to begin the process of elaboration.[10] Before describing the entry points taken by the authors of the chapters in this volume, I thought I would explore further the introduction of the term *infrastructure* into the contemporary discourse because such an understanding may help us understand the similarities and differences in the entry points which have been chosen.

Infrastructure as a Policy Focus

Back in 1978, in an Aspen Institute publication concerned with exploring a communications policy for the 1980s, Marc Porat provided an introductory article that focused on the policy process itself.[11] In seeking to bring order to the somewhat chaotic posturing which characterized policy-making in the late seventies, Porat suggested that there was theoretical uncertainty about precisely how policies actually came to be. His notion of a technological determinism which involved the complex interaction of influences from technology, markets, institutions, formal policies, laws, and public opinion is still to be found in more recent formulations of the same question by Roger Noll.[12] Porat suggested that the Hegelian model neglected the causal force of ideology that can operate at each of the levels and interactions that the technological determinist model specifies. It is clear that these influences are still very much at play in our efforts to develop a policy regarding the telecommunications infrastructure, including decisions about just what the term will come to define. The term was not used in 1978 in the Aspen volume, even though telecommunications facilities, services, and regulatory intervention were among the critical concerns of the authors invited to contribute. It was more important to promote the notion of an information economy, and the need to establish and coordinate a domestic information policy so as to insure that the potentials implied in such a macroeconomic transformation were not squandered. Because the policy process rather than any particular policy, was the focus of that report, we can understand how other readily available metaphors were ignored, only to be picked up again at a later date.

Although the term was not used in Ralph Smith's earlier appeal for public investment in the development of cable television,[13] the metaphoric similarity between the "electronic communications highway" which Smith did refer to and the highway-like infrastructure that is prominent in most framings of the contemporary discourse about telecommunications systems is hard to ignore. Smith was explicit: "In the 1960s, the nation provided large federal subsidies for a new interstate highway system to facilitate and modernize the flow of automotive traffic in the United States. In the 1970s it should make a similar national commitment for an electronic highway system to facilitate the exchange of information and ideas."[14] Smith's notion of the wired city was the indexical term which linked dozens of demonstration projects exploring advanced telecommunications in 1984.[15] A focus on cities and the "new urban infrastructure" is also common to recent policy discussions following divestiture and the shift of regulatory emphasis from the federal to the state and local levels.[16]

Even though its focus was on the constraints on the development of telecommunications systems and services represented by government regulation and monopoly supply, scholars and policy analysts brought together at the behest of the U.S. National Science Foundation (NSF) in 1984 had not yet come upon infrastructure as the code word which would carry the debate forward.[17] Eli Noam, a participant in that conference, would later expand his comments to underscore the differences between monopoly and competitive perspectives which were shifting in response to a complex of centripetal and centrifugal forces, but his references at this time were to the network rather than to the expanded notion of infrastructure. Indeed, Noam explicitly rejected the label of "infrastructure service" for telecommunications because in his view "telecommunications, unlike a lighthouse or a road, is not a public good in the classic sense: users can be excluded and charges can be assessed, breaching the major condition for a public good."[18] This is a point to which we will return.

The use of infrastructure as the term to describe the social and technological system through which information flows has come into its own rather recently, and it seems to have emerged through a process that several critical observers have identified as self-serving and instrumental.[19] Its use is not unlike the reification of the telecommunications network by AT&T in its efforts to fend off competitive entry by limiting foreign attachments, or barring other activities which might conceivably "damage the network."[20]

This form of strategic public relations is not limited to the behavior of single firms, but may be used cooperatively by an entire industry in seeking to establish or maintain privilege in markets. In describing the earlier emergence of the notion of an information society into the public discourse, Jerry Salvaggio has argued that it is in the interests of the information industry as a whole to promote a positive impression of the benefits that can come with the arrival of the information society. And by extension, a favorable impression of possible futures might also justify the redirection of public and private resources so as to insure that the arrival of this age is swift and unproblematic.[21] Although Salvaggio was writing before infrastructure became the term of choice, he also noted the strategic employment of the concepts of network and networking through advertising and public relations campaigns which featured the terms prominently. "This technique suggests that the major industries are already interconnected into vast global networks which are crucial for communications and for accessing up-to-date information. If the consumer is convinced that other firms are part of information networks they will logically not want to be left out."[22]

He further describes cycles of promotion, which move through public relations, indirectly stimulating writing in science fiction which is frequently coincident with the popularization of science through futurist writing. All of this activity is seen to contribute to the creation of a comforting vision of information technology and its promise. In Salvaggio's view "the information industry is investing billions of dollars into manufacturing an image as a guarantee that the information age is not a futuristic illusion."[23] Current examples of this process still in play can be seen in the popularity of William Gibson's notion of cyberspace[24] and the associated concepts of virtual reality which have a basis in science fiction, funded research and development, and are also featured prominently in public policy debates about the problems we might face in realizing its potential.[25]

The emergence of infrastructure into the policy discourse may be seen as serving a similar purpose for the telecommunications firms that would benefit from direct public investment, from expanded demand through the provision of subsidies or tax credits to identifiable user communities, or for specified uses such as education and health care delivery.[26] By underscoring the importance of the infrastructure to economic development akin to that realized in response to the nation's investment in transportation, the telecommunications industry can push home claims for regulatory relief and entry into markets from which they had previously been barred, or in which they have been competitively hobbled by unenforceable but troublesome separations and economically perverse regulation of rates, depreciation allowances, and returns on investment. User communities that might benefit from an increased supply of attention and resources can be seen to have similar incentives for joining in the call for improvements in the infrastructure at the same time that they push for an expansion of its definition to include their specific needs and concerns.

Amitai Etzioni suggests that such efforts to realize market power through investment in policy formation is unquestionably rational. In his view, "the government provides a commonly used and highly effective way of capturing and holding on to market shares, of curbing the entry of competitors, and as an avenue for collusion to make some economic actors powerful."[27] His discussion of interventionist power underscores the kinds of resources that firms command "as a group" in comparison with other policy actors. Indeed, he suggests that the development and use of interventionist power is quite efficient. "The costs of lobbying and organizing a PAC for a politically active corporation are much lower than the costs of R&D advertising campaigns or other economic means that may be used to attain comparable purposes, and often seem to be highly effective in comparison."[28]

The use of strategic public relations to establish a government/corporate partnership has been explored in some detail by Marvin Olasky.[29] Olasky provides examples of corporate engagement of a public interest rationale first in railroads, then in the public utilities sector in support of the development of Edison Electric, and later in the telephone industry, where Theodore Vail is said to have actively invited regulation in order to realize effective government protection from AT&T's competitors. He describes Vail's use of a Salem, Oregon, public relations firm to send out some 13,000 newspaper articles each year which were supportive of AT&T, but without any attribution as to their origins. This blurring of the distinction between the public good and the bottom line by means of strategic public relations is also discussed by Sar Levitan and Martha Cooper,[30] and the role of policy centers like Aspen, Annenberg, and the American Enterprise Institute is explored in some detail in a classic exposition by G. William Domhoff.[31] All these efforts have been directed toward promoting the impression of a pressing need matched by the identification of an achievable and preferred solution.

However, as is noted by several of the authors invited to contribute to this volume, providing empirical evidence to support many of the claims for the benefits of information technology is an exceptionally difficult task that never seems to end.

Industrial Policy. We might usefully see this discussion of the problem of the telecommunications infrastructure as just the current phase of a cyclical debate about industrial policy. This debate was recently heated almost to the boiling point around the formation of policy regarding high definition television (HDTV).[32] The identification of HDTV as a strategic (or critical) technology was made, despite the ideological contradictions it represents, because of its presumed importance to the domestic consumer electronics industry and those American companies involved in the upstream supply of semiconductors and visual image displays. There were similar expectations about the benefits to be realized downstream through the realization of production efficiencies that would be made possible following the spread of knowledge and skill derived from R&D on this consumer technology. Questions about whether HDTV is in fact a strategic industry and whether or not the beneficial externalities or spillovers will actually be realized in ways that benefit domestic firms (and domestic labor) have yet to be answered.

Although the current debate about industrial policy is particularly rancorous and politicized in the context of a long and somewhat unique recession, we should note that this debate is really not new. Discussions about the free trade regime and the uncertain future of the current

Uruguay Round of the General Agreement on Tariffs and Trade (GATT) have been marked by claims that the United States has always had an industrial policy that paid critical dividends in the form of global leadership in communications and information technology, but it was a policy that in the past went by the name of national defense, and the scientific exploration of space.[33]

There is considerable theoretical interest in describing the factors which are involved in determining when and in what ways particular technical systems emerge as the primary focus of national policy debates. Carlota Perez is credited with offering the notion of "harmonic complementarity" as a way of describing the necessary but unpredictable confluence, or interactive enhancement, that developments in the technical and economic sphere in combination with developments in the socio-institutional sphere bring to the forefront of any policy debate. This harmonic complementarity is seen to generate a particular focus at critical moments in what we understand as the business cycle.[34] Perez is one among several authors who have returned to an earlier emphasis on Kondratieff long-wave cycles. These cycles with a common period of 57 years are characterized by particular swarms of innovation[35] which mark contractions and expansions in domestic as well as global economic systems. Some observers suggest that economic downswings are characterized by swarms of process innovations, while the expansionary upswings are marked by swarms of new products. Description is not explanation, however, and long-wave theory has not advanced very far beyond some compelling representations of patterns in what otherwise might seem to be chaos. What is important, however, is that this notion of complementarity leads us to question the possibility of planning a national telecommunications infrastructure by forcing us to consider whether the coordination of such complexity has ever in fact been possible.

For example, James Beniger's periodization of the spread of innovation through what he refers to as "the control revolution" describes a complex dialectic of crisis and response which has been anything but planned, orderly, or painless.[36] Instead, we have seen the introduction of control innovations in manufacturing lead to constraints and bottlenecks in distribution which were overcome through innovations that now seem obvious and commonsense, but which at the time they were introduced heightened an underconsumption crisis that innovations in marketing are just now beginning to bring under control.

Thus, it is possible to see the development of a global telecommunications network, enhanced by the distance insensitivity of satellite links, as being complementary to the development of the transnational corporation as a dominant institutional form. We are familiar with the example of global corporations like Ford, GM, and Benetton, which are noteworthy because of their ability to take advantage of pecuniary as well as technical economies of scale and scope through the facility of the global network.[37] At the same time, we can also see another complementary relationship in the ascendancy of a post-Keynesian philosophy of governance epitomized in the administrations of Ronald Reagan and Margaret Thatcher.[38] The twin markers of this ideological shift that we find in the accelerated deregulation and privatization of telecommunications and other services marked by their ascriptive commonality as public goods are readily linked to the demands of these transnational firms for lowered costs and greater certainty about access and favorable terms of trade. While we can recognize the goodness of fit, it is surely not one of design, but one of coincidence and compatibility.

It should also be clear that the ideological debate is far from settled. Not only has untempered faith in the ideal but absent competitive market been challenged in the debate about HDTV and the place of industrial policy in the maintenance of U.S. global competitiveness, but a similarly structured debate about free trade and protectionism continues to simmer, even though a North American Free Trade Agreement (NAFTA) now wears the initials of state The future is uncertain, and uncertainty implies risk as well as opportunity.

History Has a Way of Fooling Us

Perhaps our hesitancy with regard to formal adoption of infrastructural development as an element of forthright industrial policy is based upon a late arriving but nevertheless quite salient concern that government intervention in the sphere of economics is ill-advised because of the impossibility of predicting the long-term consequences that present decisions establish for future deciders. In my own work, I have been struck repeatedly by the recognition that an intervention, ostensibly made in the interest of public welfare as conceived at the time, had generated the unanticipated and unwelcome development of an institutionalized constraint which can be seen to limit the realization of that public welfare goal. One example may serve to illustrate this point.

An increasing number of observers of the contemporary scene have come to question the advisability of granting First Amendment rights to corporations. Herbert Schiller, among others, has provided evidence of what he sees as the "corporate takeover of public expression," and suggests that at the very least, because of the vast inequality in resources and capacity, the marketplace of ideas has become distorted by the presence of monopoly power, and the democratic process which depends upon this marketplace for the development of informed public opinion is thereby increasingly placed at risk.[39] Charles Lindblom suggests that the corporate elite, which is able to speak in a very loud voice, drowning out others in critical debates about social problems, frequently speaks as though it were of one mind, and thereby represents a critical site of impairment in the process of making sense of social problems.[40]

It is the long chain of events which surrounds the evolutionary definition and eventual objectification of the "corporate person" as an entity with rights akin to those of natural persons and mature citizens, that forces us to go back to that moment in history when public policy assigned limited privileges to a convenient fiction ostensibly in the public interest.

It was in the *Santa Clara* case in 1886 that a Supreme Court decision recognized the status of the corporation as having the same meaning as that which *person* held under the Fourteenth Amendment guarantee of equal protection. Analyses by David Martin and Morton Horwitz[41] underscore the irony in the fact that this amendment was originally introduced to meet the constitutional needs of recently freed slaves. Herbert Kovenkamp's economic history of the relationship between business enterprise and the law moves our focus to a still earlier expression of constitutional influence on the realization of the public interest in the evolution of the "public purpose doctrine." This doctrine suggested that state subsidies of private activity should not be for private gain, but rather for the general public interest or welfare. This doctrine served to widen an existing gap in the relative favor with which the state treated utilities or public service corporations and a very different status reserved for general corporations.[42] Mark Tushnet suggests that "for many years, concern that corporate privilege be received only when public benefit would result led to stringent legislative control over the creation of corporations: special acts of the legislature were required to create each corporation."[43] The public service corporations were more clearly formed to serve an identifiable public purpose, and had been thereby differentially privileged until the *Santa Clara* decision, which, curiously enough, was concerned with the rights of a common carrier, the Southern Pacific Railroad. Thus, it may be argued that through a chain of connected events, which necessarily involved knowledgeable actors pushing and pulling on the legal system in pursuit of their own ends, the creation of a convenient fiction in the public interest has been transformed into a threat to participatory democracy. Is there a lesson here?

Decisions to invest in telecommunications infrastructure, perhaps involving the creation of a privileged monopoly by means of special exceptions established for the public purpose, may be seen by historians in the future as marking a critical event that led to either an uncharacteristically rapid expansion of individual freedoms and capacitation through the enhancement of access to information, or the beginning of a downward spiral toward the panoptic dystopia of constant surveillance and manufactured public opinion.[44]

The papers included in this volume are not meant to predict the future. Their only purpose is to stimulate our thinking about the decisions which are being made that will undoubtedly affect the reality and the construct we refer to as the national telecommunications infrastructure. As I have suggested, each chapter reflects a different entry point into the complexity which is before us. Each makes an important contribution to our own individual understanding of the issues we have to confront.

Getting Down to the Nuts, Bolts, Chips, and Fibers

Marvin Sirbu provides us with a quite manageable introduction to the technical aspects of our expanded definition of infrastructure. Sirbu's introduction places the debates about technological choice, investment, and transformative capacity in the context of an ongoing political struggle over who should bear economic and administrative responsibility for maintaining and improving services in the local loop.

By focusing on that part of the telecommunications system that is closest to the end users either in the local loop, or in the alternatives promised by the emerging competitors, Sirbu helps us to understand a very different economics of service delivery from that which is frequently privileged when talk turns to consideration of the high-capacity "intelligent network." Because investments have been directed toward realizing efficiencies at the level of the source, as in the case of digital signal compression, or at the subscriber's premises as seen in the form of sophisticated interfaces, Sirbu suggests that the inevitability and desirability of making investments in bringing fiber to the home is no longer to be assumed. Similarly, the rapid development of personal communications networks (PCNs) made possible by advances in microcellular digital technology raises questions about the suitability of further investments in a wired network at the same time that it facilitates the competitive supply of telecommunications services by cable and the wireless service providers.[45]

His discussion of emerging switched networks and the services they make possible raises questions about data sharing which are not otherwise addressed by the papers in this volume. As we have noted, calling number identification became controversial during hearings on the authorization of Caller-ID services. Yet, Sirbu suggests that for a PCN system to operate efficiently, information about a user's location would have to be shared among multiple service providers. This requirement raises privacy concerns not unlike those which emerge when users of bulletin boards and electronic information services wish to contribute or receive information anonymously. Questions of access, authentication, and accountability loom large in the emerging telecommunications network environment although they are addressed only indirectly in this chapter.

Sirbu's review of the politics of infrastructural development also suggests that the selection of the term infrastructure, rather than network or some other descriptor, may have been strategic, helping to move public attention away from competition and toward the motherhood and apple pie of universal service. In Sirbu's view, such a posture advantages the monopolists who would argue that economies of scale and scope would apply even to the supply of content, and therefore the socially desirable maximum can only be realized through an integrated broadband network under central administrative control. Several challenges to the familiar assumptions regarding the network economies of scale and scope are presented in unusually clear examples. The notion of contestability which implies that there will always be an incentive for potential competitors to develop technological alternatives is an argument that serves to undercut traditional claims regarding the naturalness or inherent efficiency in unduplicated large-scale supply of telecommunications services. It is an argument that is repeated in several places throughout this volume.

The Economic Basis of Infrastructural Policy

Bruce Egan and Steven Wildman address the tension between efficiency and equity concerns that tends to be ignored by most economists, but that they see as being inescapable aspects of any policy choice. Presented as a struggle between efficiency and fairness, participants in this debate have danced around, jostled, and only occasionally come directly to grips with the place of these two goals in the realization of the imperfectly defined public interest. The difficulties in making claims regarding the complementarity of these twin goals have been complicated by the emergence of a new, long-term strategic perspective on telecommunications planning. In reflecting this new (or at least newly configured) thinking about the connectedness and consequentiality of decisions taken in the realm of infrastructural investment, Egan and Wildman provide a useful catalog of the variety of benefits and enhancements which advanced telecommunications can bring through the facility of a public network.

That aspect of the system which they describe as the "basic service infrastructure" includes government and forms of public administration such as health care, education, and transportation as well as the invisible college of scientists and researchers in business, government, and university research centers. Infrastructural investments in these areas have been made with the expectation that the short-term and long-term rewards at the private as well as the societal levels will be substantial.

Reflecting concerns also addressed by Robert Benson from the perspective of the corporate manager, Egan and Wildman provide a detailed review and assessment of the rather slim evidence we have to date that expectations regarding the contribution of information technology to business productivity have any basis in fact. The analytical difficulty in parceling out the contribution of individual elements of what is essentially a complex information *system* is addressed in some detail in the context of specific decision support and transactions-based systems. Other difficulties they examine include the apparent inapplicability of traditional measures of productivity that have been developed in the manufacturing sector as applied in the services sector, or to the managerial or white-collar laborer. These difficulties are complicated still further as these systems are used to accomplish the delivery of highly varied and specialized goods and services. This specialization ensures that we have outputs that are no longer directly comparable.

In response to the claim that benefits may be more readily identified at the macro-economic level than at the level of a firm, or even at the level of operational units within a firm, they suggest that simple extrapolation is unjustified. While there is little doubt about the existence of the substantial contribution that an infrastructure of transportation made to growth and development of the economic system in the United States, few claim to understand fully how those contributions are actually expressed at the microeconomic level. Egan and Wildman suggest that the same will be true of the contributions of the telecommunications infrastructure. They suggest that recognition of the significant interaction between telecommunications and transportation—an interaction frequently marked by substitution as well as complementary relations—will complicate the analysis still further. They also warn, in ways that many other economists are less willing,[46] that a focus on the readily measurable will lead us to ignore other important benefits, especially those in the realm of social welfare that flow from investments in information technology.

In their discussion of policy options, Egan and Wildman reintroduce the equity/efficiency tensions which we seem so desperate to ignore. A hands-off, demand-driven policy is described as one which is equitable because those who benefit will be expected to pay for it and where the many will not be expected to subsidize the few. A system seen to be equitable in this way is, unfortunately, also seen to be inefficient, because the satisfaction of private information demand will be suboptimal at the level of social welfare.

Government regulation, of the kind we have experienced in the past and have noted in the introductory comments, is seen by Egan and Wildman to have introduced constraints and distortions at the same time that it was proposed as a way to advance the public interest. Their evaluation of numerous experiments and pilot programs administered at the level of states and cities leads them to offer recommendations of particular regulatory adjustments and the provision of marketplace supports which might eventually serve both equity and efficiency interests while also proving to be politically feasible.

International Relations

In addition to providing a further assessment of the general problem planners encounter when faced with rather disappointing gains in productivity in the service sector, despite massive investments in information technology, Jonathan Aronson directs our attention to the issue of global competitiveness and the status of U.S. industry, which may or may not have been hampered by misinvestments in the development of our domestic telecommunications infrastructure. Of some importance in his analysis of the contribution of information technology is the use to which this technology has been put by firms who are active in the international market. His sectoral examples focus on the global firms that utilize telecommunications to facilitate coordination of remote manufacturing, design, and marketing arms of their business. Aronson's chapter thereby adds an additional dimension to our definition of infrastructure, because the market it defines is increasingly global, and thereby including it in our expanded model requires us to consider the variety of political, economic, and ideological regimes which regulate its operation and development.

Comparisons of the U.S. telecommunications infrastructure with that of global competitors inevitably invites claims and counterclaims regarding the extent of the technical and economic success enjoyed by France Telecom, its packet switching services and its Minitel information service. As technological development is never at an end, no race is ever truly over. Thus, while France may be seen to have won early laps, the British move toward wireless systems can be argued to have been the better long-run strategy. The same kind of uncertainty about the end of the race is exemplified by Aronson's assessment of the status of narrowband ISDN (Integrated Services Digital Network). While the United States may have started late, investments in broadband alternatives may actually allow it to leapfrog her European competitors. Thus, as Aronson suggests through his carefully chosen examples, the jury is still out on this question (which, we must remind ourselves, has been undoubtedly asked as a strategic rhetorical move).

With regard to the policy deliberations, Aronson pulls no punches in his identification of the arguments of policy scholars with the economic interests they represent. Aronson's credentials as a political scientist serve him well in his characterization of the interests of the regional Bell operating companies (RBOCs), the equipment manufacturers, the telecommunications visionaries, and the information providers, known more familiarly as cable television, broadcasters, and publishers, and the usually forgotten group of large and small users. Different interests are seen to push and pull on the policy system at the stage of policy implementation as well as in the more visible stage of policy formation through debate and testimony which he characterizes as the "politics of gridlock." Aronson concludes that neither privatization, corporatization, or competition are substitutes for regulation. Concerns with interoperability and interconnection between systems, as well as continuing problems in the efficient setting of standards, lead him to suggest that there is still a need for somebody to "be in charge." In general, his recommendations are for expansion. modernization, the replacement of copper with fiber whenever the option presents itself. Where OTA presented three options for government involvement in infrastructural development: (1) a direct role in development, (2) an indirect role through the provision of incentives, and (3) an even more indirect role through the provision of a regulated environment which is conducive to modernization,[47] Aronson suggests that we should pursue all three.

The Business Decision

Robert Benson's examination of the problems involved in assessing the contribution of information technology to the corporate bottom line provides rare detail and unusual insight. Here we are concerned with specifying the impact or contribution of information technology to the generation of value because we like to believe, even if we are occasionally unsure, that businesses are operated rationally, and that managers seek to maximize owner and stockholder returns on investment. Although there is a familiar and growing literature on the limits of rationality[48] and related challenges to the assumption of profit maximization, we recognize the basis for the concerns expressed by managers who have to justify expenditures for capital resources at a time of tight budgets and heightened competitive pressure.

Benson finds part of the difficulty in specifying the nature and amount of values returned to investment in the fact that the introduction of communications resources actually changes the businesses they are brought into. As a result, Benson argues, "the values of innovations in the more complex environment clearly move beyond the ROI style of thinking." New systems restructure day-to-day operations, as well as the quality of the goods and services an enterprise delivers. Part of the functionality of a telecommunications network includes the facilitation of linkages between units within the organization, and between organizations which must interact. When the costs and the benefits are spread across units, levels, and organizations it becomes difficult to find managers willing to claim all the costs, but only part of the benefits. This is the now familiar problem of the assignment of transaction costs, which is particularly problematic when the goods or services are informational.

It is frequently argued that markets are inefficient when dealing with information goods because producers cannot expect to realize the full value of their investments, nor can they be compelled to pay the full costs of the harms they induce. This results in the overproduction of information goods marked by substantial negative externalities and the underproduction of goods marked by substantial positive externalities. And to the extent that we accept the suggestion by Charles Jonscher[49] that management decisions are generally isolated from the corrective influence of efficient markets, the problems of rationalizing informational investments within the firm are nearly insurmountable.

The problems of measurement which plague the analyses which Egan and Wildman discuss are precisely the same problems of measurement which weigh so heavily on the shoulders of managers unable to quantify the intangible benefits of consumer satisfaction, enhanced quality, and short-term competitive advantage. Benson is clear on this point: "value cannot be unhooked from measurements," but measurements cannot be developed in the absence of theory. And, unfortunately, we have not come very far in developing our understanding of the role of information in organizations.[50] Benson also makes this point rather well in his discussion of the very different character we find in organizations that manufacture tangible products from those that provide services, and from those in the not-for-profit organizations that are not saddled with the responsibility for attracting customers. Each of these organizational types will have different information needs as well as quite different indices of productivity. The problem of comparability expands still further when the products and services provided by these enterprises have a large information component where patents, copyright, trade secrets, or traditional business practices may provide a temporary but unspecifiable competitive advantage.

Benson offers a novel paradigm that suggests an analytical alternative to the traditional focus on formal business hierarchy. By focusing on business processes, or lines of business, even those relationships that cross traditional organizational boundaries, such as the intercorporate links which electronic data interchange (EDI) facilitates between manufacturers, suppliers, and distributors, can be mapped conceptually. Once mapped, Benson suggests that managers can begin the process of identifying measurable targets of influence.

Benson's analysis comes close to suggesting that the problems of measurement which are at the heart of the estimation of business value are almost beyond reach, even though they are *real problems* that won't go away because we ignore them. Although he does not go so far as to suggest it himself, we may find in the search for business value as something other than bottom-line profitability a call for the use of more qualitative and interpretative methods. As long as the manager acts as and is perceived as an honest broker, rather than merely engaging in self-serving public relations, the assessment of business values from the perspective of end users inside and outside the organization can provide decision makers with a finely textured impression of the enterprise as a whole, and telecommunications as a vital structuring[51] resource.

The Knowledge and Information Gap

Francis Fisher reminds us that it is critical that we evaluate the potential of an expanded and improved telecommunications infrastructure in terms of its potential for closing the widening knowledge and information gap which a growing number of observers have attempted to place on the policy agenda.[52] In his chapter, Fisher makes use of a hypothetical family of information users to demonstrate the variety of ways that the right technical and economic decisions can be expected to deliver on the promise of telecommunications. Fisher's prototypical family at risk of the not too distant future is an ethnic minority, educationally disadvantaged, living in public housing, and dependent upon welfare and food stamps to maintain a level of subsistence. This family has come to depend upon what may seem to many of us a rather primitive version of the kind of information utility that futurists have been promising for decades. Fisher makes a critical distinction between the kinds of "choices" which the information consumer makes when selecting from a system operating in an essentially broadcast, though broadband mode, and the kinds of interactive, iterative, and learning-based choices which are possible only in the kinds of switched systems we might commit ourselves as a nation to build.

Fisher's focus on the members of the household and their needs for information services describes a user community that is frequently ignored in debates about the nature of demand for capacity and access that we may come to recognize as the new, improved definition of universal service. His description of the variety of information services, many of which are interactive and diagnostic, argues that the social benefits to be derived from investing in an enhanced public network will be derived from the substantial savings in the delivery of health, education, and employment support services, as well as in the realm of governance through the empowerment of citizens who will become more actively involved in taking charge of their own lives. It is these ancillary social benefits that Fisher suggests we ought to see as justifying the provision of direct and indirect subsidies to users or providers in order to bring both groups into this information market. Through his argument, which is readily seen as advocacy, Fisher joins a good many others who question the ability of the unaided marketplace to supply those goods and services that are characterized by attributes that define them as akin to, if not indistinguishable from, classic public goods, not on the basis of inappropriability, but on the basis of the substantial social welfare benefits which are derived from their use.[53]

Getting to Sesame Street by Another Route

Like Fisher, Donald Stedman and Louis Bransford explore a related set of concerns about public welfare goals, but their focus is on the school rather than the home as the critical node in the telecommunications network. The tone and level of concern about the state of American education that has been expressed in dozens of policy papers and pronouncements has begun to sound almost alarmist, at the same time that the response in terms of actual programs and the allocation of resources has been slow, cautious, and arthritic when it has not been fractious and divisive. It seems that the educational system and its instructional infrastructure remain doggedly "old fashioned" and highly resistant to the kinds of changes that new communications technologies might bring.

Stedman and Bransford find that "fiscal conservatism" is in part responsible for the failure of schools to improve the quality of graduates through the use of instructional technology. They also find a failure of planning in their charge that the choice of technology tends to reflect constraints in the budget more than the goals and mission of the educational system. Although, as we have noted, members of the business community may not always know precisely what they have bought for themselves when they acquire the latest component of their increasingly sophisticated information management system, they have been more than ready to respond to its availability. This readiness of business to explore and experiment with technological innovations may eventually find its way into the educational system through the movement toward greater privatization and commercialization which we note to be approaching on the horizon. Stedman and Bransford explore both the promise as well as the risks that several new experiments in privatization might bring to education.

Just as privatization is a controversial and ideologically tinged subject of debate that has moved from telecommunications services into the educational sphere, we are also warned that the development of an advanced telecommunications infrastructure in education will again raise questions about a national curriculum, common standards, and standardized tests and assessments. Struggles over the values, principles, and social positions that are at the core of these policy debates about methods and means may serve to delay or constrain any forward movement toward the far less controversial goals we share about learning.

In Conclusion

If you have been with me this far, I am sure that you will agree that this notion of a national telecommunications infrastructure remains a construct in development. I have suggested that its expansion must move in three directions, adding the economic and the values dimension to the more traditional emphasis on technology. I have also suggested, and several of the authors echo my view, that we should also attend closely to ways in which a term like *infrastructure* is introduced into the discourse and is further shaped by strategic interests concerned with producing influence over the policy process. In a curious but still provocative analysis of the influence of the visual images of television on the images that individuals may have constructed on their own when reading the same story in a book, Jerry Mander suggests that the visual image is more powerful.[54] The private image, organized by imagination, although aided by an author's skill, is no match for the realism of the visual. Although this book is far from television its insights are very real, so as you make your way through each chapter, I ask you to reflect upon your image of a telecommunications infrastructure. You will marvel at how it has changed!

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ENDNOTES

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2. Footnote 1 in U.S. Congress, Office of Technology Assessment, *Rural America at the Crossroads: Networking for the Future*, OTA-TCT-471. Washington, DC: U.S. Government Printing Office, April 1991, p. 59.
3. Amitai Etzioni, *The Moral Dimension: Toward a New Economics*. New York, NY: The Free Press, 1988.
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16. Jurgen Schmandt, Frederick Williams, Robert Wilson, and Sharon Strover, eds., *The New Urban Infrastructure: Cities and Telecommunications.* New York, NY: Praeger, 1990.
17. See the volume which resulted from this meeting: Marcellus Snow, ed., *Marketplace for Telecommunications: Regulation and Deregulation in Industrialized Democracies.* New York, NY: Longman, 1986.
18. Eli Noam, "The Public Telecommunications Network: A Concept in Transition." *Journal of Communication* 30-48 (Winter 1987), p. 47.
19. Milton Mueller, in a draft review essay for the *Journal of Communication*, noted that organizations which would benefit from government investment, or government protection, have an incentive for linking their goals with an affirmative public interest such as economic growth. He notes further that the overwhelming majority of studies of telecommunications as urban infrastructure being developed in the states, has been funded by telecommunications firms. See "Communications as Infrastructure: A Skeptical View," unpublished manuscript.
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21. Jerry L. Salvaggio, "Projecting a Positive Image of the Information Society," pp. 146–157 in J. Slack and F. Fejes, eds., *The Ideology of the Information Age*. Norwood, NJ: Ablex, 1987.
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24. Gibson is the author of the very popular science fiction series involving characters who physically "jack into" the network by means of sophisticated "decks." His three most popular novels are *Neuromancer, Count Zero*, and *Mona Lisa Overdrive*. Less advanced versions of exploration of the electronic space known as virtual reality have been presented in the film *Lawnmower Man*.
25. Rohan Samarajiva and Peter Shields, "Electronic Public Spaces: Institutional and Strategic Analysis." Conference of the International Association for Mass Communication Research. Guaruja, Brazil, August 1992; see also conference on "Civilizing Cyberspace—Minding the Matrix" organized by Computer Professionals for Social Responsibility and sponsored by The Electronic Frontier Foundation, Washington, DC, June 1991. An explicit purpose for the conference was "educating society" as reflected in the scheduling of a workshop devoted to educating the public and the public media about just what cyberspace might mean.
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and 'Star Wars'" in *The Pay-Per Society*. Norwood, NJ: Ablex, 1989, for a more pointed critique of military R&D as a component of U.S. industrial policy.

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51. The reference here is to the work of Anthony Giddens which has become increasingly popular among communications scholars concerned with communication in organizations. Giddens' notion of structuration transforms the static sense of structure into an awareness of a process which is involved in reproduction and change. An expression and critique of Giddens' work as social theory is available in David Held and John Thompson, eds., *Social Theory of Modern Societies: Anthony Giddens and His Critics*. Cambridge, MA: Cambridge University Press, 1989.
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What the Coming Telecommunications Infrastructure Could Mean to Our Family

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Speculation on the significance to individuals of the emerging information infrastructure depends upon which individuals we have in mind, for what purposes they might use the network, and the qualities of the infrastructure that will reach the home.

As individuals, those of us already equipped with a computer and a modem on our desks do not represent the Americans who have most to gain by greater access to information. We already have the means to find out most of what we want to know, electronically or through books, magazines, and, most importantly, through telephone calls to fellow members of the informed. Moreover, our basic needs (e.g., for health, education, and a job) are largely met. While the coming infrastructure will importantly improve our lives, helping us do our jobs better and stretching our minds, the greatest contribution of the infrastructure will be to those who more resemble the Gonzales family.

THE GONZALES FAMILY

It is the year 2002. Rosa Gonzales lives with her 17-year-old daughter, Maria, 16-year-old son, John, and Maria's two-year-old child, Crystal, in a large public housing project in Center City. Maria, although pregnant with a second child, continues to attend sophomore high school classes. She wants to avoid the fate of her brother John, who dropped out last year, has been twice to prison, and is is still trying to get his act together. Maria is resolved to pursue her studies through to graduation.

Rosa has an intermittent job serving lunch at the nearby elementary school, but most of her energy goes to taking care of her granddaughter, Crystal. Crystal needs special attention because she suffers from asthma. And soon there will also be Maria's baby to tend.

The family receives welfare payments and food stamps. Even with the low rentals of public housing, and the earnings from Rosa's part-time work, it is hard to get by. Recently, John also has had a part-time job as a standby grocery packer. He is subject to being called on short notice to help out at any one of the stores of a large supermarket chain.

The family speaks Spanish at home. Rosa has trouble making herself understood in English but can read Spanish easily. John is orally bilingual but functionally illiterate in both languages, a shortcoming he ingeniously hides. For instance, he pretends he does not see the posted bus schedule when he asks someone else when the next bus is due.

The Gonzales family has a telephone and a television set. The TV is by far the family's most costly possession. Like all current models in the year 2002, it is digital and connects to the switched broadband network. The remote control permits the Gonzaleses to make choices by punching in numbers in response to menus that appear on the screen. Specific sources of information and programs are thus selected much as one rings up a particular telephone number. And once connected, the user can provide numerical information and further select exactly what it is that he or she wishes to find out. The Gonzaleses do not have a video camera that would permit them to send pictures of themselves nor a keyboard to plug into the TV that would simplify sending text messages. A keyboard is high on the Gonzaleses' "want" list.

Rosa

Rosa particularly values the information she can get about asthma that helps her manage Crystal's disease. She can select the moving picture sequences which contrast children who have asthma with children suffering from more ordinary respiratory difficulties. Rosa can specify which of the demonstrated degrees of severity matches Crystal's symptoms and get guidance on medication. Now, she only goes to the clinic when the program tells her it is necessary. It helps that the explanations are available in both English and Spanish.

Another medical program recently helped Rosa determine that a newly discovered mole on her face was undoubtedly benign. Many pictures were shown of "good," "bad," and "questionable" moles.

Increasingly Rosa is able to deal with government agencies through the TV. She used the terminal to apply for an apartment in the housing complex that would provide the family one more room. And now she can check over the network on how her application stands on the waiting list. Her entitlements for SSI and food stamps can also be verified when Rosa punches in the facts of her ever-changing family and economic situation.

Rosa can also connect to Maria's school through a TV "number" and see teachers explaining for parents what is being taught in each class that week. The teachers describe the work that students are expected to do at home, with books, paper, and pencil or by interacting with a teaching program through the terminal. Using the voice mail utility, Rosa can leave messages for Maria's teachers and check her own message box at the school for school events and for teacher comments about Maria.

Some of the parents of the school, including Rosa, are organizing an effort to get the school board to purchase the lot next to the school on which a house just burned down. This would permit the small playground to be enlarged. An explanation of the scheme and pictures of the lot and drawings of the projected playground are available over the TV. A "bulletin board" of parents' comments, some written, some oral, has been opened up. It is the first time that Rosa has engaged in any organized activity as a parent in connection with the school. In fact it is the first time that she has engaged in any social activity for a public purpose.

Maria

Maria uses the terminal for doing schoolwork at home, for learning more about healthy pregnancy (her first child was seriously underweight), and for dealing with social agencies in straightening out the amount of her child support payment. She is also a member of a support group of teenage mothers that "meets" over the network.

John

For John, the information network provides work assignment manifests for the next day's grocery packing jobs. As they are in English, only Maria can read them. But John is addressing his illiteracy directly, working with a reading program on the terminal that adjusts itself to his skill level, assuring steady progress. The program repeats exercises untiringly. John particularly likes the huge "library" of visual simulations, in which writing appears in exactly the sort of context in which he encounters it in real life, for instance, simulated posted bus schedules, street signs, and the labels on cans and bottles.

John is also studying math with the hope that when he can read better he may work up to handling a cash register at the supermarket. Both the illiteracy and math programs are available at a downtown learning center, but the distance and John's irregular work schedule make it impractical for him to go there; study at home is easier, and much less embarrassing. Another training program John uses prepares teenagers for learning to drive a car. The screen shows other cars and streets just as they would be seen through a car windshield. After John makes his choice of what to do, a voice explains why his decision was right or wrong. This program prepares John for the car simulator at the city hall which has a steering wheel, brake, and accelerator pedal.

When John registered for driver learning (over the terminal), he was shown how to access programs on organ transplants and on living wills. John has been surprised and a bit awed by the decisions he is called on to make about heroic measures that could be performed on him in a hospital, even if he were about to die. It is not something that he had thought about. The video program illustrates different hospital procedures, such as enteral nutritional support, and lets John listen to physicians and lay persons discuss them. He will be ready to make his choices and have his living will witnessed at the time he goes for his driver test.

If the Gonzaleses had a camera for transmitting video, John could confirm his whereabouts to his parole officer.

The Family

Together, Rosa, Maria, and John work on an English-as-a-second-language program available over the network. The two children help Rosa with the meaning of English words and Maria helps her mother and brother in learning to read. They are conscious that they have a family language problem and are pleased to be able to help each other.

Right now the Gonzaleses are seriously considering buying a full keyboard for their terminal. Advertisements for many types of keyboards can be accessed over the network. After they make a final selection they will invoke a customer-based shopping program in which they state their product requirements and then receive price bids from different suppliers.

After information demands of the family are met, the TV is used for looking at sports and other entertainment programs.

