Telecommunications Policy, High Definition Television, and U.S. Competitiveness

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Executive Summary

New policies are needed for the U.S. telecommunications industry. The existing policy framework impedes constructive responses to the challenges posed by foreign competition, the emergence of digital technologies, and the convergence of computers and communications. U.S. policies currently emphasize customer and convenience services to the near exclusion of developing domestically produced equipment and improving infrastructure. Continuing such policies will constrain the domestic growth of U.S. corporations and make it difficult for smaller American firms to use sophisticated equipment and services.

A new policy regime should consciously focus on linkages between network infrastructure development and technological innovations in equipment, fostering the joint development of both.

The telecommunications policies of the 1990s and beyond must also advance the international competitiveness of U.S. industries based on the merging of communications and computer technologies in the office, the factory, and the home. A new policy regime should consciously focus on *linkages* between network infrastructure development and technological innovations in equipment, fostering the joint development of both. Policies for the coming information economy should be framed in recognition that supplier firms and industries along an entire electronics "food chain" will rise or fall by decision-making processes heretofore geared to regulation or fair competition among service providers.

In contrast with the U.S., Japan and the European Community (EC) have already established policies to upgrade the existing telecommunications infrastructure, aware of the importance that advanced networks will have in serving as a testing site for new products and services for international markets. These international competitors also lead in the development of strategic technologies such as high definition television (HDTV). If the U.S. is left with only a marginal part of the HDTV industry, it could add $225 billion to our trade deficit and cost two million jobs annually by the year 2010.

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The fate of HDTV is closely tied to the establishment of an advanced telecommunications network, or Integrated Services Digital Network (ISDN). Because ISDN must be a seamless, integrated network from one end to another, its success requires a coordinated approach to management and applications. This presents special problems for the U.S. telecommunications network, which has evolved as a patchwork of standards, equipment, jurisdiction, and competing financial interests.

Again, in contrast to the U.S., Japan and the EC are rapidly organizing ISDN to be a cornerstone for the development of future high-technology industries. The Japanese initiative includes coordinated efforts by the Ministry of Posts and Telecommunications, the Ministry of International Trade and Industry, Nippon Telegraph and Telephone (NTT), and the Japan Broadcasting Company (NHK). The EC—despite the political difficulty of unifying separate national industries—is moving forward on a unified R&D effort in communications equipment development, the creation of new services, and the implementation of standards for a transnational ISDN structure.

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The U.S. needs a comprehensive and coherent approach to the industrial issues and regulatory concerns that are facing its telecommunications industry. One immediate step should be to establish an independent Department of Communications that would create a unified approach to the policies that will shape an important part of our nation's economic base in the next decades. Additional polices to strengthen the U.S. telecommunications industry are discussed in the concluding chapter.

Introduction: The Challenge of Global Competition and the Need for a New Policy Framework

U.S. telecommunications policy is at a crossroad. Without revising the antiquated policy framework that is a product of the 1930s, the U.S. cannot meet the challenges even now emerging. If U.S. policy continues to focus on communications services in isolation from the rapid shifts in equipment technology that have occurred in the 1980s, the nation will fail to control the development of its own telecommunications infrastructure for the electronics age.

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The domestic communications industry has restructured following deregulation and has begun to build the advanced networks required in the next decade. These new networks are digital in nature, gaining sophistication from the ability to use electronics based on semiconductors, or "chips," rather than the vacuum tubes common twenty years ago. But the telecommunications industry is challenged by new forces, including emerging technologies (such as high definition television—HDTV—and broadband digital communications), and by vigorous competition from foreign telecommunications firms backed by governmental industrial policies.

Current Policy: A Lack of Vision

Three legacies of the past regulatory framework weigh down current U.S. communications policies and prevent formation of a new vision. *First,* U.S. policies do not provide for the organizational authority to integrate the process of innovation in communications equipment with the development of a new framework of service delivery. *Second,* U.S. policies are extremely parochial, overlooking the competitive challenge posed by communications initiatives in other nations, particularly in Japan and the European Community. *Third,* U.S. policies are overly concerned about network services, almost to the point of excluding any consideration of new communications equipment and technologies. Consequently, policymakers are doing little to plan for the dramatic changes in technology and communications use that are likely to take place in the next decade as communications equipment, computers, and television are integrated into a single system. (Green, 1986:chapter 3)

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This lack of vision is likely to have dire economic consequences, given the close interdependence of all emerging electronics technologies. For example, the trade deficits and job losses resulting from the decline in traditional industries could be a mere shadow of the losses that might result if the U.S. fails to develop a strong HDTV industry. According to estimates we provide in a later section, trade deficits in HDTV and just three closely linked industries could result in a cumulative trade deficit of more than $2 trillion over the 1990-2010 period. The projected deficit would reach $227 billion in 2010 alone and would imply a loss of more than three-quarters of a million jobs directly and at least 1.5 million jobs indirectly.

The present structure of telecommunications policy is fragmented... and makes it impossible to devise or implement public policies that focus on specific long-range goals.

The present structure of telecommunications policy is fragmented among a number of federal agencies, including the Federal Communications Commission (FCC), the Department of Commerce, the Department of State, and others. This uncoordinated federal framework increases uncertainty for private investment decisions and makes it impossible to devise or implement public policies that focus on specific long-range goals.

The Competitive Challenge

The great strength of the policy frameworks that have been developed in Japan and Europe is their ability to support private efforts to introduce innovations rapidly. This opens opportunities for firms in both domestic and export markets and enables them to explore the broad commercial opportunities now emerging as a result of the dramatic transformation of the worldwide telecommunications industry. It is difficult to know precisely how these policies will reshape the dimensions of competition; they are clearly laying the groundwork for integrated approaches to the creation of equipment and service networks, which will surely be required for future innovation across the electronics spectrum.

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Both Japan and the European Community have also established institutional mechanisms to ensure coordinated policies. They consider advanced networks and innovative telecommunications products to be vitally linked in the formulation of new communications policies. Hence, measures to upgrade the network infrastructure are taken in full cognizance of technological changes and opportunities on the equipment side.

If these policies are successful—and we have good reason from past experience to expect that they will be at least moderately so—the U.S. industry will be at a disadvantage. Both Japan and the European Community recognize the central role that telecommunications equipment and infrastructure will play in determining economic competitiveness.

Their adjustments include giving a top priority to the development of linkages among related industries and assuring the establishment of advanced networks for communications by the 1990s.

A New Framework for Telecommunications: The Food Chain of the Electronics Industry

The recent linkage of computers and communications through digital technology has made much of the old telecommunications "highway" obsolete. These technologies, integrating voice, data, and video, significantly expand consumer electronics, electronics in factory equipment, and telecommunications services in the business world, as machines in factories and offices depend upon electronic hardware and communications controls to perform their operations. They now require new digital networks, "the essential infrastructure needed to capture the vast new economic opportunities available from the exploitation, control, and processing of information" (Borrus and Bar, 1988).

The recent linkage of computers and communications through digital technology has made much of the old telecommunications "highway" obsolete.

Telecommunications services provided over networks are inseparable from the technologies that make them possible. The communications network has become an integral element in our nation's productive structure. The telecommunications industry should be seen as part of an electronics food chain. The users of telecommunications services, communications equipment providers, producers of equipment to create communications "hardware," and producers of the basic electronics providing the building blocks for communications equipment all form an unbroken ring of symbiotic interconnections based on common technologies. Within the electronics and telecommunications food chain, each part determines the ability of another to adopt new technological advances rapidly.

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Policies that recognize the food chain relationship will make it easier for firms to assess the likely growth of markets and sales when they invest in new equipment or improvements needed to supply advanced components to the telecommunications industry. The importance of the food chain structure has been recognized in approaches adopted by Japan and the EC. Our competitors realize that advanced telecommunications networks can be used to test new communications products and services for export and for competing in the international marketplace only if a highly sophisticated infrastructure is in place. As a result, competitor nations view the new Integrated Systems Digital Network (ISDN) not only as a means to support the advancement of domestic telecommunications capabilities, but also as an essential measure to improve the competitiveness of firms in other industries.

Advantages throughout the entire electronics food chain are needed to attain a superior competitive position in global markets for communications products. Hence, the lack of coordination in U.S. policies for network services and equipment development increasingly poses competitive disadvantages to electronics firms and industries all along this chain. As long as our national and state telecommunications policies place only minimal emphasis on strengthening the food chain, the competitive challenge from world-class telecommunications and other electronics firms in Japan and the EC can only increase.

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The Challenge of High Definition Television

The aggressive policies that have already been adopted by both Japan and the EC to support the development of high definition television (HDTV) challenge the U.S. to shape new policies based on food chain linkages.

In the field of HDTV, coordinated policies in many countries help foreign firms realize competitive advantages over their U.S. rivals. These policies enhance capabilities in areas that once represented the foundation of U.S. strength in electronics, areas such as semiconductors, communications networks, and computers that provide components for HDTV or that will use HDTV screens.

The aggressive policies that have already been adopted by both Japan and the EC to support the development of high definition television (HDTV) challenge the U.S. to shape new policies based on food chain linkages.

The emergence of HDTV and digital communications systems illuminate the significance of this linkage. Recent technological advances have made it possible to transmit formidable quantities of information at high speed and much lower cost than was conceivable just a short time ago. In addition, the convergence of computer and communications technology has created a range of new challenges for telecommunications. For example, the supercomputers that are likely to be commonly used in the future demand far more communications capacity than the present mainframes. As more networks become digital and it is cheaper to gain access to the bandwidth needed for advanced communications products such as HDTV, digital high-speed communications networks will gain greater relevance by providing firms with the ability to prove the usefulness of new products and test consumer acceptance of innovative devices.

U.S. Telecommunications Policy: A Fragmented Framework

This chapter explores the recent evolution of U.S. telecommunications policy and its impacts on network planning in an advanced telecommunications environment. We focus especially on the development of an Integrated Digital Systems Network in the U.S. First, we review the AT&T break-up and the gaps that it left in U.S. policies. We then turn to a brief consideration of how state-level telecommunications policies, driven by the Public Service Commissions, further impede the development of a coherent, effective telecommunications plan. Finally, we consider ISDN as a key case study: it demonstrates how the lack of an international dimension to U.S. communications policy, combined with an inability to overcome lags in technology upgrading caused by the power of state-level regulatory interests, has created a dangerous situation for the development of the U.S. telecommunications industry.

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U.S. Telecommunications Since Divestiture

The reorganization of the U.S. telecommunications market was the culmination of a long series of court cases, administrative decisions by the FCC, and legislative pressure in the form of various bills aimed at removing from AT&T its status as a protected monopoly.

It is possible to trace the restructuring to the Communications Act of 1934, which enshrined AT&T corporate strategy as an article of U.S. telecommunications policy. Certainly, there is good sense in carrying the argument as far back as the end of the U.S. vs. AT&T antitrust litigation in 1956. That is the source for the Modified Final Judgment (MFJ), the basis for the current court-determined contours of U.S. telecommunications policy.

The terms of the Modified Final Judgment are narrowly focused on U.S. legal precedent—not the best basis for determining the future of U.S. telecommunications.

Wherever one begins, one must end by noting that the terms of the Modified Final Judgment are narrowly focused on U.S. legal precedent—not the best basis for determining the future of U.S. telecommunications. In our view, the legalistic basis of U.S. telecommunications policy is in important ways a barrier not only to the ability of the U.S. telecommunications industries to deliver services to businesses and residential subscribers, but also to the ability of the U.S. to sustain some form of control over its own telecommunications future.

Two related difficulties arise from the U.S. policy apparatus for the evolution of the U.S. telecommunications infrastructure, neither of which can be adequately addressed in the current policy environment.

The development of U.S. telecommunications policy is extraordinarily fragmented across different branches of the government.

First, the development of U.S. telecommunications policy is extraordinarily fragmented across different branches of the government. The Federal Communications Commission administers the terms of the 1934 Act, solving problems of cost and access to the public network. Its authority is solely domestic, and it is constrained to consider only technical solutions to network related problems. The Congress retains the authority to override the FCC, and periodically tries to implement its own forms of telecommunications policy (as was the case in the various bills introduced to "deregulate" AT&T).