CATEGORIES OF USE[1]

Arranging by subject the different purposes for which the Gonzales family might use the information infrastructure helps us appraise the significance of access to multimedia information from the home. And the greater the value of access to information programs from the home, the more likely it is that persons such as the Gonzaleses will make the effort to use the programs in the way imagined.

Health Information

Self-diagnosis and self-care. Health information made available in the home can substitute for health information provided in a doctor's office or at the emergency ward. Users provide information about their symptoms and in return are helped to decide whether a medical condition does or does not require immediate professional attention. For the patient, time lost in needless travel and hours of waiting is avoided. The ease of access to information helps assure that problems which might otherwise be neglected and become more serious are addressed in a timely manner. Rosa Gonzales found out that her mole did not require a trip to the hospital. Others could learn how to distinguish for themselves the danger signs of breast or testicular cancer, a deer tick bite, abdominal pain, and many other conditions.

After diagnosis and with professional hand-holding in the form of responsive health information, many maladies can be adequately treated at home. These include two common serious diseases—diabetes and asthma. Not only can accessible health information promote self-care, it can also support and guide those in the home who are charged with the care of others: infants, elderly persons, and the bedridden.

Healthier life-styles. Gains in individual health, once mostly achieved by improvements in professional care of sick persons, are today increasingly realized through improved individual understanding of how to remain healthy. A healthier life-style is promoted by information about such topics as diet, exercise, alcohol, drugs, smoking, safe sex, and how to avoid accidental injury by automobiles and in the home. The U.S. Public Health Service has identified 23 categories in health promotion and disease prevention for which specific life-style improvements can be significant.[2]

Informed decisions by patients. Information is also the basis for informed decisions by patients to accept or decline medical procedures. The right choice in medicine increasingly depends as much on the individual's preference of life-style, risk assumption, and responsibilities for others as upon scientifically proven medical outcomes.[3] Educating the individual patient about the consequences of different therapies taxes busy professionals; the pressure on their time works against the completeness and repetition of explanation by which patient understanding is achieved.

Interactive medical information programs can help. For instance one program already in use helps patients decide whether to undergo surgery to remedy benign prostate enlargement.[4] Other programs are planned to help patients in choosing cesarean delivery, hysterectomy, pacemaker implants, scarotid endartectomy, hip, knee and lens replacements, gall bladder surgery, surgery for back pain, and treatment during final illness.[5] The developers of such health information programs often assume that individuals will interact with the programs in a physician's office or other clinical setting. But since the information is presented in a manner to be understood by lay persons it could be studied in depth by individuals in the home using a network that can handle moving images. The place to first consider a living will is surely not in the emergency room of a hospital.

Value of health information. We have considered here what better access to health information might mean for the individual, sensing the serious consequences for the Gonzales family of an unattended cancerous mole, an underweight baby, or an unnecessary hospitalization of a child for asthma. But we should note that society, which largely pays their health bills, also stands to gain from the better health of individuals to which information technology can contribute.[6]

Education and Training

The power of interactivity, computer-based materials, and visual simulations to aid education has been well demonstrated.[7] A communications network that reached the home could use this power for learning independently of schools as well as for backstopping school-based learning.

Independent learning. John is not in school, but uses the information network to study reading, writing, mathematics, and automobile driving. Most of the work force could gain from upgrading basic and job skills. A recent study of small businesses alone found more than 10 million workers having trouble doing their work because their reading, writing, and math skills were so poor.[8] Skilled workers need to update their job-related knowledge. It is easier for employees to acquire these skills at home than at a work site, where the job competes for time.

Home-based learning permits the different members of a family to cooperate in overcoming shared deficiencies, a strength evident in the cooperative attack by the Gonzaleses on their weakness in English.

Backstopping schools. Rosa Gonzales is able to encourage Maria in her homework because of the connection the network provides to the school.

> Many schools have "homework hotlines" that are publicized to parents. A parent can call in and find out whether his or her child had homework assignments last night. However, the extremely low bandwidth of presently used voice communications tends to limit these services to listings of exercises ("Page 47, even-numbered problems" is the usual kind of message). Emerging network and ISDN [integrated services digital network] technology could enable parent access to all of the

> resources available to the teacher, such as suggested follow-up activities, richer explanations, etc., as well as teacher notes on goals for each lesson.[9]

Rosa also uses the network to participate as a parent in school activities.

The ability of students to interact from home with computer-based learning materials will depend both on there being such materials and on the capacity of the home terminal. Unfortunately the attention of many concerned with educational technology is now largely directed not on developing new materials nor on the connection to the home, but on delivering the existing form of classroom instruction to remote groups of students in institutional settings, e.g., using the National Research and Education Network for so-called distance learning.

Providing a teacher to a distant classroom is valuable, especially as a means to fill a void in a school curriculum. But a more valuable use of resources available for educational use of information technology would be to aid development of interactive computer-based learning programs with their powerful pedagogy aimed at the individual student rather than the class as a whole.

While such computer-based programs for the limited curriculum of K–12 could be delivered to schools without an electronic network, a network would permit students to work with the programs at home. The infrastructure foreseen would in effect give every child home-based computer power.

And only a switched network would open access to the rich variety of information materials that could respond to the wide range of learning and training interests of adults.

Dealing with Government

The Gonzales family, like most Americans, must settle problems with many government agencies, including schools, Medicaid, welfare, health and housing agencies, the parole system, and the driver's licensing bureau. Although none of the family earns enough to owe income taxes, they struggle to obtain refunds of "withholding" from federal and state tax authorities.

Electronic technology can greatly help the citizen deal with government. Expert systems can individualize complicated laws and regulations, specific problems can be resolved through interactive communication, and political action can be encouraged by the ease of peacefully "assembling" over the network.

Individualizing laws and regulations. The complication of government regulations reflects the effort of their draftsmen to cover every case. The result is laws and regulations so complicated that it takes an expert to find the definitions, clauses, and exceptions that apply to the facts of any one situation. But an electronic expert system can make that job easy. The individual citizen provides the few relevant facts of his or her specific case and receives a tailor-made response. In France, using the Minitel, those receiving family benefits can punch in age, marital status, number of children and their ages, appropriate income and asset brackets, and the amounts of any other government support benefits being received. Then the program returns the amount of the monthly assistance payment that the family should be receiving. If there is a variance, the program gives the telephone number to call.

Specific interactions with government. Rosa Gonzales is able to monitor the progress of her application to the housing authority for a larger apartment without the need to speak to anyone. Telephone tag, trips to government agencies, and long waits, with perhaps one or two children in tow, are avoided. Government employees save time spent in repeating standard messages that can be delivered electronically.

Political action. The use of electronic bulletin boards and voice message boxes facilitates participation in public life. Rosa, for example, has joined in a collective effort to enlarge the school playground. Existing on-line networks are already in use to aid public action in cities in California, Ohio, Pennsylvania, Minnesota, Wisconsin, and New Jersey.[10]

An interactive electronic information bank could improve elections by providing details on the background and positions of candidates on issues of particular interest to a voter.[11] Rosa has never voted, but if she could easily probe candidate positions in detail she might come to understand how elections affect her personally.

Support groups represent a form of private social action that can supplement, improve, or replace government action. Maria uses a support group to confer with other teenage mothers and mothers-to-be. That she can do this from home makes her participation in this group activity more likely.

Shopping and Finance

Unfortunately the Gonzaleses do not have much occasion to do electronic shopping; their financial transactions are mostly an effort to get the government benefits to which they are entitled. For others the convenience of home shopping has greater meaning. But all will gain from the efficiencies brought to a market when the consumer is the center of the transaction. Competition is heightened and buyers' exercise of rational purchasing is strengthened when comparison shopping requires no travel.

Work at home, or telecommuting, is expanding both among professional workers and clerical staff whose work consists of entering and manipulating data in a networked electronic data base. The Gonzaleses, as yet, lack the utility of easy data entry, but the infrastructure developments foreseen here could in the future open up to them home employment possibilities.

Entertainment

Entertainment will undoubtedly continue to be the "default" use of the enhanced information infrastructure.

None of the Above

Experience with new technologies in general demonstrates that the uses which turn out to be most important are often not foreseen. So while we will be surprised by many new uses, we should not be surprised that we will be surprised. Given a switched public network, the investment necessary to experiment with developing and providing new information services and products accessible from the home will not be great. Persons with creativity, initiative, and enterprise are sure to show us information products which, although we had not thought of them, will turn out to be just what we "need."

THE INFRASTRUCTURE TO THE HOME

The value of the information infrastructure for individual Americans will depend on the degree to which it offers choice, information of high quality, and ease of use—to everyone.

Choice

Perhaps, if Maria watched broadcast television for many years, a program would someday be beamed to the world with pictures of benign and malignant moles. But Maria cannot wait on that chance; she must be able to switch to information when she needs it. For meeting the widely disparate information needs of a large and heterogeneous population, the switching capability of a network is its single most important characteristic. Were we forced in 1993 to make a choice of one single information device for the home, we would choose the telephone and forgo the pictures of television just because the telephone can switch us to a hundred million different points of connection. Through the TV we will never reach our doctor or the local office of the Internal Revenue Service.

Once we are switched and connected to an information source, interactivity provides the means to further refine our choice of information. By recursive questions and answers a user can rapidly narrow the definition of the specific information sought. By stating facts and preferences to an expert system in answer to its questions, a user can be given information cut out of a massive data base and tailored to personal specifications.

We should not confuse such unlimited choice with the narrow meaning which the cable television industry gives the phrase *interactive television.*[12] For CATV, interaction means merely the power to select among a few hundred broadcast channels and someday perhaps to make further choices—the preferred angle for viewing a sports event or selecting which among the fur coats offered by a specific department store should be sent around. But such choice, offered within an unswitched and essentially broadcast mode, is by many orders of magnitude less than the choice provided over a fully switched system.

While the technology of cable television could be converted to offer a fully switched broadband system, thus providing an information infrastructure with unlimited choice, the cable TV industry has so far expressed fears that being open to all would constitute it a common carrier susceptible to regulation,[13] jeopardizing the present coveted position of cable as an unregulated monopoly.

Although some analysts of the future infrastructure have assumed it to be limited to a small number of channels,[14] the discussion here assumes that the powers available to the Gonzaleses will include full switching, interactivity, and an unrestricted network.

The Quality of the Information-Switched Moving Images

Upgrading the voice network to permit sending images will permit access to information that is essentially visual. An aural or textual description of "good" and "bad" moles does not do the job. Further, in order to convey certain information, images must move, e.g., to compare asthmatic coughing with coughing due to other causes, to experience simulated automobile driving in real time.

Even though the voice alone is able to convey information to persons who do not read well, video lends important emphasis. Watching the face of the patient describing his urinary blockage permits us to reach a better judgment of the degree of pain experienced. Since the time of cavemen "show and tell" has been the most basic form of information transfer.

No one form of information suits everyone. But through switching and interaction the user can select not just the subject of information but the form of it that best suits that particular user. The Gonzaleses may prefer pictures to words, Spanish to English. Others may appreciate the short-cuts realized by a faster paced presentation that assumes more previous knowledge.

Switching also permits the user to be the chooser. Where more information than would be offered in a broadcast advertisement or political message is wanted, it can be had. Alternative sources can be considered, and in business transactions it may someday be "seller beware."

While individuals can choose between sources, the information received will be no better than the information provided. A network of competing providers in the private information market should promote quality, but public action may be required to assure accountability, for instance, by a regulation stating that sources must identify just who stands behind the information offered.

Some information of importance to individuals will not be assured by free-market competition among suppliers. User payments alone might not return enough to support information dissemination even where it is strongly in everyone's interest that information be provided, as to those in need of education, training, health information, political participation, and efficient access to government services. The value of the social externalities of such information being available would justify public subsidies to either the user or the producer of the information products that advance these public aims.

Some telecommunications scholars have suggested that "universal service" should include not just the technology of communication but also a body of information, access to which should be guaranteed for everyone,[15] providing an "information safety net" to all.[16]

Ease of Use

Information of good quality and potential importance to the individual in the home will be of little value unless it is easy to use. Already mentioned as ways by which information can be presented to facilitate use are to present it in different formats and in different languages. But how will an individual make a choice? What will first be seen when the terminal is turned on? Or, in today's jargon, will the gateway be user-friendly, especially to those with little education or technological sophistication?

Eventually, beyond the time frame of this book, users may make choices in natural language, simply speaking about what information they want. Until then, however, the interface between user and information network must employ inventive ways of permitting commands to be in the form of numbers or selected words. But it will be difficult to make choosing information easy. Stories abound on the small number of persons who have mastered the art of programming a VCR. To aid access to a world of electronic information, something even simpler is needed for a selection task that is more complex.

So it is a big assumption that the interface will permit easy access to interactive video information. The interface we use today to search for voiced information is both awkward and incomplete. Take health information. One hundred twenty-one different *federal* health information resources, many of them offering 800-number telephone services, are listed by the Department of Health and Human Services.[17]

But the average citizen instead of starting with the special government publication that lists health numbers has at hand only the local telephone directory. Information relevant to difficulty in urinating is available but it is not listed in the directory under "U" or "P." Worse, the right telephone number for health information on a specific subject may be sold to a single physician.[18]

Telephone numbers concerning problems to which a government agency is prepared to respond are not even listed by subject but only by the formal title of the agency. To call for an absentee ballot in a municipal election in Austin, Texas, should one search the list of city, county, or state offices? It does not matter, for in none of those listings do the words *election, ballot,* or *voting* appear.

The FCC is already wrestling with the definition of the "video dial tone" of the future, the means for summoning visual information over a switched network. This effort will encounter the same problems the voice interface already faces, when instead of simply wanting a phone number for a known named person, we want alternate sources of information by subject category, and probably by cross-categories: e.g., restaurant, Thai cooking, nearby, cheap, recommended by local food critic.

The estimates made here of how valuable the infrastructure will be to the individual assume that the FCC, state commissions, and local exchange carriers will succeed in doing for interactive video what they have failed to do for interactive voice: provide individuals an easy means of identifying and choosing information sources by the subject of interest.

Ubiquitous Access

Which individuals?

Much discussion of the "home" use of the emerging information network seems to assume a relatively well-off suburban family for whom job training, underweight babies, and settling affairs concerning welfare, food stamps, and the parole system are not problems. It may represent no insuperable expense for such families to place one more kind of terminal or computer in the house if that is what it takes to be linked to the information network. But the serious information needs of the least affluent quarter of all Americans must be met through a device which we can realistically believe will be in every American home, including homes which are public housing, just as the color TV terminal is today.

The Gonzaleses live at the margin. Time spent waiting in an emergency room represents a big loss. What time the Gonzaleses do have to devote to searching for information does not match the schedules of classroom training programs or the hours when government offices are open. The Gonzaleses lack money for alternative information means: books, tutoring, the medical advice of a private physician, experts who can interpret government regulations.

In the case of the Gonzaleses, we have assumed a video terminal that is digital and interactive, connected to a switched network. The Gonzaleses have no personal computer. The computer power they need to manage interactions over the information infrastructure must be contained within their video terminal.

Yet in 1993, the federal government's initiative in building an information infrastructure, the National Research and Education Network (NREN), focuses on the link between supercomputers and between scholars located at universities. And any transition of this NREN beyond schools to include homes would seem limited to families with personal computers. Such a trickle-down expansion of the network is unlikely soon to reach the Gonzales family. So the hypothesis here is that around 1994 the FCC wisely determines that the new advanced television terminal, in addition to displaying pictures of high resolution, must be capable of supporting interaction over a switched network, making it possible for every American to have access to the information they need.[19]

Perhaps a fair test of an adequate national information technology would be whether it could at any time bring to a public housing apartment pictures of benign and malignant moles and video explanations in Spanish of how best to recognize the differences.

Universal access implies overcoming not only the boundaries of poverty but geographical boundaries as well. Extension to rural areas of a network that offers interaction with information in the form of moving images may lag urban accessibility. But offering services to rural users may be worthwhile for society as a whole where alternatives involving travel, ignorance, and economic underdevelopment are expensive.[20]

WHAT IT MEANS FOR THE INDIVIDUAL

Addressing Basic Needs

It is clear from the Gonzales family's experience that the information infrastructure could help meet the basic needs of individuals. By accessing moving visual images over a switched network the Gonzales family improves its health, education, and training, assures its government entitlements, and better spends its money.

While meeting the needs of individuals is of great importance to those individuals, by helping meet those needs the information infrastructure would also contribute directly to improving the country's human infrastructure. And today, a more healthy and productive work force may be our country's first economic priority.

Empowering the Individual

Strengthening the individual in body and mind are also goals that underlie freedom and democracy. The switched public network, when it leads users to rich multimedia expressions of the particular information needed, will alter the balance between an individual and the world. The ability to obtain particular information will mean less dependence on knowledge that is general or designed for others, less need to accept decisions that as individuals we had no part in making about what we are to know and when we are to know it. The subjects of concern and the timing of discovery will be for the individual to decide, and our political system will gain from a population of better informed, better coping persons.

Strengthening Society

At the same time, a stronger switched public network can permit individuals to engage together, to support each other, and to work on social problems. The technology overcomes distance and time, and permits an accessible electronic commons where groups of any size can "meet" on any problem whenever they want. Indeed "meet" is too limiting a word to suggest the power of asynchronous collective information sharing for social purposes. A useful and used information infrastructure will strengthen both the individual and a democratic society.

ENDNOTES

1. A good summary of many home uses appears in *21st Century Learning and Health Care in the Home: Creating a National Telecommunications Network.* Washington, DC: Institute for Alternative Futures and Consumer Interest Research Institute, 1992. The report is particularly strong in relating different uses to different technologies.
2. *Healthy People 2000: National Health Promotion and Disease Prevention Objectives.* Washington, DC: U.S. Dept. of Health and Human Services, Public Health Service, GPO, 1991.
3. S.G. Pauker and B.J. McNeil, "Impact of Patient Preferences on the Selection of Therapy." *Journal of Chronic Diseases* 34. 1981, pp. 77–86.
4. H.C. Lyon, Jr., and J.V. Henderson, et al., *A Multipurpose Interactive Videodisc with Ethical, Legal, Medical, Educational, and Research Implications: The Informed Patient Decision-Making Procedure.* Proceedings of the 13th Annual Symposium on Computer Applications in Medicaid Care, November 5–8, 1989, Washington, DC. Piscataway, NJ: Computer Society of the IEEE, pp. 1043–1045.
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6. Potential values of perhaps as much as several hundred billion dollars a year have been identified that relate to individual access to better health information. A. Melmed and F.D. Fisher, *Towards a National Information Infrastructure: Implications for Selected Social Sectors and Education.* New York, NY: Center for Educational Technology and Economic Productivity, New York University, December 1991. Currently about 40 percent of all medical expenditures are made by government agencies.
7. *Linking for Learning,* 1989; *Power On,* 1988; and *Informational Technology and Its Impact on American Education,* 1982, all by Congressional Office of Technology Assessment and sources cited therein. See also sources cited in note 4 of *21st Century Learning and Health Care in the Home, supra.*
8. Study of f' .ns with fewer than 50 employees by the Southport Institute for Policy Analysis, reported by the Associated Press in *Austin American-Statesman,* June 5, 1992.
9. *Report of a Workshop on Educational Potential of Wideband National Network* (held at George Mason University, November 1–2, 1991), A. Lesgold, rapporteur, January 1992.
10. Jerome Aumente, rapporteur, *Online for Social Benefit.* Queenstown, MD: The Aspen Institute, 1992.
11. Suggestive examples have been provided of how interactive data bases could give voters access to information on which elections might turn. See B.M. Caspar, A. Gordon, F.D. Fisher, and H. Kelly, "Electronic Information Technology to Empower Voters," a paper delivered at "Developing New Computer Software or Interactive Video Products for Education and Entertainment in the Home," Aspen Institute Workshop, February 1988. Although directed to a past election, an interactive video disc has demonstrated how election information can be individualized. See *Election-1988.* New York, NY: ABC Interactive, 1989.
12. E.g., "Time Warner and IBM Discuss Venture," *New York Times* Austin edition, April 30, 1992, p. C6.

13. Public statements by representatives of the cable TV industry at "Future of Cable TV" conference, Columb Business School, January 25, 1991.
14. L.L. Johnson, *Common Carrier Video Delivery by Telephone Companies*. Santa Monica, CA: Rand, 1992.
15. S.G. Hadden and F. Williams, *Considerations for a Redefinition of Universal Service: Results of a Policy Research Project*. Austin, TX: College of Communications and LBJ School of Public Affairs, University of Texas at Austin, 1991; F. Williams and S.G. Hadden, "On the Prospects for Redefining Universal Service: From Connectivity to Content," a working paper in the policy research project cited above, (undated); S.G. Hadden, "Regulating Content as Universal Service," a working paper in the policy research project cited above, March 1991.
16. Herbert S. Dordick, "Toward a Universal Definition of Universal Service," in *Universal Telephone Service: Ready for the 21st Century?* Annual Review of the Institute for Information Studies. Nashville, TN, and Queenstown, MD: Institute for Information Studies, 1991, pp. 109–139.
17. *Health Information Resources in the Federal Government*, fifth ed. Washington, DC: U.S. Public Health Service, 1990.
18. F.D. Fisher, *The Austin Yellow Pages: Lessons for the Video Dial Tone*. Submitted to the FCC in the matter of telephone company–cable television cross-ownership rules, notice of inquiry concerning video dial tone, Docket 91-334, January 13, 1992.
19. At time of this writing, June 1992, the FCC has under review the characteristics of the the advanced television terminal ("In the Matter of Radio Broadcast Services: Advanced Television Systems," MM Docket 87-268). Begun as a proceeding con-cerned with only broadcast television, the review has been expanded to consider how the characteristics of the terminal would effect its potential use in other media.
20. *Rural America at the Crossroads: Networking for the Future*. Washington, DC: U.S. Congress Office of Technology Assessment, April 1991.

INVESTING IN THE TELECOMMUNICATIONS INFRASTRUCTURE: ECONOMICS AND POLICY CONSIDERATIONS

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INTRODUCTION

The emergence of "infrastructure" as a prominent term in the discussion of telecommunications policy in the United States reflects an important shift in our perception of telecommunication networks and the services they provide. Until recently, most of us thought of telecommunication services primarily in terms of voice telephony and broadcast television, with cable television a later addition to the mix. Telephone and, to a lesser extent, television, had come to be viewed as essential services almost like water and power—essential to full participation in modern society. Hence the historical importance of the achievement of universal service. As with water and power, critical concerns were that telecommunication services be available to everyone and that consumers receiving like services pay similar prices—irrespective of differences in the costs of serving them.

Unfortunately, service costs differ dramatically among consumers (for example, telephone service for urban and suburban consumers can be provided at lower cost than for rural consumers), while efficiency of resource utilization—another desirable public objective—requires a close correspondence between cost of service and price. Thus, the telecommunications policymaker must deal with an inescapable tradeoff between efficiency and equity goals. The tension between efficiency and fairness objectives in the context of regulated private service providers has dominated the telecommunications policymaking process to date. Focus has been on the development of policies that perform acceptably in meeting equity objectives while holding to a minimum the overall cost of providing service. "Infrastructure" has not been a major concern in this dialogue.

The new focus on "infrastructure" reflects a growing concern with the level and nature of telecommunication services, in addition to the availability, equity, and cost of service concerns that used to dominate the policy debate. That is, historically, the primary focus of telecommunications policy has been ensuring the widespread availability and affordability of POTS (Plain Old Telephone service—i.e., simple voice service) and television service.[1] While these traditional objectives remain, we are beginning to see more advanced communication services as important contributors to economic and social well-being through their roles as facilitators and enablers of other activities and economic structures that would be difficult, if not impossible, to achieve without them. As a result, telecommunications network investments are now viewed at both the firm and national level from a long-term strategic perspective that is largely new to the telecommunications policy debate.[2] The spate of recent state and federal regulatory and legislative initiatives promoting public network upgrades is evidence of the growing concern with telecommunications as a vital infrastructure component.[3]

The hope than an infrastructure supporting advanced telecommunication services may make significant contributions to business productivity, global competitiveness, and other social policy goals is the product of both technological and social/intellectual trends. On the technological side are the increasing capabilities of the underlying technologies and a dramatic growth in private networks used for a wide range of innovative commercial applications—applications that have visibly transformed several industries and have produced competitive advantage for the firms that successfully introduced them.[4]

Coinciding with the development of impressive new technologies has been a growing perception that the United States must act quickly to either reverse or prevent a variety of economic and social problems. Communication technologies have been touted as at least partial solutions to perceived problems regarding international competitiveness, inadequacies in the public education system, and the rising costs of health care, to name just a few. Also contributing to the fascination with telecommunications as a tool of economic and social policy has been a growing appreciation among academics of the importance of effective communication to economic productivity and the role of organizational design and alternative market structures in overcoming barriers to communication (in the form of various coordination and transaction costs) among people and organizations.[5] The large and growing body of literature dealing with these topics has provided an analytical framework that has been helpful in exploring the implications of new communication technologies.[6]

The new focus on telecommunications as infrastructure making possible new, enhanced services and improving productivity and competitiveness by enabling economic activities complicates considerably what was already a complex policymaking process. Growing with the number of goals for communication policy is the number of conflicts among these goals and the difficulty of achieving consensus in the design of policy. Providing the infrastructure improvements that many are calling for will be expensive, and we must choose among a variety of approaches for financing them. To further complicate the situation, the transformational nature of the technologies makes traditional investment valuation approaches of dubious value in assessing the benefits of telecommunications infrastructure investments.

In the sections that follow, we list and describe some of the potential benefits anticipated from infrastructure improvements in areas such as public administration, education, transportation, and health care; explore the implications of new technologies for economic organization, efficiency, and competitiveness; and consider several alternatives for financing the costs of network upgrades. To place the following discussion in context, we first turn briefly to a definition of infrastructure.

What is the Telecommunications Infrastructure?

An infrastructure consists of facilities and the collection of people and skills required to utilize them that are commonly available to further the activities of both private and public parties. For example, the transportation infrastructure consists of investments in air, water, and surface transportation and the associated skilled work force that are commonly employed to move people and goods from one point to another. Note that included in the transportation infrastructure are assets that are publicly owned (such as airports and roads) along with privately owned assets such as the airplanes owned by commercial airlines and the rolling stock of trucking companies. In its 1991 report on the telecommunications infrastructure, the National Telecommunications and Information Administration (NTIA) defined the physical components of the communications infrastructure generally as "all of the facilities and instrumentalities engaged in delivering and disseminating information throughout the nation."[7] Included are facilities under both public and private control serving both the mass media (broadcasting, books, magazines, newspapers, etc.) and point-to-point communications (traditionally telephone and telegraph). Like NTIA, to keep things manageable we have chosen to limit our analysis to that part of the communications infrastructure that is used primarily for point-to-point services. While the line between point-to-point services and broadcasting has been blurring with the increased use of spectrum to support point-to-point communication, the "broadcasting" of messages through wire-based computer networks, and developments that may make cable companies viable competitors in telephone services, the distinction still affords considerable convenience for the purpose of structuring the following discussion. Thus for the remainder of this paper, we will use the terms "infrastructure" and "telecommunications infrastructure" to refer to that portion of the U.S. communications infrastructure that is used primarily to provide point-to-point electronic communication, and we will note exceptions when they are relevant to the analysis. Encompassed by this definition are both network facilities—switches, transmission lines/systems, satellites and ground stations, and microwave facilities—and the terminal equipment connected by these transmission links. Included are telephone receivers, personal computers, work stations, mainframe computers, various types of monitoring devices such as those used for fire and burglar alarm services, and specialized terminals such as bank teller machines and the terminals used by travel agents to do on-line booking of airline seats.

In examining the telecommunications infrastructure, it will be useful to distinguish between portions under public control, which we will refer to as public facilities, and the portion under private control, which we will refer to as private facilities. "Public" facilities, while privately owned, have traditional common carrier obligations (no one able to pay can be refused service) and operations generally are subject to regulatory oversight. Local exchange carriers and long distance companies operate most of the public telecommunications infrastructure, which is what is most commonly accessed in making local and long distance telephone calls. Much of the private telecommunications infrastructure consists of dedicated[8] networks that have been developed to serve the internal communication needs of organizations such as businesses, government agencies, and universities. Increasingly, private networks are being used to connect organizations to each other. In most cases, private networks also serve as points of connection to public networks.

The bulk of infrastructure investments are in the public portion of the infrastructure, although the private component has been growing more rapidly. Net investment in public networks is about $160 billion for local exchange carriers and another $40 billion for long distance networks.[9] Net investment for consumer premises equipment and private networks is difficult to estimate, but estimates are about $50 billion and $10–15 billion respectively.[10] The private component of the infrastructure has been growing much more rapidly than the public portion for some time. In fact, in recent years, for the first time annual public network capital additions have not kept pace with depreciation, which many believe to be artificially low due to regulation of depreciation rates. The result, of course, is a shrinking capital base.[11] Substantial reliance on private solutions to infrastructure needs distinguishes the United States from other industrialized countries. As a result of the growing influence of private networks, it has become necessary to incorporate both private and public facilities in an integrated national infrastructure policy.

Benefits from Infrastructure Investments

Benefits of many kinds have been claimed for enhancements to the telecommunications infrastructure. Here we provide a selective overview of the types of benefits expected from applications of advanced information technologies, focusing on those that are particularly well-suited to use of the public network infrastructure.[12] Some are covered in more depth in other chapters in this volume.

Most visible have been calls for applications of communication technology to enhance the effectiveness of other basic service infrastructures in the United States, most notably, public administration, health care, education, transportation, and the network of researchers in universities, private industry, and government. In public administration, there are many potential direct and indirect benefits anticipated from advanced telecommunications infrastructures. Some are tangible and quantifiable, like mechanization and modernization of government information and communication systems; others are difficult to assess, but still socially valuable, such as a more informed and participatory electorate, increased convenience and efficiency in individual interaction with government agencies, and improvements in the criminal justice system.[13]

In medicine, important advantages are seen in making the knowledge of skilled specialists available to patients they would otherwise be unable to treat. For example, advanced imaging technology combined with high bandwidth transmission could make it possible for specialists in rare diseases and difficult surgical procedures in metropolitan areas to participate electronically in the diagnosis of diseases and even guide local doctors performing operations in remote areas. However, Melmed and Fisher[14] see the greatest health benefits from telecommunications coming from applications designed to improve the efficiency of health care by improving public access to information and thereby increasing consumers' participation in the treatment and prevention of illness.[15]

Anticipated contributions to the productivity of the U.S. research and educational systems are also motive forces behind pending legislation including the Gore bill.[16] Substantial public moneys have already been committed to the support of telecommunications networks to further the goals of higher education and scientific research. The people best suited for working together on any given research project frequently are scattered among a variety of sites around the country or the world. Advanced telecommunication networks could help overcome time and space constraints on collaborative endeavors by facilitating file transfer and data base sharing among researchers in different locations.[17] As in health care, educators foresee benefits in making scarce and specialized talent available to wider audiences. For example, a lecture on quantum mechanics delivered by a physicist at Princeton might be viewed by graduate students at Berkeley and Stanford and any other university that wanted to pick up the transmission. Telecommunications technologies are already being used to offer college degree programs up to the master's level to residents in rural (or even urban) communities.

While current services only allow for limited interaction between students and faculty, with greater bandwidth real time interaction would be possible.[18] Similar services have been developed for schools serving grades K–12, where the need for substantial improvement in educational services is generally acknowledged.[19]

In the case of the transportation and postal infrastructures, advanced telecommunications also offer the hope of easing the load on these overburdened systems. This is already happening to some degree. Many messages that formerly would have traveled by U.S. mail or by private delivery services such as Federal Express and UPS are now sent by fax and e-mail. Millions of people telecommute, and projections are that the number could increase to a substantial portion of the work force. This produces direct savings in terms of miles traveled and time spent traveling.[20] Additional benefits of telecommuting are fossil fuel savings, reduced pollution and traffic congestion, and associated health care costs (e.g., respiratory and stress problems). Loss of the benefits of face-to-face contact with coworkers is a constraint on telecommuting, as is the inability of telecommuters to simultaneously send and receive messages for multiple applications over the (bandwidth limited) public network; but these drawbacks of telecommuting could be reduced substantially for many telecommuters if the public network were upgraded to make possible telephonic video interaction and simultaneous, multichannel communication.[21]

In addition to home health care, learning, and working, many observers foresee significant benefits from applications of telecommunications to other everyday activities such as shopping,[22] banking and bill paying, news and information consumption, and a whole host of leisure activities. Here the anticipated benefits will be realized in the form of time savings, convenience, and product and service enhancements, analogous to the benefits and time savings realized from current networks of automatic teller machines.[23] Many consumer activities take place outside of the marketplace. While it is empirically, and sometimes conceptually, difficult to measure the value of nonmarket activities, estimates range as high as one-third to one-half the value of market activities.[24] Therefore the payoff from applications of information technology to these activities is potentially huge.

Of the prophesied benefits from enhancements to the telecommunications infrastructure, hoped for improvements in productivity and international competitiveness for American business have probably received the most attention. These benefits have also been the subject of the most serious attempts at documentation and measurement, and we will treat them in more detail.

INFORMATION TECHNOLOGY AND PRODUCTIVITY

Firm and Industry-level Perspectives

The belief that advanced information technologies can be employed to significantly increase the productivity of other sectors of the economy came into full flower in the mid to late 1980s[25] and is based largely on a few compelling business case histories from the 1970s and early 1980s, where it was seen that firms employing innovative, telecommunications-based strategies were able to gain competitive advantage within their industries.[26] Following a period of relatively unabashed enthusiasm for telecommunications-based, firm-level competitive strategies, we are now entering a period of reassessment and more systematic attempts to evaluate the evidence for the communication technology-leads-to-greater-productivity-and-profits hypothesis that had been almost an article of faith for many.

The expectation of substantial productivity gains from applications of new technologies is itself a reflection of large real price declines in segments of the information industry, including computers and telecommunications. According to an MIT study,[27] "one dollar's worth of quality adjusted computing power in 1970 cost \$73.60 in 1950, and only \$.05 in 1984." Since then the unit price of computer processing has continued to fall at about a 40-percent annual rate, and is forecast to do the same through 1995.[28] Price trends for telecommunications services have been much less dramatic, but still below the average rates of inflation in the manufacturing and service sectors.[29] Falling real prices have coincided with dramatic gains in miniaturization, so today the capabilities of desktop and laptop computers exceed those of 1960s mainframes for most purposes. At the same time, fueled largely by advances in digital switching technology, fiber optics and radio, and techniques for using the existing copper plant more efficiently, dramatic gains in functionality and cost reduction were realized in network facilities.

The reaction to falling prices, miniaturization, and enhanced capabilities was a proliferation of personal computers and workstations in offices and research centers to the point of becoming commonplace. More recently, businesses have been connecting these PCs and workstations to form computer-based networks linking coworkers within buildings and across continents.

Applications of information technology came in three overlapping phases. As the price of computing power fell, it became cost effective to automate a wide variety of functions—bookkeeping, payroll, and inventory to name a few—that had formerly been performed manually with paper-based storage media. It was but a short step from automating existing functions to the use of computing power to create entirely new information products and services dependent on the computational capabilities of computers.[30] The most recent stage in the evolution of business applications of information technology has been the use of information technology as a critical driver in attempts to redesign organizations and work processes to create dramatically more productive enterprises.[31]

It is important to recognize that information products and services and the critical distribution network infrastructures that support them are all parts of a larger information *system;* therefore the components cannot be analyzed independently to determine their true economic potential. This interdependence is illustrated by two major areas where businesses employ information systems to improve productivity and financial performance: transactions-based systems and decision support-based systems. Both are very important in their respective roles.

In the case of transactions-based systems, the issue at hand is usually time and cost efficiency in highly structured and repetitive market activities, like meter reading, bill paying, order taking, credit card verification, and so forth. Computer reservation systems (CRS) for airlines and automatic teller machine (ATM) networks are familiar examples of transactions-based systems.

Electronic data interchange (EDI), the computer-to-computer transfer of fixed-format data and information, has very broad applicability for transactions-based systems to improve productivity, both in the services and manufacturing sectors. EDI is used to facilitate a wide variety of business and professional services, including those listed in the previous paragraph, that utilize standardized reports and forms. EDI represents one of the highest growth markets in the information industry. Even though it is currently used primarily for local and regional applications, its potential for use in nationwide systems is substantial.

Transactions-based systems are closely related to network infrastructure functions sometimes characterized as "service bureau" activities, where the public network serves as a flexible and efficient platform to perform related tasks such as monitoring, order taking, catalog sales, error detection, billing, collection, periodic report generation, and data base administration and maintenance. An advanced nationwide network infrastructure, with its substantial data base capability and capacity, could be used to perform service bureau activities for businesses and other organizations that, for various reasons, do not wish to own and operate their own systems. This could be especially valuable to small and medium-sized firms that may not be large enough to realize internally the economies of scale inherent in transactions-based systems.[32]

Decision support systems represent more recent applications of new information technologies, and the forms of these systems are still evolving. For decision support-based systems, the supporting network infrastructure is an integral, efficient distributor of data and information among decision makers and their support staffs—both within and across organizational boundaries. Important applications are in management strategy, negotiations, and R&D. The power of these systems has already been demonstrated by many firms, albeit on a somewhat limited scale, in manufacturing design and development work, using techniques for Computer Aided Design, Engineering, and Manufacturing (CAD, CAE, CAM).

Transactions-based systems and decision support systems are generally constructed as private networks. That is, private parties put them together and use them for their own purposes. Yet, in most cases, these private networks are dependent on the public network for the supply of vital transmission and switching services. Thus the capabilities of public networks are a constraint on the functionality of private networks.

Economy-wide Efficiency and International Competitiveness: Justifications for Infrastructure Investments

A strong argument can be made that investments in an advanced telecommunications infrastructure are justified on the basis of benefits that are realized at the macroeconomic level over and above any direct benefits to individual enterprises. In fact, this argument may hold even if no benefits materialize as profits in any given sector of the economy. The "network" nature of telecommunications systems is one justification for taking such a position, where we are using the term "network" in its general sense to characterize a technology for which the benefits to any individual user of that technology increase with the number of other individuals using it. A telephone network is an obvious example of a network technology, because the network's value as a communication device is greater the more people are connected to it.[33] Unfortunately, under these conditions it is likely that some individuals whose participation would be of r[illegible]enefit to society won't subscribe because each individual will base his or her adoption decision on the personal benefits of subscription and ignore the fact that his or her presence on the network makes it more valuable to other users. Markets may also "fail" by not adopting a beneficial network technology when each potential user knows it can realize benefits in excess of adoption costs only if the technology is acquired by a large number of other users. Each has an incentive to minimize adoption risks by postponing adoption until a critical mass of other users has already made the commitment. But if everyone pursues such a "wait-and-see" strategy, beneficial new technologies will not be adopted.[34] These characteristics of network technologies constitute perhaps the most important reason for treating telecommunications facilities and services as infrastructure and making investments in that infrastructure an active focus of policy concern.

Investments in the public telecommunications infrastructure have also been promoted as necessary for maintaining the competitive position of U.S. industry in the world economy. This was the primary focus of the recent infrastructure study by NTIA.[35] In many ways this is a straightforward extrapolation of the industry-level analysis reviewed above to the macroeconomy. If telecommunication technologies have been employed by individual firms to realize competitive advantages within their industries, then it is reasonable to assume that similar advantages might be realized by countries whose firms are quickest to incorporate telecommunications in their operations. Just about all privately controlled networks interface with the publicly controlled portion of the infrastructure and many rely directly on publicly supplied transmission and switching facilities,[36] while others rely on public networks for backup and redundancy.[37] So the capabilities of the publicly controlled portion of the network infrastructure are a constraint on the benefits that can be realized from private investments in information technology. Public support of infrastructure development may therefore be a good way of promoting infrastructure investments that would be inadequately supported by private decision makers.

Given this vision of the role of the telecommunications infrastructure in promoting the success of domestic businesses in international competition, it should not be surprising that there has been considerable interest in the quality of the U.S. telecommunications infrastructure compared to the infrastructures maintained by other advanced industrial nations. NTIA compared the public telecommunications infrastructure of the United States with the infrastructures of the other Group of Seven nations, the United Kingdom, Germany, France, Italy, Japan, and Canada. Very briefly stated, NTIA's conclusions were that, by and large, infrastructure services available in the United States are comparable to what is available in other economically advanced nations. However, the United States is not investing in infrastructure improvements as rapidly as are some other nations.

Perhaps more troubling for the future of U.S. competitiveness in global markets are patterns of R&D investments by U.S. infrastructure providers and comparable firms in other countries. In a recent study of R&D expenditures by telecommunication firms worldwide, Harris[38] found the United States to be behind in terms of R&D spending by every standard measure. In the case of local telephone companies, the United States spends only 0.3 percent of annual revenues on R&D. France, Britain, and Japan average about 3 percent, an order of magnitude greater. The Regional Bell Operating Companies' (RBOCs) combined R&D expenditures of 0.3 percent of revenues add up to about $1.3 billion since 1985, while for Nippon Telegraph & Telephone (NTT) of Japan it was 4.1 percent or about $7 billion. France Telecom and British Telecom spent 3.6 percent and 2 percent respectively or about $3.2 billion and $1.6 billion. If the RBOCs had spent at the average of the rates of the British and the French, or about 3 percent of revenues, they would have spent $2 billion more annually.[39]

Bellcore, the research consortium of all the RBOCs and arguably the premier local telecommunications research organization in the world, was awarded only 127 U.S. patents from 1984–1989 compared to over 300 for NTT, the local exchange carrier from Japan, and 255 for British Telecom. Yet, consistent with its mandate from Japanese investors and regulators, NTT does not have any significant overseas business activities and it does not do any manufacturing, even in Japan. What NTT does do, however, is enter into financial partnerships with a number of other manufacturing and research enterprises for joint research and development. Over the same time period, AT&T Bell Labs, which performs R&D for AT&T's equipment manufacturing businesses, was awarded 2,349 U.S. patents, which, while impressive compared to the RBOCs, is still lower than Siemens of Germany (3,300), and Hitachi of Japan (5,000).[40] A more detailed examination of patent activity shows that Bellcore has a higher percentage of computing and communications-related patents than these foreign manufacturers; but the manufacturers still have substantially more U.S. patents in communications-related areas.[41]

Two factors which contribute to the disparity in comparisons of patent activity data between the RBOCs and the dominant LECs in other countries are: the legal business restrictions placed on the RBOCs, and the direct and indirect financial support of foreign governments for their domestic carriers. While it is not known the extent to which these factors explain the differences, the fact remains that U.S. telecommunications firms lag far behind in communications and computing patent activity.

Between 1984 and 1989, the annual number of U.S. patents awarded to America's three leading telecommunications equipment manufacturers, AT&T, GTE, and Rockwell, fell by 15 percent, while those awarded to the five leading foreign firms, Alcatel (France), GEC/Plessey (Britain), Ericsson (Sweden), Phillips (Holland), and Siemens

(Germany), increased 74 percent, and those for the four leading Japanese firms (NEC, Hitachi, Fujitsu, and Oki) increased 119 percent.[42] To the extent that R&D translates into competitive advantage in the long run, these trends are not favorable to the United States.

Clearly there is a difference in the incentives faced by domestic public network operators and their major international counterparts regarding R&D investments. We discuss some of the policy implications of the relatively low incentives for U.S. firms to invest in new network technology in the last section of this paper.

Assessing the Evidence for Productivity Benefits

American business's expectation of significant benefits from investments in advanced communications technology is reflected in investment trends. U.S. services sector expenditures for information technologies (I/T) increased from about 3 percent of every dollar spent on durable equipment in 1972 to about 40 percent by 1989; it continues to grow in importance. Manufacturing sector spending on information technology went from about 3 percent to 25 percent over the same period. Total I/T investment per white-collar worker roughly doubled in the 1980s from about $5,000 to over $10,000.[43] Now, after a decade of heavy corporate commitments to information technologies, we are finding it hard to document the gains from these investments. This has led to a certain amount of revisionist questioning of the wisdom of further I/T investments.

In part, the current questioning of the information technology-productivity hypothesis is a natural consequence of the passage of time. Successes are more visible than failures, perhaps reflecting an optimism inherent in the human species; and the initial enthusiasm for information technology was inspired to a large degree by notable early successes. However, over time, significant failed applications of information technology have come to light as well.[44] In addition, the advantages realized by some of the early, successful innovators have not been as long-lived as anticipated,[45] and even in industries in which innovators appear to have created long-term advantage, imitators following the same strategies never realized the hoped-for profits.[46]

Studies of the productivity benefits of advanced information technologies have yielded mixed support for the hypothesis that there are productivity benefits associated with information technology.

Bresnahan[47] studied information technology investments in the financial services industry and estimated (from the costs incurred by adopting firms) the level of the benefits they expected their investments to produce. His regression analysis produced estimates of benefits approximately five times the costs of adoption. Implicit in his methodology, however, is the assumption that firms knew beforehand the benefits these investments would yield. Thus, Bresnahan's study cannot be considered as evidence refuting claims by critics of I/T spending that for the most part U.S. firms have been misguided in their applications of information technology and have not been well rewarded for their I/T investments.

Productivity studies by Stephen Roach[48] have probably received the most attention.[49] Roach attempted to determine the productivity impacts of information technology investments by comparing trends in traditional measures of productivity per worker for the manufacturing and service sectors of the economy. He found that productivity per worker showed persistent gains for manufacturing workers but not for white-collar workers, even though information technology investments have been primarily targeted to the tasks of the white collar workers that predominate in the service sector. Loveman[50] attempted to estimate directly the contributions of information technology to manufacturing productivity. On the basis of estimated production function coefficients, he concluded that a dollar invested in other types of capital equipment made a substantially greater contribution to productivity than did a dollar invested in information technology.

There are a number of explanations for why the gains from applications of information technologies that many (including the authors of this article) expected to see have been hard to document. For the most part, the other side in the debate over the productivity payoffs of information technology has focused on problems of methodology and measurement that may have introduced significant downward biases in Roach's and others' productivity estimates. One possibility, of course, is that to date there has been very little payoff from the applications of information technologies. Even if this were the case, it would not necessarily mean that investments in I/T will not pay off in the long run. We are still learning how to utilize the capabilities of information technology, so it could be the case that the payoff will be tremendous once we have a better handle on its applications.[51]

Alternatively, it may be that the benefits are there, but traditional productivity indices are not well suited for measuring them. This would reconcile Bresnahan's demand curve estimates of significant benefits from information technologies with the Roach and Loveman findings of little effect on productivity as it is traditionally measured. A generally recognized deficiency in output-per-worker measures of productivity is their inability to reflect qualitative improvements in products and services. For example, suppose that computer-controlled production processes reduced defects and increased the average service life of light bulbs from 100 hours in 1980 to 200 hours in 1992, while over the same time period output per worker in bulb factories held steady at 10,000 bulbs a month. The standard productivity measures would record no change in worker productivity over the 12-year period, when in fact the production of lighting services per worker would have doubled. Baily and Chakrabarti[52] point out that many of the applications of information technologies have produced qualitative improvements in products and services that would be missed in output-per-worker productivity measures. The convenience and time savings to consumers of withdrawing cash from a nearby 24-hour automatic teller machine rather than having to travel to a more distant bank office during business hours to have a human teller process the same transaction is an example of a welfare improvement that would not be picked up in traditional productivity measures. The ability of shipping firms to provide customers with updates on the current location of goods in transit through innovative applications of computer and satellite technology is another example. In both cases, service enhancements valuable to customers do not show up in our productivity measures. The difficulties in measuring the intangible benefits claimed for information technologies are reflected in measurement methodologies employed by the Bureau of Labor Statistics. In many cases where tangible output measures are not available, outputs are simply equated to inputs, making findings of increased productivity impossible.[53]

To test the hypothesis that the use of information technology to produce valuable, but unmeasured, product and service enhancements could result in real productivity gains that would not show up in the standard measures, Baily and Chakrabarti developed a mathematical model of a competitive industry in which firms invest in both production capital and information capital. They found that if information capital produced unmeasured information services and information capital was not too close a substitute for information labor, their simulated, competitive industry generated trends in traditional productivity measures that looked much very much like those documented by Roach. This is also consistent with Osterman's[54] finding that office workers are laid off when computers are first installed, but new workers subsequently are hired. Osterman speculates that this happens as firms find new uses for their computers.

It has also been argued that firms have increased the variety of their product offerings as they have adopted information technologies, but the benefits of increased variety to consumers do not show up in productivity measurements that focus on the number of units of output per unit of input. In fact, because buyers are likely to purchase less of any given variant of a product as variety increases, the provision of greater variety may entail a sacrifice of economies of scale and thus higher unit production costs. If benefits of variety are unmeasured and unit costs increase, information technology will appear to reduce productivity.[55]

In addition to the unmeasured benefits of improved products and services, it seems likely that investments in information technology are generating substantial benefits by reducing the costs of coordinating economic activities. These types of benefits are also unlikely to be picked up in output-per-worker (or output-per-unit of production capital) productivity measures. Here the analogy with investments in the transportation infrastructure is instructive. The development of rail links from agricultural regions to urban centers in the United States dramatically reduced the cost of transporting foodstuffs from the farm to the city in the 19th century. Competitive markets would pass these savings on to consumers in the form of lower prices. However, unless the businesses of agriculture and food retailing were simultaneously transformed, an economic historian seeking evidence of the productivity contributions of investments in the transportation infrastructure by looking at output per farm worker or sales per employee in produce stands would find none. Even if farmers responded to markets enlarged by an improved transportation infrastructure by operating larger farms for which per-unit costs were lower due to economies of scale, the usual measures of productivity in terms of output per unit of labor or capital would provide no hint of the linkage between transportation infrastructure investments and increased agricultural productivity.

As Elan Salomon[56] points out, telecommunication technologies are friction-reducing technologies. Because economists have found it analytically convenient (at least until recently) to ignore the coordination costs that constitute the friction of economic life, very real coordination-facilitation benefits of communication technologies cannot be captured in traditional productivity measures, which focus on the "productive" factors of production capital and labor. A growing body of theoretical work suggests that organizational structures are often selected for their roles in reducing coordination costs (or transaction costs, as they are more commonly called in the economics literature). The coordination problems associated with different production processes and market structures elicit different organizational designs in response. While work in this area has not yet advanced to the point of being able to measure the benefits associated with improved coordination among economic agents, empirical work has begun to emerge that supports the basic hypothesis that the need to reduce coordination costs is a significant consideration in the design of organizations and the structuring of commercial relationships.[57]

One consequence of the current questioning of the benefits of information technology investments is a greater insistence on the generation of measurable returns. While increased accountability in the investment process is to be commended, we must be careful that an obsessive focus on "measurable" results not blind us to potentially important benefits of information technologies that are not easily quantified. We should be mindful of social welfare benefits beyond those of quantifiable market activities of firms' employees, including nonmarket activities of individuals and households and public administration mentioned earlier.

What about the business complaint that even the profits of the successful information technology innovators have proven to be fleeting? At its heart, this is really a complaint about the workings of competitive markets. Eventually, most innovators are either successfully imitated or overtaken by firms riding new innovations of their own. In either case, prices fall and/or products are improved as the original leaders are challenged, so that the benefits of innovation are passed on to consumers. Business leaders may feel that they have to run faster and faster just to stay in place; but from an economic policy perspective this is the way things should work.

Finally, it should be noted that while the benefits of information technology investments have proven hard to document for the U.S. economy generally, there is strong evidence that investments in information technology by firms in the information industries have paid off.[58] The American Productivity Council has calculated annual productivity gains for the communications sector at over 4 percent, or twice as high as the domestic economy overall. Similarly, in the Federal Communications Commission's recent price-cap investigation, productivity estimates for the telecommunications sector alone were in the range of 3 to 8 percent annually.[59]

IMPLICATIONS OF TELECOMMUNICATIONS INFRASTRUCTURE FOR THE ORGANIZATION OF ECONOMIC ACTIVITY

The existence of important linkages between the transportation infrastructure and the organization of economic life has long been appreciated, if not always well understood. Businesses locate along major transportation arteries and cities grow where they intersect. The development of the railroad system in the United States in the 19th century is widely understood to have paved the way for the growth of truly large-scale enterprises in the late 19th and early 20th centuries. As information and information technology play increasingly vital roles in the design and delivery of goods and services, telecommunication networks increasingly are coming to be viewed as electronic analogs of railroads, highways, waterways, and air transportation in their effects on economic structures. While this potential is widely appreciated, we still do not understand well enough the ways in which information technologies may be integrated into the fabric of economic and social activities to make confident predictions about the influence of the telecommunications infrastructure (or enhancements to it) on the way work will be structured in the future.

That the telecommunications infrastructure has already had significant impacts on the way in which economic activities are organized is clear. For example, the benefits of railroads in hauling people and goods over long distances in the 19th century would have been considerably reduced had the telegraph not been available to help coordinate the two-way traffic of trains using common tracks.[60] The elaborate and sophisticated telecommunications system employed by air traffic controllers plays a similar role in modern air travel.

The observation that for some activities telecommunications may be a substitute for travel (e.g., teleconferences may be substituted for business trips) has led to speculation that as the telecommunications infrastructure continues to evolve in the direction of increased functionality, the influence of the transportation infrastructure on the organization of economic activities may be lessened, or, in some cases, even reversed. The research that has been done on this question has shown, however, that transportation-travel relationships are more complex than was originally imagined. While telecommunications may substitute for travel for some activities, it is complementary to travel for others.[61]

Malone, Yates, and Benjamin[62] have predicted that with increasing reliance on communication technologies, we will see more economic activities coordinated by markets and decreasing reliance on hierarchical governance structures such as the integration of sequential stages of a production process within a single firm. This prediction is based on Williamson's[63] argument that hierarchies are employed as alternatives to markets when assets[64] are highly specialized to the production of a fairly narrow range of products and when products (or production processes) are complex and difficult to understand. Both situations make it risky to place much trust in agreements struck in an impersonal market—especially when market conditions and underlying technologies are difficult to predict. Communication technologies are making it pos-sible to handle much more complexity than before and applications of information technology are making production assets more flexible (e.g., computer programmable machine tools). These effects should increase the number of situations in which markets have a comparative advantage over hierarchies as governance structures. However, other writers have pointed out that communication technologies also improve the efficiency of governance within hierarchies, so there is no unambiguous prediction concerning the effect of information technologies on the advantages of firms relative to markets as governance structures.[65] An empirical study by Kambil[66] using a cross section of manufacturing industries found a positive correlation between increased investments in information technology and growing reliance on market coordination, but much work remains to be done on this topic. While it may not be possible to make general predictions regarding the effects of advanced information technology on the organization of other economic activities, it is important that telecommunications policymakers be aware that policy decisions may have very large structural effects—both on the information industries and on the industries that are their customers.[67]

Policy Considerations

Invariably, two critical, politically charged policy issues loom when considering upgrading the current U.S. telecommunications infrastructure: (1) How much will it cost? and (2) Who will pay (and how)? A number of other less emotionally charged, but still vital, questions must also be addressed: Who will be allowed to participate in building it? How will private and public networks interconnect? What is the proper role for government in standards coordination? To what extent can the traditional goals of universal service and rate equity be served under alternative strategies? Is the level of service currently associated with universal service appropriate to an enhanced infrastructure?

It will not be easy sorting through this policy maze because the answer given to any one of these questions will impinge on the answers that can be given to any of the others. Two things that are clear are that the costs of future network upgrades will be substantial,[68] and, barring radical changes in communication policy, that upgrades will be financed almost completely with private money. Unlike most other countries, where telephone companies have traditionally been owned by the government, the telecommunications infrastructure in the United States is largely owned by private concerns, with the dominant public sector subject to extensive regulation.[69] Direct federal and state funding has been restricted to a few specialized networks, mostly for the assistance of education and research, and internal networks designed to facilitate the specialized activities of various government agencies.[70] Transition to a system dominated by direct government investments in the infrastructure is not likely in the foreseeable future.

One option is to proceed along the current course with no dramatic new initiatives. The infrastructure will be upgraded, but very unevenly. Much of the upgrade will take place in private networks operated by major corporations and a few government agencies. The amount of fiber in the public network will increase, but slowly—driven primarily by the replacement of the current copper plant as it obsolesces. Consumers and small businesses will have to be content with a level of service not very different from what they have now for a considerable time to come.

An argument in favor of this approach is that, because it is demand driven, for the most part those who benefit will pay. There is no risk that basic telephone service subscribers will be saddled with the costs of a universal upgrade that provides capabilities only a select few will utilize—those most able to procure advanced services for themselves. In addition, we avoid the danger that too much government oversight and control may stifle the vigorous competition which has fueled the advancement of the private portion of the telecommunications infrastructure in the United States.

The downside of relying primarily on developments in private networks for infrastructure upgrades is that private parties, because they are concerned only with benefits internal to themselves, are unlikely to fund upgrades or promote interconnectivity close to the level desirable from a public policy perspective. Network products that would be more useful to their adopters if developed around a common set of technical protocols will continue to be developed in incompatible forms—as has been the case with end-to-end ISDN—and many interfirm network connections that would provide benefits sufficient to justify the development of common networks will not be developed because the costs of coordinating the plans of diverse private parties are too high.[71] Small firms will be handicapped more by this policy than large firms because large firms can generate enough network traffic internally to realize many of the benefits that are achievable with high-volume usage. However, even large firms will often settle for less functionality than they would like when it comes to connections with other firms and outside contractors and customers.[72]

Greater participation by government in the development of an advanced telecommunications infrastructure could solve some of the problems of private networking, but government involvement raises problems of its own. We are in the process of moving away from an infrastructure dominated by regulated monopolies to one governed by the incentives and constraints of competitive markets. This transition is largely complete in long-distance services, where over 500 firms compete for various segments of this business and only AT&T is still subject to certain dominant-carrier restrictions. However, the bulk of infrastructure investment is still managed by rate-of-return regulated local exchange companies. It is generally accepted that rate-of-return regulation provides incentives for regulated firms to engage in a variety of inefficient behaviors.[73] But regulation at the state and local level also serves a variety of social and political objectives—such as universal service, emergency services, and rate averaging across constituencies with different costs of service—that could not be sustained in competitive markets.

We are now seeing a number of experiments with alternative forms of regulation, such as price caps, that provide incentives to greater efficiency while still providing protection against the threat of unrestrained monopoly pricing.[74] Unfortunately, these do not resolve the tension implicit in the desire to have both competitive pricing and maintenance of services that cannot pay for themselves.[75]

It appears that, for the near term at least, the most vigorous public sector initiatives promoting an advanced telecommunications infrastructure will take place at the state level. Two different approaches are being pursued. While differing radically, both rely on private money to finance infrastructure improvements.

One approach, emphasizing the profit motive and competition, is to create "Telecommunications Free Trade Zones" for major metropolitan areas in which unregulated private carriers are able to openly compete with the current local exchange carriers in the provision of local services. Originally proposed by the former chairman of the Illinois Commerce Commission, this plan would also allow the incumbent dominant carrier flexibility to compete at the margin.[76] New York City is proceeding in the same direction and has already allowed limited local competition. The underlying assumption is that competitive incentives will spur dramatic upgrades in service quality and capabilities, much as we have seen happen with private line service, while simultaneously holding prices to near-cost levels. Vigorous competition in local private line services already exists in several major metropolitan areas, with companies such as Teleport and Metropolitan Fiber Systems (MFS) using high-quality fiber networks to provide both backup and primary services to large corporate users. These companies would ultimately like to extend their services and compete with established common carriers for the patronage of consumers and small businesses.

Local loop competition raises many questions that have yet to be answered. It may only be feasible in large metropolitan areas where calling volume is sufficient to allow a number of competing companies to realize economies of scale. To the extent that this is true, subscribers in major urban areas will be the only ones to realize the benefits of an advanced infrastructure. Further, the limited regulatory proposals to allow local competitive carriers still envision a role for a dominant carrier (the current franchised monopolist) as a carrier of last resort with obligations to provide switching services on a common carriage basis to all comers at broad average rates. This might weaken the incentive of the dominant carrier to maintain the quality of the infrastructure under its control, since local loop competitors would be primary beneficiaries. Unfettered competition is also incompatible with the system of subsidies built into current telephone rate structures. Urban-to-rural and business-to-residential cross-subsidies persist only because current regulated carriers do not have to deal with competitors who would eventually force them to set prices that more closely reflect the (deaveraged) costs of services. The cross-subsidies built into the current system exist because they are politically popular. So it must be asked whether a competitive public infrastructure is politically sustainable in the long run.

If we rely on competitive markets for infrastructure upgrades, questions of who will be allowed to participate must still be sorted out. Modern cable television systems, which already provide enormous bandwidth on subscriber access lines, are particularly well-positioned to upgrade their networks to offer two-way telephone services. This is especially so if new digital radio technology for Personal Communication Services (PCS) evolves in the way many think it will.[77] However, this would require eliminating current regulations that restrict or prohibit telephone services provision by cable companies. If such restrictions were to be eliminated, this would create enormous pressures to simultaneously eliminate restrictions that keep telephone companies out of the cable business.[78]

Tennessee, New Jersey, and other states have been more traditional in their approaches to financing infrastructure upgrades. They would allow regulated carriers to raise rates above what is required to cover minimum earnings requirements by enough to finance the state-encouraged (or approved) upgrades. This approach runs the risk of perpetuating the current system of rate-of-return regulation and its attendant inefficiencies, because, to keep their end of the bargain, regulators will have to restrict competition to the degree required to ensure that dominant carriers can earn the promised capital recovery and rates of return.

Policy Recommendations

If, for whatever social and economic reasons, infrastructure network upgrades become a public policy imperative in the United States, what policy mix would be most effective to achieve the goal? Given the current regulatory system, it would be one emphasizing private incentives to increase investment. That is, policy should change to increase incentives to invest in capital and research and development; in general, policy restrictions on the business opportunities of either entrants or incumbent firms in telecommunications markets should be reduced.

Much could probably be accomplished within the current regulatory regime by modifying regulations that limit RBOC investments in infrastructure upgrades and R&D supporting them, thereby reducing disincentives to make these investments.[79] Restrictions on manufacturing by the RBOCs and their relationships with equipment suppliers are particularly attractive candidates for modification because they prevent the type of close coordination between buyer and supplier that characterizes new product development in high-technology industries.

The same argument could be made for relaxing information services restrictions. Konsynski and McFarlan[80] and other authors have shown that there are often production synergies between networks and the various systems or information applications they support. This does not imply ownership, but does imply partnering and risk sharing, which are discouraged in the current environment.

The current interlocal access and transport area (interLATA) restrictions banning the RBOCs from providing toll services may also create serious production inefficiencies for the provision of value-added services. For example, the interLATA restrictions reduce incentives to invest in so-called "intelligent networks" (backbone data base and signaling networks), which provide efficient platforms for rolling out services. A strict interpretation of the interLATA restrictions might require unnecessary duplication of every unique data base and switching node in every LATA.[81]

What safeguards should be left or instituted to protect captive consumers and entrant firms? This is where regulation must fill a new role—focusing not so much on allocating costs and turf, but on non-discriminatory interconnection policy and ceiling prices for basic service subscribers, while monitoring service quality and enforcing rules and regulations to protect universal service.

Relaxing regulatory restrictions on regulated carriers and their competitors (both actual and potential) should stimulate additional investment in the telecommunications infrastructure; but there is no guarantee that the response will be sufficient to produce an infrastructure with all of the advanced capabilities desired by policymakers. In that case, additional investment might be stimulated through tax incentives, such as investment tax credits and accelerated depreciation deductions. A value-added tax (VAT) on telecommunication service providers might also be considered. A VAT could be placed directly on consumer purchases, as in many European countries; but it would be easier to administer if it were collected from telecommunication service providers, who, in turn, would flow it through to their customers. A VAT would be relatively non-distorting at the margin and it has the added feature that those who benefit most, end users of services and the suppliers who benefit from distribution network upgrades, would pay.[82]

In one scenario, a VAT would be applied to all public network services (including services provided to interconnected private networks) and the proceeds would be invested in the public infrastructure. Complications are that for services, such as transactions processing, that could be performed using either closed private networks or public network facilities, it would raise the price of public network services relative to the costs of private networks. This would discourage use of the public network. However, this effect may be offset by the increased value and functionality that could be obtained by interconnection with the public network infrastructure.

In summary, we offer the following policy recommendations promoting infrastructure investment and competitive alternatives:

- Remove or reduce current barriers to entry, including operating restrictions on incumbents and local franchising barriers on entrants.

- Implement and aggressively enforce easy and open interconnection.

- Implement incentive regulation (such as price caps) to protect captive customers and encourage efficiency of incumbent dominant firms.

- Implement tax incentives to further stimulate investment if more infrastructure financing is needed.

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ENDNOTES

1. Advertiser supported broadcast television is perceived as "free" by many policymakers and their constituents, and this has been the television counterpart of universal service.
2. The National Telecommunications and Information Administration's (NTIA) 1991 infrastructure report is representative of this new appreciation of the strategic significance of the telecommunications infrastructure.
3. For example, New Jersey, Tennessee, and other states have already begun to implement network upgrade plans, and many states are in the investigation phase through formal proceedings conducted by either the governor's office, usually through the executive agency for state economic development, or the regulatory agency. The federal government as well has several bills pending in Congress. Prominent among them is the Gore bill promoting investment in research and education networks. This initiative is discussed in more detail by Stedman and Bransford in this volume. Other bills and sponsors promoting investment which have recently been introduced include: HR 2546 (Rep. Boucher), HR 3701 (Rep. Ritter), S 218 (Sen. Inouye), S 1200 (Sen. Burns).
4. Success stories regarding specific technologies include computer reservation systems (CRSs), automatic teller machines (ATMs), and credit card verification and debit systems. Among firms frequently cited for profiting from information technology investments are Federal Express, UPS, Wal-Mart, Holiday Inn, and Boeing. See the recent articles by Coy (1992) and Stewart (1992).
5. The literature on transaction and coordination costs builds on seminal articles by Coase (1937) and Hayek (1945). Both are recent recipients of the Nobel Prize in Economics--testament to the growing importance of this line of economic inquiry.
6. Williamson (1985) is probably the best introduction to this literature. See also Malone, Yates, and Benjamin (1987) and Kambil (1991) for applications to the study of the effects of information technology on organizational structures.
7. NTIA, 1991, p. 13.
8. Dedicated facilities usually are used by only one entity (e.g., firm).
9. FCC common carrier statistics, 1991, and annual reports.
10. Author estimate based on annual investment data from the Electronic Industry Association and the U.S. Commerce Department. The data for consumer premises equipment assumes a five-year useful life of gross investment. The private network data includes local and metropolitan area networks (LAN/MANs) and may contain some terminal equipment causing double counting. Excluded are investments in computers, software, and systems support, which may be used in some of the networks.

11. According to United States Telephone Association data for 1990 and 1991, Local Exchange Carrier annual capital additions are running at an average of 7 percent, while depreciation is a bit higher at almost 8 percent.
12. As opposed to those, like stand-alone computing applications, VCRs, and CDs, which would most likely not be linked in physical networks.
13. Egan (1992b), Section 4, and Melmed and Fisher (1991) look at a few examples of intangible benefits to public services administration through network technology adoption.
14. A. Melmed and F. Fisher, "Towards a National Information Infrastructure: Implications for Selected Social Sectors and Education." New York, NY: Center for Educational Technology and Economic Productivity, New York University, December 1991.
15. There have already been uses of remote imaging technology over high-speed fiber optic network links and the practice is expanding. In their article, Melmed and Fisher list several categories of health care costs, totaling hundreds of billions of dollars, which are potentially "avoidable" using advanced telecommunication networks and digital data bases.
16. The "Gore" bill is a proposal by Tennessee Senator Al Gore to upgrade and expand the existing National Science Foundation network (NSFnet), connecting major universities and research centers nationwide, from current digital 1.5 megabit per second transmission rates (DS1) to 45 megabits per second. Initial appropriations are for about $20 million. Dubbed the National Research and Education Network (NREN), there is also a future proposal to further expand access for primary schools; such expansion is projected to cost over $2 billion.
17. Wider application of networking technologies in and among research organizations may also lessen the tradeoff between specialization and interdisciplinary collaboration (Allen and Hauptman, 1990).
18. Telecommunications-delivered educational services may also be used to increase the effectiveness of home education for grades K-12, which, due to parental dissatisfaction with the traditional system, has been estimated to be growing at 30 percent annually.
19. See Melmed and Fisher, op. cit.,for a partial survey of this literature.
20. A.D. Little (1991) estimates $23 billion (1988 dollars) in annual benefits to society. These conclusions are disputed by other researchers, however.
210. For example, a home office worker might want to be able simultaneously to access a data base resident in the business mainframe, make and take telephone calls, and receive facsimiles. The next generation of narrowband digital network upgrade, or Integrated Services Digital Network (ISDN), operating at 144 kilobits per second on a single copper access line, would allow for such simultaneous applications. For some detail on the costs and capabilities of such a network upgrade, see Egan (1992a).
22. Teleshopping is already possible over Prodigy and smaller dedicated shopping networks in some areas. However, consumer acceptance is low. This is due in part to the lack of ease and convenience of these types of electronic transactions on the relatively low bandwidth public network.
23. For individual households, technology adoption improves the standard of liv-ing through time savings by doing things "better." Two primary sources of welfare

gains from time savings include the increase in leisure time, or time spent in an alternative productive activity previously forgone, and the quality of life generally.

24. F.T. Juster and F.P. Stafford. "The Allocation of Time: Empirical Findings, Behavioral Models, and Problems of Measurement." *Journal of Economic Literature,* June 1991, 29, pp. 471–522. Often, measurement of the value of many personal activities is relatively straightforward because they are available for purchase from third parties in the marketplace, such as child care and housecleaning. Others are hard to evaluate because they are problematical for third party performance. Some examples are: personal care activities like getting ready for work (and getting back to normal afterwards), leisure and recreation activities like enjoying a movie or reading a book, thinking, and learning. Interestingly, but perhaps not so surprisingly, personal care activities take up a substantial portion of an individual's time, in fact, double that of paid work time according to a University of Maryland study. Even personal care time, which at first glance does not seem to have any potential relationship to electronic technology adoption in a household, may be indirectly related. No doubt some portion of that time might be saved by telecommuting, shopping, or learning from home. At least dry cleaning bills may go down. See Egan (1992b), Section 4-Demand Side Considerations, for a more detailed treatment of these issues.
25. See, e.g., Keen (1988).
26. Among the best known success stories are those of American Airlines with its Apollo computer reservation system; Citicorp's cash management services and ATM network; American Hospital Supply (AHS) and its ASAP order entry system that enabled its hospital customers to use dedicated terminals on their premises to place orders through AHS's mainframe system; and Wal-Mart, which pioneered in the development of a novel ordering and inventory management system.
27. Loveman (1990).
28. Dataquest (1992).
29. From 1935-1991 inflation in the general economy averaged 4.2 percent while for telecommunications it was only 2.1 percent. Over the last decade when inflation averaged 4.1 percent for all goods and services and 5.2 percent for the services sector, telecommunications services averaged only 3.5 percent (Bureau of Labor Statistics, 1992).
30. Airline computer reservation systems evolved in this way. Cash management services offered by commercial banks to consumers and business borrowers, new financial instruments, and electronic trading mechanisms are other examples.
31. The current buzzword for this movement is *reengineering*. As a discipline reegineering is still in a formative stage, as no dominant paradigm has yet emerged that can be employed to describe the activities of its practitioners. See Hammer (1990) and Davenport and Short (1990), for introductions to reengineering. See also Stewart (1992) for a brief introduction to the topic.
32. The French state-subsidized Minitel System, which makes simple terminals connected by the public network available to all French citizens, has become an important source of facilitation services for small business in France.
33. For an in-depth treatment of the importance of common standards in telecommunications, see Besen and Saloner (1989).
34. Farrell and Saloner (1985). See Leontief (1983) for an early statement of this argument.

35. National Telecommunications and Information Administration, *The NTIA Infrastructure Report: Telecommunications in the Age of Information.* Washington, DC: U.S. Department of Commerce, October 1991. This study is reviewed in depth in Jonathan Aronson's chapter in this volume.
36. For example, ATM and CRS networks make use of the public data networks.
37. Such is the case with the extensive Wal-Mart network. For a detailed discussion of the interesting public policy implications of such arrangements, see Weisman (1988).
38. R. Harris, "R&D Expenditures by the Bell Operating Companies: A Comparative Assessment," presented at the Twenty-third Annual Conference, Institute of Public Utilities, Michigan State University, Williamsburg, VA, December 9, 1991.
39. R. Blau and R. Harris, "Strategic Uses of Regulation: The Case of Line-of-Business Restrictions in the U.S. Communications Industry," forthcoming in J.E. Post, ed., *Corporate Social Performance and Policy.* JAI Press, 1992.
40. Ibid.
41. Private correspondence from Robert Blau, July 1992.
42. Blau and Harris, op. cit.
43. S.S. Roach, "Policy Challenges in an Era of Restructuring." Morgan Stanley & Co., January 8, 1992.
44. Federal Express's failure with ZAP-mail is one example.
45. For example, Citicorp, an early and successful innovator with information technology in banking, is now struggling and its woes are attributed in part to an outdated technology strategy (Caldwell, 1992).
46. B.L. Dos Santos and K. Peffers, "Rewards to Investors in Innovative Technology Applications: A Study of First Movers and Early Followers in ATMs." Krannert Graduate School of Management, Paper no. 1014, Purdue University, November 1991.
47. T.F. Bresnahan, "Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services." *American Economic Review* 76, September 1986, pp. 742–755.
48. S.S. Roach, "America's Technology Dilemma: A Profile of the Information Economy." Special Economic Study, Morgan Stanley & Co., April 22, 1987; "The Technology Trap." *Economic Perspectives,* Morgan Stanley & Co., December 15, 1989, "Services Under Siege – The Restructuring Imperative." *Harvard Business Review,* September-October 1991, pp. 82–91; "Policy Challenges in an Era of Restructuring." op. cit. Roach has written extensively on this subject, including several articles not cited here. For a more comprehensive review see the references in Panko (1991).
49. A number of other researchers, such as Strassman (1990), have reported studies supportive of Roach's position. For an extensive and insightful review of the mushrooming literature on this topic, see Brynjolfsson (1991).
50. G.W. Loveman, "An Assessment of the Productivity Impact of Information Technologies." MIT Working Paper 90s: 88-054, September 1990.
51. Roach, the most prominent critic of information technology spending, is now predicting that we have turned the corner and will soon begin to see substantial improvements in productivity figures (Roach, 1992).
52. M.N. Baily and A.K. Chakrabarti. *Innovation and the Productivity Crisis.* Washington, DC: The Brookings Institution, 1988.

53. See, e.g., Panko (1991) and Baily and Gordon (1992) for particularly harsh critiques of BLS methodologies and productivity estimates based on them.
54. P. Osterman, "The Impact of Computers on the Employment of Clerks and Managers." *Industrial and Labor Relations Review* 39, January 1986, pp. 175–186.
55. Brynjolfsson (1991) attributes this argument to Brooke (1991).
56. E. Salomon, "Geographical Variations in Telecommunications Systems: The Implications for Location of Activities." *Transportation* 14, 1988, pp. 311–327.
57. Baily (1992) is an example of recent empirical work on this topic.
58. Baily and Gordon (1988, p. 389) state: "Outside of manufacturing, the communications industry stands out as a service industry that has invested heavily in electronics and achieved rapid productivity growth by doing so."
59. Evidence submitted in FCC Docket CC 87-313, the "Price Cap" docket.
60. DuBoff (1983).
61. Salomon (1988).
62. T.W. Malone, J. Yates, and R. Benjamin. "Electronic Markets and Electronic Hierarchies." *Communications of the ACM* 30, June 1987, pp. 484–497.
63. O.E. Williamson, *Markets and Hierarchies. Analysis and Antitrust Implications*. New York: Free Press, 1975; and *The Economic Institutions of Capitalism*. New York: Free Press, 1985.
64. Productive assets may be physical assets such as machines and buildings, human assets such as specialized knowledge or skills, or intangible assets such as business reputations and brand image.
65. See, e.g., Gurbaxani and Whang (1991).
66. A. Kambil, "Information Technology and Vertical Integration: Evidence from the Manufacturing Sector." in M.E. Guerin-Calvert and S.S. Wildman. *Electronic Services Networks: A Business and Public Policy Challenge*. New York: Praeger Publishers, 1991, pp. 22–38.
67. For example, new market structures and practices stemming from the adoption of information technologies have been the subjects of investigation and intervention in banking and airlines. Policy issues raised by transaction processing networks are examined in Guerin-Calvert and Wildman (1992).
68. In fact, so substantial that the research to date indicates a serious capital shortfall in private markets to wire the entire nation with digital fiber optics, or even hybrid fiber/metallic/radio combinations for broadband services. For a survey of costs see Egan (1991, Chapter 7; 1992b, Section 2, Supply-Side Considerations; and 1992c, Table of Network Upgrade Costs).
69. However, an international trend encouraging privatization and competition in telecommunications has developed.
70. For example, the Federal Aviation Administration has a nationwide network for monitoring air traffic and coordinating air traffic controllers.
71. The importance of a full set of end-to-end standards is often not appreciated. In the United States, more than 10 years after initial, and supposedly universal, technical standards for ISDN were thought to have been worked out, we are finally beginning to realize the benefits of truly compatible equipment in the new National ISDN Plan to go into effect by 1993. It took a lot of trial and error and about three generations of negotiated ISDN standards agreements to finally get to where we are today. We risk similar problems with public network

upgrades for broadband ISDN and new digital radio technologies and their software operations and support systems.

72. This is evident in the interview with Hewlett Packard executives reported in Bar (1990).
73. For example, under certain conditions rate-of-return regulated firms may find it profitable to raise prices on regulated services to subsidize their offerings in competitive markets. See Kahn (1971) for a general treatment of this and related issues, and Crandall and Owen (1984) for a discussion of the application of the underlying theory in the government's case against the Bell System that ultimately led to divestiture.
74. Price cap regulation is basically an agreement between the regulator and the telephone company to freeze the overall level of prices for captive customers (e.g., basic residential and small business services) in return for a profit incentive provided by a relaxation of the strict rate of return on the net investment (rate base). For a description of price cap regulation in practice see the documents filed in FCC CC Docket 87-313.
75. It is impossible to know to what extent business investments in private networks are responses to prices for public network services that are substantially above marginal cost--a consequence of current policies governing the pricing of public network services.
76. Barnich, Clausen, and Monson (1991). See also Andrews (1991).
77. Cable network operators are rapidly upgrading the trunk portions of their systems with fiber optics to prepare for enhanced service offerings, including two-way service. For a discussion of the status of cable plans see *The Cable-Telco Report*, June 1992.
78. For a comprehensive discussion of these issues, see Egan (1991, chapters 9-11; 1992b; and 1992c) and Reed (1992).
79. Under current restrictions, not only are profits on capital capped by traditional regulation, but returns to R&D are restricted. Basic research is allowed, but all returns from software or hardware applications can only accrue to others not bound by restrictions on design, development, and manufacturing work (the "D" part of R&D). Partnerships and risk sharing are also disallowed.
80. B.R. Konsynski and F.W. McFarlan. "Information Partnerships—Shared Data, Shared Scale." *Harvard Business Review*, September-October 1990.
81. While probably intended to foreclose the RBOCs from participating in traditional toll service markets, a strict interpretation of the current Modified Final Judgment restriction indicates that it may be illegal for RBOCs to share network data bases or signaling nodes among LATAs. As there are many LATAs, this could result in a manyfold increase in the total cost of deployment.
82. For some details on how such a tax might work, see Egan (1992d).