Other agencies play critical roles as well. The Department of State maintains telecommunications policy—making authority over U.S. participation in international treaty organizations (e.g. Intelsat and the International Telecommunications Union and its subsidiary organizations). The Department of State also acts on behalf of the U.S. in the arena of trade policy, as does the U.S. Trade Representative. Recently the Department of Commerce has taken a lead role in defining its own policymaking authority regarding telecommunications, particularly in the areas of U.S. industrial competitiveness. Recognizing linkages to the defense industrial base, the Department of Defense has entered this arena as well.

Telecommunications has become deeply embedded in the production infrastructure...carrying video images and computer commands to design, manufacture, or deliver products half a continent or half a world away.

This division of policymaking authority, in turn, has a crippling effect on the development of a public network. The public network has become—or should become—more than a telephonic "highway," and this requires a coherent view of its broader functions. Telecommunications has become deeply embedded in the production infrastructure of the U.S. and worldwide economies, carrying video images and computer commands to design, manufacture, or deliver products half a continent or half a world away. It makes very little sense any longer to speak about telecommunications policies without recognizing this change. Telecommunications networks now link sectors of economies and whole economies to each other. The substance of this chapter is an exploration of that point in the context of existing U.S. policy.

The U.S. Telecommunications Market

The present U.S. telecommunications market was given shape by the January 1982 settlement of the AT&T antitrust suit. The terms of the agreement were called the Modified Final Judgment; they entailed modifications of the 1956 consent decree that first defined for AT&T the principle of separating captive from competitive markets. According to the MFJ, AT&T would, as of January 1, 1984, once and for all surrender its control over the captive local-exchange telecommunications market. In return, it would be permitted to enter the competitive telecommunications marketplace.

Under the terms of the MFJ, AT&T was permitted to retain control over: AT&T Long Lines, its long distance operations; Western Electric, its manufacturing arm; and Bell Labs, the world-renowned industrial laboratory. It was then obligated to spin off the operating companies into the current Regional Holding Companies (RHCs) architecture: the 23 Bell Operating Companies (BOCs) were distributed into one or another of the seven RHCs.

The state Public Service Commissions...must approve any acceleration of depreciation...but are reluctant to do so because making the necessary changes would involve increasing rates.

The existence of substantial state authority radically complicates the matter. The state Public Service Commissions, under the terms of the MFJ and divestiture, still regulate the local operating companies. In consequence, they exert a major impact on the ability of the BOCs, such as New York Telephone, to plan for new network concepts. The most important power of the commissions is in the domain of depreciation schedules. They must approve any acceleration of depreciation schedules for telecommunications firms operating in the state, but are reluctant to do so because making the necessary changes would involve increasing rates for local telephone calls. In consequence, during a period of major technology upgrading by the BOCs, states regulating these companies can and do have different approaches.

The BOCs...can only fully implement the technical advances of a digital network when the last piece of analog equipment is physically removed from the systems....This delay...has given major companies and banks strong economic incentives to set up their own private networks.

This lack of coordination has serious consequences for network development and technological innovation. It is precisely those companies with major investments in a large state—the ones most likely to fund network upgrades—that are most affected by roadblocks to the implementation of a digital network. The BOCs face constraints in upgrading networks under current schedules of depreciation; they can only fully implement the technical advances of a digital network when the last piece of analog equipment is physically removed from the systems. In some states, New York, for example, it won't be feasible to do that at least until the turn of the century.

This delay in upgrading equipment has given major companies and banks strong economic incentives to set up their own private networks. Such "bypassing" of the public switched network, while perfectly rational for an individual firm, is irrational for the nation. It fragments a system that needs to be integrated into a seamless national network.

Equipment Manufacturing

Under the terms of the MFJ, the regional holding companies are prohibited from manufacturing telecommunications equipment. They were obligated by the MFJ to develop procurement procedures that were both rigorously competitive and insulated from any possible preferential treatment for AT&T. The RHCs were given positive incentives to promote competition among all possible suppliers of network equipment: competition would allow them to negotiate with suppliers in order to obtain better equipment at lower prices.

Foreign manufacturers were quick to take advantage of the new rules of the U.S. telecommunications marketplace.

Foreign manufacturers were quick to take advantage of the new rules of the U.S. telecommunications marketplace. The point is most clear in the case of the all-important digital central office switching market—a point of confluence for the telecommunications, microelectronics, and computer equipment markets.

Northern Telecom, formerly the manufacturing arm of Bell Canada, rapidly took advantage of the situation. As a North American affiliate of the Bell System, Northern Telecom had geared itself toward production of central office switching equipment for North American standards. However, by 1979, it had only nominally penetrated the U.S. market: the company had a mere three percent share of the U.S. central office switch market. In 1984, two years after the MFJ and year one of divestiture, the company's share had reached 28 percent of the U.S. market. By 1986, according to U.S. Department of Commerce statistics, Northern Telecom had managed to secure more than a third of the U.S. digital central office switching market.

In 1986, four of the six principal telecommunications equipment manufacturers that divided up the U.S. digital central office switching market were foreign-based.

Furthermore, in 1986, four of the six principal telecommunications equipment manufacturers that divided up the U.S. digital central office switching market were foreign-based: Northern Telecom (Canada); Stromberg-Carlson (UK); Alcatel (France); and Nippon Electric Corporation (Japan).

Network Development

The digital central office switching equipment just discussed is intertwined with the development of an integrated digital system network. ISDN is essentially a software-driven service implemented by digital central office switching equipment and delivered over the public network. Therefore, the fragmentation of the office switching equipment market, coupled with the decentralization of regulation, is preventing the orderly development of a comprehensive ISDN.

The problems of divestiture have been compounded over time. The reasons for this are most clearly set forth by Wigand in his 1988 paper, "Integrated Services Digital Networks: Concepts, Policies, and Emerging Issues." Wigand argues that the U.S. communications structure has been fragmented in a number of ways by divestiture and various FCC regulatory requirements. We quote him at some length:

> First, the [RHCs] are now autonomous corporations following their own competitive strategies under intermittent regulation by the Department of Justice and the FCC. *It is entirely up to the [RHCs] to comply voluntarily with the recommendations of such standards-setting bodies as [the International Consultative Committee on Telegraphy and Telecommunications... or] Bell Communications Research Inc.* Second, the [local exchange] communications services provided by the BOCs are separated from the [long-distance] services offered by AT&T and the other common carriers. Third, the [RHCs] are allowed to provide both regulated basic services, and the so-called enhanced services, yet they must provide an open architecture allowing "comparatively efficient interconnection" by private sector providers of enhanced services. Finally, the [RHCs] are permitted to interconnect customer premises equipment but may not manufacture or control the purchase of such equipment (Wigand, 1988:40).

The U.S. communications structure has been fragmented in a number of ways by divestiture and various FCC regulatory requirements.

This fragmentation causes numerous problems for the subsequent evolution of the U.S. telecommunications infrastructure. The key point is that ISDN requires a managed implementation effort built from the top down. As the trade journal *Telecommunications* put the matter in a December 1987 editorial: "ISDN is a technology that almost demands a unified system of application and management to be implemented successfully, since, by definition, it is intended to be a seamless integrated *end-to-end* digital network" (Valovic, 1987:8).

The key point is that ISDN requires a managed implementation effort built from the top down.

To some extent the FCC is now attempting to solve problems generated by the AT&T divestiture. Prior to the FCC's "Computer III" inquiry in the mid-1980s, the RHCs were constrained from manufacturing telecommunications equipment and from developing and bringing to market "enhanced" information services. That is in the process of changing now, particularly in the case of the RHC entry into the "enhanced" services markets. The FCC recognized that as the public network changes from an analog to a digital format, so does the definition of "enhanced" services. For example, protocol conversion—the introduction into the network of computer-format information that would allow a user attempting to communicate in one data communications protocol to talk to another user whose equipment would be otherwise incompatible—was recognized as having become a basic service, though previously falling under the definition of an "enhanced" service.

The constraints against the development of a national ISDN still exist.

To the extent that ISDN promises to incorporate "intelligence" into the public network, it exerts further pressure on the definitions of enhanced and basic service. In any case, once the precedent of permitting protocol conversion was achieved, it became inevitable that regulatory decisions would have to be made on other bases—bases that would eventually allow the RHCs to participate in the enhanced-services markets.

As a conclusion to the Computer III inquiry, the FCC put forth the Open Network Architecture (ONA) plan, with the intention of allowing the RHCs to participate equitably in information services from which they had been barred. In a nutshell, the ONA plan calls for the RHCs to yield a significant measure of their control over the public network. The ONA requires RHCs to implement a public network architecture into which all who seek to do so can plug their equipment. In addition, the RHCs are required to provide for "comparatively efficient" network interconnection. Finally, the FCC made public the terms of the ONA and stipulated that any attempt by the RHCs to alter its form will be subject to FCC approval.

Each of the RHCs is building from the level of the local network up in an attempt to develop an ISDN capable of addressing the needs of the largest business customers in their service territories.

However, none of this alters the fact that there is still a mandated wedge between each RHC and the others, and between the RHCs as a group and AT&T. And that is a matter of significant consequence for the development of ISDN. The constraints against the development of a national ISDN still exist, as do the incentives to continue to reproduce the split between the RHCs and AT&T. Observers have identified at least three clear consequences of the division.

First, each of the RHCs is building from the level of the local network up in an attempt to develop an ISDN capable of addressing the needs of the largest business customers in their service territories. It is a sensible strategy for them because (a) the largest business customers are also the most profitable customers in the subscriber base, and (b) large business customers have extraordinary power with the RHCs because they are able to implement a network bypass strategy whenever doing so seems advantageous.

However, in the rush to serve the large business users, the RHCs are defining courses of ISDN development that might be at odds with each other. While future coordination of the regional ISDNs may still be technically possible, building a national ISDN on the basis of a bottom-up strategy is a slower process than a strategy that calls for national coordination from the outset.

Second, AT&T efforts to develop ISDN services must proceed on their own, according to conditions defined by the MFJ, separately from RHC developments in ISDN. As a result, even if Bell Communications Research succeeds in coordinating RHC trials and eventually negotiating a coordinated RHC interface, as many hope will occur, separate ISDN service packages are expected to emerge among the RHCs, and certainly between the RHCs and whatever ISDN service packages AT&T eventually brings to market.

In the rush to serve the large business users, the RHCs are defining courses of ISDN development that might be at odds with each other....[B]uilding a national ISDN on the basis of a bottom-up strategy is a slower process than a strategy that calls for national coordination from the outset.

Third, at the time of this writing, the terms of the divestiture still prohibit the RHCs from manufacturing their own telecommunications equipment such as the central office switches critical to the introduction of ISDN capabilities. Antitrust law prevents them from coordinating their market power to ensure that their collective requirements are met in a systematic fashion by the companies that can provide such equipment. Furthermore, the short-term conditions of competition—fast ISDN implementation to suit the requirements of their larger customers and the prospective benefits to be had from "winning" the race to ISDN—create an incentive for the RHCs to absent themselves from coordinated efforts as well.

Each of the BOCs, plus a few of the larger independent telephone companies, initiated ISDN field trials during 1988. Figure 1 (page 14) indicates the number and diversity of these U.S. ISDN developments.

The short-term conditions of competition—fast ISDN implementation to suit the requirements of their larger customers and the prospective benefits to be had from "winning" the race to ISDN—create an incentive for the RHCs to absent themselves from coordinated efforts .

However, U.S. domestic carriers have not agreed to a standard for the purpose of routing ISDN services, and draft International Consultative Committee (CCITT) standards represent the only international agreements made in these areas at this time. Other technical groups and trade associations are moving forward on setting standards, but results of these efforts, on which much of the future of ISDN depends, are not expected until the early 1990s.