TELECOMMUNICATIONS INFRASTRUCTURE AND U.S. INTERNATIONAL COMPETITIVENESS

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The relationship between telecommunications infrastructure investment and competitiveness is clouded by two unresolved debates. First, the "productivity paradox" notes that since the 1970s, despite heavy investment in infrastructure, service sector productivity appears to have stagnated. It is unclear, however, that new investment in telecommunications infrastructure will increase productivity and improve competitiveness. Second, debate rages over whether the United States is safely ahead or falling dangerously behind its key competitors in modernizing and extending its telecommunications infrastructure. Policymakers cannot decide what they should do, if they have no idea how they are doing. This paper considers these debates, suggests what needs to be done and how it might be implemented. It pays particular attention to whether monopoly modernization or market competition is best equipped to produce an efficient, affordable communications infrastructure in a timely manner and to the responsibilities of government regulators under these arrangements. Finally, it raises several broad questions that require further study.

This paper explores the relationship between modernizing telecommunications infrastructure and maintaining global competitiveness.[1] Many countries now believe that modern telecommunications is critical to their future productivity and competitiveness in global commerce. Telecommunications and information services represent a growing share of GNP almost everywhere. Modern telecommunications helps other services to act globally and think locally. Additionally, telecommunications accounts for an increasing share of the value added to almost every manufactured product. Today, academics and policymakers routinely assert that just as transportation was at the heart of postwar industrial expansion, telecommunications is the key to thriving in the emerging world information economy. Firms are told that they need better communications and information systems to retain their competitiveness.[2] For individuals, it is claimed, "information is power, and the key to empowering Americans is to give them access to it. Information is the public's No. 1 need."[3] If these statements approximate reality, then they have profound policy implications about government's regulatory role and responsibilities within the unfolding information economy.

The first section of this paper reviews the evidence that improved communications allows for cheaper, improved access to information which leads to greater productivity and competitiveness while creating as many new jobs as it makes redundant. The next section examines the debate over how the U.S. telecommunications network compares to networks in other countries. It considers whether the U.S. lead in telecommunications has eroded or remains ahead of the competition. The third section explains how the vested interests of major U.S. corporate players translate into the policies they support. The fourth section suggests priorities and strategies for policymakers to break the policy logjam.

INFOSTRUCTURE AND COMPETITIVENESS: RAILROADS FOR THE INFORMATION ECONOMY

Productivity

Many countries recognize the need to reorganize their telecommunications systems to make them more of an engine of growth for future development. Since the mid-1980s, telephone companies from Germany to Japan have been privatized or corporatized (separated from their regulators but still are owned by the government). In addition, all or part of the national telephone companies of Chile, Argentina, Venezuela, Mexico, and New Zealand were sold to foreign interests.

Many other telephone companies in places as diverse as Hungary, the Netherlands, Portugal, Australia, Brazil, Malaysia and Singapore, Panama, and Uruguay could be sold. Moreover, Australia and Thailand are creating second telephone companies to compete with their long-established monopolists, and in mid-1992 Canada decided to permit competition in long-distance telephone service. None of these new arrangements provides for complete foreign ownership and in every country governments continue to regulate telephone company behavior.

Suppliers and users of communications equipment and services throughout the industrial world are trying to persuade their governments to increase infrastructure investment to promote growth and development. So far, however, direct evidence of the consequences of new investment are largely anecdotal. Charles Jonscher contends that "studies in Kenya, the Philippines, and Costa Rica indicate that benefits (of additional telecommunications infrastructure investments) exceed annualized costs by a factor of at least 5 to 1."[4] His model also suggests that the introduction of productivity-enhancing information technology will increase national competitiveness and that while at first these new technologies reduce labor input requirements, in a strong economy the ultimate result will be increased output, not reduced employment.[5] Predictably, Jonscher's theoretical framework has been criticized and efforts to replicate his finding using data from the United Kingdom and Australia have faltered.[6]

So far few firms have tried vigorously to use new communication and information technology to redesign their business processes, but it is often suggested that firms that make the commitment will realize major productivity gains.[7] An important empirical study undertaken by Data Resource/McGraw Hill for 11 major U.S. telephone companies, including all seven regional Bell operating companies (RBOCs), concluded that since 1963, "the average industry increased its rate of telecommunications consumption by more than 150%; some industries increased their usage by more than 800%." In addition, the "empirical evidence comparing the use of telecommunications in the economy in 1963 and 1982 strongly supports the conclusion that increased telecommunications investment and usage causes economic growth in later years."[8] However, when the analysis focuses on the individual firm, the results are more ambiguous. It is unclear whether the provision of advanced communications and information technology results in productivity gains. Apparently while computing and communications power increased dramatically since the 1970s, service sector productivity stagnated. Explanations of this so-called "productivity paradox" are overlapping and conflicting. Hypotheses that begin to explain the paradox include measurement error, time lags in productivity payoffs, redistribution among firms without adding to total output and mismanagement, misallocation, and overconsumption by managers.[9]

Competitiveness

In 1984 a report prepared by the New York Stock Exchange argued that, contrary to popular perception, U.S. manufacturing industries were as competitive internationally as in previous decades and that they were for the most part completely competitive with their European and Japanese counterparts.[10] Since then, economic tension involving the United States, Europe, and Japan has increased and fears that American firms were losing their competitive edge became a U.S. national obsession. In 1990 the Technology Administration of the U.S. Department of Commerce reported that the United States was losing ground badly to Japan on a wide variety of cutting edge technologies including: advanced materials, biotechnology, superconductors, digital imaging equipment, advanced semiconductors, high-performance computing, high-density data storage, medical devices and diagnostics, sensor technology, fiber optics and lasers, and other technologies. They identified no key cutting edge technologies where the United States was widening its lead versus Japan. By contrast, although the United States lost ground to Europe in areas such as digital imaging technology, flexible computer-integrated manufacturing, and medical devices and diagnostics, the Technology Administration found that in many other areas it had retained or widened its lead.[11] The Bush administration, to deal with the perceived decline, established the U.S. Council on Competitiveness chaired by Vice President Quayle, which has tried to remove or limit environmental and other regulations it believes might hamper the competitiveness of large U.S. firms. However, the Bush administration explicitly avoided actions to promote a proactive government-business partnership that might be characterized as an industrial policy.[12]

One way the United States might rebound is to invest heavily in new telecommunications infrastructure to bolster U.S. productivity and competitiveness. The European Community estimates "that every dollar invested in current generation telecommunications infrastructure produces 1.5 dollars of increased economic activity. This is one of the highest known indirect industrial multiplier effects."[13] Clyde Prestowitz puts it succinctly: "In the next century, roads and bridges will not be enough. To compete, Americans will need digital libraries, high speed trains, and a telecommunications network based on optical fibers. Europe and Asia are already ahead of the United States in developing such an infrastructure, but it need not be terribly expensive to catch up."[14] Alarmed that public infrastructure spending fell from 2.3 percent of gross domestic product two decades ago to just 1.3 percent in the 1980s, *Business Week* now supports the establishment of an explicit U.S. industrial policy even though it might be labeled as a growth policy or a technology policy.[15] It argues that part of the answer is to refurbish the decaying transportation infrastructure, but that it also is critical in the 1990s to build "up a communications infrastructure that can support information-intensive industries. A communications conduit made up of fiber-optic cables and high-speed digital switching equipment . . . could have an economic impact such as the interstate highways did in the 1950s and 1960s."[16] Similarly, former Reagan White House Science advisor George Keyworth argues that the "single most important thing that the U.S. could do now to promote U.S. industrial interests is to speed the wiring up of this country with a fiber optic communications network." More ominously, he warns that the United States is "rapidly approaching the point where lack of that digital network will become our competitive disadvantage."[17]

Similarly, Robert Cohen argues that large investments in broadband communications technologies would "represent a major new source of sales for a number of critical U.S. industries, such as computing, communications equipment, imaging, and storage devices. The new revenues could greatly bolster U.S. competitiveness by increasing the chances that these industries take the lead in a key area of technology development that has vast resources to support new research and development. Given the massive, government-backed efforts to create advanced communications infrastructure" in countries like Japan and France, this could contribute to the long-term competitive status of U.S. firms.[18]

Sectoral Examples

In many industries communications accounts for an increasing share of total costs. As they spent more on communications, these industries grew concerned about controlling costs. Large business users no longer were willing to pay more than their fair share so that governments could subsidize post offices, rural communities, small business, and local calls. Large users began to organize and lobby for more cost-based pricing schemes first in the United States, and now worldwide.

The finance, insurance, health care, travel, and tourism industries and major manufacturers all depend on affordable, efficient long-distance and international communications for voice and data traffic. For example, the Society for Worldwide Interbank Financial Telecommunication (SWIFT) provides interbank clearing functions globally for member banks. SWIFT's computer and communication system must be extremely accurate and efficient because each week the value of interbank transactions equals the total annual value of global trade.[19] If the system breaks down transactions worth millions of dollars could be lost in the network.

Airline reservation systems, such as Sabre and Apollo in the United States, Galileo and Amadeus in Europe, and Abacus in Asia, allow international airlines to track luggage and passengers around the world. As these regional airline reservation systems become linked, they provide their owners with global competitive advantages. Similarly, Reuters has created a new global ordering system which for the first time allows long-distance competition in many automobile parts markets. These examples reflect a dual trend. Greater information capabilities allow firms to globalize and also make it more efficient for firms to work with others to build cooperative networks geared to global markets.

Similarly, doctors increasingly are using information technologies tied to communications to assist in diagnosis and treatment, and to manage hospital administration.[20] In addition, the insurance industry now relies more on electronic processing of claims, transforming claims administration "from a proprietary service into a commodity. This means insurers increasingly will compete on ability to gather medical as well as financial data and to use them to manage the health costs of their customers."[21]

Many firms, to improve management efficiency, are turning to global Electronic Data Interchange (EDI) to link manufacturers, their suppliers, and their customers. One reason General Motors purchased Ross Perot's EDS was to acquire the expertise to tie together all of its disparate operations into a single integrated system which could then be extended to cover suppliers, dealers, and even customers. Similarly, a textiles or apparel firm might benefit enough from the efficient just-in-time management of its inventory and production runs to offset differences in labor costs between the United States and Asia. A striking case is the operations of Benetton, an almost hollow corporation with only two strategic assets, its brand name and a leading EDI network. Its sales of clothing exceed $1.2 billion annually, but Benetton owns virtually no manufacturing capacity. Instead, it spends millions of dollars each year on information systems to tie together its supplier mills, headquarters, worldwide agents, and more than 50,000 stores in 80 countries (many of which have point-of-sales terminals). Benetton developed a new set of standards to describe the colors of textile fabrics so that it could mix and match suppliers as needed. Its EDI system provides virtually all of the paperwork, ordering, and logistics of its network of suppliers and distributors. The sales information that comes in throughout the day allows for almost instantaneous ordering of new supplies and adaptation to the market. As a result, Benetton can respond rapidly to market conditions, and it has cost advantages made possible by relatively speedy delivery, low inventory costs, and customized delivery services which can preclear customs. Benetton provided a set of industry classifications to make the system work, but the assembly and delivery of the EDI network was done by General Electric Information Services (GEIS), which some analysts estimate has at least 40 percent of the global EDI market.

Schools also are beginning to use advanced communications to improve education and make it more cost effective. Several countries, notably France and Singapore, have made computer literacy and computer facility for their students and ultimately their entire work forces a top priority. The United States has lagged, but in early 1992 discussions that included the military, the U.S. Chamber of Commerce, academics, MCC, and computer manufacturers discussed putting a personal computer (preferably made in America by American workers) on every desk in every U.S. classroom by the end of the century. Schools would receive free computers, software, networking assistance, and teacher training. The military and business firms might be granted access to the computers and the network in the evenings and on weekends to help train National Guard and reserve units and workers. Discussions stalled, but Whittle Communications (which is 37.5 percent owned by Time-Warner and 25 percent by Philips) is proposing to create by 1996 a network of 200 for-profit schools, dubbed the Edison project, linked by sophisticated computer and communication networks.

INTERNATIONAL COMPARISONS: HOW IS THE UNITED STATES DOING?

Proponents of making modernization and expansion of the telecommunications infostructure a U.S. policy priority make two main assertions. (1) On the positive side they make a "Field of Dreams" argument—"If you build it, they will come."[22] They contend that if the modernization of the existing telecommunications network is accelerated, huge new demand for telecommunications services will develop. These optimists also caution that "public demand will not manifest itself in the absence of a public access network."[23] (2) Pessimists warn that if the United States does not accelerate network modernization, U.S. productivity and competitiveness will suffer relative to its major strategic competitors—Japan, Germany, France, and even Canada.

Other groups challenge these assertions. They worry that network modernization will turn into a wasteful giveaway that will accelerate the replacement of copper with optical fiber, but will mainly benefit the RBOCs, not the public. They fear that policies that are designed to accelerate the installation of the RBOCs' fiber networks will squeeze out investments that might otherwise go to smaller companies that champion innovative and perhaps more promising communications technologies. Critics are particularly concerned that network modernization will provide little or no return on the investment for consumers and business users which ultimately will have to pay for the new investments.

This section focuses mainly on the second issue, whether U.S. network modernization is keeping pace with its major competitors. This debate, which is examined in detail in a major report prepared for the National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce[24] is described and then recast in wider terms.

There are three main disputants and a late entry into the fray: (1) MESA Associates, in a report funded by the RBOCs and other local exchange carriers, argues that the United States is beginning to lag dangerously behind;[25] (2) A report on capital formations prepared by Larry Darby for the telephone companies also supports this view;[26] and (3) In contrast, a report by Economics and Technology, Inc. (ETI),[27] which was sponsored by the Consumer Federation of America and the International Communications Association, attacks Davidson's data and analysis and presents a rosier picture of the state of telecommunications investment in the United States compared to what is happening elsewhere. The differences in views are so vast that the NTIA Infrastructure Report devoted an entire chapter to an analysis of the relative merits of the positions.[28] Subsequently, both sides refined their positions and jousted in public forums and in print.[29]

In 1992 a new voice, the Electronic Frontier Foundation (EFF), founded by software developer Mitchell Kapor, entered the debate arguing that there were better ways to improve the U.S. telecommunications network than concentrating on laying fiber. EFF favors rapidly deploying narrowband Integrated Services Digital Networks (ISDNs) and to provide a "digital information platform" from which it will be possible to jump start an information revolution."[30]

Davidson's core position is that although the United States may have a larger investment in installed communication infrastructure than any of its competitors, in recent years U.S. investment per access line (an indicator of network modernization) has trailed most of its key industrial country competitors. Focusing on public telecommunications networks, Davidson complains that although "total U.S. investment in public network infrastructure averages less than $200 per access line per year, and has declined for four consecutive years (1986–1989), Japan, the United Kingdom, Canada, Switzerland, Germany, and other nations report sustained investment programs at levels 50 to 150% higher than the United States."[31] In addition, Davidson strenuously argues that the United States is lagging badly in the deployment of several advanced technologies, particularly digital switching capacity, fiber optic cable, ISDN rollout, and SS7 (Signaling System 7, an advanced out-of-band signaling system). On the basis of his data and analysis, Davidson concludes that compared to its main competitors the United States is soon likely to have an old-fashioned communications infrastructure and thus that U.S. productivity and competitiveness vis-à-vis its major industrial country competitors is at risk. Predictably, he favors policies that would unchain the telephone companies and make it profitable for them to spend more heavily on new technologies and network modernization.

By contrast, Montgomery, et al., contend that the U.S. telecommunications system is in "great shape." They point out that the capital stock of U.S. infrastructure dwarfs what is installed elsewhere, that penetration levels are among the highest in the world, and that U.S. usage and quality levels are unsurpassed. They disagree with Davidson at almost every turn. They question his data, disparage his methodology, and attack his conclusions. Their key criticisms, which Davidson fends off with varying degrees of persuasiveness in subsequent interventions, include: that his comparative investment figures are not compatible and often are misleading, that he does not properly take into account exchange rate changes, that he does not properly take into account investment in private networks, and that his U.S. sample is limited to the regional Bell operating companies but excludes other local exchange carriers.

Part of the problem in reconciling this debate is that it is a "grass is green—sky is blue argument." Montgomery, et al., are most convincing when they focus on the impressive "stock" of investment in U.S. telecommunications infrastructure. Davidson is sometimes bloodied, but his fundamental point that the trends in current investment (the "flow") do not favor the United States appears to stand up. (Darby also makes the stock/flow distinction.) Both sides score points. This is reflected in NTIA's attempt to grapple with the differences. Trying to stake out some middle ground, NTIA concludes that "the United States is a nation with a highly developed infrastructure, characterized by a very high access-line density, a robust level of telephone usage, and a heavy emphasis on 'modernization.' At the same time, the U.S. annual growth rate in public telecommunications investment per line related to modernization during the 1980s, on average, was negative."[32]

What is curious about the exchanges on comparative modernization, beyond the deep disagreement, is that both sets of authors and, indeed the NTIA which refereed the bout without declaring a victor, chose not to place the debate into a broader context. Yet these trends and data can be viewed through at least three different lenses.

First, there is the "declining hegemony" or "growing plurilateral" perspective. Political scientists, economists, and historians all have noted that although the United States still is the economic pivot of the world economy, the gap that separates the United States from its competitors is narrowing. The United States still is first among equals, but international decision making is becoming more plurilateral. Postwar U.S. economic hegemony has eroded as other industrial countries scrambled to catch up. From this perspective it is entirely predictable that Japan, France, Germany, and other industrial countries as well as aspiring developing countries such as Korea and Singapore would spend heavily on infrastructure to close the gap that separates them from the United States. These changes are as much about Europe and Japan and rebounding as they are about the United States failing to keep pace. Take the case of Germany. Not only must it spend heavily to replace the old East German network, but it must compensate for past mistakes. For example, the German Bundespost made a mistake when it continued to install cross-bar switches throughout the 1970s and 1980s. In the late 1980s only 2 percent of German's switches were digital. Not only did this slow down Siemens' technological progress, but now Germany must invest much more than its counterparts to catch up.[33] Thus, nobody should be surprised or alarmed that the gap is closing in the area of telecommunications investment. It was inevitable that as the power gap narrowed other industrial countries would spend heavily to close the infrastructure gap as well. Indeed, as the sophistication of the networks in other countries approach parity with the United States, this may improve the competitiveness of U.S. firms. This would be the case if U.S. firms, many of which still have better internal communications systems than their competitors, can manage their global operations more effectively because networks are improving elsewhere.

A corollary point that springs from this same perspective relates to the dichotomy between the *modernization* of an existing network (e.g., replacing copper with fiber or analog with digital switches) and the *extension* of networks (green field investment) to new customers or services. To the extent that investment funds are available and returns on new investments are probable, the incentive to pour new money into telecommunications infrastructure is greater where penetration and usage lag. As long as existing service is reliable and affordable, there is likely to be less demand from customers for fancy, expensive new services which have yet to prove their value. As a result, U.S. telecommunications providers inevitably worry more about modernizing existing networks while other countries are relatively more concerned about expanding their networks. This often makes telecommunications infrastructure investment a higher political priority outside the United States than within it. Moreover, once funds are allocated, the logic and temptation to try to leapfrog existing technologies for a small incremental price increase are great. Predictably, countries where investment funds are available will opt for state-of-the-art equipment.[34]

The second perspective hinges on the ongoing argument being waged around the globe about how to most efficiently modernize and extend national networks. Most countries are opting either for a monopoly modernization model or to introduce far-reaching competition. There is growing consensus in most countries that it is desirable to streamline regulation and allow at least limited competition in the provision of customer premises equipment, information services, and mobile services. The lines are much more sharply drawn about the benefits of competition in the provision of local and long-distance voice services.

Battles are under way in many countries to determine who will control the national network in the future. On one side, the established telecommunications organizations (TOs), which long have supplied basic telephone services, argue that they alone possess the technological expertise and financial wherewithal to build and operate the new networks. They favor a monopoly modernization approach that stresses steady, predictable expansion of services that would be difficult to offer in the absence of a long-term commitment. They argue that the logic of universal service provided by a single monopoly still is intact and that it would be wasteful lunacy for countries to invest scarce capital in expensive, duplicative networks. They paint a dark picture of the future where new competitors will fail to provide promised services or will charge prohibitively high prices. They warn that problems of incompatible standards and poor interconnection will balloon. As a result, they assert, national economies everywhere will suffer if competition is allowed to run rampant. They concede that competition in the provision of information services may be acceptable, but they want those services provided over their own standardized, backbone networks. Furthermore, the established TOs still want the right to provide all new services in competition with would-be newcomers.[35] Finally, although the TOs have started to drop their prices substantially in the face of new competition, they often continue to collaborate to provide international services.

On the other side, potential new competitors, many based on computer, mobile, or broadcast technologies, clamor to be allowed to compete to provide services across the board. They argue that changing technology, economics, and politics make old-style arguments for monopoly provision of services and infrastructure obsolete and urge that the market be allowed to decide. According to this view the TOs are doing everything possible to cling to their power and prerogatives. Their primary goal is to fend off and if possible bankrupt their new competitors. The new entrants contend that the TOs resist change and have introduced new services and tariff reforms only because of competitive pressure.[36] They argue that if they want to risk their money to provide better services at a better price, they should be encouraged to do so. Large customers, most of which do not want to enter deeply into the business of providing telecommunications services themselves, favor competition.[37] Equipment manufacturers, eager to expand the ranks of their customers, also would like new firms to sell to, but they are quieter in this position because they do not want to alienate their TO customers.

Although the monopoly-competition dichotomy rarely is articulated in the Davidson-Montgomery debates, it underlies their differences over infrastructure investment. Davidson comes down squarely on the side of monopoly modernization. He has frequently expressed his admiration for the Singapore monopoly modernization model of telecommunications development and for France Telecom and particularly its Minitel experiment. He has testified as an expert witness for Bell Canada against the introduction of extensive competition, arguing that allowing new entrants into the core communications business would be counterproductive and inefficient. In general, he supports the RBOC-TO position that they have the expertise to modernize the network and would do so if regulators would remove barriers that limit returns on investment and discourage modernization. Davidson notes that ceding the initiative to interlopers and large users could force a rebalancing of rates in ways that would seriously undermine small and rural users and could damage the commitment of many governments to provide universal telephone service at affordable prices.

By contrast, Montgomery, et al., worry that the RBOCs and other TOs mainly are interested in maximizing their own profits and discouraging new entrants. They concur with the variety of economic and technological rationales that have been used in the United States, the United Kingdom, Japan, and most recently Canada to justify sanctioning competition in basic services and the construction of competing infrastructures. In essence, Davidson and the RBOCs favor the planned expansion and extension of new services on a rational timetable to keep costs in line while Montgomery, et al., prefer a demand-driven model in which large users and other customers are the final arbiters of what services are successful.

A third perspective, which is an extension of the second, focuses not on investment to modernize telecommunications infrastructure but on the results of the investment. Put simply, what if those who invest the money make bad choices? What if they choose the wrong technologies?

Again, underlying the Davidson-Montgomery debate is the question of results, not just expenditures. Thus, Davidson, in effect, embraces the idea that increased infrastructure investment (so long as it is for advanced technology) will lead to productivity and competitiveness payoffs. In essence, although Davidson does not claim that every new investment will be worthwhile, he deems it unlikely that much progress will be made unless the investment pie keeps expanding.

By contrast, although Montgomery, et al., do not really focus on this issue, they could have noted that what matters is bringing new or better services successfully to market, not just spending money on new infrastructure. They do favor more investment. They could argue that the market would do better than either governments or RBOCs and other TOs at picking winners.

Examples and counterexamples abound on both sides. On the one side there is evidence of increased infrastructure investments in Europe and Japan. In France, for example, the rapid pace of digitalization, the rollout of ISDN, the success of Transpac (France Telecom's commercially successful packet switching service), and Minitel all are hailed as successes by supporters.[38] Skeptics are less kind about France Telecom's claimed successes. They note, for example, that: (1) France does not hold a commanding lead in digitizing its network over AT&T, MCI, or Sprint; (2) "France is 10 years behind the United States in building a fiber trunk infrastructure";[39] (3) Transpac's "success is in part artificial, since more than 40 percent of traffic comes from the six million Minitels France Telecom gave away in the 1980s";[40] and (4) that according to a report prepared by Coopers & Lybrand, by the year 2000 France Telecom will have spent $9 billion on Minitel and that it is unlikely to break even on its investment until 1996 or 1998, 18 years after the program was launched. (Supposedly under pressure from France Telecom, Coopers & Lybrand revised its estimates.)[41] Others note that in the long term the choice of private investors (British, American, and now Singaporean) to concentrate on mobile and cable television services in the United Kingdom may prove to have been the better selection.

There also has been a great deal of publicity about joint EC-corporate consortia such as Esprit (the European Strategic Programme for Research and Development in Information Technology) and RACE (Research for Advanced Communications in Europe) that were meant to emulate the Japanese R&D model, boost European research and development, and spawn generic manufacturing processes that would serve European producers.[42] Efforts related to telecommunications and information sectors received approximately 45 percent of EC R&D expenditures from the mid-1980s through the early 1990s. By 1992, however, EC officials with responsibility for telecommunications and information sectors privately conceded that Esprit was a failure and that RACE was largely a failure. They placed most of the blame on the intransigence of European TOs for failing to open to greater competition which in turn meant that European equipment companies kept misreading opportunities.[43] These efforts demonstrate yet again that simply throwing money at a problem does not guarantee that a solution will be found.

Even if a technology works, that does not mean that it will be a long-term success. Davidson (and EFF, which sees it as a digital information platform) extols the virtues of ISDN. But the early narrowband ISDN that is being rolled out by Alcatel and others in Europe is not a sure winner. If narrowband ISDN is a flop, massive amounts of money will have been lost, if not wasted. Perhaps the United States, which was slow to implement narrowband ISDN, may prove to be the eventual winner if it can leapfrog the competition and move directly to broadband ISDN or other promising technologies. Indeed, one study estimates that if broadband investments increase significantly and access to national networks improves, "U.S. industries could add as much as $321 billion in net new output to the national economy" by the year 2007. This gain would be in addition to the gain of $191 billion likely to be achieved if present trends continue.[44]

The situation in Japan also is problematic. At this stage many expensive investments in experiments like Teletopia appear to be floundering. In addition, there is anecdotal evidence that suggests that the real reason for much of the increase in Japanese telecommunications investment was an effort by the ruling LDP to funnel projects to their most important supporters, the large construction companies. A large percentage of the government-supported investment may have been payoffs. To date, at least, the major benefits for the Japanese economy appear mainly to be a heated competition, including infrastructure competition, that has been unleashed since 1985. Perhaps there will be a competitiveness payoff as well, but the evidence is not yet in.

Finally, the short investment record of the RBOCs is not encouraging. So far, the RBOCs' investments outside their core business in the United States in everything from computer stores to real estate have been a disaster. The wisdom of their purchase of telephone companies and cellular and cable operations around the globe is an open issue. Critics may fairly ask whether American taxpayers should subsidize modernization of these companies, even if part of their investment problems were caused by restrictions placed on them by the Modified Final Judgment.

In short, the debate over how the United States compares with other major industrial countries in terms of telecommunications continues. The United States appears to still hold the lead, but other countries are working hard and with some success to narrow the gap. That others are spending more per access line than the United States is not alarming or fatal to U.S. productivity and competitiveness. What will have enormous impact on U.S. competitiveness is which countries are able to make available useful new telecommunications services that are easy to use and affordable. Three key choices need to be made by each country before deciding how to approach telecommunications infrastructure investments: First, should established TOs be the main vehicle for providing telecommunications in the future or should a wider array of firms, some of which may be foreign owned, be encouraged to compete to provide services? Second, should the government regulate and mandate service providers to offer certain services to specific groups at ordained price levels or should the market be allowed to operate free from most government intervention? Third, if governments decide to rely more on market competition, what continuing regulatory responsibilities should they retain? Once these choices are made, it is easier to know how to proceed.

WHAT SHOULD BE DONE ACCORDING TO WHOM? OR WHERE YOU STAND DEPENDS ON WHAT YOU SELL

Before considering how governments should proceed, it is helpful to place the jungle of data, claims, and wish lists into better perspective by examining the preferences and interests of the key U.S. corporate players. Predictably, firms want more government help and permission to enter new areas, but also seek safeguards that will prevent would-be competitors from encroaching on their business.

The RBOCs: What's Mine is Mine; What's Yours Should be Mine

In the United States the RBOCs all strongly support accelerated modernization of their networks, particularly if someone else helps pay for it. They also want the remaining strictures which prevent them from offering long-distance services and from manufacturing their own equipment lifted so they can provide goods and services, nationally and internationally. They want to be allowed to link their unregulated international activities to their home territories so they can integrate their offerings to customers, but, with the partial exception of Pacific Telesis, they want to retain their dominance of the local loop which provides them with a steady, secure stream of cash.

The RBOCs complain that existing regulations, particularly long depreciation schedules and caps on what they may earn, limit the returns on their investments in their regulated businesses and force them to concentrate more on the unregulated side of their operations. Their investment in modernizing their infrastructure has been flat, but all seven RBOCs went on a spending spree on the unregulated side, investing heavily in new ventures including cellular franchises in their home territories, elsewhere in the United States, and overseas.[45] In addition, at least four of the RBOCs acquired interests in overseas cable television operations to learn that business, correctly anticipating that the Federal Communications Commission would allow carriers into the cable business.

The ETI report succinctly states the main line of attack against the RBOC's motives:

> The root of the telecommunications infrastructure debate is money. The advocates of accelerating capital expenditures for this sector, who are principally the regional Bell operating companies, support policies that would serve to increase the relative dollar transfers from telephone rate payers to local telephone companies. These transfers could be accomplished through any or all of three *regulatory* devices—a higher authorized rate of return for telephone companies than would otherwise be required, a higher annual index change under price cap regulation than required by current industry productivity, and/or by increased rates of depreciation for existing telephone plant. All three of these policies might be applied simultaneously.[46]

Of course if these changes were instituted, the RBOCs also would invest more money to modernize and extend their infrastructure and service offerings.

AT&T, MCI, and Sprint: Explore the New; Keep New Competitors in Check

The U.S. long-distance carriers are competitive at home and pro-competition internationally, but would rather keep the RBOCs and foreign carriers out of the U.S. long-distance market. They are caught in a bind about new infrastructure investment. MCI and Sprint operate impressive digital fiber networks and AT&T is closing the gap rapidly. To the extent that the RBOCs modernize their networks, the long-distance carriers will be able to improve their services. But, as the RBOCs become major suppliers of new information services or if they are allowed to compete in the provision of domestic or international long-distance services, the competition could hurt AT&T, MCI, and Sprint.

AT&T, in its unique position as a service provider and equipment manufacturer, is particularly squeezed. It needs to continue to supply equipment to the RBOCs and recognizes that major new infrastructure investments by the RBOCs would lead to additional sales. At the same time AT&T opposes lifting restrictions that prevent the RBOCs from providing long-distance services and undertaking their own manufacturing operations. AT&T also must be cautious overseas because the established TOs are their service partners and equipment customers, so they cannot move too aggressively to open international markets to service competition. Reciprocally, AT&T would like to discourage British Telecom, Cable & Wireless, Telefonica, and other international service providers from widening their invasion of the U.S. market. These cross-cutting pressures make AT&T, MCI, and Sprint less visible lobbyists on the issue of infrastructure investment.

Equipment Manufacturers: Hold the Old; Expand the New

Manufacturers want to encourage the telephone companies to replace old equipment and extend their networks so they can sell as much switching and transmission equipment as possible. More quietly, they support the introduction of competition so that they will have more companies to supply. Firms such as Corning, a leader in fiber optic technology, are concerned that the U.S. telephone industry has invested about $6 billion outside the United States since the end of the 1980s to buy or build telephone, cable, and cellular networks.[47] Yet during the 1980s, according to the U.S. Telephone Association, investment by local telephone companies in their own domestic networks remained flat, varying between $19 and 23 billion. In fact, investment declined in real terms from $21.2 billion in 1980 to just $12.6 billion in 1989.[48]

This trend also concerns Northern Telecom (which still depends on Canada, the United States, and the Caribbean for most of its sales) and the equipment side of AT&T, whose share of RBOC procurement slipped after divestiture. Northern Telecom and AT&T are trying to expand their overseas sales, so growing investment in U.S. infrastructure would help them increase their equipment sales in the face of strong competition from European and Japanese firms.[49]

According to the manufacturers, part of the reason for this investment situation is that local telephone service is growing at only about 3 percent a year and in most jurisdictions returns from the regulated side of their business is capped at about 11.5 percent. Therefore U.S. manufacturers are eager to encourage the introduction of market-based incentives to redirect local telephone company investments into the local networks. The preferred mix of incentives varies depending on the type of equipment that the manufacturers try to sell, but all of the manufacturers appear to concur that a commitment to new infrastructure would increase employment and spur U.S. economic growth. For example, Corning was a major supporter of the recent FCC decision that allowed the telephone companies to offer "video dialtone" services. Corning is concerned that too often when local telephone companies modernize they replace old copper with new copper instead of glass because it still is marginally less expensive. Therefore, it strongly supported "allowing the telephone industry the opportunity to provide video services on an unregulated basis which will require network upgrades."[50]

In the past Japanese manufacturers have been quick to recognize what kinds of standards and trade rules would play to their strengths and benefit their sales. Once they understood their interests, they worked with Japanese negotiators to seek favorable arrangements. (U.S. negotiators, enchanted with the rhetoric of free trade, more often begin with positions which would, if implemented, undercut their own industries.) In general, universal standards, particularly production standards, work to Japan's advantage. If Japanese competitors can compete on the basis of mass-produced products (such as consumer electronics) they usually win. But, if the game is to provide system integration of incompatible products which use different standards or customized, software-driven equipment, U.S. and European firms do much better.[51]

New Competitors: Searching for a Level Playing Field

The RBOCs and TOs and most major equipment manufacturers conceive of a world of incremental change which they can manage and predict. Others accuse them of "failures of imagination" and believe a major paradigm change is under way that will revolutionize communications.[52] Telecommunications visionaries believe that customers soon will grow accustomed to multimedia terminals on every desk and in every home with voice instructions and response commonplace; a mobile telephone in every pocket; global broadband networks and very small aperture satellite terminals as cheap as today's transistors. According to this view, as intelligence moves outward from the network to the customer the bargaining position of customers vis-à-vis carriers will continue to improve. Ultimately, the carrier business could become a commodity business where the TOs would have no special advantages.[53] George Gilder, in a similar vein, predicts that in the near future computer-based telecommunications "will blow away consumer electronics."[54] Or, according to the now familiar "Negroponte switch," in the future communications services which now usually are broadcast through the air will use fiber optic cables and communications that presently rely on cables will be switched through the air. If these visions approach reality, then, advocates argue, promoting investment in telephone infrastructure controlled by existing telephone companies will be a mistake.

It is not government support of infrastructure investment that backers of new computer and communications technologies oppose, but infrastructure investments that lopsidedly favor TOs. They worry that if the RBOCs get what they want they will choke off effective competition and slow, rather than increase, the pace of technological change. That, they argue, could truly undermine U.S. innovation and competitiveness.

Cable, Broadcasters, and Publishers: Not in Our Backyard

Other groups oppose strengthening the position of the RBOCs for precisely the opposite reason. Long ago Koji Kobayashi, the legendary head of NEC, recognized that a television was just a monitor; it could evolve, becoming a computer or a telephone. Not surprisingly major cable operations such as TCI are poised to enter the communications business. At the same time, now that the FCC has sanctioned telephone companies moving into the cable realm, the cable concerns will try to make it as expensive and difficult as possible for the telephone companies to expand into their domain. The movie companies, television networks, and advertising industry are united in their alarm that video dialtone controlled by the telephone companies could adversely impact their businesses. They are reluctant to allow the telephone companies to develop the capability of bringing full-motion video to the home. They have no problem with the idea of video conferencing, but do not want households to be able, for a minimal fee, to order a wide range of television programs, sports events, or movies from the telephone company at any time. Easily understandable, pay-for-view programming and the spread of asynchronous viewing habits among the public could undermine the financial viability of these industries.

By the same token, newspaper, magazine, and book publishers, which successfully inserted restrictions on the RBOCs providing information services into the original Modified Final Judgment, remain wary of facing the RBOCs as head-to-head competitors. When publishers tried to enter the videotext business they lost money, but they do not want the telephone companies (or the cable industry) as direct competitors over a television, computer, or video telephone monitor.

Large Users: More Choices at Lower Prices

The large business users and the public want the widest range of easy-to-use services at the lowest possible price. But they only want to pay for the services they use, not for services that exist but for which they have no need (or at least no idea they need). Users support new investment in telecommunication infrastructure and even are willing to help pay for it, so long as they believe that they will receive a fair return on their money.

The large users became more sophisticated, better organized, and more cost conscious as communication and computer costs increased as a percentage of their total costs during the 1980s. Most large users prefer to hire the telephone companies to manage most of their communications, but they do not want to be locked into any one standard or carrier. They want to retain a credible threat that they might switch carriers if they become dissatisfied. They also try to maintain enough in-house competence that if necessary they could bypass the telephone company if rates become excessive or service unacceptable. So long as they do not have to pay an exorbitant share of the direct or indirect cost of installing the new infrastructure, large users strongly support investment in new infrastructure, whether owned by the RBOCs or by newcomers, because such investment expands their choice and increases their bargaining power. They strongly support efforts by the International Chamber of Commerce to foster competition in the provision of infrastructure in Europe and other industrial economies.

The Public: Make it Cheap; Make it Simple

Individual users quickly grew accustomed to cellular phones, fax machines, VCRs, powerful personal computers, electronic notebooks, and other new toys, even if they are incapable of making them operate anywhere close to their capacity. They are getting used to other new services such as call forwarding and voice and electronic mail. However, although a few enthusiasts press for more new services on faster lines as soon as possible, most of the population is still struggling to incorporate into their lives services that already are available. Moreover the public is not well organized and is mostly pleased that the power of the new computer, electronic, and telephone equipment continues to increase while prices continue to fall rapidly. Since they are not using most of the services now available, the public has not led the call for new infrastructure that would make possible even more services. In general, they are likely to embrace or reject services that are offered to them, but not to demand new ones. Thus, the "public good," broadly defined, usually is not reflected in the pressures on firms and policymakers regarding communications infrastructure.

These conflicting interests have resulted in a stalemate in which U.S. policymakers are pushed in different directions and so far have been unable to formulate a coherent, balanced policy regarding infrastructure investment. During the past decade, lobbyists, trade groups, and political action committees proliferated in Washington. Each group wanted to persuade Congress to enact legislation and the Executive to promulgate policies that it favored. However, efforts to do anything mostly were thwarted by opposing groups that marshalled their own lobbyists and arguments. At a minimum the lobbyists wanted to make certain that nothing was done that would undercut their clients' interests. The result was the politics of gridlock.[55] The challenge facing U.S. policymakers is to craft and implement a coherent set of policies.

WHERE DO WE GO FROM HERE?

In short all major U.S. corporate interests agree that advanced, interconnected telecommunications infrastructure would contribute to U.S. global competitiveness. None of the major players, though, is willing to allow it to proceed if it means risking its own relative power and position. It is not an accident that the United States still functions within the boundaries of a communications law enacted in 1934, before the advent of television, computers, satellites, or fiber optics. What is remarkable is that anything gets done at all, not that it is so difficult to put in place a coherent policy to encourage telecommunications investment and U.S. productivity and competitiveness.

An array of proposals was on the policy table in 1992. Vice President Quayle's Competitiveness Council advocated improved communications infrastructure as a route to improved U.S. competitiveness. Governor Clinton made building a fiber optic communications infrastructure for the United States a priority within his plans to achieve domestic economic revival. Several bills in Congress were meant to spur innovation and help modernize the network. Senator Gore introduced a bill to create a National Research and Education Network (NREN, or, less formally, the gigabit network) to meet the communication needs of scientific researchers in and out of universities.[56] In October 1991, the Telecommunications Act of 1991[57] was introduced in the House of Representatives to amend the Communications Act of 1934 to encourage competition in the provision of electronic information services and to foster the continued diversity of information sources and services. In May 1992, George Brown, chairman of the House Committee on Science, Space, and Technology, and Tim Valentine, chairman of the Subcommittee on Technology and Competitiveness, introduced the American Technology and Competitiveness Act. Its objectives include the enhancement of U.S. competitiveness by strengthening U.S. technology, prmoting investment in U.S. technology, and supporting manufacturing infrastructure development.

Granted, superior telecommunications infrastructure is better than inferior infrastructure and strong leadership from the top is needed to change that situation. (It is, after all, the job of the president to take hard decisions about winners and losers.) What should regulators be doing and how much from what sources should be spent on what technologies on what time schedule?

Regulatory Responsibilities of Government

Increased privatization, corporatization, and competition may alter the goals of regulators, but it is not a substitute for regulation. Even if many of the networks and providers are private and competitive, governments still believe they should work to promote some approximation of universal service,[58] assuring that the telecommunications needs of poorer and rural communities remain a government objective throughout the industrial world. All governments want to make certain that these users will be able to be interconnected to the public network.

At the same time, as networks become more complex and the number of competing service and equipment providers and technologies proliferate, governments may be required to assume new responsibilities that were less important when a single monopoly dominated national telecommunications. Thus, governments are likely to assume more responsibility as guarantors of interoperability and interconnection, more involved in ensuring reliability and, in collaboration with large users, more active in standard-setting exercises. In short, government regulators still are needed so the "nobody is in charge" problem does not arise and because competitive markets in the absence of regulation are unlikely to move toward efficient solutions.

The government also still needs to spearhead efforts to open up foreign markets, shake up discriminatory pricing arrangements, and make certain U.S. firms are not being "whipsawed" by foreign monopolists which seek end-to-end service between the United States and their home markets without offering U.S. firms comparable access to their markets.

What Needs to Be Done

Despite doubts raised here about implementing a lopsided plan to modernize and extend the U.S. telecommunications structure that would disproportionately benefit established carriers, the idea of rapidly improving the U.S. telecommunications infrastructure is sound. More is better than less, even if there is some waste. But whatever plan is ultimately accepted and implemented should spread the incentives to modernize widely, recognizing that no single company or sector is likely to have all the answers or to develop all the winning technologies. It is impossible to predict where the "killer technology" that will make current telephone technology obsolete will emerge, but it is more likely to come from outside the telephone sector than ever before. It is important to adopt policies and regulations that will encourage the emergence and growth of new technologies. It is most likely that innovations able to secure U.S. competitiveness vis-à-vis the rest of the world will emerge from a fiercely competitive environment.

How Much Will it Cost? How Long Will it Take? and Who Should Pay?

Estimates differ about how much it would cost to install a nationwide fiber optic network, but it is likely to be on the order of $200 to $400 billion over a period of 20 to 30 years.[59] The price tag for other technologies that might supplement or supplant fiber is less certain, but is probably on the same order of magnitude. To put these figures in perspective, the United States ran a budget deficit of about $400 billion in 1991 on total expenditures of approximately $1.4 trillion. To better appreciate the cost of installing fiber, it is useful to differentiate between the absolute cost of replacing existing copper with fiber and the marginal difference between replacing the network with fiber or of reinstalling copper. As the price of fiber drops to the price of copper (and perhaps ultimately below it) the marginal difference of installing fiber comes down. Presuming that replacement continues at the present rate of about 3 percent per year, the marginal difference of installing fiber throughout the network is likely to be on the order of $12 to 18 billion. One clear recommendation is that in almost all cases, when new cable is being run or old cable is being replaced, fiber should be used, perhaps even up to the home.

Speeding up the modernization of the network also makes sense. U.S. competitiveness probably would be helped by accelerating the installation of the fiber network and other new infrastructure investments. But as noted earlier, what is done with the fiber and other existing technologies is as important as having the fiber in place. The RBOCs and other carriers should be offered incentives to invest to modernize and extend their networks, so long as equivalent incentives are provided to backers of other technologies who might otherwise be discouraged from competing to provide better services. If the RBOCs force other would-be entrepreneurs out of the market and continue to try to lock in customers, policy will have failed. Indeed, in return for incentives the RBOCs, GTE, and other local exchange carriers might be asked to "help" others try to provide new services in the local loop. (Competition at this level appears to be succeeding in both Japan and the United Kingdom.) If genuine competition does not emerge, the government might even encourage the RBOCs to swap their cellular operations in their own territories for cellular operations in other RBOCs' territories.

Governments should use regulation to extend and multiply service offerings available to business and the public and to continue to ensure some form of universal service, interoperability and interconnectivity. But, with these exceptions, once government has initiated the reform process, competitiveness will be best served if the government gets out of the way and allows market competition to work most things out. Overall, so long as indicators show that small users continue to have access to reliable, affordable communications services of one sort or another, the government should be supportive.

There is precedent for government investment in high technology infrastructure. Between 1950 and 1960, for example, the National Security Agency alone contributed at least $10 billion toward unclassified R&D for computing and computers. What is unclear is who should provide the bulk of the investment needed to modernize America's infostructure and how these incentives should be provided. At the heart of this issue is the question of whether policies should encourage existing firms with proven technological capabilities, particularly the telephone companies, to monopolize or at least dominate the new networks. Presumably, this would hasten the introduction of new technologies that meet uniform standards. Or, should infrastructure competition be encouraged as the better way to develop the kinds of services needed by customers at prices they can afford?[60]

What is needed now is action, the momentum for which may be available for a short period after the 1992 election. As in all successful negotiations an appropriate bargain is likely to be one in which all the major parties win on part of their agenda, but are disappointed about some of the concessions they must make. In this case, as with the highway system that was built during the 1950s and 1960s, the taxpayers are going to be asked to shoulder much of the bill. In return they can legitimately demand (through the legislative process) that they receive appropriate returns.

Users also are going to be asked to commit some of the money by committing to use the networks and services as they become available. They will readily do this if they are convinced that new, useful services will be made available in response to their needs instead of on the basis of what RBOCs and other TOs believe they want and need. Ideally, large users want to be able to choose between service providers and mix and match their purchase of services from various providers. Interconnectivity, reliability, and price matter.

Finally, the RBOCs, GTE, AT&T, and the rest are going to need to take investment risks as well. The government and taxpayers may assume some of the risk, but the carriers also are going to be asked to place their bets. There already has been significant differentiation among the seven RBOCs. It is likely that over time there will be more differences. Provocative scenarios are surfacing (e.g., Pacific Telesis spinning off its regulated phone company, Bell Canada or a large industrial firm buying Ameritech). Although the RBOCs will be granted more latitude in the future, they are going have to pay a price for this freedom, just as AT&T did when it accepted divestiture in return for the freedom to enter businesses from which it was previously barred.

NOW WHAT?

Different companies foresee different futures for interconnected global telecommunications. The core technologies that will inevitably tie together people and computers at nodes spread around the globe could come from telephone, computer, or broadcast realms. How it will be used is less clear and the time frame is nearly impossible to predict. Ideas like video conferencing, "Dick Tracy" wrist communicators, and global computers linked to every individual in real time have been popular for decades. But popular acceptance ultimately depends on a combination of value provided, ease of use, and price. Telephones, fax machines, and cellular telephones are simple to use, declining in price, and user friendly. The number of data links among personal computers is climbing at an astounding rate. Yet it still is not clear whether companies and particularly individuals are ready to make use of the vast bandwidth that potentially will be available to them in the near future.

Two examples clarify the extremes in views. On the one side there are critics like Michael Noll, dean of the Annenberg School of Communication at the University of Southern California, who ridicules the idea that individuals will ever efficiently use a fiber link to the home that is capable of receiving the equivalent of more than 200 paperback novels per second. At the other extreme proponents of new services such as the data broadcast service proposed by McCaw-Oracle envision a time when, for a few dollars, companies like Boeing could update their technical manuals worldwide daily, or Microsoft could deliver updates of computer documentation directly to the computers of subscribers worldwide. In the end, however, the mix of services that will find favor will depend on what users use. Simply put, nobody knows what the future of telecommunications will look like. Therefore, governments and firms need to be flexible and open enough to allow the technology, the economics, and the demand for a wide array of services to drive the industry. Modern telecommunications infrastructure will be critical to the way the United States and national economies function in the future, but they too need to be open and flexible to many services delivered in a variety of ways if future growth, jobs, and prosperity are to be guaranteed.

Telecommunications infrastructure also will be critical to the world economy functions in the future. Although there is a growing literature on the potential impact of new information and communication technology on the conduct of U.S. foreign economic and security policy,[61] less has been written on what the existence or absence of first-rate telecommunications infrastructure providing efficient service at affordable prices might mean for the functioning of the world economy. Yet this issue will gain growing importance because the state of the global telecommunications infrastructure has immense implications for the operation of global business and the management of the world economy at a time of emerging globalization and rampant fragmentation.

The most striking feature of the world economy today is that it is becoming more global and is fragmenting simultaneously. Europe is integrating and Germany is one. Canadian, Mexican, and U.S. negotiators have agreed to form a North American Free Trade Area. There is even talk of greater regional cooperation in Asia. Moreover, the economic and telecommunications linkages between Japan, Europe, and the United States have never been closer. At the same time the Soviet Union has ruptured into 15 states and Yugoslavia and Czechoslovakia have been torn asunder.

New telecommunications investments in infrastructure promise to reinforce both these trends. Motorola's Iridium project and a number of other groups are striving to create a network of low-earth-orbiting satellites which will make it possible for individuals to make telephone calls or transmit data from any point on the globe. New fiber cables, which are being laid one after another and soon will crisscross the globe, promise to tie national economies even closer together into a global network. For example, by the end of 1994 seven separate regional fiber cables are scheduled to be installed in the Pacific region alone.[62] Simultaneously, the presence of global communications makes it simple and inexpensive for ethnic groups scattered far from their countries and regions of origin to stay in touch with their roots and reinforce their old allegiances instead of being assimilated into new cultures.

Similarly, to be competitive today global firms must seek global competitive advantages and not just national competitive advantage. Access to global communications networks and financial markets is at the heart of future competitiveness for global firms. Firms need global communications systems to operate effectively. Indeed, firms without access to such global communications networks are at a severe disadvantage. Therefore, large users are pressing for global competition. Already a few firms such as MCI, Sprint, and Cable & Wireless and now groups like Telecom, PanAmSat, Orion, IDT, and Viatel are offering direct competition at lower prices. AT&T, British Telecom, and even KDD are rising to meet these challenges. Tariffs are dropping across the board in the wake of this new competition.

Thus, as countries integrate their economies and companies look at their operations from a regional or global perspective, issues of national competitiveness will need to be considered in conjunction with strategies for ensuring that new telecommunications infrastructure investments everywhere augment global growth and prosperity. At the same time, infrastructure planners need to find ways to keep countries and regions that fragment in touch with each other and the world. The breakup of the former Soviet Union, of Yugoslavia, and the projected division of Czechoslovakia pose m. ior challenges for telecommunications planners. In the future these planners also may need to worry about how their infrastructure would function if Wales and Scotland or Quebec and western Canada went their own way.

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31. Davidson, "Analysis of Errors in Economics and Technology, Inc.'s "The Telecommunications Infrastructure in Perspective,'" op. cit., p. 2.
32. NTIA, op. cit., p. 175.
33. Darby, op. cit., p. 10.

34. However, Eastern Europe, the former Soviet Union, and developing countries which cannot afford to buy massive amounts of modern equipment will buy cheaper alternatives. Some countries now allow foreign firms to own, build, operate, and pay for new mobile communications systems; are experimenting with very small aperture satellite terminals (VSATs); and are buying used equipment.
35. A fascinating comparison of philosophies was evident at the 1992 World's Fair in Seville. The European TOs invested in an expensive, flashy pavilion to showcase their vision of the interconnected household of the future which included exciting new technologies like fax machines and call forwarding. By contrast IBM had no pavilion. Instead they set up kiosks around the fair where visitors could leave full action video messages for other visitors. In short, they provided fair goers with an opportunity to use a future technology.
36. Critics contend that TOs often introduce "gold-plated" services that are supply not demand driven. To make a return on their investment, TOs must subsidize losers by hiking prices on the winners.
37. International Chamber of Commerce, Position Paper No. 17, "Toward Greater Competition in Telecommunications: Basic Services and Network Infrastructure." Paris: ICC, adopted December 1991.
38. Marie Marchand, *A French Success Story: The Minitel Saga*. Paris: Larousse, 1988.
39. Jeff Gould, "As Goes France, So Goes Europe." *Communications Week International*, September 7, 1992, pp. 28–30.
40. Gould, ibid.
41. Henry Ergas, "France Telecom: Has the Model Worked?" A paper for a seminar organized by the Royal Norwegian Council for Scientific and Industrial Research on "The Interplay of Government, Industry and Research in France," Oslo, January 29, 1992. See also *Communications Week International*, September 1, 1991, p. 1.
42. Esprit and RACE depended heavily on the European roundtable group of companies, particularly GEC, ICL, Plessey, Thomson-Brandt, CIT-Alcatel, Bull, Siemens, AEG, Olivetti, Stet, and Philips. These same companies received much of the early Esprit funding. Notably, the TOs were absent from these R&D consortia.
43. I thank Peter Cowhey for these observations.
44. Cohen, op. cit.
45. Governments usually license their local TOs as one of two cellular franchises in their territory. This license may allow them to strengthen their hold over communications and repulse competition. As mobile overlay networks become less expensive, they could become competitors to the wire line network, and not just a complement to it. OECD, "Mobile and PSTN Communications Services: Competition or Complementarity," note by the Secretariat, Working Party on Telecommunications and Information Services Policies of the Committee for Information, Computer and Communications Policy of the Directorate for Science, Technology and Industry (Paris: OECD, November 1991), examines the extent to which mobile communications services eventually will "compete with, or substitute for, fixed linked telecommunications services in terms of tariffs, traffic and subscribers" and asks "for how long will mobile communications continue to be regarded as a complementary service to the traditional telephony?"
46. Montgomery, et al., op. cit., p. 1.
47. The four largest overseas investments by the regional Bell operating companies and GTE since divestiture were in New Zealand ($2 4 billion by Ameritech and

Bell Atlantic), in Venezuela ($961 million by GTE which owns 54 percent of a consortia which purchased 40 percent of Venezuela's telephone company), in Mexico (by Southwestern Bell for a large share of Telmex), and Germany (where Pacific Telesis expects about $500 million as its share of the second cellular network).

48. Corning Glass, "Telecommunications Growth Initiative." Background paper.
49. At divestiture in 1984 AT&T had about 250 employees based overseas; today the number has reached approximately 25,000. AT&T has been particularly aggressive in marketing equipment in Eastern Europe and the former Soviet Union. Although there is little hard currency available, AT&T can hold back settlements due on long-distance service between the United States and these countries to service the debt on the equipment. Northern Telecom, which has steadfastly refused to consider entering into competition with its customers in the provision of services, cannot use this ploy.
50. Corning Glass, op. cit.
51. For example, in the battle over HDTV standards the U.S. government supported a standard proposed by Sony and Japan, but opposed by Philips and the European Commission until U.S. computer manufacturers intervened after belatedly recognizing that their imaging businesses were at risk.
52. Richard Jay Solomon, "Past & Future Perspectives on Communications Infrastructure." Presented at "Integrated Broadband 2," Columbia University, February 3, 1989.
53. Jonathan Solomon, "Telecommunications and the New World Order." Speech to the Networked Economy Conference sponsored by Communications Week International and Blenheim Online. Paris, March 4, 1992.
54. Federal Communications Commission Hearing on "Network of the Future," May 1, 1991.
55. It did not always work. AT&T was broken up. But, exceptions were rare and usually required a combination of deft maneuvering, accident, and personal courage as with the passage of the revised tax code in 1986. See Jeffrey H. Birnbaum and Alan S. Murray, *Showdown at Gucci Gulch: Lawmakers, Lobbyists and the Unlikely Triumph of Tax Reform*. New York: Random House, 1987.
56. H.R.656, S.272, High Performance and Communications Act of 1991. See also Albert Gore, "Infrastructure in the Global Village." *Scientific American*, 265 (March 1991), pp. 150–153.
57. H.R.3515, the Telecommunications Act of 1991, a bill introduced in the U.S. House of Representatives to amend the Communications Act of 1934 to encourage competition in the provision of electronic information services.
58. Eli M. Noam, "Private Networks and Public Objectives," in *Universal Telephone Service: Ready for the 21st Century?* Annual Review of the Institute for Information Studies. Nashville, TN, and Queenstown, MD: Institute for Information Studies, 1991, pp. 1–27.
59. Henry Geller, "Fiber Optics: An Opportunity for a New Policy." A report of the Annenberg Washington Program, Washington, DC: Annenberg Washington Program, 1991.
60. Similarly, with the coming together of the European Community and the closer cooperation of at least some of eastern Europe and western Europe, the rules are changing at an unprecedented pace. The TOs argue that they are the only ones

capable of handling such massive changes. Others argue that they are the main culprits holding up integration. Hungary and Poland, and even Bohemia and the Ukraine, may well be willing to experiment with technologies, particularly ones that can be installed quickly and economically, that the TOs have so far managed to exclude from the EC (e.g., two-way voice telephony over VSATs).

61. Ronald H. Hinckley, "Information Technology and Foreign Policy," in *Paradigms Revised: 1989 Annual Review of Communications and Society*. Nashville, TN, and Queenstown, MD: Institute for Information Studies, 1990, pp. 45–76. See also National Research Council, Summary Report of the Workshop on "The Revolution in Information and Communications Technology and the Conduct of U.S. Foreign Affairs," National Academy of Sciences, Washington, DC, September 14–15, 1987. Washington, DC: National Academy Press, 1988.

62. The seven fiber cables and the date they are scheduled for installation are: TPC-4 between Japan, Canada, and the United States (November 1992), HAW-5 between Hawaii and the United States (January 1993), Pacific Rim East between Hawaii and New Zealand (March 1993), ASPAC linking Japan, Taiwan, Hong Kong, and Malaysia (October 1993), China to Japan system (late 1993), Link between Hong Kong and the Philippines (mid- to late 1994), PacRim-West running between Australia and Guam (late 1994). John Williamson, "Asia's Fiber Glove," *Telephony*, September 7, 1992, p. 32.

EDUCATIONAL TELECOMMUNICATIONS INFRASTRUCTURE: FERMENT, FLUX, AND FRAGMENTATION

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The crusade to develop and establish an educational telecommunications infrastructure bears some resemblance to the 12th-century search for the Holy Grail. "Infrastructure" has come to be viewed as the god-sent solution to educational problems. Periodically, at conferences and seminars, and delivered via "sound bites" from the White House or some other political venue, we are told that there is technological light at the end of the rhetorical tunnel. We need only climb aboard this infrastructure express and it will carry us at 9600 baud to the promised land where teachers teach and students learn.

Whether establishing an educational telecommunications infrastructure will lead to reform or further confuse the efforts remains to be seen. Much depends on how technology is accepted and integrated into educational systems and whether the research, resources, and training required for that integration are made available.

THE FOCUS OF THIS PAPER

This discussion of the educational telecommunications infrastructure intentionally focuses on the preschool through high school sector of public education. Much can and needs to be said about the impact of infrastructure development on post-secondary education. Indeed, one of the weaknesses of the educational structure in the United States is that differences between K–12 and higher education have weakened. But, for this discussion, K–12 is the center of attention for two reasons: (1) the current condition of elementary and secondary education in the United States is in serious disrepair; and (2) the reform movement working to improve and change the educational system is floundering for lack of direction and leadership at the national level and in many states.

The current trend toward linking our global economic competitiveness to the effectiveness of our public schools continues to gain momentum. The corporate community in concert with educational leaders in several states appears to appreciate the connection and the urgency of strengthening our schools more than do other sectors, but the growing public concern for educational reform is rapidly equaling its alarm at the problems of accessing and affording adequate health care.

The major waves of reform thus far have focused on incremental modifications in standards and expectations—for student performance, for teacher performance, for professional certification, and for school effectiveness—and on reorganization and restructuring of the governance and management systems for the public schools. However, the most essential reform remains to be carried out—a serious revision of curriculum and how it is delivered to young children. That is where technology will have its most potent effects. Distance learning using telecommunications technology has clearly demonstrated its ability to expand the reach of educators to underserved populations, but the critical interaction between teacher and learner in processing information remains a problematic issue.

THE TELECOMMUNICATIONS AND INFORMATION ERA

Along with the reform movement to bring education up to speed in the telecommunications and information era is an increasing awareness that the system itself needs an overhaul. The current school system is a product of late-19th-century thinking and the needs of an agrarian economy. Today's demographics point to the nuclear family as an exception rather than the norm; more than 90 percent of school-aged children do not come from two-parent homes with adequate incomes where dad works and mom "keeps the home." Further, there are large numbers of children with special educational needs, and there are even more whose negative home environment places greater strain on an already overburdened, antiquated school system.

All these features require deep system changes, something schools are not well known for doing. There are strong indications that if there is to be change it will be imposed from outside, not by laws or political pressure, but by families that value education and their children, and by children whose expectations and demands will force change. The system of schooling that we now know will shift drastically to meet the needs of its "customers." There is also evidence that children from homes where technology has become part of everyday living will be a major influencing factor in the schools.

In the context of inserting technology into the educational infrastructure, concerted efforts in recent years by federal agencies, commissions, councils, and task forces have generated numerous reports on a myriad of topics and policy issues associated with educational applications of electronic technologies. There is ample evidence that many innovative initiatives among educational institutions have been made; the efforts have just not worked well for very long. In many cases, the absence of a champion to maintain the momentum once the planning meetings were over has been identified as a contributing factor. The funding patterns in U.S. schools which dictate annual reviews and negotiations only compound the problem. This lack of continuity has plagued education over the years and the so-called infrastructure has been a victim at the receiving end of the criticism. It has been observed that the infrastructure can be everything and anything: bricks, mortar, technology, software, teacher training, state certification, architectural design.

INHIBITIONS AND CONSTRAINTS

The political, administrative, and economic difficulties encountered in implementing recommendations across institutions and geography within the current regulatory infrastructure have been an inhibiting factor in adopting telecommunications technology in education.

Dr. Arthur D. Sheekey, in "Education and Telecommunications Technologies: National Leadership, Coordination and Policy Development," a report for the Office of Educational Research and Development, U.S. Department of Education, had some observations on this matter:

> Studies have shown that many existing federal and state laws actually constrain the use of telecommunications technologies in the delivery of elementary and secondary education. Many other hurdles have been identified. According to Michael Goldstein, "the basic policy issues surrounding the expansion of telecommunications-based learning are not related to the technological aspects of the instruction. Rather," he claims, "they are tied to the willingness . . . to let go of a traditional system that has served since the adoption of the concept of formal schooling."
>
> More than twenty years ago, the HEW report, *To Improve Learning*, concluded that the organization of schools and colleges fails to take into account what is known about the process of human learning. And, at about the same time, Anthony Ottinger found the "structure of the American school system . . . ideally designed to resist change." Realizing institutional change and reform in education has been more difficult than expected. Using technology to change the role and responsibility of teachers has posed the greatest problem. The National Alliance of Business [in 1990] found that "Most school buildings are designed and constructed based on estimates of current rather than future needs. . . ." And "New or renovated facilities should be planned and designed to provide the fewest constraints so that emerging education strategies and technologies can be put in place."

Dr. Sheekey has operationally defined the principal dimensions of the educational infrastructure. However, when education is factored in with technology there are other important questions left unanswered:

- How do we circumvent course approval and teacher certification?

- How do we address the issues of access and equity?
- How do we avoid letting technology dictate the curricula?
- How do we generate new educational methods and materials to fit the technology?
- How do we close the research/practice gaps?
- How do we improve functions: budgeting, scheduling, transportation, purchasing?
- How do we go about expanding evaluation opportunities?

TEACHING THE TEACHERS

Most teachers teach the way they were taught. If teachers are to acquire the techniques and attitudes necessary to infuse technology into the public school curriculum, then the trainers of teachers must be provided with the technology skills necessary to teach as well. This will require a significant effort to retrain the college and university faculties which prepare prospective teachers. Given the lack of adequate resources and technology in the majority of schools of education and in colleges of arts and sciences, it will require a major investment in hardware, software, and training on the part of the universities to bring teacher training faculties up to speed.

One example of an approach to reforming teacher preparation programs may be found in the "Teach Tech" program at the University of North Carolina at Chapel Hill. The School of Education, in cooperation with Northern Telecom Inc., Southern Bell, Apple USA Southern Operations, IBM, Microelectronics Center of North Carolina, the UNC Center for Public Television, and local public schools, has developed a special program that includes research, training, and public service elements. It emphasizes technology applications research, instructional research, faculty development, teacher preparation, information and technology transfer, and technical assistance. This comprehensive approach carried out in a university/corporate/school partnership is more likely to result in rapid reform of teacher education and in-service teacher education activities than many other strategies.

NATIONAL GOALS AND ECONOMIC REALITIES

As political campaigns unfold, the educational infrastructure becomes a major election issue. The June 30, 1992, *New York Times* dedicated more than a full page to President Bush's performance as the "education president" and quoted many educators on both the political left and right. The overall consensus seems to be that perhaps a "B" for effort is in order, but performance merits a far lower grade. Both sides of the political spectrum complain that the president has "articulated lofty conservative principles, but has failed to rally the nation behind them or to follow through so that his plans are actually put into action." The other presidential candidate has espoused ambitious goals but has offered no specifics.

The prevailing view, according to the *Times*, is that "the ills of American schools require a larger Federal plan, a more detailed urban agenda and a great deal more money than Mr. Bush shows any sign of wanting to spend." While the article focused on one high school, Washington High in Memphis, Tennessee, comments made about it are broadly generalizable. To quote further from the *Times:*

> These educators say there is little hope that Washington High's students can conquer the poverty and despair that are the blight of so many inner-city lives until the Government also offers broader initiatives to counter the urban ills that so often lead to school failure. Chief among them are drugs, street violence, inadequate health care, glaring inequities between rich and poor school districts and broken families.

The article went further. It recorded the praise bestowed by educators for the 1989 "education summit" in Charlottesville, Virginia, at which the president and the nation's governors agreed on six broad national goals. These ambitious goals are:

- By the year 2000 all children in America will start school ready to learn.

- By the year 2000 the high school graduation rate will increase to at least 90 percent. (We're currently at 72.6% —by dividing the 1988 high school graduating class by the number of 9th graders who entered schools.)

- By the year 2000 American students will leave grades 4, 8, and 12 having demonstrated competence in challenging subject matter, including English, mathematics, science, history, and geography; every school will ensure that all students are prepared for citizenship, further learning, and productive employment in a modern economy.

- By the year 2000 U.S. students will be the first in the world in science and math. (Among 20 countries, our 8th graders are ranked 10th in arithmetic and 12th in algebra. Of 15 countries, our 12th graders are ranked 14th in algebra and 12th in geometry. In science, our 14-year-olds are ranked 14th. Our high school students are ranked 13th in biology, 11th in chemistry, and 9th in physics among students in 13 nations.)

- By the year 2000 every adult will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.

- By the year 2000 every school will be free of drugs and violence and will offer a disciplined environment.

These goals articulated in *America 2000* are inspirational and measurable but they are neither feasible nor enough. Thoughtful educators estimate that as many as 50 percent of all children will never attain the goals, given current lack of national direction and the inability of local schools to provide the resources necessary to address them. Just as the highway and transportation infrastructure requires national attention and major capital investment, so too does the educational infrastructure. In many ways education provides the foundation for everything else this country does and requires strong national policy and financial support that is simply not within reach of the states and traditional state-local taxes.

It was further pointed out that "the Federal Government has never spent much money on education—it now pays six percent of all public education costs from kindergarten through high school, a drop of almost 40 percent from the level before President Ronald Reagan took office."

The criticisms above relate essentially to funding and policy. There is also a great deal of controversy about the use of technology to make up for the fiscal shortfalls. While it seems true that from technological innovation to adoption generally takes seven years, in education it may take 50 years to create a new infrastructure. Time, however, is a relative factor; society cannot afford to wait.

This fiscal conservatism has inhibited creative growth in the schools. As seen by the National Association of Secondary School Principals in a recent study, the primary goal of education is teaching students how to read, write, and compute, with fostering good human relations and problem solving ranking second and third. This seems fairly straightforward. However, it is becoming increasingly clear that these goals are still out of reach for many. Nationally, two-thirds of all employers consulted assessed their current pool of entry-level applicants as being insufficiently prepared, and a large percentage of high school graduates require remediation in reading, writing, and mathematics skills when they enter college.

The overwhelming mandate to deliver more course offerings and more educational resources has led many school districts to turn to electronic alternatives for expanding educational opportunities. These alternatives include stand-alone courses taught at a distance through video or audio technology, interactive computer conferencing or videodisc, as well as a myriad of support materials for courses taught on site in a more traditional manner. To some extent, however, it appears that the introduction of technology is budget driven, rather than driven by clearly defined educational goals and objectives.

THE CONDITION OF EDUCATION

As numerous reports and studies have documented, there are many ways to consider the educational situation in this country and the desire to do something about it. Maintaining a dominant role in an increasingly information-intensive society will hinge on successful reform. However, finding answers poses both some chicken-and-egg problems as well as those encountered by the blind men seeking to describe an elephant. A lot depends on where you sit, what set of optics you employ, whether you believe in what Lewis Mumford called the technological imperative ("If it can be done, it must be done"), and economic, political, and social goals and objectives.

If research as reported by the media is accurate, the prospects are frightening. Surveys have shown that some aspects of the nature of this crisis include the superficially amusing: high school students identified Jesse Jackson as a baseball player and Chernobyl as Cher's last name. One quarter of final-year college students recently surveyed in a Gallup poll thought Columbus's voyage took place after 1500; more than a third chose Stalin, Rasputin or Nicholas II as the leader of the Russian Revolution; two-fifths could not place the American Civil War in the correct half-century.

Some see the deficiencies in the educational infrastructure as basically an economic problem—a problem, that is, which will have a fundamental and negative effect on the way we do business worldwide. Workers lacking the skills of literacy and numeracy are having a negative effect on America's business and industry and its ability to produce and compete. College graduates lacking expertise in mathematics and foreign languages could affect the country's trade performance as business becomes increasingly international. The aforementioned *New York Times* article quoted a businessman involved in high-technology ventures:

> We have extraordinary dropout rates or effective illiteracy rates. We have a work force, particularly in the inner city, that is being prepared for nothing but third-world jobs in a society that requires first-world incomes to live a happy and productive life.

Some view it in political analogy terms. While the education summit of 1989 took note of this overall state of affairs, the following statement from Albert Shanker, president of the American Federation of Teachers, clearly indicates that doing something about it will be a formidable task:

> It's time to admit that public education operates like a planned economy, a bureaucratic system in which everybody's role is spelled out in advance and there are few incentives for innova-

> tion and productivity. It's no surprise that our school system doesn't improve: It more resembles the communist economy than our own market economy.

Shanker's comment does not reflect certain supplemental efforts being made by business, industry, and labor. Nor does it reflect the fact that, although communism itself is history, the condition of education has not realized significant change. An item in *The Wall Street Journal* described the motivation for these stopgap measures:

> ... Pressure for change comes mostly from businessmen whose middle- and lower-level employees often fall below minimal levels of acceptable competence.
>
> Business in turn has finally convinced most politicians that the continued success of an increasingly sophisticated economy is at some peril if the work force doesn't improve.

This statement was made in the context of an editorial on the education summit which had just taken place. The businessman from Memphis, James Calaway, quoted in the *Times* article, also had this to say:

> We have a severe national security problem: it happens to be in our education system. Why don't we scrap 22 entirely unnecessary B-2 bombers, take that $44 billion and create a really important "Manhattan Project" for our national security? That would be to build an extraordinary fiber optic network that would be linked to all education centers, primary, secondary schools and universities.

To sum up to a limited extent: the businessperson touching the educational elephant is apt to feel that neither the American economy as a whole, nor business and industry, can wait for the necessary improvements to find their way slowly into the system. The domestic and worldwide competitive situation requires faster action.

However, and this might be a thoughtful educator's perspective, what is also the case is that even those who are working on the problem and are doing something about it are not fully aware of what is being done in other parts of the country or in projects not their own, how well it works, what it costs, and how economies of scale could be achieved especially through the use of various telecommunications technologies and computers.

TECHNOLOGICAL ADVANCES

Given the hyperbole that characterizes each announcement of a newer and faster computer chip, the driving engine of the computer revolution—and, to some, of the education revolution—educators might just want to pause for a bit and ask education where it is going and how fast it wants to get there.

In addition to computer technology, recent advances include the provision of educational services by carriers and distributors involved in basic telephony, as well as those concerned with distance learning, radio and television broadcasting, cable operators, access to data bases, and business and governmental needs.

It may be instructive to take a walk through the technology landscape. We are dealing with a rapidly proliferating number of technologies and if there is a common thread to them it may be that they are rapidly merging together, and in many instances getting cheaper.

Transmission and service technologies currently receiving attention include low earth orbit, direct broadcasting and mobile satellites, VSATs (very small aperture terminals) and USATs (ultra-small aperture terminals), fiber optics, cable systems, freeze-frame/slow-scan television, mobile and cellular telephony, radio and television broadcasting via AM, FM, and shortwave, old-fashioned telegraphy and new-fashioned wireless telegraphy, CB radio, amateur radio and television, wireless cable, digital radio, ISDN (integrated services digital network), compression techniques, worldwide paging systems, facsimile, packet switching, remote sensing systems, voice-mail, phone-bridges, voice-operated computers and word processors, videodiscs, electronic and satellite news-gathering units, audio/video and computer teleconferencing, narrowcasting, high-definition and advanced television, dedicated network services, data nets, optical discs including CD-ROMs (compact disc, read-only memory), WORMs (write once, read many times), ONA (open network architecture), LANs (local area networks), LAWNs (local area wireless networks), speech synthesizers, automatic translation, machine reading of printed or typed text, and videotex and teletext.

Virtually each and every one of these, often mixed with others in some alchemist's brew, has been proposed, by someone, at some time, as the universal solvent in which to (dis)solve the problems of American education.

EDUCATIONAL NETWORKS

The educational landscape has also sprouted a number of timely proposals for consideration. The secretary of education has come forth with Education 2000, a White House-blessed set of solutions that emerged from the Governors' Conference. Whittle's EDISON project represents a private sector approach that already has some predecessors and is bound to have imitators. EDSAT is convinced it has the answer with its dedicated educational satellite network, but the Public Broadcasting Service regards the EDSAT plans as duplicative of its own efforts. The Learning Channel and I*Learn are on the scene, as are TI-IN and the Mind Extension University. The Star Schools Program is operational as is the Department of Defense's EDUSAT. Hughes Communications is planning its own satellite-delivered educational program network, The Galaxy Classroom, which recently received a $4-million National Science Foundation grant for production. CNN has plans for an educational program service. Channel One, an educational satellite news program, is praised by many, condemned by some.

In 1992, 686 proposals to improve the condition of education were submitted to the New American Schools Development Corporation (NASDC). Only 11 were funded. Unfortunately, the funds required for the Corporation's work have fallen short of targeted projections. A review of the winning NASDC projects revealed that technology was not the integral force in the "Break the Mold" designs. Changes in the people infrastructure (students, teachers, parents, administration) were inherent in each of the proposals. Back to basics best describes the collective underlying theme.

There is a diversity of opinion on what needs to be done. Some say we need educational vouchers; some say educational vouchers will contribute to segregation. The secretary of education says we need a "GI

Bill for Kids." The Chamber of Commerce, frustrated by the efforts of others, has prepared an educational infrastructure initiative of its own.

Fortune magazine not too long ago made much of what some 85 leading U.S. corporations were doing around the country in terms of establishing partnerships with schools and school systems to remedy the shortfalls in terms of corporate/industrial needs. *Fortune* did not address the relationship between education and industry.

THE NATIONAL RESEARCH AND EDUCATION NETWORK

NREN, the National Research and Education Network, bears mention here. The network, signed into law last year as the High-Performance Computing Act, will link millions of researchers, educators and students in government, industry, and universities around the country, providing access to high-speed data transfer for research and educational purposes. This new high-capacity network will enhance activities already under way in the 600–800 colleges and universities linked to the Internet. In addition, there are estimated to be some 1,000 high schools now connected through the Internet. These schools are using computer linkages for information exchange on a wide variety of subjects, including science, math, foreign cultures, and others.

NREN further offers an opportunity for linking institutions of higher education, industry, private R&D, and other agencies and data bases with the K–12 system. Indeed NREN, once established, will offer an opportunity in each state for the designation of "school-grant universities" commissioned to provide technical assistance and support to K–12 schools in the state similar to the way in which the establishment of "land grant institutions" in the last century nurtured farming and agricultural communities toward the incredibly productive system of agriculture and agribusiness we now have.

The follow-on bill to the High-Performance Computing Act is the Information Infrastructure and Technology Act (S.2937), which assigns various agencies responsibilities to ensure that the technology developed through the program is applied widely in K–12 education, in libraries, in health care, and in industry. However, it remains to be seen how quickly these changes will take place in the current budgetary environment.

THE PRIVATIZATION OF EDUCATION

The reform of education and schools continues to be based on the analogy between a business and a school. Schools are not businesses; they are a public service utility. They may not be orderly and managed in a business sense, yet both have "customers," "clients," and "products" that are diverse and different. There are other comparisons. Schools should involve consumers in the design phase of their curriculum development. Schools should be measured by the performance of students but agreement has yet to be reached on what children should know and be able to do and how their behavior and competence can and should be measured. It is a complex process that does not lend itself to simple restructuring or placement of accountability. These approaches are driving many of the best teachers and principals out of the school "business."

Along with words like *information highway* and *infrastructure, privatization* has become a popular buzzword. Privatization and commercialization initiatives in telecommunications and education have increased significantly in recent years. The motivation, typically, is to upgrade services or facilities, to establish relationships with organizations with more diverse resources, and to generate revenue or hard currency.

Channel One is one example of a private-sector initiative in the schools. Much has been made of questioning the appropriateness of Channel One's commercially driven relationship with kids and schools even though it provides access to high technology in return for access to a target audience.

In theory, privatization will benefit both parties by creating opportunities for new businesses that never before existed as well as opportunities for new ways to do business. Drawing on experiences in telecommunications globally, there is a valid analogy here if, for "business," one substitutes "education" in the context of this discussion. It has been observed that when government-owned companies are sold to the private sector the quality of service and labor relations goes up and the costs of production go down.

Privatization is obviously predicated on the premise that it will serve the public good by enhancing business: this is analogous to improving education. There are, however, some pitfalls.

The absence of consistent policy compounds the problem for both parties if privatization is oversold. As we have experienced in the recent past in telecommunications, certain countries may have to pick up the pieces after the novelty has worn off and economic reality sets in. On a sad note, after short-term profits, or educational benefits, are exhausted, it is quite possible that many of the promises remain unfulfilled.

There has been a spate of reports which are, to some extent, guiding this whole process. "The Unfinished Agenda: A New Vision for Child Development and Education" and "Business Impact on Education and Child Development Report," by the Committee for Economic Development (CED), call for a strategy that involves a wide range of public and private resources to improve the nation's schools.

The Business Roundtable published "Education Public Policy Agenda," which identifies the essential components of a successful education system. The document states that corporate America should be at the forefront of change in the schools, and technology, once again, is mentioned as a tool to raise student and teacher productivity and to expand access to learning.

It would be premature to comment on Education 2000 other than to mention that the whole matter of vouchers, as a privatization option, has raised fears. This is equally true of Whittle's EDISON Project; it seems destined for several years of planning, a period of fundraising, and most likely a rather lengthy period of operation and evaluation. Whittle's Channel One, replete with commercials to a captive audience (as some see it), has been surrounded by controversy since its onset. It is currently involved in litigation in several states which seek to block its access to their schools.