U.S. Companies Involved In ISDN Trials And Service Rollouts

Company	Switch	Access	Carrier	Status	Note
Aetna, Hartford, Conn,	AT&T 5ESS	Basic	Southern New England Telephone	Installation underway	
Alverna College, Milwaukee	Siemens EWSD	Basic	Wisconsin Bell	Started March 1988, ends 1989	Trial.
American Express, Phoenix, Ariz.	AT&T System 85 PBX/4ESS	Primary	AT&T	Started July 1988	First customer of AT&T's Primary Rate.
American Transtech, Jacksonville, Fla.	AT&T System 85 PBX/4ESS	Primary	AT&T	Started Dec. 1987	Beta test site for AT&T's Primary Rate.
Arizona, State of, Phoenix	Northern Telcom DMS-100	Basic	US West Communications	Started Nov. 1986, officially ended	
Boeing Co., Seattle	AT&T 5ESS	Basic	US West Communications	Scheduled start Nov. 1988	
Carnegie Mellon Univ., Pittsburgh	AT&T 5ESS	Basic		Contact pending	
Chevron Corp., San Francisco	Northern Telcom SL-100/ DMS-100	Primary/ Basic	Pacific Bell	Installation underway	
Contel Corp., Atlanta	AT&T 5ESS	Basic	Southern Bell	Started April 1988	Paying customer.
Control Data Corp., Minneapolis	NEC NEAX 61E	Basic	US West Communications	Started Nov. 1987, ends NOv. 1988	Trial.
Duke University, Durham, N.C.	AT&T 5ESS	Basic	Southern Bell		
Eastman Kodak Co., Rochester, N.Y.	Northern Telecom SL-100PBXs	Primary		Started Aug. 1988	First Primary Rate using two SL-100s
Federal Nat'l. Mortgage Assoc., Wash.	AT&T 5ESS	Basic	C&P Telephone	Started June 1988	
First Data Resources Inc. (American Express subsidiary), Omaha , Neb.	Northern Telecom SL-1 PBX and AT&T 4ESS	Primary	AT&T	Unannounced	
Glaxo Inc., Research Triangle Park, N.C.	SL-1 PBX and DMS-100	Basic	Carolina Teleophone	Scheduled start Jan. 1989	
Hardees, Rocky Mount, N.C.	Northern Telecom DMS-100	Basic	Carolina Telephone	Scheduled start Jan. 1989	
Hayes Microcomputer Products Inc.,	AT&T 5ESS	Basic	Southern Bell	Started April 1988	Using ISDN to develop ISDN products
Norcross, Ga.	AT&T 5ESS	Basic	Pacific Bell	Sept. 1987 to Sept. 1988	
Hershey Foods Corp., Hershey, Pa.	AT&T 5ESS	Basic	Contel of Pennsylvania	Schedled start Oct. 1988	Will includeISDN satellite transmission
Honeywell Information Systems (Honey ????), Minneapolis	Northern Telecom DMS-100	Basic	US West Communications	Started Jan. 87, officially ended	Applications included data/voice transmission between office and employees at home.
Intel Corp., Chandler, Ariz.	AT&T 5ESS	Sasic	US West Communications	Started Feb. 1987, ended Aug. 1987	Trial.
Johns Hopkins Medical Center, Baltimore	AT&T 5ESS	Basic	C&P of Maryland	Contract pending	
Lawrence Livermore Laboratory (University of California), Livermore, Calif.	AT&T 5ESS	Basic	AT&T Federal Systems		
Lockheed Missiles and Space Co. Inc., Sunnyvale, Calif.	AT&T 5ESS	Basic	Pacific Bell	Started Sept. 1987, ended Sept. 1988	Trial.
Mass. Institute of Tech., Cambridge	AT&T 5ESS	Basic		Scheduled cutover Oct. 1988	Using AT&T 5ESS as PBX for private network.
Mather Air Force Base, Sacramento, Ca.	AT&T 5ESS	Basic	AT&T Federal Systems	Started Aug. 1988	Model for ISDN deployment at 50 bases.
McDonald's Corp., Oakbrook, Ill.	AT&T 5ESS	Basic	Illinois Bell	Started Dec. 1988	
McDonnell Douglas Corp., St. Louis		Primary	AT&T	Unannounced	
Microcom Inc., Norwood, Mass.		Basic	New England Telephone	nstallation underway	Part of centrex contract.
Motorola Inc., Schaumburg, Ill.	Northern Telecom DMS-100	Basic	Illinois Bell	Planning stage	
NASA, Washington	AT&T 5ESS	Basic	AT&T Federal Systems		
Nice Corp., Ogden, Utah	Northern Telecom SL-1s	Primary			Telemarketing co. using privateISDN.
North Carolina State Univ., Raleigh	Northern Telecom DMS-100	Basic	Southern Bell		
Northeast Utilities, Hartford, Ct.	Northern Telecom SL-1s	Primary			PBXs in Rocky Hill, Ct. and Meriden, Ct.
Pennsylvania, State of, Harrisburg	Northern Telecom DMS-100	Basic	Bell of Pennsylvania	Contract pending	Statewide network with ISDN in Harisburg
Pratt & Whitney, East Hartford, Conn.	AT&T 5ESS	Basic	SNET		
Prime Computer Inc., Natick, Mass.	AT&T 5ESS	Basic	Southern Bell	Started April 1988	Paying customer.
Rockwell Communication Systems, Richardson, Texas.	AT&T 5ESS with two remotes.	Basic	Southwestern Bell	Scheduled start Dec. 1988	40 buildings in a campus environment linked via ISDN.
Shearson Lehman Hutton Inc., New York	AT&T 5ESS	Basic	New York Telephone	Started June 1988	Part of 8,000 line centrex contract.
Shell Oil Co., Houston	AT&T 5ESS	Basic	Southwestern Bell	Start Sept. 1988	Plan to use 5,000 ISDN lines.
Southern Methodist University, Dallas	Siemens EWSD	Basic	Southwestern Bell	Started Feb. 1988	
SunTrust Service Corp., Atlanta	AT&T 5ESS	Basic	Southern Bell	Started April 1988	Paying customer.
3M Corp., St. Paul, Minn.	AT&T 5ESS	Basic	Southwestern Bell	Started Aug. 1988	Plan to use 3,165 ISDN lines.
Tenneco Inc., Houston	AT&T 5ESS	Basic	Southwestern Bell	Started June 1988	Plan to use 3,900 ISDN lines.
Texas A&M University, College Station	GTE GTD-5 EAX	Basic	GTE Southwest		
University of Arizona, Tucson	AT&T 5ESS	Basic	US West Information Systems, Inc.	Planning stage	Using AT&T 5ESS as PBX in private network.
University of Connecticut, Storrs	AT&T 5ESS	Basic	SNET		
University of Indiana, Bloomington	Northern Telecom DMS-100		Indiana Bell		
University of Maryland, College Park				Unannounced	
University of South Florida, Tampa	AT&T 5ESS		GTE South	Started Oct. 1987	
U.S. Dept. of Treasury, Wash.				Contract pending	
U.S. Bank of Oregon, Portland	Northern Telecom DMS-100	Basic	US West Communications	Started March 1987	Trial.
Virginia, State of, Richmond	AT&T 5ESS	Basic	C&P Virginia	Started April 1988	
West Virginia University, Morgantown	AT&T 5ESS	Basic	C&P of West Virginia	Scheduled start Dec 1988	Plan to use 660 ISDN lines.

Note: This chart was compiled by *Communications Week* with information provided by Teleos Communications Inc., Eatontown, N.J., as well as from news releases and published reports. Carriers, switch manufacturers and their affiliated laboratories are not listed.

Figure 1

U.S. Network Development in Comparative Perspective

In the end, these problems are best understood when placed in a comparative perspective.

The European Economic Community is committed to a two-step program for the implementation of advanced telecommunications systems as part of the larger plan for an EC Internal Market. The Research in Advanced Communications for Europe (RACE) program was begun as an effort to pool research and development resources. It aims to create, in effect, a transnational telecommunications network and a set of standards that would allow for the efficient transmission of services across all quarters of the member states of the European Economic Community. The "Green Paper," to be discussed in the next chapter, provides a coherent strategy for relaxing the trade restrictions that would otherwise stand in the way of this process.

For Japan, ISDN was and remains an instrument of overall industrial development. The effort is intended to integrate the computer and communications industries.

The EC plan is an attempt to effect a regional industrial policy, while at the same time maintaining maximum possible flexibility for the telecommunications administrations of its member states. The plan is based on the assumption that all member states will derive material benefit from the coordinated research and development plan, leaving to each national telecommunications organization the problem of transferring the technology to domestic companies interested in manufacturing equipment and/or developing services for the European market. At the same time, the scheme allows for each national telecommunications organization to manage closely the procurement of network equipment and to introduce new network-based services according to its own internal agenda.

The very concept of a U.S. plan for ISDN is an oxymoron. There is nothing that resembles an integrated industrial policy for telecommunications infrastructure.

The Japanese ISDN plan also uses a "top-down" methodology, coordinated through the combined efforts of the Ministry of Posts and Telecommunications and the Ministry of International Trade and Industry. For Japan, ISDN was and remains an instrument of overall industrial development. The effort is intended to integrate the computer and communications industries, allowing them to make the maximum possible contribution to the development of Japan's public network.

Set against these examples, the very concept of a U.S. plan for ISDN is an oxymoron. There is nothing that resembles an integrated industrial policy for telecommunications infrastructure. The federal-level policy apparatus with specific domain over telecommunications is fragmented to

The fragmentation of the telecommunications policy regime has created...network concepts and equipment that actually make the goal of a seamless end-to-end ISDN an impossibility.

the point where, in the example of an ISDN plan, some portions of the policymaking machinery have conflicting interests with others. Most notably, the fragmentation of the telecommunications policy regime has created a set of positive incentives for the RHCs to capture as many large business customers as possible, and to do so with network concepts and equipment that actually make the goal of a seamless end-to-end ISDN an impossibility. The longer this particular type of problem goes unremedied, the longer it will take for the U.S. telecommunications network and equipment industries to dig themselves out of the hole.

Telecommunications Policies In Japan and Europe

Our main competitors formulate their policies in a context that permits equipment manufacturers to benefit from advances in network technology and vice-versa—a sensitivity to technology development that has yet to be adequately reflected in the formulation of U.S. policies. Thus, other nations appear to be more conscious of the food chain structure of the electronics industry and the significant opportunities for expanding new product markets that can result from strengthening the various links in this chain. By anticipating technological change, they formulate policies to capture its benefits.

By anticipating technological change, [our competitors] formulate policies to capture its benefits....NTT has acted as the vehicle for a thinly disguised industrial policy.

Japanese Telecommunications Policies: The Role of NTT

Japan's Nippon Telegraph and Telephone Company (NTT) was a government-owned telecommunications monopoly until April 1985, and has operated as a private corporation since then. Under whatever formal ownership, NTT has traditionally engaged in joint development projects on network technologies for Japan's communications network. Many of these projects have had leading electronics and communications firms as members, a structure that became so commonplace that these firms were considered family members. This family has included NEC, Fujitsu, Hitachi, and Oki, but also others for specific product needs. Much of the research effort promoted by NTT is supported by its network of "nine very advanced electronics R&D and systems engineering laboratories, many of which are noted the world over for the extraordinarily high caliber of research, e.g. NTT's Atsugi Microelectronics Lab" (Bar and Borrus, 1987:11-12).

By the year 2000, NTT plans to complete the INS, Japan's integrated digital broadband network.

In effect, NTT has acted as the vehicle for a thinly disguised industrial policy. This has been accomplished through a series of mechanisms, particularly the funding of R&D and procurement, where favored Japanese telecommunications companies could develop and commercialize new technologies in an environment that offered them unusual protection. NTT subsidies minimized risk, thus accelerating the development and diffusion of new network technology (Bar and Borrus, 1987:12).