EXPECTATIONS FOR THE FUTURE

There are solutions to be found in aggregating and sharing resources, cooperating and collaborating on planning, and making group purchases, whether they be of hardware or software. The very nature of the technologies makes such efforts easier. Most telecommunications planners firmly believe that no single technological delivery system—fiber, satellite, or microwave—is in the best interest of education, but that multiple and complementary delivery modes will best serve needs. Underlying the technology, and perhaps more to the heart of solutions to educational problems, is that access and equity questions are vital, otherwise the "haves" get more and the "have-nots" get less.

What are the expectations for the future? Many of the technologies listed above are still foreign to educators. Even more esoteric ones, mostly in the computer field (optical computers, artificial intelligence, parallel processors, even biological computers), will arrive. Computing and communicating probably both will become relatively less expensive as time goes on, but unless funds are provided, they will remain too expensive for many schools. Data bases and data banks will proliferate and the new communications technologies will make remote access to them easier, if they are properly designed and there are built-in institutional provisions to support technological alternatives.

According to Dr. Louis A. Bransford, president of the Public Service Satellite Consortium, in comments prepared for a seminar on telecommunications technology at the United Nations:

> It is difficult to distinguish between technologies and services, especially as computers and communications converge. One should not need to distinguish between them; a truly effective technology (and the services it enables) should be transparent to the user. We have studied technological adoption, that process of the acceptance and effective utilization of innovative technology. It begins with awareness and knowledge of the technology in question. However, awareness does not necessarily ensure understanding.
>
> Likewise, understanding does not always lead to acceptance and acceptance does not guarantee utilization. It is a process dependent on many major variables such as commitment, politics, advocacy, attitudes, resources, time, training, and integration. Other variables include cost, adaptability, competition, reliability, and obsolescence. Any telecommunications-related innovation is also subject to a combination of hardware, programs, transmissions, logistics, maintenance and, most important, human factors.

HUMAN FACTORS

It is the human factors issue that perhaps deserves the greatest attention as we talk about the development of an educational telecommunications infrastructure. While advances in communications technology are dramatically changing traditional work, education, and entertainment patterns, many people are unable to gain access to or accommodate changes brought about by the information revolution. They are what we call the information poor. They include those with no money; those who are isolated; those who are untrained, uninformed, uneducated; the handicapped; the elderly; the rural; the migrant; the inner-city resident.

Michael Schrage, who writes the "Innovation" column for the *Los Angeles Times*, commented, "In the real world, technology isn't just a medium of information but a medium for relationships. Information matters, but it's the relationships—the formal and informal networks of people—that really govern how the organization runs and how value is created." Some students and teachers may find that it is more convenient, more comfortable, and more productive to interact with a machine than with each other. Ultimately, the dynamics of human or personal interaction, one of the cornerstones of education, could be diminishing. What will not change is the need for guidance and motivation that only a teacher can provide.

The results of the 1988 National Assessment of Educational Progress may also reflect on the influence of technology in the schools. The report, the findings of which are still applicable, revealed that students did not demonstrate advances in thinking critically or communicating ideas. This ability is predicated on human interaction: questioning, challenging, probing, clarifying, reinforcement, smiles, proximity. The inherent nature of telecommunications inhibits face-to-face human interaction. Vicarious interaction may satisfy many distance-learning authorities, but it doesn't necessarily stimulate spontaneous, critical, and creative thinking. Perhaps with more sophisticated techniques using artificial intelligence, machine interaction will compete favorably with the human factor, but for the foreseeable future educational policymakers should recognize that the success of distance learning, be it video-, audio-, or computer-driven, is built on interaction that depends heavily on the professional skills and competence of the instructor.

TRANSFORMATIONAL EFFECTS

The transformational effects of the educational infrastructure must also be considered. As telecommunications systems become more and more a part of everyday life, the modes of thought in young children will be modified so that learning habits will be sharply different. Changes in access to information and the forms in which information will come will reform learning styles. One result of these changes will be to render current curricula and methods of teaching inadequate or inappropriate. The educational menu available will have to change for the diner to digest the information meal.

Neil Postman, from New York University, who takes a dim view of television as an educational tool, warns us of the failure to recognize that the preschool curriculum in a telecommunications-rich world is severely disjunctive when the traditional learning environment of the present-day school remains as it is. This mismatch, left uncorrected, can and probably will lead to both learning and behavior problems in children in first through fourth grades, characterized by low attention spans, low performance scores in math and reading, and a general alienation of children from nontechnology environments.

RESEARCH AND POLICY ISSUES

One of the fundamental weaknesses of the public school systems is the lack of regular access and involvement in educational research and development. It has been estimated that the research-to-practice gap in education still ranges in the 20-year time-frame. On an optimistic note, certain experts claim that a state-of-the-art telecommunications infrastructure would make available, to all schools, information and training on evaluations of alternative educational programs, new techniques and materials for improving student achievement, and new methods for managing classrooms and schools. If successful "reform" of public schools is to take place, then a strong federal or national policy and direction must be established.

The integration of telecommunications technology makes possible increased research on learning in young children, especially in classroom settings and school settings. This is a much neglected activity and needs energizing. What is missing is directional policy that provides guidelines on curriculum; funds for research, development, evaluation, and dissemination; and access to a national data base through a national telecommunications infrastructure.

The majority of teachers now in the classroom will still be there in the year 2000. This means that an effective in-service education program must be mounted for teachers and administrators using telecommunications technology. The current use of technology in schools is irregular. Many schools organize computer labs with no understanding or assistance with regard to software or program. School-wide networks are rare and the drama and notoriety given to magnet or demonstration technology-driven schools obscures the fact that the vast majority of schools do not have access to technology or do not know how to effectively utilize technology they may acquire or access.

The school of the future will rest on a telecommunications infrastructure—for curriculum, management, reporting, transportation, food service, and personnel systems—both within schools among classrooms, and among schools, school systems, and national and international networks. This will allow the school to be an *organization* and not a *place* so that homes, businesses, and a full range of "places" can become part of the educational network.

Developments in technology applications such as IBM's *TeamFocus* lend themselves readily to the needs of local schools to engage in long-range planning and shared decision making as a method of changing, managing, and governing schools. This is an example of a technology application of small group processes for cooperative planning and priority setting that is neither administrative nor instructional. Adaptations of this approach for student, parent, and teacher use seem endless.

EDUCATION REFORM AND A NATIONAL CURRICULUM

The mere mention of a national curriculum in the United States sparks an emotional argument. The autonomy of the local schools and the sovereign rights of the chief state school officer will have to be negotiated if educational infrastructure reforms that defy borders, because of the nature of the technology, are to be systematically adopted in the schools. Ultimately the issue of political control must be reconciled if technology is to make a significant contribution to educational reform. One must ask whether long-term systemic change will be a function of the educational system's willingness to compromise, the harnessing of the unbridled technology, or the instruments used to measure effectiveness and success. One interpretation is that the current fragmentation in formulating and managing state and national communications policies will continue to dictate how educational programs and services are produced, delivered, and regulated until decision makers in the schools can conquer the threat of a national curriculum.

The advent of a telecommunications infrastructure will advance the current and inevitable drift toward a national curriculum. This could be a positive event although it will be decried as subversion of the honored tradition of local curriculum and school control. It just makes little sense for nearly 16,000 school districts to develop and offer their own curriculum even if it must reflect some state-level guidelines or standards. Ultimately, any national curriculum would be softened and fitted locally by thoughtful teachers who already know how to ignore or manipulate state requirements and plug in their own lessons. National lessons are not drugs and (sadly) there is no "FDA" in the education business.

A coupling of telecommunications infrastructure and national curriculum, of the consistency of the new standards presented by the National Council of Teachers of Mathematics or the guidelines of the American Association for the Advancement of Science Project 2061, would focus our work on new assessment strategies and perhaps help us move away from the basic skill-oriented curriculum to a focus on teaching for understanding and on improving children's planning and reasoning abilities, critical thinking skills, and analytic and problem-solving abilities. Technology applications thrive in this setting and all children—those with information-processing disabilities, those who are "normal," and those who are gifted and talented—benefit and grow.

FORMULA FOR SUCCESS

The essential elements of an effective educational system are based on three major assumptions:

- All children can learn at high levels.

- We know how to teach all children.

- Expectations for higher levels of performance produce higher levels of performance.

Given the above assumptions, the three elements that will produce effective schools and high-performing students are:

- Early childhood education intervention programs. The provision of language, social, and learning skills required for all children to begin formal schooling ready to learn and develop their abilities to the fullest.

- Effective leadership at the school level. Principals prepared and regularly retrained in instructional *and* management skills. There are no good schools without good principals.

- A core curriculum consisting of basic reading, writing, and listening skills and strong programs in math, science, technology, history, English, and foreign language study. No frills.

All three of these elements could benefit greatly from an effective telecommunications infrastructure.

A solid core curriculum, well taught through infusion of technology, delivered to students who begin their educational experience ready to learn, under the supervision of effective instructional leadership, is a recipe for a strong, effective educational system. Link schools and communities through a telecommunications infrastructure, open schools year-round, and provide for free access and interchange, technology transfer and sharing, and continuing professional development for teachers, and you will have a sound and productive educational system.

A CALL FOR DIALOGUE

In light of the current educational landscape, one could seriously question whether the apparent technological future is achievable without major changes in the educational infrastructure. Some policymakers are proposing a major restructuring of the educational precepts behind a system that has served this country well almost since its inception. To do this without sufficient public dialogue, without analysis and consideration of the underlying causes of the current situation, may create an intellectual stalemate.

It has been suggested that a forum for public dialogue might be the Paideia seminars. These are cooperative learning projects; seminars enhanced by technological access to information; and simulation, role-playing, and case-study projects which will humanize the technological systems and allow even greater learning experiences from them.

Of course there is good reason to stress urgency, regardless of ideological positions and commercial and industrial imperatives. But urgency without direction, without a sense of purpose, without unified and agreed-upon goals, may be counterproductive. Despite the miraculous surface appearance presented by virtually all of the technologies proposed to be brought to bear on the cutting-edge problems of education, technology is not a goal; it is simply a tool, which, when used appropriately, can make a difference.

It would be highly improbable for anyone to list all of the problems of education, other than to note that this country faces far more fundamental problems than seems apparent in the design of many of the current quick-fix approaches to educational reform. What is evident is that many of the problems manifested in the schools are not academic. They are basic social and economic problems.

Technology alone will not solve the problems of poverty which are, in turn, fed by racial inequality, poor housing, single-parent households, unemployment, homelessness, substance abuse, hunger, and malnutrition. A hungry child can't learn. A child who learns that selling drugs (or guns) is a faster way to some sort of economic improvement will not invest his or her time in a crowded, often dilapidated classroom, even if television is piped in regularly.

Educational leaders need to take a longer, closer, and deeper look at the root causes of educational problems, and fix them. Leaders need to think through what our curriculum ought ideally to be. They need to think through the entire issue of localism, since it may well be that planned telecommunications highways will tend to move policymakers toward a national curriculum. They need to think through the facilitation of change, especially as we move toward the delivery of educational services through technological means that are perceived as complex.

A CONTROVERSIAL NOTE

The current fashion favors interconnections, via computers, phones, and modems, and thus access to the accumulated wisdom of the world, stored in libraries and data bases as well as in the minds of individual teachers at locations far distant from one's own. This is made to seem easy. It is not. Computers and modems, while coming down in cost, are still not readily available to all teachers and students. Nor are they easy to learn to use. Perhaps before we succumb to the lure of an Apple at every teacher's desk—or every student's—we ought to give serious and prolonged thought to standardized information protocols and command sequences, and to making the technology transparent to the user. This would enable students and teachers to more readily interact and acquire information without problems of compatibility, and to gain access to numerous data bases readily available. Data-base use in schools is proliferating for those chosen few with compatible computers and access. The increased number of phones in the classroom is clearly an encouraging sign.

For those students and teachers who have worked out the problems of access and compatibility, it is evident that the technology is being used. A message that appeared on one of the many rapidly proliferating computer networks for kids best illustrates this observation. A 12-year-old entered the following on the keyboard: "I'm sorry I can't send this letter to you by mail since we're out of stamps. . . . I hope you get this letter because this thing just flashed a few thingamaboppers on screen. Bye for now."

If there's a conclusion to be drawn from that message, it may well be that we might want to keep some stamps handy before we put all our faith in machines that flash thingamaboppers on our screens. Obviously, there is still a comfort factor. The currency behind those stamps? Protocols and standardization. Access. Affordability. Ease—real ease—of use. Perhaps even a rejection of the technological imperative which favors some fad or fashion or quick fix. Careful planning about the real problems, the root problems, lest we fix something that's not broken and thus avoid the things in our society that are broken and need to be fixed first.

All these examples, and dozens more, depend for their implementation on an educational infrastructure and a trained teacher corps to put them into effect. One obstacle is limited resources. Another is lack of understanding and foresight by legislators, policymakers, and political leaders. In addition, policy gaps are still evident, especially those that would establish communication as a basic societal infrastructure and a personal right.

Otherwise, the disadvantaged will not gain access to information networks and the fruits of restructured schooling that flow from telecommunications technology. That situation would serve to aggravate further the already fast-developing rift between the have and have-not families and children in this country. We cannot afford two societies, one with access to information, learning, advancement, productivity, and wealth, the other shut out from a world that would set them free.

FINAL THOUGHTS

Schools of the future imbedded in a telecommunications infrastructure may not *look* too different from today's schools, but they will be significantly different in many ways.

First off, the observed pace of educational change predicts that educational reform will take effect in 50 years, not in five years. If, by the year 2000, we as a nation have dedicated ourselves to a serious effort to change to a national system of education open to and effective for all children, that will be enough. The question is not whether all children will be ready for school by the year 2000 but whether all schools will be ready for all children by the year 2000.

The "school of the future" will include the following essential components:

- It will operate on the assumptions that all children can learn at high levels; that we know how to teach all children and that not all will learn or be taught the same way; that expectations for learning and behavior must be high, and that every child must have an advocate.

- It will provide early identification and educational intervention services for all preschool-aged children (three to five years) and collaborate with health and social and family service organizations to assure all children a healthy start and readiness for school.

- It will offer a developmentally appropriate curriculum by teachers knowledgeable about child development and their subject matter areas.

- Teachers will be able to work with a diverse group of students in a ratio of one teacher to 25 students at a maximum, with adequate assistance and technology to provide seminar teaching, coaching, cooperative learning, individualized teaching, and regular assessment of student performance.

- Schools will be open year-round and offer 210 days of study at minimum in schools that do not exceed 600 total enrollment.

- Schools will be student-focused and classrooms, schools, and school systems will be networked in local, regional, state, and national telecommunications networks to provide maximum access and interchange among students, teachers, principals, parents, school board members, and community leaders on a global basis.

- There will be a national curriculum and national standards and assessment processes in all core subjects—math, science, history and social studies, English, foreign language and international studies—and federal support of public schools at a level of 20 percent of local budgets. The curriculum will be infused with cultural and global perspectives that will strengthen national and world citizenship.

- All public schools will be tied to higher education through NREN for information exchange, professional development activities, innovative program transfer, common administrative needs, and teacher preparation.

- Centers for educational leadership development will be established as partnerships among schools and universities to provide training, evaluation, and research support for principals, superintendents, school boards, legislators, parents, and community leaders.

If there's a caveat to be drawn from all of the above, it may be that, in addition to a vision, as educators make a leap to the next level of exciting new technologies, they need to ensure that teachers, administrators, parents, and children make the leap with them. In planning for technology, educators must address concrete issues like partnerships, network options, financing, and training. They must also convey a broader vision of how technology could transform all facets of the educational infrastructure. Without a concentrated and coordinated effort at the outset, we will never know if we will see light at the end of the tunnel. Nor will we even know if we are in the right tunnel.

Educational infrastructure is an elusive—perhaps illusive—phenomenon. It is a catchall, not yet clearly defined. It is seen as a problem. It is seen as a solution. It is seen as both cause and effect. Experience says that we cannot deal with the educational infrastructure in isolation. There must be a cohesive set of guidelines to ensure that all the players are playing the same game with consistent rules. Perhaps most important, the infrastructure must be conceptualized, designed, and built with the broad goal of educational restructure and reform in the forefront.

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Realizing the Business Value of National Communications Infrastructure

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INTRODUCTION

The idea of building a national telecommunications infrastructure excites the imagination. It would enable a wide array of products and services deliverable to the office, home—wherever people want them. It *is* exciting to imagine what we could do: new ways to entertain, work, learn, communicate, restructure enterprise, redefine competitiveness, even redefine how we live. All this appears possible because of an easily available, extremely high-capacity communications infrastructure. Perhaps our nation's competitiveness depends on it, and our future way of life can be largely defined by it.

On the other hand, who will pay for it? Do we need it? Would it succeed in achieving its potential effects on competitiveness?

These are questions of *business value*. We know the capabilities of the technology, and we are confident it can work as promised. The question is whether it is worth what it will cost and whether the investment will produce the results we want. In particular, will the exciting products and services a national infrastructure would enable emerge? Would enterprises invest in products and services using the network, and would customers exist in sufficient numbers to make such products and services viable? Would enterprise business and technical managers do what is necessary to use a national telecommunications infrastructure profitably?

We discuss the business value and the national telecommunications infrastructure from a perspective drawn from experience in answering similar questions about computers and information systems. The problem is similar: like a national network, computers enable enterprises to create products and services and to change how they do business. Whether enterprises are successful at it depends on a number of factors, almost none of which are technical in nature. Computers and networks are also part of the same problem; applying the national telecommunications infrastructure requires the use of computers and information systems to supply the products and services on the network. In both senses we believe the lessons learned from business value of computers can be applied to the business value of the national telecommunications infrastructure. We will generalize both by discussing the problem of the *business value of information technology.*[1]

Marvin Sirbu's paper in this volume offers an interesting parallel of the transportation infrastructure used by the trucks, trains, and airplanes on which we depend. Who pays for this infrastructure? What is the value of a highway, for example? We believe no intrinsic business value flows from the transportation infrastructure except as it is usefully applied by business enterprises. In general, the value of infrastructure comes from the application enterprises and individuals make of it. In this sense an empty highway or an empty airplane—or an unused computer or communications network—has no intrinsic value except in terms of prospective enterprise or individual uses. We believe infrastructure value is an *opportunity value;* an infrastructure provides opportunities to enterprise and individual application. This leads to the principle that realizing its business value is dependent on overcoming the hurdles to its application and use.

What are the hurdles to realizing the business value of the national communications infrastructure? As indicated, we consider this question from the general perspective of the value of information technology (I/T). We can apply lessons learned from computers, information systems, and general information technology.[2] Since we are exploring business value we also consider the questions from the perspective of enterprises which might employ the infrastructure to offer products and services. Further, because we believe the problems are similar to and connected with computers, we consider value from the perspective of information technology professionals who would accomplish the development of business value through computer software and related developments needed to exploit the availability of the network.

Business value is important. Computer and communications vendors, in particular, should recognize that the business value of their technologies lies at the heart of the success of their technology. Technical marketers and managers can too easily focus on the technology itself and *assume that it is important to prospective customers simply because of its power and elegance.* Technology vendors are particularly subject to a myopia that effectively places the business value (recognition and justification) burden on the customers that buy the technology. In practice real enterprises and real managers make business decisions about technology, and these decisions are driven by the likelihood of gaining business value derived from technology application. Selling the idea of the network demands persuasiveness on its *real* business value.

THE BUSINESS VALUE OF INFORMATION TECHNOLOGY

The General Business Value Problem

The idea of investing in an information technology infrastructure such as a high-performance data communications network raises two management problems. First, any investment in infrastructure tends to be at least one step removed from "real" business value, namely profitability and return on investment. Those results come from the applications enabled by the infrastructure. A network, for example, could enable a corporatewide electronic mail system that in turn reduces the cost of coordinating production or responding to customer inquiries. Second, the achievement of "real" business value depends not on the successful technical implementation of the technology but on the change in behavior of the business itself. Technical success is irrelevant without success in applying it in the enterprise. The network must work reliably—but managers and workers have to use the thing and accordingly alter how they do business.[3] In both cases enterprise management faces choices, for other alternatives exist for investment in the business. Management can purchase delivery trucks, new product designs, more marketing staff, for example; a decision to employ an information technology is a decision that this is a better investment of scarce enterprise resources than the alternatives.

The combination of these factors is synergetic. The idea of infrastructure investment and its second-order effect on financial performance, combined with the behavioral requirements for change in business practices, puts real pressure on an I/T manager intending to persuade enterprise management to make the investment. Enterprise managers face many alternative demands for funds: why should they invest in information technology? Of course, these managers are also inundated with clarion calls for investment in information technology and because of its (obvious) importance to the business, it offers great potential.[4] The problem is not voicing the potential, the problem is getting management to see the potential in business terms, agree on the business desirability of making the investment, and getting it done. This is the real problem of value.

This is not a new problem. For five decades information technology has promised its enthusiasts a change in how business is done. The point of emphasis has shifted from time to time, from cost-saving automation to management information[5] to customer-focused information[6] to electronic highways to customer and supplier. Yet the central problem of "getting it done" has remained the same: to express in business terms how an enterprise can best take advantage of its information technology opportunities for maximum business impact, and how management can best overcome the hurdles to achieving that impact.

This is an important problem to solve. The next generations of information technologies, based on high-capacity communications, especially those with opportunities such as interenterprise and enterprise-to-customer communications, should not suffer from the same hurdles and barriers that past generations of information technologies have. We believe future information technology, and communications in particular, offers dramatic new ways to add value to the enterprises that are able to successfully employ them. Solving the "value problem" is necessary, however, to overcome the hurdles.

The Evolution of the Business Value Problem

Enterprise management may understand that using a national telecommunications infrastructure is an investment that may enable them to achieve important business goals.[7] For example, an enterprise may use a communications network to offer new products and services, increase the level of service it offers to customers and suppliers, and enable internal changes such as reduced cycle times and increased productivity in their business processes. The basic management question is the same for all information technology investments: *Should they?* That is, should an enterprise make the considerable investment in software and hardware necessary to accomplish such goals? The nature of communications technologies, in particular the technologies that offer easily used networking within and between organizations, makes the problem especially vexing now. The business opportunity lies in linking business processes, linking customers to suppliers, and linking partners in joint ventures and alliances. This is not a question of making the technology work, it is a question of changing the way the enterprise does business.

Whether such goals *are* important to an enterprise is one set of issues. Another is whether extensive use of technologies such as telecommunications networks is the best approach to achieving such enterprise goals. Answers to both depend on a clear link between the technology solution to enterprise business goals and enterprise management plans and objectives; that is, we need to define the business grounds on which enterprise managers can agree that a communications technology investment is the wisest application of scarce enterprise resources.[8] Addressing the challenges involved requires new ways to think about the ways in which the enterprise plans, organizes, manages, and justifies information technologies.

The problem is not new; and the value problem has evolved over time through stages of development within an enterprise. Typically, an enterprise began with a relatively simple production cycle and administrative support for its products or services. At some point information technology began to be applied largely to substitute automation for manual efforts. For example, an automated order entry system may have replaced the manual effort of opening the mail or answering the telephone and handwriting orders. In such simple circumstances the business value of the substitution was easy to determine. The business task itself remained the same, entering orders, but the means for doing so changed. The value of the information technology was created by cost reduction or perhaps quality/error improvement.

Over time things have become much more complex. Enterprise operations are geographically dispersed. The enterprise becomes tightly connected to both suppliers and customers. (Consider, for example, a manufacturer who supplies a major defense contractor or airframe manufacturer; becoming a part of the supply chain for large companies carries real complexity to the ways in which products are designed, orders negotiated, material acquired, and products distributed. Large companies find it easy to demand I/T sophistication disguised as just-in-time or quality methods from their suppliers.) Products themselves are more complex with technology, product quality considerations, and global supply chains and distribution requirements. (Consider, for example, functioning as a supplier to leading discount chains with their innovations in the retail equivalent of just-in-time inventory resupply systems.)

The origins and evolution of the I/T technology culture, with emphasis on transaction processing and glass-house technologies, intrudes here. Past I/T practices emphasized transactional systems, automation as substitutes for people, and relatively simple organizational impact. In the context of this history, the values of I/T-created innovations in the more complex enterprise environment of today clearly move beyond ROI[9] style of thinking; they are more connected to a clear understanding of the foundations of the business itself. For an I/T management culture that began by doing payroll systems, communicating and interacting with general managers who cope with the complex issues of today's interconnected businesses is very different from the old-style negotiations with financial managers about the desired content and functionality of the payroll system.

The value problem *is* a problem, and it continues to evolve. Enterprise management has become more experienced in the success and failure of information technology within the enterprise. The intellectual and credibility hurdle rate gets higher as technology costs increase and the difficulties in realizing its value become more apparent. The value problem, left unresolved, will get in the way of realizing the full value of information technology in general, and the national communications infrastructure in particular. V ̈ : need to solve the value problem to achieve the large and important business potential for the technology reported in the other papers in this volume. The other papers in this compilation, and the many examples of the prospects for the infrastructure, serve to emphasize the need to solve it.

The Need to Solve the Value Problem

As the other papers note, telecommunications has immense capabilities to change how business is done. Peter Keen[10] and Michael Earl[11] have recent books that give new emphasis to this. Joseph Pelton's article in last year's *Annual Review* offers a number of indicators of its future impact on business enterprise.[12] Previous work of the Institute for Information Studies has served to highlight the business potentials for communications. Last year's *Annual Review,* for example, contains a number of important articles on the subject that give important testimony as to the impact of information technology on enterprise, national, and global economies.

One has only to use an airline or visit a rental car desk to observe, in some detail, how things have changed in just the last few years. The collection of products and services these firms offer customers is determined very much by the information systems they employ and the communications networks they use to deliver them throughout the world. On the other hand, does all this have real economic value? That is, have past investments in information technology produced benefit to the enterprises that made them? Should an enterprise invest in information technology for future economic value? How can an enterprise determine the answer for its specific situation? These are, of course, complex questions, and illustrate just one dimension of the issues we propose to discuss.

To summarize our thesis: To realize business value, a communications network must result in change to the business enterprise itself. The technology must enable basic and fundamental improvement in business behavior and business performance. The change is not only in measured economic terms but also in the way enterprises manage themselves and their information technologies. *The adoption of effective management solutions to the problems this creates is necessary to attaining the appropriate change in enterprise performance, and to realizing the business value of information technology in general and communications technology in particular.*[13]

The problems largely revolve around management attitudes toward the allocation of scarce resources to information technology. I/T can be expensive, and as we've previously remarked, with infrastructure investments like networks, somewhat distant from "real" business benefits. Senior management always has a limited amount of money available, and this creates a real need to understand why that money should be spent on I/T versus more trucks, or more marketing personnel, or more distribution channels, or whatever other investment alternatives may exist. At the same time it is not completely clear that previous large investments in information technology have paid off. When we add the disruptive aspects of change caused by modern I/T impacts on how business organizations function, the conditions exist for a real disconnect between management willingness to invest in I/T opportunities and the achievement of lasting business value through such investments.[14]

The Connection of Business Value to I/T Organizations: Are They Really Part of the Problem (and Its Solution)?

Absolutely, and the major reason is that computing in some form is the engine for *applying* the network in the enterprise. Using it implies application, and application implies the involvement of a technology organization in the enter ·se. That is the problem. We can learn from the experience of applyi.g computing in the enterprise to understand the problem of realizing the value of communications networks; the problems are quite inextricably linked.

This is a big and long-lasting problem. During the evolution of information technology, the emphasis for the first 30 years was on technology management and the major challenges focused on getting the technology to work reliably. Anyone active in the 1960s and '70s can remember the thrill of seeing the first screen appear on an on-line application and seeing it appear the second and third time. I/T management practices evolved to assure proper technology implementation and operation—for example, systems development methodologies, change management methods, data administration, communications network management—these rose largely as ways to reduce the unreliability of information technology in the enterprise.

In parallel, information technology emerged as a centralized resource for most enterprises. The I/T organization became the center of technology management and technical innovation, particul ·v insofar as the technology itself had centralizing characteristics. On .ne systems, enterprisewide corporate systems, corporatewide communications networks, and single-image corporate data bases are good examples of technology applications with these characteristics. Of course, personal computers (and the related defensive measures I/T organizations used, such as information centers) focused some attention on the users, and on decentralizing technologies. The 1980s focused on these matters, by and large, including the emergence of end-user tools (e.g., query languages, relational data bases.) The 1990s offers even more of the same: communications is a critical technology that further enables enterprise management to respond to the organization's latent tendencies to disperse information technologies throughout the enterprise. Local networks, enterprisewide networks, and national networks serve to make it easier to do, and easier to move information around, within, and among enterprises and their components.

The foregoing is, essentially, a technical view of the impact of communications on the enterprise. It is easy to look at the issues as a technology management matter. The real impact, however, is in business and organizational terms. The prospect—and in many existing cases, the reality—of widespread communications capabilities accelerates the need to address the business management issues.

The Special Problem of Infrastructure Value

The idea of *infrastructure* probably originated with a manager somewhere struggling to justify an investment in something that couldn't be directly tied to a useful result. The fellow buying a very large computer has this problem; he will enable many applications, but nothing directly tied to what he's purchasing. The city manager investing in streets and highways has the same problem; there's no direct "return on investment" from the expenditures, yet certainly many good things, such as police access to neighborhoods, trucks to industries, ambulance services, and school buses, are enabled by the improved highway. "Infrastructure" surely seems like a good idea in these situations.

In an ideal world a manager could tote up the value of every application enabled by the infrastructure, and impute their value to the infrastructure investment. This is straightforward if all projects are contemporary with the infrastructure investments, but of course this is rarely the case. In a second ideal case, the manager could organize the infrastructure as a utility and recover the investments through direct usage charges. Where this is possible the value of the infrastructure investment can be determined in terms of future revenues to be earned. Even the first case could be addressed in this way, and the manager could look to the costs of alternatives (if, without the road, what the transportation costs for police services would be . . .).

All this obscures the basic issue: evaluating infrastructure is tough. One participant noted in an Aspen Institute meeting that simply letting this tough problem slide doesn't make it go away.

We observed earlier that we can usefully think of infrastructure value as a category of *opportunity value*. In modern enterprise opportunity value is more than a passive asset. Enterprise wants to use infrastructure to deal with complexities such as geographic dispersion, interconnection of organizational units, and interconnection of suppliers and customers. Doing so is difficult, and an enterprise that can do so successfully possesses a significant value in its management ability to cope successfully with complexity. This can add further dimension to the idea of infrastructure value. The very complexity raises a *competency value* not unlike the kind of competency value a manufacturing company might exploit in the use of specialized materials. ("We're world leaders in composite materials," which gives this company opportunities for future business exploiting this leadership.) The telecommunication technology capabilities, such as local area networks, wide area networks, image processing, network control, and the like, are clearly advantageous to a corporation intending to compete in markets for which these things are important to the customer. Perhaps a simple example is a financial institution; the capability of operating a worldwide financial network certainly means something. Value can be found in this capacity. We treat this idea of competency value the same way as the general value problem. However, such capabilities, unrelated to business intent to deploy the capabilities, are meaningless.

THE IMPACT OF BUSINESS VALUE

We will argue that business value is much more than a computation or investment justification issue; that successful recognition of value has a number of consequences. To summarize the argument and highlight where the next sections are headed, we offer four statements about value. (1) The *business value of information technology lies in its application*. The previous sections make this point, and it is the starting point for the next sections. (2) *Value is found in change.* The purpose of information technology is to change how business is done, and consequently this is how its value is measured. (3) *Traditional measures of value (e.g., ROI and cost-benefit analysis) are inadequate.* This point is a direct consequence of the nature of information technology. Its application, which changes how an enterprise does business, is reflected in all aspects of how the enterprise measures and assesses its strategies, organization, and basic business performance. Most of these are not directly measured in financial performance terms but in business performance terms.[15] (4) *I/T organizations must shift practices and perspectives in adopting business value.* I/T developments have focused on technology management; the new reality requires a focus on business performance.

If nothing else, enterprise experience in managing information technology has demonstrated that we have solved most of the hard technical problems. Technology generally works. It is reliable. It can deliver the technical promises. To deliver business value, however, requires solutions to problems created by the use of the technology in the organization. We have faced these sorts of problems from the beginning and have evolved a range of solutions. But modern information technology that transforms the enterprise and changes how it does business creates new problems and management impacts. We propose to consider four dimensions of the value problem of impact, and suggest approaches that deal with the problems presented.

THE CROSS-ORGANIZATION IMPACT: Modern information technology crosses organizational lines within the enterprise and among multiple enterprises.[16]

THE INVESTMENT IMPACT: Information technology requires clear, business-based investment justification.[17]

THE PERFORMANCE IMPACT: Any effective justification for information technology is linked to improvements in business performance.

THE IMPACT ON I/T MANAGEMENT: Realizing business value with information technology changes the I/T management job.[18]

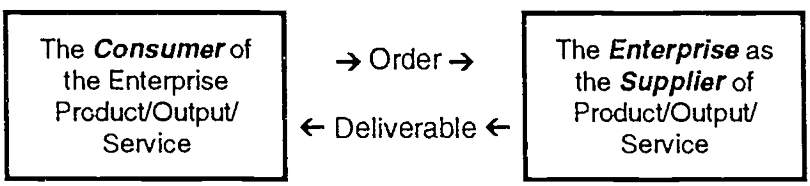
The Cross-Organization Impact

Modern information technology crosses organizational lines within the enterprise and among multiple enterprises.

Over the last few years information technology applications have become more complex. Twenty years ago, applications tended to be bound by departmental lines and by functional lines. Justification and value were issues in a relationship with a single manager responsible for a specific function or department. Lately, there has been much talk about reengineering, cross-functional business processes, integration of business activities, etc. (communications and networking technologies are certainly an enabling technology for this). But as organizational lines have crossed, the value and justification of computing have become more subtle issues. At the least, finding effective sponsors for I/T costs when the benefits are spread across many organizational units is more difficult. The benefits themselves are harder to define, for I/T managers deal more with intangibles now. They deal with the idea that I/T value does not come from cost reduction alone, and it is harder to deal with quantification in business terms of intangibles (for example, customer satisfaction, time-cycle reduction).

The ideas of "key business process" provide important clues here. Consider the basic economic enterprise model:

Figure 1 Economic Model of the Firm[19]



The customer requests a product or service; the enterprise produces it. This model describes the fast-food restaurant, the aircraft manufacturer, the lawyer's office. From our perspective, we want information technology to make the internal enterprise processes more timely, less costly (for example, collapse the business process that produces each key deliverable to the customer by an order of magnitude in cost or time or both). We also want information technology to add value to the customer by providing information or improved services and quality.

This model shows why information technology raises the stakes. It becomes possible for the enterprise to employ communications networks to both collapse cycles (say, by reducing the communications time among the tasks needed to complete the customer request) and to control the many participants in the production process (for example, just-in-time manufacturing processes that employ many suppliers of critical product elements). The capability for doing this is competitively important—and equally important to the ways the enterprise controls and manages its development of processes and supporting information technologies. This is cross-organizational, indeed multi-organizational, in ways that threaten the old ways of managing information technologies. This creates enormous new management challenges requiring new management approaches and skills. One of these is performance-based, value-based management of information technology.[20]

The Investment Impact

Information technology requires clear, business-based investment justification.

The stuff is expensive. The multiorganizational character which blurs the specific justifications for each organization unit makes it more difficult. Of course, this is not a new problem. Managers have made investment decisions about computers for 50 years. Generally such decisions reflect business-driven choices made by managers, usually many managers, and the choices are made among many kinds of alternatives. Computations such as return-on-investment can be helpful if they can be consistently done for all alternative choices in compatible fashion.

But financially derived computations intended to reflect the linkage between information technology investment and business goals miss the main point, that the investments are intended to achieve business goals that have a broader base in time and impact (e.g., increased customer satisfaction, market share, product quality) than can be credibly reflected in current-period financial measures. That these business goals have ultimate financial importance to the enterprise is unquestioned; the ability to calculate the exact financial impact in advance is difficult. Consequently methods to connect information technology investments to the achievement of business goals are needed.

particularly with investments in infrastructures such as a national or international communications network. Among other attributes, such methods need to provide industrial-strength management consensus-building on the business value of information technology. We have found that what management believes about the value of I/T is critical to its justification and development.[21]

Two areas are particularly difficult. First, modern I/T projects result in hard-to-quantify benefits such as quality, customer satisfaction, and competitive benefits; analysis of these sorts of proposed I/T projects probably does not result in measurable economic impact (e.g., projects that add to customer satisfaction or to service quality) in standard ROI terms. Second, investment in I/T to create or add to I/T or enterprise infrastructure (e.g., large-scale networks, application development infrastructure) produce benefits bound up in the I/T projects and applications that use them. The justification of such projects does not cleanly demonstrate measurable business benefit. Given that I/T investments compete for management attention and support with other possible investments, the difficulties associated with these two areas can be important to resolve effectively.

Whereas we describe these two difficulties in terms of justification, they could just as easily be described in terms of "linkage." That is, I/T management's goal is to create projects in information technology that can be closely linked to enterprise business objectives. Justifying and valuing I/T projects that lack clear-cut economic computations, and I/T infrastructure projects that lack clear-cut economic impact, can be stated as difficulties in achieving linkage to business planning.

Business value helps with the linkage[22] and answers the questions managers have about I/T: retrospectively—"Am I getting my money's worth from I/T?"—and prospectively—"Should I invest in I/T? What should my investment priorities be?" In this paper our interest is in the prospective definition of value. However the two questions are related: in both cases "value" results from the linkage of I/T to the enterprise. Management recognizes value by linking I/T investments to business goals of the enterprise and its components.

The Performance Impact

Any effective justification for information technology is linked to improvements in business performance.

Our work in Enterprise-wide Information Management (EwIM)[23] has helped in understanding the relationship between I/T and business performance. In some ways the result is simplistic: *The value of information technology is derived from the improved performance information technology provides* the enterprise and its component parts. An order-entry system has value when it improves productivity or customer satisfaction, assuming this is important to the enterprise. In another sense this result has forced a more complete understanding of the ways an enterprise articulates to itself the things that are important and the consequent ways an information technology project has to be linked to these things. This more complete understanding falls into two categories:

Value through linkage to the enterprise

Value is an extension of management planning.

Value cannot be unhooked from the management processes that define priorities and set objectives for the enterprise itself.

Measurement and recognition of value

Value is relative (not absolute) and is a function of time.

Value cannot be unhooked from measurements.

Value is based on business performance improvement.[24]

These principles have evolved during the experiences of applying business value to the justification for information technology. At the same time it is important to note that the concepts of ROI and cost-benefit analysis and their focus on measurable economic benefits have not been abandoned or downgraded. Business value is founded on economic impact. The concepts of value and linkage are necessary to deal with the difficulties involved, the nature of modern I/T benefits, and infrastructure investment justification.

We have learned that the achievement of measurements depends very much on the character of the line of business. More specifically, three clusters of business types exist. A line of business that primarily manufactures tangible products, such as automobiles or consumer goods, is concerned with attracting customers, delivering quality products, and in so doing, performing profitably in financial terms. A line of business that primarily provides services, such as a hospital, a lawyer, or a fast-food unit, is also concerned with attracting customers, but has a customer-response need rather than the delivery of quality products. An organization that is nonprofit or government in nature, including utilities and similar organizations, is not concerned with attracting customers so much as adequately serving those that need the governmental service. This is an access and capacity problem. The choice of measurements of performance, and consequently the contribution of I/T to their improvement, is based on the characteristics of the business, the line of business, for each enterprise. We consequently define the simple idea that information has value if it "moves the measures of performance." A key way to do so is to provide full information about the customer and enterprise performance with respect to the customer to the key actors in the enterprise. We assert that the information system user and the I/T professional are capable of defining the appropriate performance measurements that represent value. We suggest these define customer choice (such as market share), quality (such as product returns), and financial condition (such as profitability). Information system planning concentrates on linking the information system goals to the cause/effect the information system has in moving these measures; with this linkage the information produced then has value and should be the basis of investment by management.[25]

This is not easy. In the United States, the I/T organization has historically served users that are not directly engaged in the lines of business. Rather, the I/T organization developed to serve the overhead units such as finance, accounting, payroll, and plant, rather than the business units responsible for the performance of lines of business. Often I/T has reported to an administrative or financial officer. Some important consequences: I/T has grown to "serve the users needs" and—essentially—reduce expenditures for the overhead units. This is important, but certainly is not the basis for true value which is based on improving the business performance of the lines of business. This means serving the customer's needs, satisfying the customer's expectations.