NTT's influence has spanned several parts of the electronics industry. Its procurement of billions of dollars worth of telecommunications equipment containing semiconductors has enabled it to act as the "driving force behind Japanese firms' adoption of automated mass production facilities, which manufacture high quality semiconductors efficiently" (Howell et. al., 1988:79). NTT's commitment to improve semiconductor manufacturing is so great that its Atsugi laboratory which conducts R&D jointly with Japanese firms, has a complete experimental production line.

NTT and the Information Network System Project

Since this network requires substantial increases in capacity, NTT is turning to fiber optics....[and] plans to have 60 to 70 percent of Japan's entire trunk network composed of fiber optics in ten years.

The Information Network System project (INS) has been NTT's key project during the 1980s. By the year 2000, NTT plans to complete the INS, Japan's integrated digital broadband network (comparable to European and U.S. plans for ISDN). The INS will be built before it can be fully used, but its applications will be developed through model programs and pilot projects targeted at business and residential users. Thus, INS is to serve as a "remarkable engineering prototype which may well succeed in giving the Japanese an edge in understanding and developing future telecommunications applications and the products with which they will be implemented" (Bar and Borrus, 1987:12).

Since this network requires substantial increases in capacity, NTT is turning to fiber optics. It is constructing the first part of a nationwide fiber optic network by extending a fiber-optic trunk network that was built during 1986 and 1987. In addition, NTT plans to have 60 to 70 percent of Japan's entire trunk network composed of fiber optics in ten years. NTT will also upgrade the local loop network by installing fiber-optics and using digital equipment. Roughly ten percent of local exchange lines will be made of fiber in the next ten years. Initial testing of the advanced services linked to INS revealed that business users appreciated the need to establish a nationwide INS network as early as possible (Bar and Borrus, 1987:12-13).

Since the lead government agencies...have never lost control over the liberalization process, liberalization has served to reorganize the Japanese telecommunications sector.

The INS network is part of Japan's plan for deregulating the communications industry. In the mid-1980s, the Ministry of Posts and Telecommunications (MPT) began the process by privatizing the 30-year domestic services monopoly held by NTT. It then permitted private networks into the telecommunications infrastructure and, in 1984, established two classes of competitive carriers. In 1986, the MPT opened the international services arena to competition.

Since the lead government agencies—the MPT and the Ministry of International Trade and Industry (MITI)—have never lost control over the liberalization process, liberalization has served to reorganize the Japanese telecommunications sector. Japanese policy for the sector has resembled a coordinated industrial policy (Kalba, 1988:97).

The long-term NTT strategy for INS implementation is based on the schedule for the digitization of the Japanese telecommunications network. According to Wigand (1988:39), that process began in 1985 with the establishment of links between Tokyo, Osaka, and Nagoya, and the process is expected to move forward to all cities with populations larger than 100,000 by 1990. Plans call for the full digitization of the Japanese public network by 1995, when every user of the network will be able to summon ISDN capabilities.

The entire INS project will cost $120 billion over the next 15 years....[I]nvestment and products, including terminal equipment and information services, will have a market that approaches $250 billion.

One of the strengths of the Japanese approach is that the development of the model INS has been closely tied to several parallel projects, a number of which can benefit from the INS infrastructure. The projects that are being developed include: interactive visual communications networks (NTT's Video Response System or VRS); integrated voice-data and voice-video equipment; optical scan document terminals and fast mini-faxes; and optical instrumentation and control systems for industrial and office applications. According to estimates, the entire INS project will cost $120 billion over the next 15 years (Bar and Borrus, 1987:12-13; Davidson, 1986:chapter 3).

The expected size of the markets for INS and the related investment by private corporations are far larger than that. According to Japanese sources, investment and products, including terminal equipment and information services, will have a market that approaches $250 billion. Success in these areas will provide additional support for NTT and the Japanese telecommunications companies to develop other new technologies (Bar and Borrus, 1987:13).

The Very Large Scale Integration (VLSI) project...can be used as a paradigm for successful technology development; it offers lessons that we in the U.S. should be able to apply.

The Japanese Approach: Government-Business Coordination in the VLSI Project

When it was still Japan's government telephone monopoly, NTT became the major source of support for the development of more sophisticated technology in the Japanese computer industry through its participation in the Very Large Scale Integration (VLSI) project. This project, carried out in the late 1970s, can be used as a paradigm for successful technology development; it offers lessons that we in the U.S. should be able to apply.

The most notable success of the VLSI project was its creation of critical components, especially semiconductors, without which an internationally competitive Japanese computer industry might have never developed. Up to the late 1970s, more narrowly based Japanese programs had failed to bring the sophistication of Japanese semiconductor production up to the levels attained by large-scale integrated chipmakers in the U.S. Without significant progress, the Japanese risked falling further behind and, possibly, surrendering dominance in the computer industry to U.S. firms. Following the success of the VLSI project, Japan's computer industry experienced a substantial growth in commercial sales.

A similar effort by the U.S. government in VLSI...because of its... narrow military focus, did not have the dramatic impact on commercial products that the Japanese program achieved.

One goal of the VLSI project focused on the technology needed to produce chips with up to one million bits. The project lasted from 1976 to 1979, and cost 72 billion yen—30 billion yen of which came from the government. Individual Japanese firms contributed the remaining 42 billion yen. NTT played a central role in the Japanese VLSI project by developing a number of the new chips in its own laboratories. These innovative chips were then directly transferred to the companies in the VLSI project, enabling them to create the more powerful computers needed to compete with the U.S. (Cohen and Wheeler, 1989; Howell, et al., 1988).

Between 1979 and 1984, a similar effort by the U.S. government in VLSI required a similar investment, $200 million (or 40 billion yen) for the Very High Speed Integrated Circuit Project. But the U.S. project concentrated on VLSI for military use, developing VLSIs having up to two million bits per chip (Anchordoguy, 1988:173). Because of its narrow military focus, the U.S. program did not have the dramatic impact on commercial products that the Japanese program achieved.

Breakthroughs achieved in the VLSI project... contributed substantially to Japanese chip makers' ability to produce low cost, high quality VLSI in the late 1970s.

The Japanese project focused on research that all firms would need for VLSI production. This reduced the need for firms to use their own know-how while inviting participation for long-run technological benefits. Anchordoguy notes:

> They chose six themes: micromanufacturing technology (especially technology for drawing narrower lines on wafers), silicon crystal technology, and design, process, device, and testing and evaluation technology. The topics covered not only developing the technology for producing VLSIs but also the technology and devices to test the reliability of the VLSIs produced by the machines (Anchordoguy, 1988: 176; Tarui, 1984:144).

Another feature of the Japanese approach was that it concentrated on the weak links in the production chain that existed in Japan, rather than focusing on a broad range of technologies. This enabled the private companies involved in the program to make critical choices and to gain directly from joint efforts in research and development. In a sense, the approach also took the Japanese government role closer to developing systems and closer to aiding in the production of products. This marked an evolution beyond the R&D support (and product development insulated from the market) that had characterized earlier efforts.

The main breakthroughs achieved in the VLSI project, which contributed substantially to Japanese chip makers' ability to produce low cost, high quality VLSI in the late 1970s, were in two areas. The first breakthrough was in devices such as the variable rectangle beam system and the x-ray beam exposure system, which were needed to draw more intricate patterns on VLSI. The second breakthrough was in silicon crystal technology, which reduced the defects in VLSI (Anchordoguy, 1988:176-177).

This pattern of joint research has been continued in recent projects, such as the Key Technology Promotion Center that was established in June 1985. This new research center undertakes telecommunications research, including joint projects with two or more private companies. It will receive six billion yen from the Industrial Investment Special Account, and a three billion yen loan fund from the Japan Development Bank for loans to private firms to undertake risky research projects. The funds for the Special Account come from the dividends on now-privatized NTT shares held by the government. An additional 4.5 to 5 billion yen for the Promotion Center is to come from the private sector.

The Key Technology Promotion Center has already formed a ten-year industry-government project to develop synchrotron orbital radiation generation equipment that will be needed to produce 16-megabit and denser semiconductors (Howell et al., 1988:112-113). In 1988, the Key Technology Center established a consortium and a new company to work on graphics display technology and high resolution screens for HDTV (Ulsaner, 1988:12; Inaba, 1989:69).

The Japanese government uses a number of other policy levers to promote the growth of the telecommunications sector. In many cases, mechanisms have been established to limit foreign entry into the Japanese markets. Product standards and certification procedures have been used by MPT and NTT to limit what products are approved. These standards and certification procedures were set by NTT until the Telecommunications Business Law of 1984 transferred them to the Ministry of Posts and Telecommunications.

Key Technology Promotion Center has already formed a ten-year industry-government project to develop... equipment that will be needed to produce 16-megabit and denser semiconductors.

The Japanese government uses a number of other policy levers to promote the growth of the telecommunications sector... [and] limit foreign entry into the Japanese markets.

In spite of...recent changes, the Japanese telecommunications market remains strongly biased against outsiders.

Japan's success with the VLSI project has demonstrated how technological innovations can act as a "driver" for promoting a series of technological advances in other industries.

The law "requires that the Ministry of Posts use a 'designated approval agency' to certify the acceptability of what Nippon Telegraph calls 'consumer provided equipment' and what the Americans call 'interconnect equipment' (everything from PBXs to computers)" (Howell, et al., 1988:50). Since the designated agency must be Japanese, labs outside Japan cannot be incorporated into the system. This has been taken to imply that the approval agency will be unlikely to accept U.S.-generated technical data, and the agency's directors have been as saying that they would not.

After negotiations with the U.S., the Ministry of Posts and Telecommunications lowered somewhat the number and stringency of standards. In addition, MPT added two foreign firms to the standard-setting Telecommunications Deliberation Council, and experts from a number of foreign firms were permitted to join the Council's board of technical advisers (Johnson, 1986:60-63). This gives foreign firms more opportunity to present their point of view in the deliberations of these bodies, but it provides them with little power to affect decisions.

In spite of these recent changes, the Japanese telecommunications market remains strongly biased against outsiders. Few foreign companies have succeeded in their efforts to penetrate the Japanese telecommunications market. As Raymond Ahearn has noted:

> The procurement policies of NTT, Japan's telecommunications monopoly, have [meant that]...less than 1 percent of NTT tenders traditionally were awarded to foreign suppliers; the vast majority (approximately 96 percent of NTT procurement) went to four family suppliers—Nippon Electric, Oki, Fujitsu and Hitachi" (Ahearn, 1985:53).

Japan's success with the VLSI project has demonstrated how technological innovations can act as a "driver" for promoting a series of technological advances in other industries. Having the basic semiconductor devices that are competitive on world markets opened the way for development of advanced networks. These networks in turn drive the use and development of semiconductors and the more advanced equipment that uses chips as building blocks.

This establishes a cycle of highly beneficial linkages in the Japanese economy. Moreover, it offers Japanese corporations many new avenues for exploiting in one market the competitive advantages that they have gleaned from their success in technology commercialization in others.

European Policies for the Telecommunications Industry

Until the European Commission (EC) established a more coordinated approach to policy for communications, national policies had not achieved great success in establishing the framework for technological advances. Some nations (France and West Germany, for example) had achieved a measure of success, particularly in network development, but progress toward establishing an integrated communications network and a competitive communications base in Europe was quite limited.

European policies have increasingly taken on a Japanese flavor.... creating links between equipment manufacturing firms and the firms that will provide the services on more advanced networks.

European policies have increasingly taken on a Japanese flavor. This is evidenced particularly in the joint initiatives between firms from a number of nations, which are now the main vehicle for precompetitive technology development. This means that European policies have moved away from basic research, as have Japanese policies, and are now more concerned with commercial success. In addition, European policies clearly are concerned with creating links between equipment manufacturing firms and the firms that will provide the services on more advanced networks.

In emulating the Japanese approach, European policies are also putting a greater premium on forcing national firms to compete in the international marketplace, given some protection and support to become more innovative in Europe. But the shift is clearly away from the old order of closed economies, where close ties often led to ingrown relationships between Ministries of Posts and Telecommunications and large suppliers of communications equipment, thus failing to stimulate adequate investment in innovative R&D. Foreign competitors still find it difficult to gain entry to the marketplace, although they may have more opportunities under recent EC proposals.