This history of working primarily for the overhead units has created the result that I/T is considered a cost, not an asset of the enterprise. This is not a surprise when we consider the historic bias toward serving masters in the overhead arena. We have come to understand that the real value of information lies in the impact it has in the lines of business. This is true even for I/T services provided to the corporate units if the connection can be made between the availability of information in the overhead units that results in improved customer services or reduced costs that otherwise burden the financial performance of the lines of business.

The response, of course, is simple: By linking to business performance information technology becomes a powerful tool for the enterprise.[26]

The I/T Management Impact

Realizing business value with information technology changes the I/T management job.[27] And it changes the relationships between information technology organizations and the rest of the enterprise.

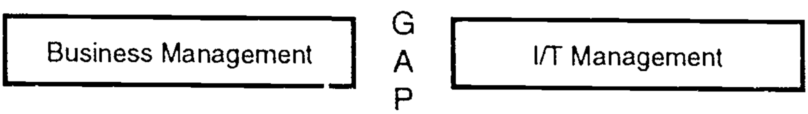
The dimensions of change are reflected in four challenges:

- Information technology management must deal with a "value gap."
- I/T management needs to rethink the I/T organization.
- I/T management must focus senior management attention on the value of I/T investments.
- I/T faces real internal problems in addressing business value.

Information technology management must deal with a "value gap." The symptoms are easy to spot. I/T management fights to prevent uncontrolled dispersion of computing activity. A particular business manager, often a line-of-business head, installs dedicated facilities and staff to solve a local need. Managers dependent on I/T complain about cost and time delays. Senior management requires extraordinary justification for major investments in computing. I/T managers make the case for infrastructure investments (e.g., networks, new computers) in largely technical terms. Senior managers have little understanding of the contribution of I/T to business performance.

At the same time I/T is very visible. I/T may be the single largest cost pool visible to senior managers. The good news: many I/T organizations can point to real success. Projects are done. Operations are satisfactory,

Figure 2 The Value Gap



with increasingly good reliability. First-line users are satisfied; new workstations offer productive tools and services, training is appropriate to user needs, and user support organizations are active in responding to problems. Yet the gap remains when it comes time to consider large new investments in I/T. The senior I/T executive often does not feel a full member of the team; the senior user managers are lukewarm in their support for what is needed in subsequent action plans.[28]

Symptoms of the business value gap—when management is heard to say:

> I/T is not responsive to real business requirements.
> I/T has no clear business vision for the next major steps.
> I/T values are not the same as enterprise business values.
> I/T is technical managers hiding behind their technology.

Yet I/T management knows there are real challenges ahead: process reengineering is merely one of them, and additional investments in needed infrastructure including systems development automation also are needed. The business value gap can prevent management acknowledgment and understanding of the investments required; worse, the size of the investments for infrastructure and complex applications such as reengineering keep getting bigger.

Figure 3 The Value Gap Messages[29]

Business Management		I/T Management
Executives	*"We're not getting enough business value from our investments in I/T"*	CIOs and I/T Directors
Line and Line-of-Business Managers	*"You take too long and cost too much. And you don't address our real business needs."*	I/T Technical Managers and Project Managers
Department Supervisors and Staff	*"Your systems work pretty well. . . . We just need a few more enhancements."*	I/T Operations and Technical Support

The value gap is a set of mixed messages. End users, those with their hands on the keyboards and using the systems, are satisfied with what they have. Supervisors and department managers, generally, like the functions they have available to them. But managers who really have a stake in their business performance, particularly those who are responsible for corporate performance and for achieving strategic business requirements, are expressing great concern for the real return their investments are getting.

"Business value" is a real problem. Paul Strassmann in *The Business Value of Computers*[30] reports his study into the relationship between information technology investment and bottom-line performance for the enterprise. Sadly, he finds no correlation between I/T investment and enterprise financial performance. This result extends to a study of comparable companies in the same industry. His argument is that investment in information technology, by itself, doesn't guarantee improved enterprise performance; there is something else, something additional involved in those companies that do in fact achieve improved business performance. A similar argument is made by those looking at the service industry; here, the argument is that investment in I/T has produced little discernible improvement in service worker productivity. Recently one *Wall Street Journal* article noted that companies with large I/T investments show a worse return on assets than those that have small I/T investments.

It is no wonder that there is a value gap between business management and information technology management. This gap has two related elements. The first is the disbelief managers express about the real business value contributed by both on-point costs and new development projects. This disbelief is expressed both in terms of aggregate value—"we're not getting an adequate return from our investment"—and in terms of specific projects—"you're costing too much, and you aren't addressing my real business needs."

The related element is that I/T may not be addressing all the business needs that exist, that attention is not sufficiently placed on what business value really is. This latter problem, of course, feeds the first one; even without it, the first one is serious enough.

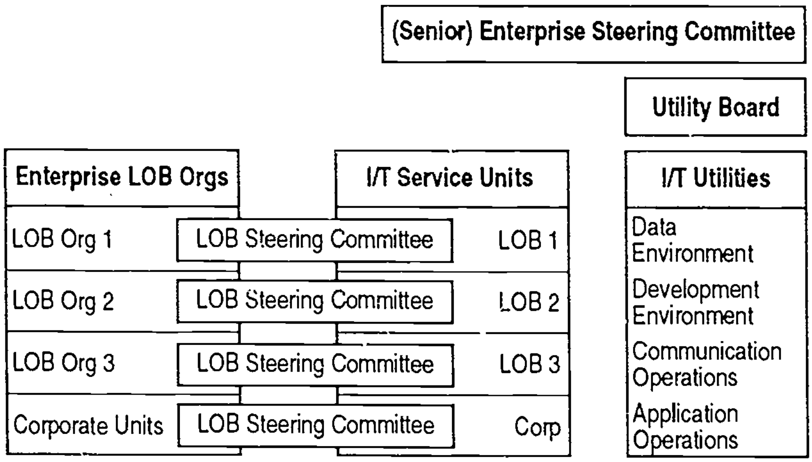
I/T management needs to rethink the I/T organization. The value I/T brings to an enterprise is entirely dependent on the purposes a computer application supports. The accounting department obtains value when the effect of I/T is to make better and more productive accountants. I/T accomplishes this by providing access to and processing for the financial information of the enterprise. Similarly, a functional unit such as an insurance claims department obtains value when the computer application maintains the critical customer and policy information and keeps track of the transactions with the customer. Delivering value to the enterprise is entirely a function of delivering value to individual business units, solving their specific problems, and supporting their specific objectives.

Consequently, the I/T organization must optimize its relationships with its diverse user organizations. This principle is the basis for the "I/T service organization," which is organized to be aligned with each of the specific business units I/T serves. However, this organization does not address technical management matters as well. In fact, for technical management—both effectiveness and efficiency—ideas of critical mass, centralization, and specialization are an integral part of the best approaches. Achieving this critical mass is best done with a utility-based management approach.

The combination of utility management for the technology component of I/T, and service management for the application support component, allows concentration and focus on the important management issues. The I/T utilities organization is, in general, a part of the enterprise I/T organization. Figure 4 lays out some of the relationships. The diagram uses the expression "LOB" as "line of business." For many enterprises alternative organizational forms are appropriate, perhaps business functions (e.g., marketing, accounting, manufacturing) or perhaps key business processes (e.g., billing/invoicing, customer service, product distribution). Though the following descriptions focus on LOBs, the reader is encouraged to substitute his own best terminology.

This organization diagram represents the complete business-driven I/T organization. The LOB organizations are the I/T users, differentiated by each specific line of business. A retailing enterprise, for example, may have a catalog line of business and a retail store line of business. The corporate units are the overarching service units such as corporate marketing or human resource management groups. In each case a steering committee and an I/T service organization meet their

Figure 4 Business-driven Enterprise Organization[31]



specific I/T requirements, and focus on improving the performance of their specific line of business. The I/T utilities manage the technologies needed to provide the services used by the lines of business. The I/T utilities work for the I/T organizations at the line of business level; they in turn work for the enterprise line of business managers.[32]

I/T management must focus senior management attention on the value of I/T investments. A senior marketing manager looked at the I/T director with a small smile. "I hear your I/T plans, and I find them interesting. I know your systems are well constructed, because my managers and their staff like them. But . . . I'm not willing to authorize the $1 million project you're proposing. I understand the technical reasons you want to do it; and I understand that my staff will get some advantage from it. But frankly, your system will cost too much, and it will take too long to develop. Our conditions will change too rapidly for us to wait for your system to be completed. But that's not the real reason. Frankly, your system won't address my real business needs. I'm not getting value from your organization."[33]

The senior executive remarked to his I/T director: "I'm really concerned. We're spending $30 million per year in your area, and this is the largest single cost center in our company. And frankly, I'm not convinced we're getting adequate return from this enormous expenditure. I think we'd be better off if I could put that money directly into the business—at least there I'm convinced I can get real value, real return."

These management concerns characterize the value gap that can exist between business mangers and their technical managers. This gap results from the difficulty managers have in seeing the real business value from their investments in information technology.

We have had the opportunity to look at the way I/T is managed in a large number of U.S. and European companies. This has led to several conclusions about I/T organization and management practices as they relate to, first, the achievement of business value, and second, the ways in which large-scale infrastructures are justified, such as national networks and other aspects of large-scale communications. We conclude that the issues raised here, namely the problems of multiple organizations, complicated by the "value gap" and other management disconnects, have led to unfortunate things. In particular we note that, for the typical large organization, the I/T organization becomes frozen in place. We observe a disconnect with management in explaining what is possible, what is happening. Management sees huge unresponsive costs which lead to focus on cost-views as compared to business contribution. Dismantling of the central I/T organization is considered; with a sense of confusion and no direction. I/T professionals don't know what they should be doing.

We can't think of a more important challenge to I/T managers. Adopting *business value* as the theme for the organizations they manage is *the* critical success factor for I/T this decade.

I/T faces real internal problems in addressing business value. I/T organizations have significant difficulties in addressing the problems outlined here. We can summarize them in four categories:

REAL PROBLEM ONE: Enterprise management lacks an objective, comprehensive, business-based view about information technology—about the business-based value of I/T.

REAL PROBLEM TWO: I/T professionals lack the tools and methodologies to give the objective, comprehensive, business-based views to enterprise management.

REAL PROBLEM THREE: I/T professionals need the business-based tools and methodologies to enrich the partnership with their user managers, to give the objective, comprehensive, business-based views about the business value of I/T.

REAL PROBLEM FOUR: I/T may not be willing to take the steps to implement the changes needed.

This last point is key. We believe that change is needed to achieve the lasting impact of information technology. To give some perspective on the issues, the appendix describes four ways in which I/T may take steps to address business value.

Summary

This paper has described a number of management issues associated with the achievement of business value through the application of information technology. Communications, and in particular nationwide communications networks, are a particularly powerful form of such technologies. They enable the dispersion of information technologies throughout the enterprise, linking business processes within and among enterprises, and generally make it possible to use information effectively to manage, to give better service to customers, to improve the quality and desirability of products.

Though the paper does not focus exclusively on communications-related technologies, the principles apply, indeed they apply with all the force of any other information technology. It is a powerful tool for business value. The true test of management's ability to deal with the matters raised here is achieving business value with lasting impact. That they do so is imperative. The technology has the potential to change, in fundamental ways, how business is done.

In the beginning of the paper we suggested some questions whether all this has real economic value, some questions of *business value*. The capabilities of the technology are known and we are confident it can work as promised. The question we posed is whether it is worth what it will cost and whether the needed investments will produce the results we want. We are convinced of it, but believe the hurdles of business value can stand in the way. We believe the telecommunications infrastructure depends on addressing the problems successfully.

APPENDIX: BUSINESS VALUE AND THE I/T ORGANIZATION

We believe the challenge of business value requires significant change in the way I/T is managed. The problems of achieving business impact with information technology, complicated by the cross-organizational aspects and the imperatives to link I/T investments to business performance, stress technology management. Instead of managing technology, the traditional view of their role in the enterprise, *technology managers must put on "business" clothes to be effective.*

This has real impact, and is an important shift in perspective. We redefine the purpose of information systems organizations and information technology. I/T does *not* exist to serve "user" needs per se. Rather, I/T exists to add value to the business unit—to improve the functioning of every unit, including those internal to the enterprise as well as those that deal with customer matters. Information is valuable—I/T adds value to the enterprise—when the performance of the business unit is improved. Value is added when those measures of customer choice, quality, and financial performance are changed. Information that is not linked directly to such changes is valueless; by extension, information systems and information systems organizations that are not so linked are also valueless.

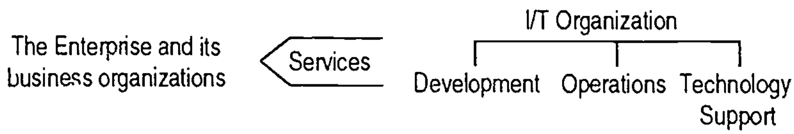
Specific areas of change include:

- Business value requires I/T managers o focus on the business.
- I/T managers must contend with dispersion.
- I/T managers must link plans with the business.
- I/T managers must work with a broader set of management groups.

The combination of the four is difficult. Twenty years ago the I/T organization could successfully control I/T; centralization was the dominant paradigm, and managing the technology itself was the dominant requirement. Decentralizing technology reduces the ability to control things, and makes it much more difficult to assure that technology plans are linked to business plans.

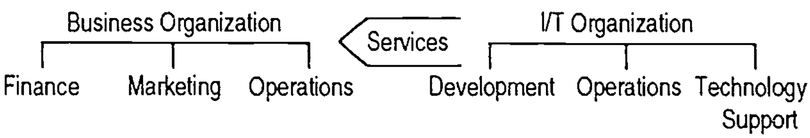
Business value requires I/T managers to focus on the business. Over the last 50 years I/T evolved largely as a single organization within the enterprise, supplying information and information systems services (e.g., development and operations) to individual operating units. As a consequence I/T organizations evolved into monolithic organizations, applying common methods and single large systems solutions to the complex businesses they served. This paradigm is based on a technology management perspective of the role I/T organizations are to play in the delivery of information systems and services to the business organizations, with something of the following organizational form.

Figure 5 The I/T Organization



Business also evolved in functional terms with hierarchical management and organizational forms. This has meant that the I/T organization evolved in ways that tended to optimize its relations with the business hierarchical forms (business functions and departments).

Figure 6 The I/T Organization with the Business Hierarchy



The current I/T paradigm is thus characterized by management patterns evolved from technical management. (1) Technology is characterized by specialized management functions. (2) Critical mass and economy of scale are essential factors. (3) The I/T organization should optimally serve the needs of the organizational units of the enterprise, and develop appropriate methods and tools to do so.

This optimization is a natural outgrowth of I/T's desire to serve user requirements and the evolution of systems themselves. I/T organizations generally started by developing single-department systems. That is, I/T first did systems for users such as the accounting department, the human resources department, and the marketing department. These represent corporate staff and not line business functions. (An interesting confirmation of this is illustrated in the early Nolan/Norton portfolio analysis ideas[34] which describe the enterprise in terms of the Anthony Triangle and map the business functions onto that triangle. This is comparable to mapping systems onto an organizational hierarchy.)

This approach to delivering I/T remains effective and acceptable in organizations for which information systems support remains bounded by single organizational units. If I/T develops systems for well-defined and separate organizational units and the systems are distinct by organization, then initiatives to optimize the I/T organization to match the business organization are the appropriate direction to take. Some of the actions that can occur include: (1) Adoption of departmental computing platforms; (2) dispersing the systems development group into the functional departments; (3) reliance on traditional systems development methods and/or adoption of new techniques on dispersed platforms where the decision affects the single department individually. A mixture of approaches can be adopted.

However, the basic principles on which I/T is managed break down under current business and technology changes. These conditions attack the hierarchical view in both business and technology organizations. In particular the challenges are observed when (1) systems cross organizational boundaries, and (2) when business requirements are significantly different across those organizational boundaries. A good example is the current interest in reengineering basic business processes. In these cases the basic assumption of the central I/T organization—that it exists to manage and deliver technology-based services to the enterprise—must be replaced by a new set of assumptions.

The Emerging Paradigm

In business, the hierarchical organization as the sole arbiter of plans, business strategy and performance is giving way to the recognition that many of these matters are more effectively addressed by new organizational frameworks. These frameworks are characterized by terms like process (for example, the enterprise's customer billing process), activity (for example, the enterprise's marketing activity), and line of business (for example, the enterprise's consumer products line of business).

In these cases information systems intended to effectively serve business requirements must collect, manage, and deliver information across organizational boundaries; no one tends to "own" the resulting system. In other cases the focus of management responsibility exists in the business, but without a parallel information technology focus. A single I/T department may confront multiple lines of business or business process organizations, each with significantly different types of problems which are not well served by a monolithic information technology approach.

At the same time, technology has radically changed. In the past the assumption was that "the bigger, the better," meaning more powerful and less expensive. Recently it has become clear that smaller technologies such as personal computers can have superior characteristics, power, and economics. Hence the assumption that only single systems operate in massive organizations does not always hold true; indeed, the complexities that large systems bring, by themselves, can seriously complicate the problem of addressing complex cross-organizational business problems. The communications network infrastructures, national in scope, make possible a very considerable movement of information technology out to the organization units.

The emerging paradigm is characterized by business management issues rather than technology management issues. But it is more subtle than merely optimizing I/T management to the business organization. The value emphasis on the business itself, with focus on business process, business activity, and lines of business, brings additional changes to the paradigm.

Perhaps one key point is the focus on the relationship between the enterprise and its customers. This crosses business organizational lines: the issue is improvement of quality and productivity of services and products extended to the customer, which requires a cross-functional consideration of the best ways to do so.

The new paradigm is characterized by a different set of principles. (1) Serving the customer well is a specialized management function. (2) Critical mass (of information about customers, products, and services) and economy of scale (business processes and activities) are essential factors. (3) The I/T organization should optimally serve the needs of the enterprise, and develop appropriate methods and tools to do so. This means matching to the requirements of business process and activities and lines of business, including matching according to different technology needs.

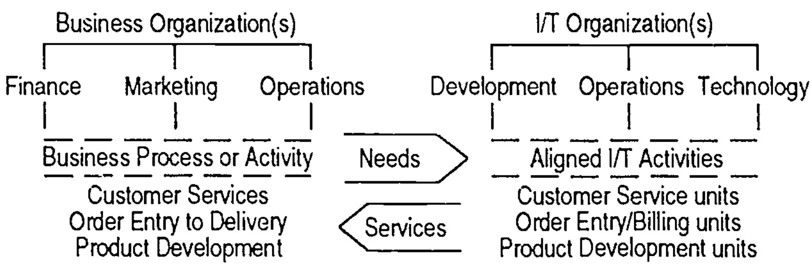
The Resulting Paradigm

The key to the paradigm is the shift away from information technology management and information systems development, as the driving components, to information management aligned to the requirements of business activity. The components of the paradigm, then, are made up of new imperatives:

- information networking
- systems bounded by business process and activity
- high-productivity systems development

The resulting I/T organizational forms take on a different kind of business linkage from the current paradigm. Rather than linking to the existing business hierarchy, the new paradigm links to business processes or business lines of business (see Figure 7).

Figure 7 Aligned Business and I/T Organization



Note that the driver is the business requirement, aligned to the specific business activity to be supported. A key is the shifting focus of both business and technology organizational forms. The reality is that the central or single-image form is no longer required.[35]

I/T managers must contend with dispersion. We believe that for most enterprises I/T is a necessary infrastructure investment for the company to remain in business. Its justification is the same as any other part of the business. In addition we will have other applications of I/T for specific parts of the business; for example, strategy-specific applications such as a bank that chooses to emphasize EDI services for value-added services to its corporate clients.

The result is that the management cycles applied to I/T need to be rethought. The old ways of doing the I/T business will not be satisfactory. In particular, the old ways have resulted in hierarchical, top-down means for planning and managing. Where these ways result in impediments to doing business in the new way, they must be changed.

Consequently we propose a new management life cycle for I/T. This new life cycle, covering I/T planning, organization, management, and implementation and control, must examine the requirements to serve dynamic business needs, flexible organization forms, and rapidly changing strategic business positions. In a fundamental way the basic assumptions change. In the past, the assumption was that cost, perfection, and long life cycle stability were the imperatives. The assumption was that I/T stands for building permanence and long-lasting structures. The desired result was an elegant, cost-efficient infrastructure. Now, the requirement focuses as much on time competition, flexibility, and continuous change. The difficult part is not that the new forms are entirely replacing the old. Rather, flexibility and time-based competition completely dominate; infrastructure approaches to thinking about I/T investments get in the way; and infrastructure approaches to I/T management practices place impediments in the way of achieving business value.

One idea that demonstrates this is the "lifetime" of the I/T investments. Just like a building, I/T has an expected useful life. But just like a building, its components have varying useful lives. Within a building, walls, space assignments, ownership, and usage patterns have varying life-cycle requirements. But basics such as elevators, electrical power, and similar aspects have a longer, more enduring life cycle. This example doesn't merely differentiate between applications and underlying delivery of useful lives. Applications themselves have varying useful lives and varying life cycles depending on changing circumstances. What might be important at one point of an enterprise development, or between enterprises, (such as a common accounting framework or a common human resources system) may not be important in different circumstances for different enterprises. Being able to accommodate fundamental changes in the basic assumptions that govern what applications do, and their relationships to one another and to other enterprises, is what underlies the new management life cycles for I/T.

The real key is to not lose the technology planning requirements. Technology management is hard enough—and it has to be done successfully. Our particular strength is to retain the fundamental information technology management practices that must be done successfully, but done fully linked and driven by the changing business realities. In short, successfully managing technology together with driving its management by business imperatives is the particular strength we apply. This is hard. Good technology implementation carries some of the baggage of the old bureaucratic top-down planning. What we offer is the correct balance.[36]

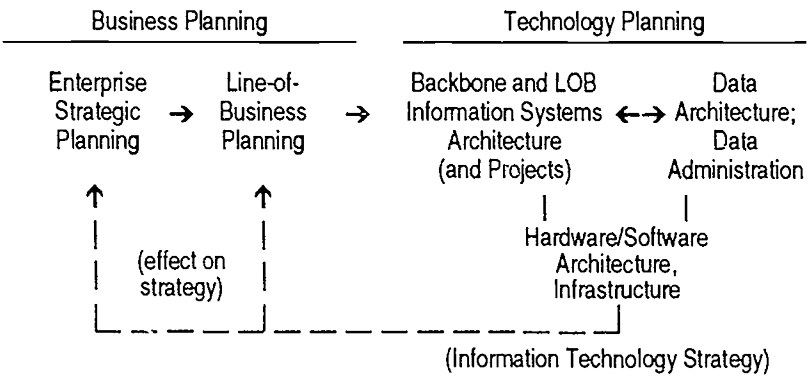
I/T managers must the link plans with the business. Enterprises plan for information technology by examining the business plans and strategies for each line of business, and by determining the best investment opportunities for information technology from those plans and strategies. From a planning results perspective, an enterprise should work toward a planning and decision process that produces some or all of Figure 8. The figure shows a set of planni_ results and relationships possible in a particular enterprise. Such processes are needed and should be linked. The challenge is to define the appropriate relationships. The results of the planning and decision process are in five categories:

- enterprise strategy
- line-of-business planning
- information systems architecture
- hardware and software architecture and infrastructure
- data architecture and data administration

The first two are included in planning processes in the business domain; the other three are primarily I/T organizational issues.

A successful information technology project achieves both technical and business goals. The technical challenge is to make the system function through effective application of technology. The business challenge is to cause real business impact. The achievement of both technical and business goals is a matter of linkage. The goals for information systems must be linked to the aims, aspirations, and

Figure 8 Business-driven Planning[37]

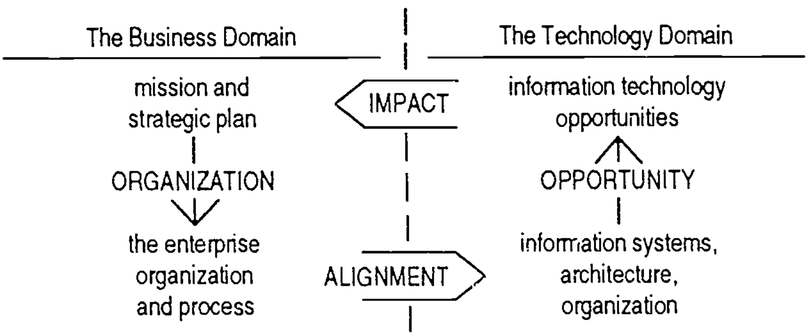


objectives of the business organization that intends to apply the system. Achieving linkage, meaning achieving close links between information systems technicians and business managers, requires appropriate tools and techniques of planning and management. Technology-based tools derived from systems development (e.g., data models, process descriptions) are not sufficient. At the same time, effective development of information systems is increasingly complex due to expanded scope (e.g., companywide applications, customer-driven systems) and broader technologies (e.g., widely used local networks and workstations, imaging, intelligent systems). Successful linkage to business goals adds to increased complexity of applications themselves to create the need for effective planning and development tools for I/T.

Figure 9 shows the emphasis on the linkage between business and technology planning. Real planning in real enterprises, however, occurs in ways that are more like projects. Annual or quarterly planning meetings and planning activities may occur. The specific enterprise business goals are unique for every enterprise. The achievement of linkage between business and technology planning is a function of specific adaptation of EwIM components to meet the specific requirements of the enterprise and its I/T organization.

The planning linkages themselves are in four categories: alignment, impact, organization, and opportunity. The result is a linked plan between the business organization and the I/T organization. *Alignment* starts from the existing business organization and its needs, and gener-

Figure 9 Technology-driven Planning[38]



ates the supporting information technology plan—the information systems master plan—to satisfy the needs of the business. *Impact* starts from technology opportunities and generates changes to the line-of-business business plan in terms of new products, new customers or customer interfaces, new strategies, and new markets. *Organization* starts from the line-of-business strategic business plan and defines the effective organizational form needed to carry it out. *Opportunity* starts from the existing information technology and I/T activities and defines current and future resources and assets that can be deployed to change the business plan and/or to align to business needs. Planning itself typically is of two kinds. "Strategic" views of planning are characterized by linkages between the business and the technology domains. The planning focus is on business performance and the way information systems can contribute to improvements in the performance of the business. The second kind is a "project" planning process: the focus is on what the business organization needs in the way of individual application projects.

I/T managers must work with a broader set of management groups. We all agree that information technology has a major role to play in transforming the business enterprise. Much of the appeal is based on competitive industry and economic conditions. For example, an enterprise may find it critical to reduce its order-to-delivery or product-development-to-market cycle times. Much of this competitive impact is created by information technology. Its realization is a complex matter of many ideas. The business vision itself, encompassing product, services, relationship to customers, and internal organization, is obviously critical. At the same time, the exact manner in which information technology is developed and deployed, including change management, cost justification, and management commitments to the process, is equally critical. This process is a multiple-step connection of concepts and practices.

Figure 10 Moving from Business to Technology

vision to planning to implementation

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SOFTWARE ENGINEERING
SYSTEMS ENGINEERING
BUSINESS PROCESS
BUSINESS VISION

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technology to changes in business vision

This is a good deal more complicated. The implementation stages may well involve new technologies (e.g., computer-assisted systems engineering [CASE]) and operational technologies (e.g., client-server). The connection of the development stages is itself difficult. The connection between business vision and the deployment of information technology involves considerable issues of value and justification as well as business management changes. This matter is also more complicated in that the ideas and concepts and practices in each area do not effectively talk to each other (except as asserted in methodologies like information engineering). The four components are, in effect, parallel activities and developmental processes, much like overlaying templates upon the enterprise itself.

Conclusion

We believe business value is the most difficult challenge I/T organizations have faced. The organization evolved to manage and deliver technology to the rest of the enterprise; it is now asked to take on partnership roles and closer interactions with the business units it serves. This is an enormous change, difficult and complicated to accomplish. We are convinced it is necessary and that leading enterprises are already well on the way to accomplishing the change. We particularly believe information technology vendors are both a part of the problem and its solution. The latter is the key point; vendors can contribute to the understanding of business value among their direct customers. This is a challenge not to be overlooked.

ENDNOTES

1. This paper limits its considerations to *business* value. Aspects of societal value, e.g., public safety and convenience, are considered only to the extent products and services are developed in response to such needs.
2. See Marilyn M. Parker and Robert J. Benson, *Information Economics: Linking Information Technology and Business Performance*. Prentice-Hall, 1988.
3. For insight into the nature of behavioral change in business, see books like Peter Senge's *The Fifth Discipline: The Art and Practice of The Learning Organization*. Doubleday, 1990, and Mary Beth Kantor's *When Elephants Learn to Dance: Mastering the Challenge of Strategy, Management, and Careers in the 1990s*. Simon and Schuster, 1989.
4. See, for example, any number of books on the future impact of information technology. Some good ones include Peter Keen's *Shaping the Future: Business Design through Information Technology*. Harvard Business Press, 1991, and Charles Wiseman's *Strategy and Computers: Information Systems as Competitive Weapons*. Dow Jones-Irwin, 1985.
5. In the late 1960s the computer press was full of projections about how information systems would support "the total system" and "the management information system." The natural evolution of these ideas is the current interest in enterprise models, encouraged by the evolving computer-assisted systems engineering (CASE) tool developers.
6. This is a theme of the late 1980s with reports of companies such as Frito-Lay and its success in deploying information to manage its business.
7. Most of the language of this paper addresses for-profit enterprises, particularly as language like "profitability" and "business goals" is used to exemplify the purposes of information technology. Public enterprises, however, also exhibit the problem of value in similar ways. Information technology can accomplish improved performance of government agencies and other nonprofit institutions. Although the rhetoric in this paper is biased towards for-profit enterprise, the observations apply equally to public enterprise.
8. The Diebold Group published *Evaluating I/T Expenses and Investments: Summary of Findings* in 1990 with considerable treatment of the way the "value problem" has evolved and been treated by different organizations. It can be referenced as Document Number 264E. The Diebold Group is located at 475 Park Avenue South, New York, NY 10016.
9. ROI, "return on investment." We use this terminology to represent the class of cost-benefit analysis techniques that has grown up around information technology in the last 30 years.
10. See note 3.

11. Michael J. Earl, *Information Management: The Strategic Dimension.* Oxford Press, 1988.
12. Joseph N. Pelton, "The Globalization of Universal Telecommunications Services," *Universal Telephone Service: Ready for the 21st Century?* Annual Review of the Institute for Information Studies. Nashville, TN, and Queenstown, MD: Institute for Information Studies, 1991, pp. 141–184.
13. See "Information Economics and the Business Value of Computers," POSPP Report P-34-1, Chancito Publishing Company, 3230 Commander Drive, Carrollton, TX 75006. This paper reviews the principles of business performance improvement in some detail and features a bibliography of related publications.
14. See Walter M. Carlson and Barbara C. McNurlin, *Measuring the Value of Information Systems.* United Communications Group, Bethesda, MD, 1989.
15. The inadequacies of traditional financial measures of value are well known by now. Chapter six of *Information Economics* dwells on this point at length. More directly, it is instructive to note the dictionary definitions: *Value:* 1. A fair return or equivalent in goods, services, or money for something exchanged. 2. The monetary worth of something. 3. Relative worth of something. *Worth:* 1. Monetary value. 2. The value of something measured by its qualities or by the esteem in which it is held. *Benefit* (noun): 1. An act of kindness (archaic): "benefaction." 2. Something that promotes well-being: "advantage." 3. Useful aid: "help." (verb): 1. To be useful or profitable to. . . . See *Webster's Ninth New Collegiate Dictionary,* 1984. The point is directly made that "benefits" as a concept is much too limiting; though not obvious here, "costs" are too.
16. See any discussion of business reengineering to see how important this is. The Keen reference earlier is excellent on this point.
17. This is the main point of *Information Economics.*
18. The paper discusses the impact on I/T management; the Appendix discusses the impact on the I/T organization.
19. An early proponent of using this model to describe the enterprise was Don Burnstine and his coworkers at IBM. They developed the BIAIT model, described in the following reference.
20. Read any one of a number of books on service quality for an appreciation of the size of the challenge. We like Valarie Zeithaml, et al., *Delivering Quality Service: Balancing Customer Perceptions and Expectations.* Free Press, 1990. Also, Peter Mills (*Managing Service Industries.* Ballinger, 1986) and Leonard Berry, et al. (*Service Quality: A Profit Strategy for Financial Institutions.* Dow Jones-Irwin, 1989), are excellent on the showing the basis for the connection between I/T and performance-based business value.
21. See, in particular, "Information Economics and the Business Value of Computers," POSPP Report P-34-1, Chantico Publishing Company. POSPP is a group of over 100 Fortune 500 companies, and can be reached at 3230 Commander Drive, Carrollton, Texas, 75006.
22. See "Enterprise-wide Information Management: An Introduction to the Concepts," available from the Business Value Institute, Box 170020, St. Louis, MO 63130. This was the original paper from the IBM Joint Study between the IBM Los Angeles Scientific Center and Washington University, and was initially published as a Scientific Center report, G320-2768, May 1985.
23. See another EwIM report, "A Report on the Joint Study in Enterprise-wide

Information Management (EwIM)." LASC Report G320-2807, also available from the Business Value Institute.

24. An interesting commentary from the public enterprise perspective is in a recent General Accounting Office report: "Perceived Barriers to Effective Information Resources Management—Results of GAO Panel Discussions, GAO/IMTEC C-92-67, available from the U.S. General Accounting Office, P.O. Box 6015, Gaithersburg, MD 20877. On page 10 the discussion focuses on the need for measurable improvement and laments that "lack of performance measures is a barrier to effective IRM." That's not to say there aren't problems in devising the appropriate measures.
25. Again, see the references to service and quality, previous footnotes.
26. Patsy Aucoin and Mark Gardner, *Strategic Information Systems Planning*. Critical Technology Report C-9-1, Chantico Publishing Co., Dallas, TX (ISBN 1-55611-131-6).
27. The professional magazine *CIO* has said as much, in "Changing the Rules," *CIO*, Volume 5, Number 2, May 15, 1992, pp. 30–34, and "Many Happy Returns," *CIO*, Volume 5, Number 14, June 15, 1992, pp. 66-75. The latter covers six case studies appropriate to the point. See also "Managing I.S. Technology as an I/T Utility," Report PIE-57, Business Value Institute, June 1992.
28. See POSPP Report P-34-1.
29. Adapted from "Information Economics and the Business Value of Computers," POSPP report P-34-1, Chantico Publishing Co, Dallas, TX, January 1992.
30. Paul Strassmann, *The Business Value of Computers: An Executive Guide*. Information Economics Press, 1991
31. Adapted from *Information Economics*, 1988, and further developed in "Information Economics and the Business Value of Computers," POSPP Report P-34-1, 1992.
32. "Managing I.S. Technology as an I/T Utility," Business Value Institute, 1992.
33. See POSPP Report P-34-1.
34. See Richard Nolan, *Managing the Data Resource Functions*. Free Press, 1983.
35. "Getting the Relationships Right," POSPP Report P-4333-1, Chantico Publishing Company, Dallas, TX, March 1992.
36. "Creating the Business-Driven I.S. Organization," Business Value Institute, 1992.
37. Adapted from *Information Economics*, 1988.
38. Adapted from *Information Economics*, 1988. First described in "EwIM, An Introduction to the Concepts," 1985.

TELECOMMUNICATIONS TECHNOLOGY AND INFRASTRUCTURE

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INTRODUCTION

It is popular today to talk about "information infrastructure" in the same way we talk about our transportation system, or electricity distribution.[1,2,3] Yet, if we look closely at our transportation system we see that the broad term "infrastructure" covers a dazzling variety of technologies serving very different needs. From cow paths to eight-lane expressways, from cars to trucks to barges to supersonic transports, our transportation infrastructure means many different technologies carrying many types of traffic at widely varying speeds.

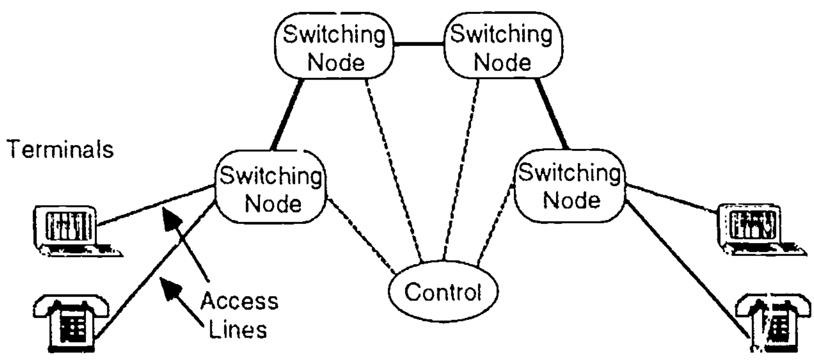
Similarly, when we look at the technology issues behind the phrase "information infrastructure," many techniques are used to meet an ever-wider range of service demands. The National Telecommunications and Information Administration (NTIA) has defined the information infrastructure as "all of the facilities and instrumentalities engaged in delivering and disseminating information throughout the nation," including not only the telecommunications (e.g., telephony) industry but also mass media (broadcasting and cable television service), the postal service, publishing, printing, and the production and distribution systems of the motion picture industry.[4] It would take an encyclopedia to review all of the technologies used in providing our communications infrastructure. In this paper we have a much more modest agenda. First, we shall attempt to provide a framework within which to situate a discussion of communications technologies. Second, we will identify some of the key technical developments that have occurred in the last decade and the critical future developments that are expected to substantially alter the nature of our communications infrastructure. Third, we examine the current political debate over communications infrastructure and discuss how technology developments are both framing and likely altering the terms of the debate in coming years.

A Generic Telecommunications Network

The economic imperatives of providing telecommunications services lead virtually all telecommunications networks to have a very similar generic architecture, as illustrated in Figure 1. The user interacts with the network through some sort of user terminal. It may be a telegraph key, a telephone handset, a computer, or a TV camera; its function is to capture information from the user and to convert it into a form suitable for electronic transmission. Next there is a telecommunications link from the user's terminal to some type of switching node. This first access link has a unique characteristic: the link must be capable of carrying the maximum instantaneous traffic capacity the user will ever need; but since most users do not spend all their time communicating, the link is frequently inactive and its capacity unused.

The third element is the first level switching or concentration point, sometimes referred to as an *end office*. This first level of switching may be a telephone company switching office providing residential service and business Centrex, or it may be a corporate-owned Private Branch Exchange (PBX). Such a node serves two important functions. First, it

Figure 1 Communications Network Architecture



may make connections between two users' access lines, allowing them to communicate with each other. Second, it can concentrate traffic from multiple users onto a single high-capacity communications link which carries traffic to a higher level switching node. Because high-capacity communications links exhibit substantial economies of scale, network providers can realize great savings in transmission as a result of this concentration function. Moreover, the same interswitch link can be shared sequentially by many different callers, as the conversations of first one subscriber and then another are carried across the trunk.

Higher level switching nodes, interconnected by high capacity links, provide long-distance transport between regions served by end-office switching nodes.

Finally, there is the logical element of the network, indicated by the box labeled *control*. The control function provides the intelligence for setting up the switching paths needed to interconnect two parties that wish to communicate. While Figure 1 shows it as a centralized abstraction, control can be distributed either to each interface or to each switching node.[5]

From this simple abstraction, a number of profound observations can immediately be made. First, communications network costs per user are typically dominated by the investment in the "last mile"—the link between the user's terminal and the first concentration point. Capital in the last mile is dedicated to a single user and not shared, as contrasted with switching nodes and interoffice trunks whose costs are shared by the traffic of many callers. The capital investment of the nation's local exchange carriers in what is referred to as the "local loop" is more than the investment in all other parts of the network combined.