A technically advanced, Europe-wide and low-cost telecommunications network [will]...provide an essential infrastructure for improving the competitiveness of the European economy.

This Japanese orientation is particularly apparent in the approach to telecommunications. The Green Paper on the Development of the Common Market for Telecommunications and Services and Equipment that was prepared by the EC saw the development of:

> A technically advanced, Europe-wide and low-cost telecommunications network [as the way to]...provide an essential infrastructure for improving the competitiveness of the European economy, achieving the Internal Market and strengthening Community cohesion... It also applies to trade in goods; and to the goal of European industrial co-operation. The emerging new telecommunications services...will have a major

impact on the future tradeability of services in general and on the location of economic activities (Cohen and Wheeler, 1989).

According to the Green Paper, the European Commission intends to improve the coordination of future development in telecommunications in the Community through common infrastructure projects, especially network development. This will occur through the construction of an ISDN and of digital mobile communications. The Commission will also create a Community-wide market for terminals and equipment and promote the development of Europe-wide open standards. These efforts will be combined with the EEC RACE program to provide each member-state national telecommunications entity with support for precompetitive R&D in integrated broadband communications. A video-communications system will also be established (Cohen and Wheeler, 1989).

The coordination of future development in telecommunications in the Community...will occur through the construction of an ISDN and of digital mobile communications.

ISDN in Western Europe

ISDN development in Western Europe is proceeding at national levels and at the level of cooperative programs created and managed by the EC. France and West Germany are the most advanced in their ISDN programs.

The French ISDN project began in 1983. Commercial Basic Rate ISDN services based on 144 kb/s access lines began in the west of France in December 1987. The service was expanded to the Paris metropolitan area in late 1988.

By the end of 1989, Primary Rate ISDN services will be available to connect PBXs and large computers; connections will be completed to Lyons, Marseilles, and Lille, and international ISDN links will be established. All of France is scheduled to be covered by ISDN services by the end of 1990.

The publicly owned French telecommunications network is among the most hospitable in all of Europe to the introduction of ISDN features. First, France already has one of the highest proportions of digital switches in the world; as of the end of 1987, 65 percent of the trunks and 50 percent of the local exchanges were digital (Law, 1989:54). The network offers digital access to more than 50 percent of its customers, concentrated in the large metropolitan areas. In addition, it offers the world's largest packet-switching network with more than 50,000 direct-access lines. Because it has these capabilities, the French network allows for the progressive integration of ISDN features onto the public network.

The publicly owned French telecommunications network is among the most hospitable in all of Europe to the introduction of ISDN features.

The initial ISDN marketing plan was based on a strategy of serving small- and medium-sized businesses. In particular, customers were expected to come at first from the health, newspaper, banking, publishing, and advertising industries. The first wave of marketing research based on the western regional trials indicated that the new technological advantages offered to customers by ISDN services (voice/data integration) were ignored, suggesting that the services most clearly evolved from telephony were the most easily accepted.

Indications are that France Telecom will push ahead in any case. Law writes that it will "pitch ISDN to the large corporate user based on its capabilities for voice/data integration, Group 4 fax, EDI [Electronic Document Interchange], CAD/CAM [Computer-Assisted Design/Computer-Assisted Manufacturing], and LAN [Local Area Network] interconnection" (Law, 1989:55). The company is confident enough to project capture of 95,000 of an estimated national market of 150,000 equivalent basic-rate connections. According to U.S.-based trade journalist J. Williamson (1989:36), France Telecom expects that market to swell to an estimated 700,000 by 1995.

In the national race for ISDN in preparation for the 1992 Unified Internal Market, West Germany, led by the DBP, has charged to the front of the pack.

West Germany's Deutsche Bundespost (DBP) has been pushing ISDN developments since the early 1980s as part of a long-range plan to upgrade the predominantly analog telephone network. In the national race for ISDN in preparation for the 1992 Unified Internal Market, West Germany, led by the DBP, has charged to the front of the pack.

The Deutsche Bundespost ISDN....plans call for a narrowband digital information network to be created by 1990 for the purpose of linking separate voice, data, and text-transmission networks.

West German ISDN policy is based on the concept of a seamless coordination of the installation of ISDN-capable digital equipment at the local and trunk levels. The earliest substantial ISDN pilot projects expected to have direct relation to ISDN implementation began in 1987. Carl Law writes:

> In 1987, the Deutsche Bundespost (DBP) began an ISDN pilot project with 400 subscribers in Mannheim and 400 more in Stuttgart. This pilot was completed at the end of 1988, and commercial service was offered at eight locations: Berlin, Hamburg, Hannover, Dusseldorf, Frankfurt, Stuttgart, Nurmberg, and Munich....These nodes consist of local exchanges, each with 1,000 basic rate ISDN subscriber lines, that are connected to Class 4-type digital central office exchanges using Common Channel Signaling System 7... (Law, 1989:54).

The Deutsche Bundespost ISDN strategy is based on a parallel network plan where the ISDN will exist alongside present networks, in part because they cannot handle some specialized data applications. Nationwide ISDN service is targeted for 1993-1994. According to Law, "[O]nce the initial stages of ISDN deployment have been completed, DBP will begin to implement broadband ISDN services and change-out its copper plant for fiber optics" (Law, 1989:55). These activities could commence in 1995.

A large annual trade deficit was the basic driver behind the formation of the Research in Advanced Communications for Europe (RACE) program.

The plans call for a narrowband digital information network to be created by 1990 for the purpose of linking separate voice, data, and text-transmission networks. Ninety percent of the services to be offered over the eventual broadband ISDN will be for individual communications (e.g. voice, facsimile, interactive videotex, videoconferencing). Annual conversion expenses over the course of the plan require more than $2.5 billion a year (Wigand, 1988:36).

The RACE Program

A large annual trade deficit was the basic driver behind the formation of the Research in Advanced Communications for Europe (RACE) program. Consider the following statistics drawn from Herbert Ungerer and N.P. Costello's research, sponsored by the European Community:

> Broadly speaking, the U.S. and Japanese exports are on the same order of magnitude as those of the Community. The differences are on the import side. In 1987, the Community exported to the United States a total value of telecommunications equipment—including telecommunications components—of 417 million ECU [European Currency Units], and to Japan only 40 million ECU. Yet it imported from the United States 910 million ECU worth of equipment, and from Japan 984 million ECU worth (Ungerer and Costello, 1989:111).

The EC faced....the problem of developing a sense of collective mission that would allow each member state to participate and at the same time secure for its own "national champions" a unique set of benefits.

No single European country could marshall the resources to address a problem of that dimension, and no European market was considered large enough to sustain profitability. In consequence, a series of development programs were launched with the intention of providing a basis for each member of the EC to fully participate in worldwide high-technology markets.

The EC faced two sets of problems early on. First was the problem of developing a sense of collective mission that would allow each member state to participate and at the same time secure for its own "national champions" a unique set of benefits appropriate to its own strategic situation.

Second, and a bit more to the immediate point, the EC had to develop a forum for sharing the costs.

RACE was established in late 1986 as part of an EC-wide industrial policy for telecommunications. At the time, a trade journal report explained its purpose as follows:

> The objectives of RACE are ambitious. It aims at the introduction of Integrated Broadband Communications (IBC), taking into account the evolving ISDN and national introduction strategies, progressing to Community-wide services by 1995. Moreover, RACE requires cooperation between a large number of players, including the Telecommunications Administrations and telecommunications user industries and services. It involves concrete planning of the introduction of broadband services in the Community; and it involves elaboration of common standards and specifications (Ungerer, 1988:116).

RACE was established in late 1986 as part of an EC-wide industrial policy for telecommunications.

To that end, RACE proposed the following set of main objectives, as summarized by Cohen and Wheeler:

> To promote the European Community's telecommunications industry, so as to assure that it maintains a strong position at European and world levels in a context of rapid technological change;
>
> to enable European network operators to confront the technological and service challenges with which they will be faced;
>
> to offer opportunities to service providers to improve cost performance and introduce new or enhanced telecommunication and information services which will both earn revenue in their own right and give indispensable support to other productive sectors of the Community;
>
> to make available to end users, at minimum cost and with minimum delay, the telecommunications services which will sustain the competitiveness of European economy over the next decades and contribute to maintaining and creating employment in the Community;
>
> to contribute to regional development within the Community by supporting the development of common functional specifications for equipment and services permitting the less prosperous regions to benefit fully

The broad purpose of the RACE program is to identify the technical and economic issues in developing IBC.

Total investment in the RACE program, to be made by all participating parties, could amount to as much as...$1.2 billion in 1988 dollars; half of that amount will be contributed by the European Commission.

European efforts to implement ISDN have not been without problems and delays, especially by comparison with the single-minded effort in Japan.

from the introduction of advanced telecommunications in Europe (Cohen and Wheeler, 1989, in preparation).

The broad purpose of the RACE program is to identify the technical and economic issues in developing IBC. In its first year and a half, RACE concentrated on the development of an IBC reference model, which included modeling the network and the terminal equipment attached to it, in addition to the network and applications and services. This involved establishing programs with a long R&D lead time, and establishing goals for the critical components of the network. As in the case of the Japanese VLSI program, a number of technology options had to be assessed by undertaking research to define the required full-scale R&D effort.

Ungerer and Costello note: "On the basis of the successful completion of the definition phase, the main RACE programme was developed covering the period 1987-1991. It was adopted by the Council of Ministers on 22 December 1987. The total allocation from the Community budget for this period is 550 million ECU [about $650 million]" (Ungerer and Costello, 1989:154).

Total investment in the RACE program, to be made by all participating parties, could amount to as much as one billion ECU [$1.2 billion in 1988 dollars]; half of that amount will be contributed by the European Commission. About 70 percent of the total funding will be devoted to technological research and development, and ten percent will be devoted to strategic studies and consensus development. The remaining 20 percent will be spent on functional integration, system verification, and pilot applications. In 1988, following the first call for proposal evaluation, 46 contracts for about 3,500 person- years of work were signed. The Commission is to contribute 186 million ECU ($220 million) over three years.

European efforts to implement ISDN have not been without problems and delays, especially by comparison with the single-minded effort in Japan. The first set of EC guidelines for ISDN implementation was issued in 1986. It called for a phased introduction of services, and for ISDN access lines to be made available by 1993 for the number of lines equivalent to five percent of all main lines in use in 1983. Not one single deadline contained in the 1986 guidelines has been met at the time of this writing, yet forward movement continues.

In October 1988, the four largest European telecommunications administrations—the Deutsche Bundespost, British Telecom, France Telecom, and the Societa Italiana per L'Esercizio Telefonico (SIP)—signed a memorandum of understanding concerning common technical interfaces and signalling standards in and between countries. The memorandum contains nothing, however, regarding tariffs or terminal equipment harmonization (reported in *Communications Week*, October 3, 1988, p. 30).

The memorandum of understanding may lead to a definition of the minimum set of services and details concerning how each national network will migrate for international interconnection, both of which may be sticking points for smaller EC member states with low levels of telephone penetration.

The EEC and Japanese ISDN programs are advancing their nations into a twenty-first century infrastructure.

Conclusions Concerning Other Nations' ISDN Efforts

The EEC and Japanese ISDN programs are advancing their nations into a twenty-first century infrastructure. Japan's efforts are the most advanced. Japanese programs are aimed first at the domestic market, but ultimately at the export market. Europe has only recently undertaken significant programs. But in 1992 Europe becomes the Single Market—the largest, highly developed consumer market in the world. Its progress could then accelerate. Given serious, continued substantial industrial policies, either Europe or Japan (or both) could leave the U.S. far behind.

Trade and Employment Aspects of Communications Policy: The Role of HDTV as a "Driver"

Compared to the coordinated efforts within Japan and the EC to lead the "electronics race," the U.S. has made only minimal advances.

It is in trade statistics that the effects of the patchwork U.S. policies discussed earlier are most clearly reflected. Compared to the coordinated efforts within Japan and the EC to lead the "electronics race," the U.S. has made only minimal advances. Japan's all-out effort has achieved quite impressive results. In dollar terms, Japan's exports of telecommunications equipment rose from $519.5 million in 1979 to $3.5 billion in 1987, not quite matching the nearly tenfold rise in exports of electronics products during this period. Just about $1.4 billion in telecommunications equipment was imported into the U.S. in 1987, up from $116 million in 1979 (Russell, 1988).

But the future appears to hold even more opportunities for Japanese growth. Total demand for the Japanese version of high definition television, which includes the cameras, receivers, VCRs, and software for both consumer and industrial use, is expected to grow from one trillion yen ($5.6 billion) in 1995 to five trillion yen in 2000 ($27.8 billion). The development of image equipment production and of graphics software is likely to represent a major part of this growth. Overall, cumulative spending on these products is expected to reach 30 trillion yen ($166.7 billion) by the year 2000 (*Japan Electronics Almanac*, 1988:27).

Japan's corporations are moving rapidly to position themselves as leaders in the entire food chain of electronics industries for the foreseeable future.

This striking picture of how pivotal advanced television and imaging likely will be to the Japanese economy of the next decade should raise U.S. policymakers' concern. Japan's corporations are moving rapidly to position themselves as leaders in the entire food chain of electronics industries for the foreseeable future. Japan's share of patents registered in the U.S. has risen to 26 percent in 1986, compared to 14 percent in 1975. Canon, Hitachi, and Toshiba were the three firms that obtained the greatest number of patents in the U.S. in 1987. In telecommunications, the Japanese gains in obtaining patents are even more impressive than the share increase. In 1975, U.S. firms received 1665 patents compared to 346 for Japanese firms. In 1986, Japanese firms obtained 1028 American patents compared to 2043 for U.S. firms (Sullivan, 1988).

A particularly alarming insight into Japan's strategy is provided in a recent report by the Ministry for International Trade and Industry called *MITI 2000 Vision* (Japan Ministry of International Trade and Industry, 1988). This report projects that the Japanese telecommunications industry will have a nine percent compound annual growth rate between 1984 and 2000 if Japan attains a five percent growth in GNP. Information services will grow at a 17 percent rate. While these projections assume very strong shifts in investment to the "information" industries and strong incentives to attain these levels of growth, they are not overly optimistic (Sullivan, 1988). Clearly, HDTV is expected to play an important role in these projected gains.

The Consequences of Failing to Develop a Strong HDTV Industry in the U.S.

The U.S. could face an annual trade deficit of more than $225 billion in electronics and lose more than two million jobs a year by 2010 if it fails to develop strong HDTV and flat-display-screen industries.

The U.S. could face an annual trade deficit of more than $225 billion in electronics and lose more than two million jobs a year by 2010 if it fails to develop strong HDTV and flat-display-screen industries. The trade deficit under a weak HDTV scenario, where the U.S. industry takes only ten percent of the world market, would be $227 billion in the year 2010 for just four electronics industries: HDTV receivers and VCRs, personal computers, semiconductors, and automated manufacturing equipment. The main contributors to this enormous trade deficit would be the personal computer and semiconductor industries, which would suffer annual deficits of $114 billion and $76 billion, respectively.

As a result of this trade deficit, the U.S. would lose 792,000 jobs in these four closely linked industries, because weakening the HDTV base weakens demand and technological innovation in the other electronics sectors. An additional 1.5 million jobs would be lost through reduced spending in the economy by people who would have been employed in these electronics sectors. These multiplier effects are based on a rather conservative estimate of approximately two new jobs for every one new job in electronics.

Strong linkages between HDTV and the rest of the electronics sector....make ...HDTV...a critical driver of technological advances.

As these figures show, our nation stands at a critical juncture. If we do not create a strong industrial base centered on the development of HDTV and flat-display screen technology, it will not only weaken our industrial base, but also reduce the number of skilled jobs that are needed to make us more competitive.

Linkages: One Key to Creating Competitiveness

Our failure to develop a strong HDTV industry would have a dramatic impact on the trade balance and competitiveness because of the strong linkages between HDTV and the rest of the electronics sector. These sectors are expected

HDTVs will be used in the home, as display screens for personal computers, and by the nation's businesses to improve controls over automated production.

While the U.S. market would have $84 billion in estimated HDTV sales over this period...only $42 billion in world shipments would be accounted for by U.S. firms.

to expand at a rapid pace over the next two decades. The linkages make the HDTV sector a critical driver of technological advances, since the improvements and expansion of the market that it stimulates will ripple through the rest of the electronics sector, bringing about advances that are critical to the development of our industrial base.

This driving function occurs in the following manner. When a personal computer with a high-resolution display appears on the market, this will not only create additional demand for such advanced PCs, but will also increase demand for the electronics parts and components that the PC incorporates, such as the screen and advanced semiconductors, including memory chips. The use of these inputs will boost demand for the products from the related industries, contributing to increases in their output and improving the chances that they will be profitable and have the funds to support further innovation.

Consequently, such linkages create a kind of feedback mechanism, one that provides the greatest advantages to our industrial base when the entire food chain of the electronics industry is improved. This will occur when the demand for basic components, such as semiconductors and digital display screens, is expanded to a wide range of applications of the final products in our economy. HDTVs will be used in the home, as display screens for personal computers, and by the nation's businesses to improve controls over automated production in auto, steel, and manufacturing plants, to integrate video and print media in newspapers, and for the collection and transmission of important medical results, such as x-rays and computer tomographs.

Cumulative Sales and Trade Impacts, 1990-2010

Figures from a study prepared by the American Electronics Association's "Advanced TV Task Force Economic Impact Team" can be adapted to illustrate the impact of HDTV on trade and employment (Russell, 1988). In Table 1 we have summed the totals from that study for cumulative sales over the 1990-2010 period for HDTV and the three industries that are most likely to be affected by its growth. These figures show that while the U.S. *market* would have $84 billion in estimated HDTV sales over this period, in the most optimistic scenario (where U.S. firms attain 50 percent of the U.S. market for HDTV) only $42 billion in world shipments would be accounted for by U.S. *firms*. In the medium scenario, U.S. firms would have 30 percent of U.S. HDTV sales, or $25 billion, during this period. In the weak scenario, U.S. firms would only attain a ten percent share of the U.S. market, or $8.4 billion in world market sales over the 1990-2010 time period.

The results for the three associated electronics industries illustrate some of the positive and negative impacts of the growth of the HDTV industry. With a strong U.S. HDTV industry, there is more support for U.S. firms in these sectors. For example, with a strong HDTV effort, U.S. automated manufacturing equipment firms would be expected to capture a large share of the world market, with $469 billion in sales between 1990 and 2010. But with a weak HDTV industry that controls only ten percent of U.S. sales, U.S. automated manufacturing equipment producers would have only $364 billion in world market sales over this period. This is $105 billion less than in the strong HDTV scenario, and represents a shortfall in sales of about $5 billion a year.

With a weak HDTV industry...U.S. automated manufacturing equipment producers would have...a shortfall in sales of about $5 billion a year.

The sales differences are far greater for the personal computer industry, as Table 1 indicates. Assuming the U.S. fails to develop an indigenous HDTV base, the estimate of worldwide sales for U.S. personal computer firms falls from $2.1 trillion dollars over the 1990-2010 time period to just $1 trillion under the weak HDTV scenario. This represents a loss of about $50 billion in sales per year. Similar stark differences would occur in the sales of the semiconductor industry, where a strong U.S. HDTV industry would enable semiconductor makers to achieve estimated worldwide sales of $1.2 trillion, compared to $626 billion with a weak HDTV sector.

In the...semiconductor industry...a strong U.S. HDTV industry would enable semiconductor makers to achieve estimated worldwide sales of $1.2 trillion, compared to $626 billion with a weak HDTV sector.

In order to examine how differences in the scenarios would affect U.S. *net trade*, as opposed to U.S. *company sales*, we have adjusted the figures developed by the American Electronics Association Task Force to provide more precise estimates of *production* that would take place in the U.S. This requires taking into account the share of U.S. production in the total shipments by U.S.-based companies (and also production in the U.S. by foreign companies) that are provided in Table 1. These production estimates are summarized in Table 2.

We have assumed that in the strong scenario, 50 percent of the U.S. manufacturers' sales in the world market would be produced in the U.S., with the remainder being sourced from overseas. This is supplemented by U.S.-based foreign production, which we are estimating would be equal to 30 percent of the world market sales of U.S. manufacturers.

Thus, we have taken 80 percent of the world sales of U.S. manufacturers given in Table 1 to obtain the estimated *production in the U.S.* in this strong scenario. For the medium-strength HDTV scenario, these figures are 40 percent and 20 percent, respectively, since the U.S. market would be weaker and more likely to source from overseas. To obtain the scale of U.S. production in the medium scenario, therefore, 60 percent of the amounts in Table 1 are used in Table 2. For the weak HDTV scenario, these figures drop to 30 percent and 10 percent, so 40 percent of the figures for this scenario in Table 1 are used for the size of U.S. production.

One glimpse of the future is contained in the Next computer, which sources nearly 85 percent of its parts from overseas....[T]he weaker the U.S. is as a site for electronics production, the more likely U.S. firms will market foreign electronics products.

TABLE 1

Cumulative Sales in the World Market, U.S. Market, Size, and U.S. Firms' Worldwide Sales of HDTV and Related Industries' Products Under Three Growth Scenarios 1990–2010
(In billions of dollars)

Sector	World Market	U.S. Market	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	$ 264	$ 84	$ 42	$ 25	8
Automated Manufacturing Equipment	1,192	397	469	416	364
Personal Computers	2,999	1,500	2,101	1,680	1,049
Semiconductors	3,054	1,018	1,250	1,001	626

Note: The figures on U.S. firms' worldwide sales are derived from estimates that are close to the current share size, namely 50 percent of the world market for shipments of U.S.-based producers in the personal computer industry, and about 25 percent for semiconductors. It is assumed that U.S. firms' world share of automated manufacturing will be 25 percent. The HDTV share size is given in the study from which these sales data are derived: David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

It should be noted that the sales estimates here represent sales controlled by U.S. firms that result from production in the U.S. and overseas. These figures are adjusted in later tables that present trade estimates and employment projections by creating estimates of how much production is likely to take place in the U.S. by either U.S. or foreign producers under each of the three scenarios.

Several factors lead us to believe that the adjustments in Table 2 are plausible. One glimpse of the future is contained in the Next computer, which sources nearly 85 percent of its parts from overseas. In addition, we would argue that the weaker the U.S. is as a site for electronics production, the more likely U.S. firms will market foreign electronics products. For instance, Kodak is currently marketing the cameras that Sanyo has designed for HDTV rather than taking the risk to develop their own. In addition, few U.S. computer makers considered the need to develop the digital displays that will be required if computers are to move into the digital era, although Japanese firms have been active in commercializing these technologies. This is another example of how

TABLE 2

U.S. Market Size and Domestic Cumulative Production of HDTV and Related Industries Under Three Growth Scenarios 1990–2010
(In billions of dollars)

Sector	U.S. Market	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	$ 84	$ 34	$ 15	$ 3
Automated Manufacturing Equipment	397	375	250	146
Personal Computers	1,500	1,681	1,008	420
Semiconductors	1,018	1,000	601	250

Note: These figures assume that for the strong scenario, 50 percent of the U.S. manufacturers' share is produced in the U.S. and an additional 30 percent comes from foreign-owned production in the U.S. For the medium scenario, the figures are 40 percent and 20 percent, and for the weak scenario, the figures are 30 percent and 10 percent. These adjustments are used to alter the estimates for world share of production by U.S. firms in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

weakness inclines firms to resort to overseas sources of leading technology products.

Domestic production figures for personal computers...differ greatly when the strong and the weak scenarios are compared: almost $1.7 trillion in cumulative... sales of domestically-produced PCs under the strong scenario versus $420 billion in...the weak scenario.