Second, high-capacity communications links will make their first appearance in the long-distance trunking part of the network. Even if the traffic of each individual user is small, the aggregation of traffic from many simultaneous users can require large-capacity transmission lines. Third, high costs associated with high-speed transmission can be justified in the trunking plant where costs are shared over many users; only when these costs are greatly reduced can we expect to see high-capacity links migrate out toward the user from the carrier's end offices.

Fourth, as we imagine new end-to-end services such as digital data transmission or video dialtone,[6] changes are required throughout the network: in terminal equipment, loop plant, switching, control, and interoffice trunking. The pace of service introduction is determined by the last of these items to be upgraded. Because of the capital invested in the local loop, there is a great incentive to find ways to use existing local loops to deliver new services. Conversely, would-be competitors with the existing local exchange carriers must focus their attention on reducing costs for the last mile—if not the last few hundred meters—if they hope to be successful.

From Wires to Services

The previous discussion focused on the geographic elements of communications infrastructure. An alternative decomposition looks at the different levels of added value. At the lowest level, communication requires *transmission channels.* These channels may consist of copper or optical fiber, radio waves from terrestrial or satellite transmitters, or free space lasers.

While there are many companies today that sell only point-to-point communications channels, a communications infrastructure generally means a *network.* A network implies a set of channels linked by some form of switching that enables any two parties connected to the network to send signals between them.

Finally, at the highest level, there are complete *services,* such as Plain Old Telephone Service (POTS), electronic mail, video telephony, or enhanced services involving protocol conversion and interaction with stored data. Complete services require many ancillary functions ranging from sophisticated billing and reporting to directories or complex data processing.

Charles Jonscher has observed[7] that the businesses providing each of these different levels of added values are very different indeed. The transmission business consists of delivering a highly standardized commodity—each bit transmitted is the same as every other bit. Success in a commodity business requires low-cost production. That in turn requires investment in state-of-the-art technology for production—i.e., transmission facilities. The successful vendor of transmission focuses on process innovation as opposed to product innovation. Commodity businesses are also characterized by capital intensity and large economies of scale.

At the other extreme is the business of providing services, particularly enhanced services such as electronic mail, protocol conversion, and information services. These services are characterized by a high degree of customization for each end user or vertical market segment. Successful participants in this end of the business will focus on product not process innovation. Skilled system developers, not capital, are the scarce resource, and comparative advantage requires a focus on the customer and his needs as much as on the processes of production.[8]

The networking part of the business is intermediate between these two. While not as much a commodity business as transmission, there is much more standardization than in enhanced services. The cost of switching nodes is increasingly dominated by design and software costs, which exhibit significant economies of scale. At the same time, various traffic types require different switching technologies; thus there is significant variation among networks optimized for different traffic types or different peak channel speeds.

We will return to these distinctions as we examine more carefully the major trends in the underlying technologies of communications and their implications for information infrastructure.

TECHNOLOGY TRENDS

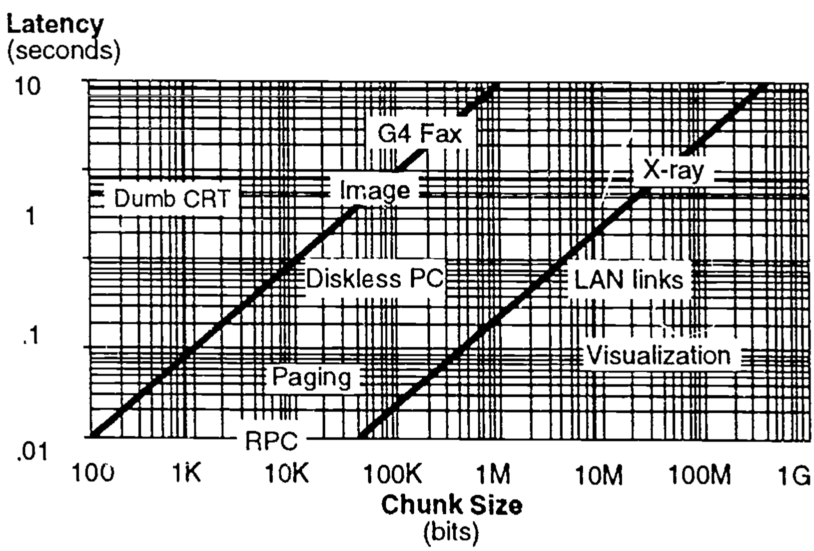
The New Traffic

For years the nation's telecommunications infrastructure was optimized to carry voice telephone calls. Analog signals of 3 KHz bandwidth were the dominant form of information carried. Today, data traffic is steadily increasing its share. Unlike voice traffic with its well-defined characteristics, data traffic requirements vary from a few hundreds of bits per second for telemetry data to billions of bits per second for supercomputer interconnection.

The new data traffic differs from voice traffic in two fundamental ways. First, it is largely bursty traffic. That is, unlike voice traffic, where an open network connection will typically be used almost continuously by somebody speaking, data traffic flows in fits and starts. A user types a few characters at a terminal, receives a screenful of data in response, and then may pause for many seconds while he or she studies the information received. Second, whereas a digital channel with a peak speed of 64 kbps can carry a 3 Khz voice channel, many data applications require much higher peak speeds to provide the desired quality of service. Consider a doctor examining an image sent electronically from a Magnetic Resonance Imaging (MRI) scanner. A single image might consist of 2,000 by 2,000 picture elements, each requiring 24 bits to encode a full range of color, for a total of 12 megabytes of data. To transmit that data in a time comparable to the rate at which a doctor can flip through a series of film images requires a peak transmission rate of several hundred megabits per second.

A simple way to understand this demand for higher speed networks is to look at both the typical size of a "chunk" of information needed by an application, and the elapsed time the user is willing to wait for it—known as the *latency*. When the user is a person, acceptable latencies are measured in seconds; when the user is a computer however, waiting one millisecond might mean 50,000 wasted instruction cycles for a typical workstation. This concept is illustrated in Figure 2, which shows chunk sizes and latencies for a variety of applications. The axes are drawn to a logarithmic scale, covering many orders of magnitude. The diagonal lines correspond to transmission speeds of 64 kbps—one voice channel—and 45 megabits per second. They illustrate how the combination of low latencies and larger chunk sizes leads to demands for networks where a single user can consume hundreds of megabits per second, even if only for a brief burst of traffic.

Figure 2 Selected Applications



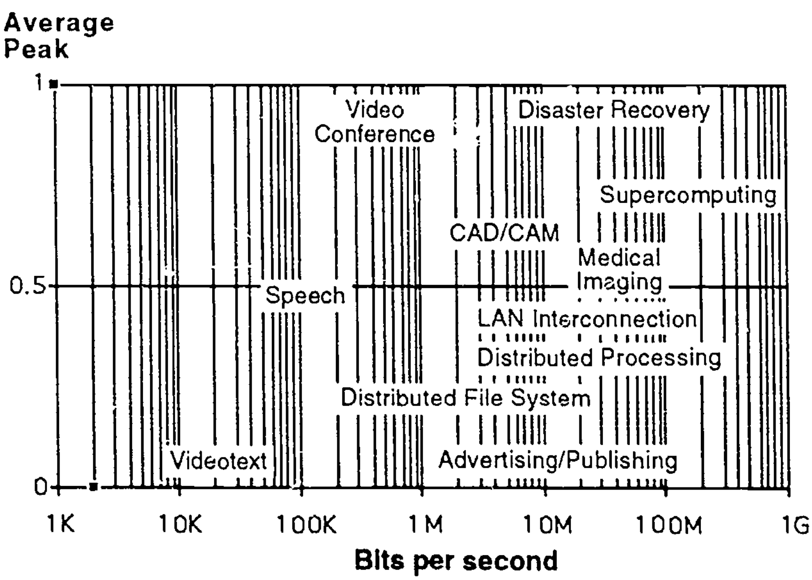
While the peak capacity demanded may be high, the *average* usage may still be very low. Figure 3 illustrates the average to peak ratio for a number of different applications.

The preceding figures paint a picture of network requirements far different from those of voice. The most critical differences are in the access link and in switching. The need to carry a large number of phone calls between major switching centers means that the peak capacity of some interoffice trunks is already more than a gigabit per second.

Evolution of the Local Loop

The 64Kbps needed to carry a speech signal is well within the capability of the majority of existing copper loop plant. However, as demand for data and video traffic expands, the limits of the existing copper plant are being severely tested. In 1987, industry prognosticators such as Richard Snelling of BellSouth were predicting that by 1990 all new loop construction would use fiber so that the network could handle video services to the home.[9] The economic problems of fiber, particularly fiber networks capable of providing switched video services, have proved far more difficult than the early optimists imagined. These problems include installation costs, electro-optics costs, and powering

Figure 3 Traffic Characteristics



issues. More recent analyses suggest that it will be the end of this decade, if then, before fiber loop networks capable of carrying video on demand will be economical[10,11] in new construction situations, let alone as an upgrade technology. Significantly, adding the capability to carry video on demand nearly doubles the cost of Fiber in the Loop (FITL) compared to narrowband-only systems.

In the meantime, significant progress has been made on two fronts which will prolong the viability of the existing copper plant. First, advances in image compression technology make it possible to encode VCR-quality video at bit rates as low as 1.5 Mbps, and broadcast quality at rates below 5 Mbps. Second, advances in digital signal processing have raised the ceiling on what can be transmitted over a copper loop with acceptable error rates. AT&T and other manufacturers have announced a technology known as Asymmetric Digital Subscriber Loop (ADSL), which, by installing appropriate interfaces at the subscriber's premises and in the central office, would allow a majority of existing copper plants to carry 3–4 Mbps downstream—enough for a single broadcast-quality video signal or two VCR-quality signals—while carrying a lower speed voice/signaling channel upstream.[12,13]

These developments suggest that the inevitability of fiber to the home and the optimal time schedule for deployment are still quite uncertain. Moreover, we may well see a mixed scenario in which fiber is used out to a neighborhood concentration point and copper pairs for the last few hundred meters. Shortening the copper link allows it to support higher data rates.

For medium to large business customers, however, fiber has clearly proved its worth. Large business users, because they concentrate traffic from many offices, can make use of high-capacity links from their premises to the carrier's central office. While technology similar to ADSL can provide up to 24 channels on one or two copper pairs,[14] increasingly, business users need the capacity of fiber. Fiber not only provides more capacity than copper today, but also promises easy expansion of capacity simply by installing more capable electronics in the future. The local exchange carriers are rapidly installing fiber rings in major metropolitan areas with alternate path routing in the event of a cable break.

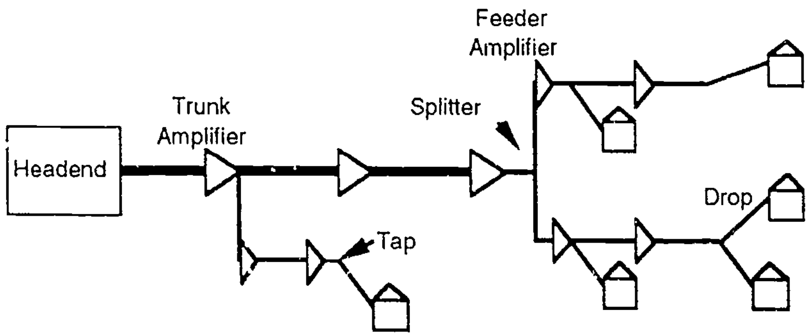
The demand by businesses for fiber-based access has induced a number of new companies to construct metropolitan fiber networks to compete with the local exchange carriers. By providing quick service, competitive prices, and an alternate path for reliability, these Competitive Access Providers (CAPs) have gained many satisfied customers. The CAPs may eventually become full-fledged competitors to the local exchange carriers; to date, however, they have been limited—by regulation as well as by strategic choice—to bypassing the local exchange carriers (LECs) and providing leased access to the interexchange carriers. The FCC has recently issued a tentative decision and notice of proposed rule making which would allow the CAPs to begin to compete in the provision of switched access to the interexchange carriers.

While the telephone companies wrestle with their copper versus fiber dilemma, two other approaches to providing the access link to the subscriber continue to garner attention: the use of coaxial cable of the type already installed to some 60 percent of U.S. homes for the carriage of cable television, and radio technology.

Earlier generations of cable television networks used a tree and branch architecture (Figure 4), which distributes a common set of video channels to all households in a franchise area. The constant branching of the cables coupled with normal attenuation with distance requires the installation of numerous amplifiers in the network to boost the signal power to adequate levels. When 30 or more of these amplifiers are cascaded together they introduce distortion in the signal, especially at higher frequencies, thus limiting the capacity of the network. Older networks may support as few as 12 channels, though more recent systems go up to 450 or 500 MHz, or about 70 video channels.

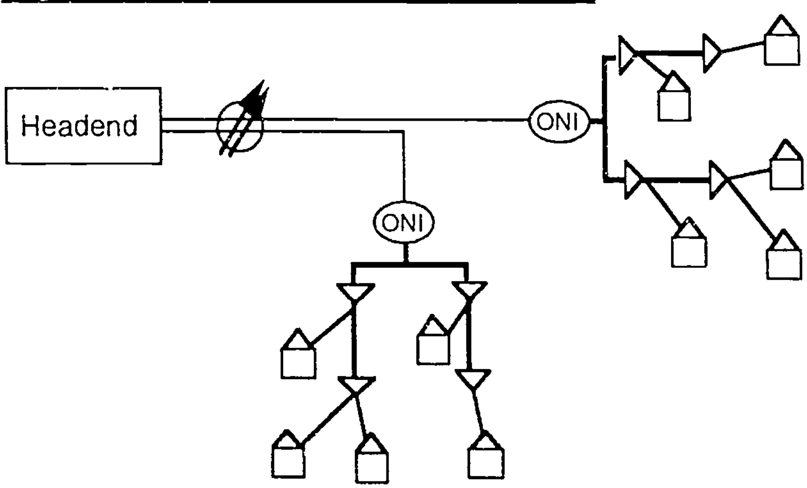
As the cable franchises come up for renewal, and the operators are asked to upgrade their networks, many are installing optical fiber

Figure 4 Cable Television Networks



backbones from the headend to an optical network interface (ONI) point much closer to the subscriber (Figure 5). This design drastically reduces the number of amplifiers needed, thus increasing network capacity to as much as 1 GHz or 160 6 MHz video channels. At the same time, it allows for different combinations of channels to be sent on a backbone to any particular neighborhood. In the limit, as the number of homes served by an ONI is decreased, and the number of video channels is increased—for example by the use of digital compression—a cable operator could have enough channels available to send a unique video signal to every household. The cable operator could then provide video dialtone service at a cost lower than what it would cost a telephone company to build an integrated voice/data/video all-fiber network from scratch.[15] Indeed, if you look at the plans of the cable operators for installing fiber backbones, they talk about six fibers to every ONI. Their planning documents label two of the fibers for cable TV, two for resale to a competitive local access provider, and two for resale or use in linking radio base stations for cellular telephony.[16] The wide bandwidth of the coaxial cable access link provides sufficient capacity that a portion can easily be allocated to offer high bit rate data services, or even conventional telephone service along with video delivery. In the United Kingdom several joint ventures between U.S. local exchange carriers and cable television operators are installing fiber backbone/coaxial cable networks to provide both cable television and telephone access

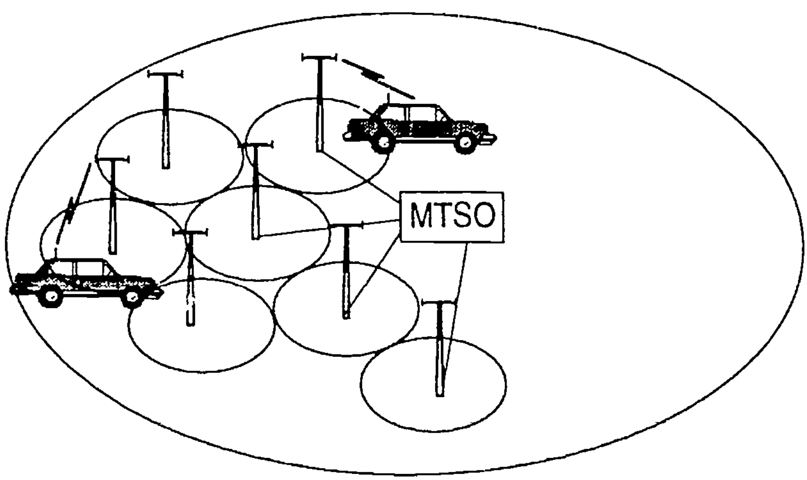
Figure 5 Fiber Backbone Cable Networks



line service.[17] Recently, US West announced that it was exploring the combination of coaxial cable plus fiber for future residential telephone network expansion.[18]

Besides telephone company-provided fiber, or cable TV company fiber/coax hybrids, a third alternative for the local access link is the radio spectrum. Already some 7 million subscribers make use of wireless telephone service provided by one of the two franchised cellular telephone operators in each metropolitan area, or about 5 percent of the total number of wired loops. In a cellular telephone system subscriber terminals are linked to a base station by radio signals rather than wires. These base stations are then linked by wire or microwave to a switching node. As mobile subscribers move from the area or "cell" served by one base station to a cell served by another, the wireless access link is automatically switched to the new base station (Figure 6). Increasingly, cellular operators are finding that some subscribers use their cellular service as their primary telephone line, abandoning wireline service altogether.[19] While existing cellular service was designed to support automobile-based telephones, work is rapidly progressing on technology and standards for so-called Personal Communications Services (PCS), which will support personal telephones the size of a cigarette pack. The FCC has recently issued a Notice of Proposed Rule Making (NPRM) asking for comment on whether it should grant PCS licenses for individual cities, as it did with PCS for regions as large as Local

Figure 6 Cellular Telephone Network



Access and Transport Areas (LATAs), or grant one or more nationwide licenses of spectrum to PCS providers.[20]

As new technology developments increase the capacity of wireless systems and reduce their cost, it is likely that existing communications networks based on fixed wires for the access link will find themselves in direct competition with new technology based on wireless local access. Already GTE is using "wireless local loops" based on radio technology to provide basic telephone service to a new subdivision in Texas. In Eastern Europe small businesses cannot wait until their entire neighborhood is wired in order to have telephone service. Using wireless access, these important customers can be served quickly. In some urban areas in the United States, carriers are looking at wireless loops as less susceptible to vandalism. The ultimate radio access link could be satellite based. Proposals such as Motorola's Iridium would link user telephones via a network of low earth-orbiting satellites.

In order to conserve spectrum, most proposals for new radio access technology assume the use of speech compression to reduce the channel rate to 16 or 32 kbps, which limits the usefulness of these access links for data by comparison with 64 kbps wireline channels.

Radio spectrum is basically an access technology; someone must still supply the switching. Treating wireless only as a loop substitute, the switching could be handled by the existing LECs; that is, the wireless operator would simply hand over the traffic collected at the base stations to the existing carriers; or, the cellular operator could install its own switching center to serve customers directly. A long-distance company could choose to compete for the new radio licenses, build a radio access network, and handle all switching in existing or expanded toll switching offices. Finally, there is potentially great synergy between cable television companies and wireless telephony providers: excess fiber in the cable operator's plant can be used to interconnect local radio base stations to a central switching center.[21,22]

To date, wireless local access has focused on voice communications. However, as companies like AT&T, Apple, and Sharp introduce their "Personal Digital Assistants," handheld computers designed to link their owners via wireless access to an enormous web of information and computational power, the demand for wireless data services seems poised to explode.[23] Limitations in available spectrum at the frequencies currently used for cellular kbps data rate at 32 kbps and below. However, new research on wireless access at frequencies around 30 GHz may make possible wideband wireless access links. These higher frequencies are currently more costly to exploit, however, and more susceptible to interference due to inclement weather.

The significance of this litany of local loop developments is that it suggests that the simple notion of five years ago that a single integrated broadband network based on fiber access was the "obvious" path for future telecommunications network development is today not nearly so obvious.

Inside Wiring

Prior to 1980 most companies as well as most homes were wired for communications only with twisted copper pairs. If a computer terminal was needed in the office, special wiring would be pulled on an ad hoc basis. Between 1980 and 1990 many companies went from fewer than 20 percent of white collar workers with terminals to more than 70 percent. As a consequence, they began to think of data communications wiring as part of the building infrastructure that should be installed once and managed as infrastructure. Accordingly, the industry developed a number of standard data wiring schemes based on coaxial cable, shielded twisted pair cable or unshielded data grade twisted pair, with some use of fiber as well. Today most new office buildings provide a data wiring infrastructure just as they include electric wiring. With advances in technology, copper pair wires have been made to support data rates up to 100 Mbps for short distances from the desk to a wiring closet. At the wiring closet sophisticated wiring "hubs" provide the first level of traffic concentration, justifying the use of more expensive optical fiber to link these concentration points in campuswide networks. The ability to carry up to 100 Mbps on copper seems likely to forestall widespread introduction of fiber to the desktop for another 5 to 10 years.

Switched Networks

The function of switching is to allow the same transmission link to be used to support communications between different users. With *circuit switching*, a chunk of capacity—for example between two switches—will be dedicated to two users for the duration of a call. When voice was the primary form of traffic, telephone networks were optimized to use circuit switching in units of 64 kbps—the size of a single voice channel. Circuit switching is inappropriate for bursty traffic.

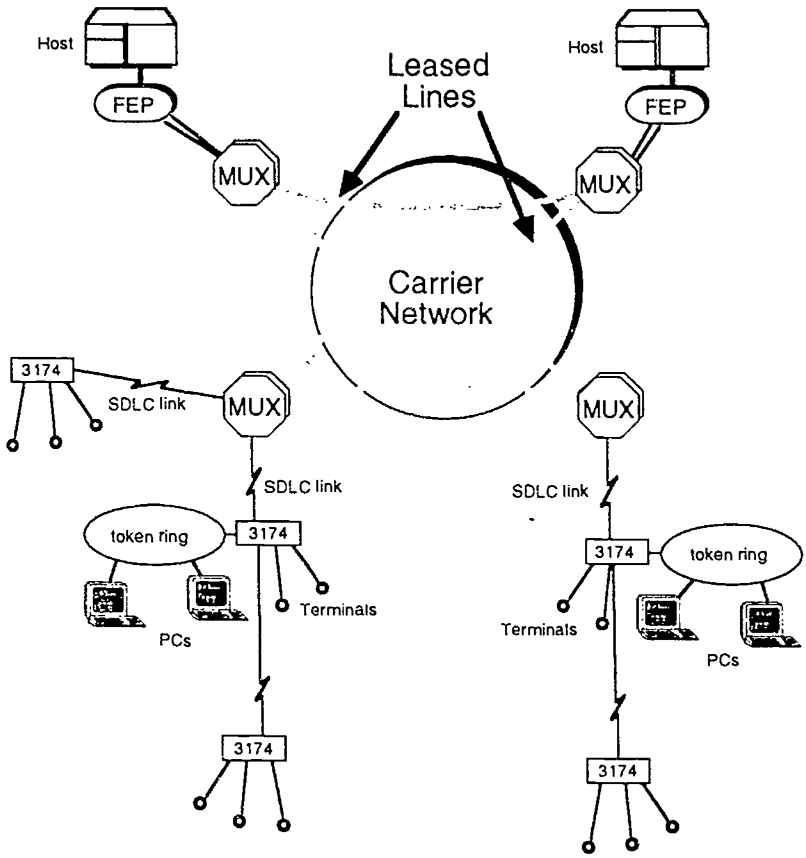
Packet switching was invented in the 1960s to respond to the traffic requirements of data. Instead of reserving a dedicated circuit for the length of a call, a packet switching network allows many users to share transmission capacit' by breaking up information into small chunks, called packets, and then using a transmission line to alternately send packets from several different users. The concept was used first in private networks built by end users. Until recently, users had to build their own data networks by leasing full period channels from the telephone carriers and adding their own premises-based data switching equipment. Leasing full period channels is costly, however, when traffic has a high peak requirement but relatively low average throughput. This creates demand for switched data services from the carriers who can take advantage of traffic statistics to provide high peak capacity to each user while charging only for the average throughput actually consumed.

The first carrier service meeting these objectives was public switched packet networks (PSDNs), which carried data in packets of 128 characters at speeds up to 48 kbps. These served primarily terminal-to-mainframe computer traffic.

The introduction of desktop computers created a demand for high-speed switching of bursty traffic between machines. The idea of distributing the switching function among all the attached machines rather than having a central switch led to the development of Local Area Network (LAN) technology. In early LANs, the transmission medium is configured as a bus or ring and its capacity is shared by all of the users as they transmit their data in high speed bursts.[24] Each node on the LAN is responsible for assuring that its transmissions do not interfere with any others. Very quickly many companies found themselves with campuswide LANs capable of efficiently handling bursty traffic at speeds of 4 Mbps or more. By comparison the data services offered by the public carriers were slow and not well suited to computer-to-computer—as opposed to terminal-to-computer—traffic. Corporate users again had to rely on leased lines and premises-based switches ("routers") to link LANs at their various locations (Figure 7).

In the early 1990s, carriers began to introduce new higher speed switched services suitable for linking the high-speed LANs. Frame

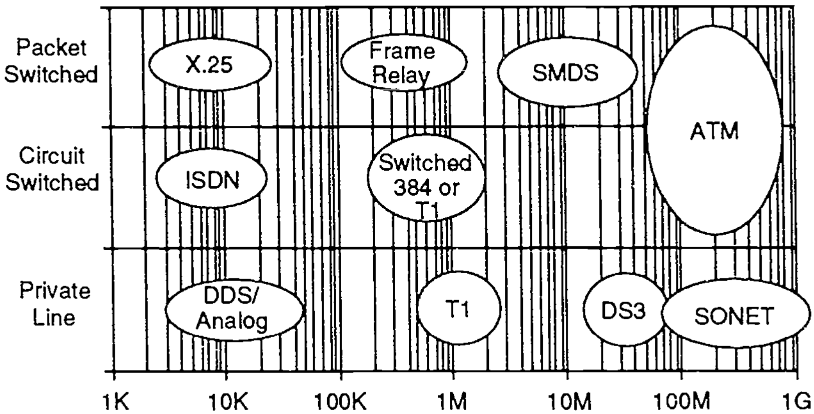
Figure 7 Corporate Data Network Using Leased Lines and Premises Switching



Relay is a stripped-down version of traditional packet switching. Relying on the lower error rates of fiber-based transmission and the increasing intelligence of data terminating equipment, frame relay nets dispense with the error correction service offered by traditional PSDNs and in return realize high speeds, lower delay, and lower costs. Responsibility for error correction is left with the equipment at each end, much as is done in LANs Figure 8 illustrates the range of new higher speed and switched services being rolled out by the carriers.

From a carrier perspective deploying and maintaining multiple switching nodes for circuit and packet, and maintaining separate access

Figure 8 New Network Services



Frame Relay: High-speed connection-oriented packet switching service

SMDS: Switched Multi-megabit Data Service, a connectionless packet switching service offered over cell relay

ATM: Asynchronous Transfer Mode, a cell switched service

ISDN: Integrated Services Digital Network

T1: A 1.544 Mbps service

DS3: A 45 Mbps channel

SONET: A family of standards for multiplexing channels on an optical fiber at multiples of 50 Mbps up to 2.4 Gbps.

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facilities for each, is an operations nightmare. The Holy Grail for a carrier is a single-switching technology capable of handling the full range of traffic characteristics. Circuit switching works well for constant periodic (*isochronous*) traffic like voice and video, but is ill-suited for data. Packet switching works well for data but introduces too much delay for use by voice and video. The solution is a new kind of fast packet switching known as *cell relay*. In a cell relay network, all traffic is broken up into fixed length cells which are switched by parallel hardware elements. The hardware parallelism allows cell relay switches to be scaled up to handle thousands of links each operating at 150 Mbps or more for aggregate throughputs measured in terabits (10^{12}) per second. Because the cells are short and link speeds are large, delays are minimized so that continuous bit rate services like voice and video can be carried. At the same time, bursts of cells generated by data traffic can also be carried.

The International Consultative Committee for Telegraphy and Telephony (CCITT) standard version of cell relay is called Asynchronous Transfer Mode (ATM) and is the basis of proposed Broadband Integrated Services Digital Network (BISDN) standards at 155 Mbps. Interexchange carriers are expected to offer ATM switching services beginning in 1994. By 1992, several LAN vendors had begun offering ATM switches as successors to LAN hubs for linking increasingly powerful workstations at speeds above 100 Mbps.[25] An interim step to customer use of cell relay is Switched Multimegabit Data Service which provides a LAN-like packet switching interface familiar to end users on top of a cell relay infrastructure.

While there are some who still question whether ATM switching will prove to be the optimum solution for integrated broadband networks,[26] the concept has such momentum within the international telecommunications community that it is virtually certain to be widely deployed. There are also some who question whether a single integrated network will actually prove to be as cost effective as several networks each specialized for various traffic types. ATM switching, if successful, will provide carriers with the ability to offer "bandwidth on demand"—i.e., to carry all types of traffic over a common transmission and switching infrastructure.

Control

The flexibility of service offerings over the network is greatly affected by the mechanisms implemented for control of the switching functions. These include rules for routing information, load sharing, simplified addressing, and sophisticated accounting and billing. In 1979 AT&T began to introduce a technology based on Common Channel Signalling—the use of a separate control network for communications between switching nodes—to provide a much greater sophistication in the control of its network. For example, when an 800-number call is dialed, the area code does not indicate where the call should be routed. Using common channel signalling, a switching node can retrieve from a centralized data base call routing instructions for 800-number calls. The same technology is used by MCI and Sprint as well as AT&T to offer virtual private network service with customized call addressing and call screening features for large corporate and government users.

The local exchange carriers have begun to introduce Common Channel Signalling in their own networks to provide such services as call return, repeat call, and caller ID. Common Channel Signalling (CCS) is also a prerequisite for full deployment of Integrated Services Digital Networks which bring the common channel signalling right to the end user's terminal. However, deployment has been slow, partly due to disputes between the RHCs and Judge Greene over whether they can transport CCS data across LATA boundaries or must interconnect with the Inter Exchange Carriers (IECs) in each LATA.[27]

Further innovations in the control of switching are being developed by the local exchange carriers under the heading "Advanced Intelligent Network" (AIN). The goal of AIN is to make it easier for carriers to offer advanced call control features on a customized basis.

Common channel signalling is also central to Personal Communications Services. With PCS, a user would have a single telephone number for his portable terminal which would never change, no matter where the customer traveled. Using a sophisticated control system based on CCS, calls to an individual's number would always be routed to the radio base station nearest his portable handset anywhere in the country, and eventually throughout the world.

As call control becomes more sophisticated, however, the problems posed by multiple providers sharing a geographic area become more complex. For example, for PCS to function properly, information on my whereabouts may need to be shared among multiple service providers if I am to receive calls in any jurisdiction. It is quite likely that the diffusion of competition in the local loop will be paced by the difficulties in resolving control issues, not merely problems of the interconnection of transport facilities. It is perhaps interesting to note that the National Science Foundation in its recent solicitation for proposals to provide services in support of the Interagency Interim National Research and Education Network (IINREN) has advocated the separation of the "Routing Authority" from the provider of transport. One might envision operation of the software systems for the intelligent network eventually being separated from the competing service providers and operated either by a cooperative association or by an independent party.

Services

In contrast to the rapid progress of recent years in developing and deploying new transmission technologies or new switching techniques, we are just beginning to comprehend what a services infrastructure might consist of, and what will be required to put it into place. The leading edge in developing such an infrastructure exists within the education and research communities linked together via a network of networks known collectively as the Internet. With roots going back some 25 years to an experimental network supported by the Defense Advanced Research Projects Agency (DARPA), the Internet today consists of some 6000 interlinked networks, both public and private, extending around the globe and hosting more than 400,000 computers. In that crucible we are beginning to see take shape an image of what a services infrastructure might really look like.

Given connectivity among millions of students and researchers who clearly have a need for information sharing, how far have we come in making information sharing simple and available to the average user? The answer is not very far at all. Mail and bulletin boards are the most developed application, accounting for some 15 percent of total network traffic.[28] Bulletin boards on selected topics, many having to do with computers, provide a way for information in a particular field to circulate rapidly among interested researchers. Yet the usefulness of mail is limited by the total absence of a directory system for finding out someone's electronic mail address.

Many universities or even individuals have taken to making information available to others via anonymous retrieval using the File Transfer Protocol. FTP accounts for some 50 percent of all traffic on the National Science Foundation Network (NSFNET). While the amount of information thus available is enormous, the tools for finding out what information is available are still quite primitive.

A number of separate projects undertaken at different universities are beginning to provide models for how overall structuring of information access might be accomplished. Each of these projects incorporates a client server model in which software on a user's machine (the "client") talks to software on one or more "server" machines connected to the Internet. These servers may be repositories of both indexing information and of data, or they may be organized in a hierarchy in which the records at one server contain index information as to the data indexed and stored at yet another server. The Wide Area Information System (WAIS) developed at Thinking Machines Inc. uses a notion of indexes and documents at each server. A client searches across one or more indexes and identifies documents of interest which can then be retrieved. A "document of interest" might be a reference to another server with its own index to be searched. WAIS uses sophisticated weighted searching techniques to support searching one or more indexes for articles similar to a previously retrieved article of interest. The Gopher System, developed at the University of Minnesota, uses a menu interface to allow users to search across many different servers for documents of interest. Each server can be an entry point into the entire space of documents since menus are organized as an unrooted graph, not as a tree. The Mercury Project at Carnegie Mellon University has developed a client server system for retrieving citations to journal literature, and then to fetch facsimile images of journal pages.

Another form of information sharing, somewhat more transparent than FTP, which involves copying a file from one machine to another, is provided by the Andrew File System marketed by Transarc, Inc. The Andrew File System allows file servers at multiple institutions to share a single hierarchical name space from which users can read and write copies of files no matter where in the world they are located. Thus, two co-authors collaborating on a paper can always have access to the most current version rather than sending copies to each other via mail or FTP.

Each of these systems gives a hint as to the kind of robust information sharing that might be possible as we develop a true information—as opposed to communications—infrastructure, but there are many unresolved problems. Among them:

- Development of standardized methods for information finding: White Pages directories, Yellow Pages, information indexes.
- Development of widely standardized methods for retrieving information which may be scattered across hundreds of different hosts.
- Mechanisms for security and authentication.
- Development of billing and accounting systems which can track the transfer of intellectual property and provide a mechanism for compensating authors and maintainers.

- Development of standard document representation formats which go beyond ASCII text and allow sharing of graphics, images, voice annotation, animated sequences, and video.

Research and demonstration prototypes of systems solving these problems have been called for in the Information Infrastructure and Technology Act of 1992, introduced by Senator Gore as a follow-on to the High Performance Computing and Communications Act of 1991, which has funded network infrastructure.

TECHNOLOGY AND THE POLITICS OF INFRASTRUCTURE

Over the last 30 years, the telecommunications policy authorities in the United States have moved steadily to open more and more elements of the industry to competition. *Hush-a-phone*[29] and later *Carterfone*[30] led to vigorous competition in Customer Premises Equipment. *Specialized Common Carrier*[31] and *Execunet*[32] brought competition in interexchange services. Six years ago, in an article entitled "Back to the Future,"[33] a former head of the Federal Communications Commission envisioned a future of vigorous competition in local exchange communications, harking back to the proliferation of local exchange companies that followed the expiration of the original Bell patents at the turn of the century.

The proponents of competition have generally argued in favor of competition in all segments of the communications network: in the local loop as well as in the switching and long-haul portions of the network; in transport and networks, as well as in enhanced services.

The view that vigorous competition is the desirable state of affairs for the nation's telecommunications was at first fiercely resisted by the existing local exchange carriers. More recently they have come to accept the idea of competition as long as there is a "level playing field." In casting about for a political argument that could help to swing the debate away from competition, the local exchange carriers have recently focused on the code word *infrastructure*. By refocusing the debate on universal service and a "public good" model of networks, the existing carriers have highlighted the risks of competition and created a climate in which they may be better able to expend ratepayer funds to invest in networks for the future. The fact that such investments tend to raise barriers to entry is merely a side benefit.

The heart of the LEC argument is based on the notion that a single integrated broadband network based on fiber optic transmission facilities and ATM switching will be able to meet all the varying needs for communications services, from simple POTS to the most exotic supercomputer interconnection. The implicit assumption behind such arguments is that integrated broadband networks have such economies of scale and scope that there can be little room for multiple providers each offering differentiated services oriented towards specific market niches. Further, they argue, any restrictions on the type of services that telephone companies can carry—information services, video services—would inhibit the realization of these scale and scope economies to the detriment of the consumer. In its most extreme form, the argument takes the position that the scale and scope economies extend beyond transport and networking to the provision of information itself. Thus carriers must also be free to originate content on their integrated broadband networks if the full benefits are to be realized.

This argument is reflected in legislation such as the Burns-Dole bill (S.1200) or the recent telecommunications policy legislation in New Jersey and appears frequently in articles written in telephony trade magazines.[34]

In return for permission to provide the full range of networking services, voice data and video, the telephone companies would continue to operate as common carriers, providing nondiscriminatory access to their network to all users. This is the bargain inherent in the FCC's recent video dialtone decision which authorizes telephone company entry into the delivery of video services, but only on a common carrier basis.[35] The common carrier model is seen as the best approach to fostering competition among information providers. Further, the single integrated common carrier would be in a better position to ensure universal service by rate averaging among its customers.

The adherents to the competition paradigm envision a much different future. They question the extent of economies of scale and scope in the communications infrastructure. If economies of scale and scope are limited, then there is room for multiple providers of competing communications networks. Moreover, in a period of great technological ferment, competition is seen as more likely to ensure that technological opportunities are exploited. Thus, the way to ensure that our communications infrastructure is based on the most cost-effective technologies is to encourage competition at all levels.

If the communications infrastructure is provided on a competitive basis, then the job of regulators is greatly simplified. Regulators no longer have to monitor costs in detail to determine if prices provide only "reasonable" profits: the pressures of competition can be relied on to reduce prices to cost-based levels. If the communications infrastructure is provided on a monopoly basis, great care must be taken to ensure that monopolization of transmission or networking does not lead to monopolization of enhanced or information services, for, as we have discussed above, these are likely to be better provided by many smaller firms which are more flexible and more customer oriented. In a competitive environment there would be less need to be wary of carrier participation in the preparation of content since no one carrier would control the only avenue for information dissemination.

To what extent does our review of technology shed light on the above debate? First, the case for a single, fiber optic-based integrated broadband network is still economically uncertain. Moreover, cable companies are sufficiently well positioned that they may well be able to evolve their networks to carry integrated broadband traffic more cost-effectively than can the telephone companies.[36] Indeed, US West recently issued a request for information to the traditional cable TV vendors for equipment and architectures that would allow the carrier to upgrade its loops using a mix of fiber and co-axial cable.[37]

Second, Jim Utterback has observed that whenever a radically new technology appears that threatens to displace an entrenched alternative, it often stimulates rapid productivity improvement in the older technology which staves off its demise.[38] In the years immediately following the invention of the electric lightbulb, gas lamp manufacturers realized a sixfold improvement in light output through research on better wicks and other improvements. In much the same way we are seeing rapid improvements in the carrying capacity of copper which may well enable the lead broadband product—entertainment video—to be delivered to the home without the need to install fiber.

Third, the most difficult problems of multiple networks are likely to be in interworking the control systems, particularly as these become more and more sophisticated. Little thought has been given to how AIN services might be delivered in a competitive local environment.[39]

Fourth, we have paid far more attention to date to the development of the transport and networking layers of our information infrastructure than to the numerous unresolved issues at the services layer that must be addressed if information is to be readily available and shareable throughout the society. Developing simple user metaphors which allow information to be found may not appear as exciting as work on gigabit networks, but it will probably have far more impact on the efficiency and competitiveness of U.S. firms and educational institutions.

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