Comparing Table 2 with Table 1, we see that *domestic production* will be much less than U.S. company *worldwide sales* under any of the scenarios and for each industry's products. However, the domestic production figures for personal computers and semiconductors differ greatly when the strong and the weak scenarios are compared: almost $1.7

trillion in cumulative estimated sales of domestically-produced PCs under the strong scenario versus $420 billion in cumulative estimated production in the weak scenario. Similarly, for semiconductors, cumulative estimated production in the U.S. would rise to $1 trillion over the 1990-2010 period while it would only be $250 billion in the weak HDTV scenario.

In HDTV production... [cumulative] trade deficits of $50 billion [occur even] in the strong HDTV scenario, compared with an...$81 billion deficit in the weak HDTV scenario.

In Table 3, we have estimated trade balances using the figures presented in Table 2. These are derived by subtracting U.S. production from the estimated market size of each U.S. market for the electronics products that are analyzed. Domestic production in excess of U.S. demand for an industry's output would mean the U.S. had a trade surplus. In most cases, however, as Table 3 shows, trade deficits are projected.

TABLE 3

Cumulative Trade Deficits for HDTV and Related Industries' Products Under Three Growth Scenarios 1990–2010
(In billions of dollars)

Sector	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	- $ 50	- $ 69	- $ 81
Automated Manufacturing Equipment	- 22	- 147	- 251
Personal Computers	181	- 492	-1,080
Semiconductors	- 18	- 417	- 768
Total	$ 91	- $1,125	-$2,180

Note: Derived from results presented in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

There are dramatic contrasts in trade outcomes among the three scenarios. In HDTV production itself, the adjustments used here produce estimated trade deficits of $50 billion in the strong HDTV scenario, compared with an estimated $81 billion deficit in the weak HDTV scenario. For the PC and semiconductor industries, however, the estimated trade deficits could be enormous. In PCs, the trade balance shifts from an estimated *surplus* of $181 billion over the 1990-2010 period in the strong HDTV scenario to an estimated *deficit of nearly $1.1 trillion* in the weak HDTV scenario. In the semiconductor industry, where there is a small deficit of $18 billion over the 1990-2010 period in the strong HDTV scenario, there is a cumulative deficit of $768 billion over the same period in the weak HDTV scenario.

All in all, in the strong HDTV scenario, there is an estimated trade *surplus* of $91 billion over the 20-year period considered. However, the figures indicate that if the U.S. is only able to develop a weak HDTV industry, *it will have to cope with trade deficits from these electronics industries alone that total more than $2 trillion for the 1990-2010 period.* Approximately $100 billion would be added to the U.S. trade deficit *each year* in a weak HDTV scenario. This *increase* is about three-quarters of the already huge U.S. trade deficit in 1988.

All in all, in the strong HDTV scenario, there is an estimated trade surplus of $91 billion over the 20-year period.... However,...[with] a weak HDTV industry,...[the U.S.] will have to cope with trade deficits from these electronics industries alone that total more than $2 trillion.

Sales, Trade, and Employment Impacts In the Year 2010

All of the estimates in Tables 1 through 3 pertain to *cumulative* sales, production, trade, and so on. Over the period, however, the *annual* sales, production, and, unfortunately, U.S. trade deficits would be increasing as well.

Estimates for sales in 2010 of HDTV receivers and VCRs, automated manufacturing equipment, personal computers, and semiconductors present dramatic differences between the three possible scenarios. Table 4 presents the unadjusted figures for worldwide sales by U.S. firms, as given in the AEA study. As in the cumulative figures above, personal computers and semiconductors show the greatest contrast between the strong HDTV scenario and the weak HDTV scenario. Estimated sales in 2010 in the strong HDTV scenario are about double those in the weak HDTV scenario for both of these products.

[Annual] sales in 2010 in the strong HDTV scenario are about double those in the weak HDTV scenario for [computers and semiconductors].

Table 4 shows that with a strong HDTV base, the U.S. PC industry would attain an estimated $221 billion in annual sales. This contrasts with an expected $110 billion in annual sales in a weak HDTV sector, a difference of $111 billion in forgone sales if the U.S. has a weak HDTV base. The contrast is equally striking for the semiconductor industry. In this sector, sales would reach an estimated $124 billion with a strong U.S. HDTV sector, and only an estimated $62 billion with a weak HDTV industry, a difference in of $62 billion in semiconductor sales by 2010.

These figures are adjusted in Table 5 using the same procedure that was employed in Table 2, with a further adjustment to U.S. market size in line with more conservative projections in the literature. This permits us to create projections for U.S. *domestic production* under each of the three scenarios for the year 2010. These estimates can be used with projections of total U.S. sales to compute the annual trade surplus or deficit that would be expected under each scenario in 2010. As can be seen in Table 5, the differences between the strong and weak HDTV scenarios remain striking, particularly for the PC and semiconductor industries. In the case of the PC industry, annual production in the U.S. would reach an estimated $176 billion in 2010, while it would only reach $44 billion under the weak HDTV scenario. For semiconductors, U.S. production would grow to an estimated $99 billion under the strong HDTV scenario but to only $25 billion under the weak HDTV scenario.

In...the PC industry, annual production in the U.S. would reach an estimated $176 billion in 2010, [with a strong HDTV effort] while it would only reach $44 billion under the weak HDTV scenario.

TABLE 4

U.S. Market Size and U.S. Firms' Worldwide Sales in 2010 of HDTV and Related Industries' Products Under Three Growth Scenarios
(In billions of dollars)

Sector	U.S. Market	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	$ 11	$ 5.4	$ 3.3	$ 1.1
Automated Manufacturing Equipment	58	48.7	40.6	32.5
Personal Computers	210	220.5	176.4	110.3
Semiconductors	151	124.3	99.4	62.1

Note: Derives from results presented in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

While these differences are quite large, they are not surprising. If the U.S. HDTV industry generates little local production and only a small amount of innovation in electronics products, it is likely that even the largest companies will obtain many of their components overseas, earning profits by the added value they gain from assembling the components into computer or automated manufacturing equipment.

If the U.S. HDTV industry generates little local production and only a small amount of innovation...it is likely that even the largest companies will obtain many of their components overseas, earning profits by the added value they gain from assembling.

TABLE 5

U.S. Market Size and Domestic Production in 2010 of HDTV and Related Industries Under Three Growth Scenarios
(In billions of dollars)

Sector	U.S. Market	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	$ 11	$ 4.3	$ 2.0	$ 0.4
Automated Manufacturing Equipment	39	40.0	24.4	13.0
Personal Computers	158	176.4	105.8	44.1
Semiconductors	101	99.4	59.7	24.8

Note: These figures assume that for the strong scenario, 50 percent of the U.S. manufacturers' share is produced in the U.S. and an additional 30 percent comes from foreign-owned production in the U.S. For the medium scenario, the figures are 40 percent and 20 percent, and for the weak scenario, 30 percent and 10 percent. These adjustments are used to alter the estimates for world share of production by U.S. firms in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

In 2010...the trade balance in these four industries would range from an estimated surplus of $10 billion to an enormous estimated deficit of $227 billion in just one year.

Table 6 sums up the trade impacts of the different scenarios in 2010. It shows that the trade balance in these four industries would range from an estimated surplus of $10 billion to an enormous estimated deficit of $227 billion in just one year. The main contributors to this deficit would again be the personal computer and semiconductor industries, which would contribute deficits of $114 billion and $76 billion, respectively, to the overall trade deficit in the weak HDTV scenario.

Employment Impacts

Employment impacts can be obtained by dividing the sales figures in Table 5 by the amount of sales per employee that we would expect in these industries. There is currently about $150,000 in sales for each employee in the computer and telecommunications industry in 1987. However, we used an estimate of $300,000 in sales per employee, allowing for substantial productivity gains by the year 2010. If productivity does not rise rapidly, Table 7 underestimates employment losses.

The personal computer industry would grow to an estimated 588,000 employees in 2010 in the strong HDTV industry scenario, compared with just 147,000 employees in the weak HDTV scenario.

TABLE 6

Trade Deficits in 2010 for HDTV Related Industries' Products Under Three Growth Scenarios
(In billions of dollars)

Sector	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	- $ 7	- $ 9	- $ 11
Automated Manufacturing Equipment	1	- 15	- 26
Personal Computers	18	- 52	-114
Semiconductors	- 2	- 41	- 76
Total	$ 10	- $117	-$227

Note: These figures assume that in the strong scenario, 50 percent of the U.S. manufacturers' share is produced in the U.S. and an additional 30 percent comes from foreign-owned production in the U.S. For the medium scenario, the figures are 40 percent and 20 percent, and for the weak scenario, 30 percent and 10 percent. These adjustments are used to alter the estimates for world share in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

These estimates are based on an assumption of $300,000 sales per employee, in contrast to $150,000 for the key parts of the electronics industry in 1987.

According to these estimates, the personal computer industry would grow to an estimated 588,000 employees in 2010 in the strong HDTV industry scenario, compared with just 147,000 employees in the weak HDTV scenario, a difference of slightly under 450,000 jobs. A similar difference in estimated employment gains can be expected in the semiconductor industry, where 331,000 jobs would be created in 2010 in the strong HDTV industry scenario, while just 83,000 jobs would be present in the weak HDTV base option.

Table 7 also allows us to compare the *total* estimated employment levels in all four industries under each scenario in 2010. The differences are substantial. In the strong HDTV scenario, there will be nearly 1.1 million estimated jobs in these four industries, but only 274,000 jobs in the weak HDTV scenario.

The U.S. will directly forgo more than three-quarters of a million jobs in 2010 if it develops a weak HDTV industry rather than a strong one. Multiplier effects...could push economy-wide job losses to more than two million.

TABLE 7

Employment in 2010 in the Production of HDTV and Related Industries' Products Under Three Growth Scenarios
(In thousands of jobs)

Sector	Strong HDTV	Medium HDTV	Weak HDTV
HDTV Receivers & HDTV VCRs	148	7	1
Automated Manufacturing Equipment	133	81	43
Personal Computers	588	353	147
Semiconductors	331	199	83
Total	1,066	640	274

Note: These figures assume that in the strong scenario, 50 percent of the U.S. manufacturers' share is produced in the U.S. and an additional 30 percent comes from foreign-owned production in the U.S. For the medium scenario, the figures are 40 percent and 20 percent, and for the weak scenario, 30 percent and 10 percent. These adjustments are used to alter the estimates for world share in David Russell, "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association ATV Task Force Economic Impact Team, November 1988.

These estimates are based on an assumption of $300,000 sales per employee, in contrast to $150,000 for the key parts of the electronics industry in 1987.

This means that *the U.S. will directly forgo more than three-quarters of a million jobs in 2010 if it develops a weak*

HDTV industry rather than a strong one. Multiplier effects, as noted earlier, could push economy-wide job losses to more than two million.

A Critical Juncture

The U.S. stands at a critical juncture that will shape the growth of its electronics industry well into the next century.... [H]igh definition television and flat-display screens are likely to have an enormous impact.

The U.S. stands at a critical juncture that will shape the growth of its electronics industry well into the next century. Since the new industries of high definition television and flat-display screens are likely to have an enormous impact on our electronics industry, the fact that we have lost much of the consumer electronics base may lead some to minimize the potential of the new "digital revolution." But this revolution holds out the possibility of a dramatic revival of industries that could form the base for the creation of at least two million jobs and for a gain in our trade account of more than $225 billion by the year 2010.

Policies to Strengthen the U.S. Telecommunications Industry

We conclude this report with a review of some policy approaches we believe are needed to strengthen the U.S. telecommunications industry. These points are framed by our understanding of strategic changes that are likely to occur over the next ten years. We intend our views to support the adoption of appropriate new policy regimes capable of giving U.S. industries effective support from the U.S. government in responding to these expected changes.

A major issue is how U.S. policies developed for promoting new technologies can help overcome bottlenecks to progress that arise from sizable existing investments in equipment and infrastructure. The answer, we believe, turns on the importance of advanced networks in fostering product and service innovation. However, this key role of networks in commercializing technological advances points up a significant gap in the development of U.S. policies—the lack of an institutional form to solidify the linkage between communications infrastructure/services and new product development.

[The] key role of networks in commercializing technological advances points up a significant gap in the development of U.S. policies—the lack of an institutional form to solidify the linkage between communications infrastructure/services and new product development.

Many observers recognize that the increased use of digital communications and the replacement of voice-based analog devices has narrowed the distance between applications that use computers, electronics, and telecommunications. The failure of U.S. communications policies to appreciate adequately these linkages magnifies the barriers our firms face in developing new niches in the marketplace. The policy approach that the U.S. government has chosen does not help communications firms to overcome the risks inherent in commercializing new products for the international market.

Although deregulation has increased competition in the domestic market for communications services and equipment, the ability of the U.S. to compete in international markets has declined sharply.

The Strategic Setting

Many signs indicate that although deregulation has increased competition in the domestic market for communications services and equipment, the ability of the U.S. to compete in international markets has declined sharply. Statistics indicate that there has been a "hollowing" of the U.S. electronics industry, including important segments of the telecommunications equipment industry (such as PBXs). This real decline in the international competitiveness of the U.S. telecommunications industry is especially troubling, since it comes during a time of tremendous international change in the industry. Strategies must be formulated to address U.S. interests in communications during this period of instability—strategies that recognize the need to maintain both a strong communications equipment base and a sophisticated network infrastructure.

The decline in the U.S. trade balance for the telecommunications industry is striking; it has fallen from a trade surplus of nearly $12 billion in 1981 to a deficit of nearly $3 billion in 1987.

The decline in the U.S. trade balance for the telecommunications industry is striking; it has fallen from a trade surplus of nearly $12 billion in 1981 to a deficit of nearly $3 billion in 1987. Much of this deficit is accounted for by telephone and telegraph equipment, which changed from a $817 million trade surplus in 1981 to a trade deficit of $2.5 billion in 1987. In the broad electronics products industries, whose well-being is closely tied to the competitiveness of our communications industry, a U.S. trade surplus of $6.04 billion turned into a $15.01 billion deficit in 1986 (U.S. Department of Commerce, 1989, in draft; National Telecommunications and Information Administration, 1988:5).

The turnaround in U.S. competitiveness, often treated as a problem of "sunset" industries, has been particularly rapid in electronics and telecommunications equipment.

The turnaround in U.S. competitiveness, often treated as a problem of "sunset" industries, has been particularly rapid in electronics and telecommunications equipment. Further erosion of our ability to compete in international markets would pose a threat to our nation's ability to develop the leading technological base for communications called for in the telecommunications review by the U.S. Department of Commerce's "NTIA Telecom 2000" (1988). Beyond this, it would signal a decline in telecommunications equipment, an industry that is a prime driver of consumption of basic electronics products such as semiconductors. This weakness would translate into weakness in the broader electronics sector.

Some observers trace the weakness in our telecommunications industry to a failure to match Japan in terms of R&D spending. Certainly the figures on such spending show that it is smaller for U.S. firms, with companies in the U.S. electronics industry spending about 0.55 percent of GDP on corporate non-defense R&D expenditures, compared to 0.7 percent in Japan.

Even more worrisome, however, is the drop in market share of U.S. firms in end-product markets. In PBXs, the world market share of U.S. firms has fallen from 56 percent in 1984 to 43 percent in 1987. In addition, as demonstrated in a forthcoming study by the Department of Commerce, shares of world shipments in nearly all parts of the electronics industry have declined appreciably (U.S. Department of Commerce, 1989, in draft).

Given the Japanese aim of establishing control over market share, in contrast to the top U.S. corporate objective of return on investment and a major focus on stockmarket values, both short term objectives, there is a need to redirect policies at the national level to ensure that a long-range focus is provided to national objectives in communications.

A Framework for Formulating New Policies

In face of the strong government role played in promoting the development and commercial success of telecommunications and linked electronics industries in Europe and Japan, it is no longer logical for the U.S. government to avoid effectively supporting those industries that are critical to the future growth and development of our industrial base. If we continue to lose the skilled jobs and the innovative spirit of entrepreneurship that has supported the vitality of the U.S. electronics industry since its inception, our economy will suffer substantial dislocation of industries and workers as we settle for a position as a "branch plant" economy. But with a revitalized electronics sector, U.S. companies will have the opportunity to regain a leadership position in what have been called the "crown jewel" industries of the future.

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Thus, the nation must establish a new framework for the telecommunications industries, allowing them to respond to the changes in communications and information processing that are likely to occur over the coming decade. This policy framework should be built around several keystone ideas that could enable the industry to compete with Japanese and European rivals.

First, the U.S. needs a Department of Communications to coordinate policy for the communications equipment and services industries. It should be charged with setting and implementing a coherent, consistent telecommunications policy for the U.S. The other cabinet agencies currently involved in the fray must be relegated to supporting the leadership of a Department of Communications.

First, the U.S. needs a Department of Communications to coordinate policy for the communications equipment and services industries.

Second, the new department must develop a national plan to overcome the bottlenecks that now exist in implementing a digital network structure. The goal should be to create a competitive national telecommunications network that is not impeded by local interests. This plan must supersede the policies of state Public Service Commissions (PSCs), which determine depreciation schedules and, hence, the speed of network upgrading.

Third, since network development has now become an urgent national need, a special non-partisan, government/industry/labor Telecommunications Infrastructure Board should be created to implement this plan. The board's sole mission, with support of the Department of Communications, would be to coordinate development and implementation of a sophisticated network infrastructure, seamless from end to end. The board could be modeled after the Civilian Aeronautics and Aviation Board, which successfully oversaw the development of the commercial aviation industry in the U.S. during the 1920s.

The powers of the board would include authority to formulate and recommend...tax policies aimed at speeding up the replacement of existing equipment and infrastructure.

Fourth, the powers of the board would include authority to formulate and recommend to the Congress and the executive branch appropriate tax policies aimed at speeding up the replacement of existing equipment and infrastructure. It would overcome the effects of overlapping regulatory jurisdictions, such as PSC powers to limit the depreciation of existing equipment and infrastructure.

Fifth, the board should be financed by a special trust fund, following the precedent of the National Highway Trust Fund. The funding for the Network Trust should come from two sources. One, levies on all telecommunications operating companies that currently benefit from either price-cap or rate-of-return regulation (these are the companies that would most quickly derive the greatest benefit from policy coordination). Two, a tax on all forms of inter-exchange, long-distance telecommunications services. The U.S. government—through the Department of Communications—would be encouraged to level the playing field to create an even policy footing with Japan and the EC.

The U.S. government should act quickly to establish a national HDTV industry....[recognizing] the need to support the associated electronics industries. The plan would build on U.S. strengths.

Sixth, expertise and talents within the U.S. government should be focused on tasks confronting the National Telecommunications Infrastructure Board. In particular, work at the Office of Technology Assessment, the Defense Advanced Research Projects Agency (DARPA), and National Institute for Standards and Testing (formerly the U.S. Department of Commerce National Bureau of Standards) should support the efforts of the board. Their collective efforts should be enhanced to provide the ability to assess (1) technological changes that will affect the industry, (2) increased foreign competition in both services and equipment, and (3) pricing in the marketplace, given the dramatic differences in market power in some segments of the industry.

Seventh, the U.S. government should act quickly to establish a national HDTV industry. Any funding for HDTV planning must be framed by an understanding of its long-term impact. Support should include a system of guaranteed loans, grants, licensing arrangements, etc.

Eighth, a national planning effort for the telecommunications industries and HDTV must also recognize the need to support the associated electronics industries. The plan would build on U.S. strengths.

Ninth, this effort should include a rethinking of the impact of current antitrust legislation on the ability of the U.S. to control its economic future.

Tenth, within a planning environment, there is a need to broker the conflicting claims of different interest groups. The National Telecommunications Infrastructure Board should play this role, with support from the Federal Communications Commission and the Department of Communications.

There is a need to broker the conflicting claims of different interest groups.

Bibliography

Ahearn, Raymond J. "Market Access in Japan: The U.S. Experience," in U.S. Congress, Joint Economic Committee, Subcommittee on Economic Goals and Intergovernmental Policy, Japan's Economy and Trade with the United States. Washington, D.C.: U.S. Government Printing Office, 1985.

Anchordoguy, Marie. *Computers, Inc.* Boston, MA: Harvard University Press, 1988.

Bar, Francois, and Michael Borrus. "From Public Access to Private Connections: Network Policy and National Advantage," Berkeley Roundtable on the International Economy, University of California, Berkeley, BRIE Working Paper No. 28, September 1987.

Carelli, C., and M. Decina. "ISDN in Europe: Challenges and Opportunities," *Telecommunications*. October 1987, pp.63-70.

Cohen, R.B. and J. Wheeler. *Policies for Promoting the Electronics Industry in Nine Nations*, study prepared for the U.S. Department of Commerce, August 1988, forthcoming as a book by Westview Press, 1989.

Transnational Data and Communications Report. "Creating a New European Telecom Environment." July 1987, p.5.

Davidson, William H. "The Japanese Telecommunications Industry: Policy, Structure and Performance," in National Science Foundation, Japanese Technology Evaluation Program, *JTECH Panel Report on Telecommunications Technology in Japan.* Washington, D.C.: May 1986, chapter 2.

d'Oultremont, P. "The RACE Programme: The European Route Towards Integrated Broadband Communications," *Telecommunications Policy.* June 1988, pp.119-126.

ISDN Strategies. "German PTT Reports on ISDN." December 1988, p.9.

Green, Paul E., Jr. "Networks," in National Science Foundation, Japanese Technology Evaluation Program, *JTECH Panel Report on Telecommunications Technology in Japan.* Washington, D.C.: May, 1986, chapter 3.

Hayes, D. "EC Gives the Green Light to Open European Market," *Communications Week.* February 29, 1988, pp.1, 37.

Howell, Thomas R., William A. Noellert, Janet H. McLaughlin, and Alan Wm. Wolff. *The Microelectronics Race.* Boulder: Westview Press, 1988.

Inaba, Minoru. "Japan Teams Up for LCD-Based HDTV Research," *Multichannel News.* April 10, 1989, p. 69.

Japan Electronics Almanac 1988. Tokyo: Dempa Publications, 1988.

Johnson, Chalmers. "MITI, MPT and the Telecom Wars: How Japan Makes Policy for High Technology," Berkeley Roundtable on the International Economy, University of California, Berkeley, BRIE Working Paper No. 21, September 1986.

Kalba, K. "Opening Japan's Telecommunications Market," *Journal of Communications*. Vol. 38, No. 1, 1988, pp.96-106.

Law, C.E. "1992—The Pivotal Year for European Telecommunications," *Business Communications Review*. July-August 1988, pp.70-72.

_______. "Update on ISDN's Progress in Europe," *Business Communications Review*. January 1989, pp.54-56.

Transnational Data Report. "Maximum Feasible Open Competition." December 1987, p.8.

Narjes, K.H. "Towards a European Telecommunications Community: Implementing the Green Paper," *Telecommunications Policy*. June 1988, pp.106-108.

_______. "Telecom Policy Reform and International Trade," *Transnational Data and Communications Report*. January 1988a, pp.21-25.

National Telecommunications and Information Administration, U.S. Department of Commerce. *NTIA Telecom 2000: Charting the Course for a New Century*. Washington, D.C.: U.S. Government Printing Office, October 1988.

Russell, David. "High Definition Television (HDTV): Economic Analysis of Impact," Report of the American Electronics Association, ATV Task Force Economic Impact Team. Washington, D.C., November 1988.

Sullivan, D.J. "A Perspective on Japan—Globalization of the Defense Industrial Base," presentation to the Defense Science Board, July 20, 1988.

Tarui, Yasuo. *IC no Hanashi, Toranjisuta Kara Cho LSI made* (The Story of Integrated Circuits, from Transistors to VLSI) Tokyo: Nihon Hoso Shuppan Kyokai, second edition, cited in Anchordoguy, 1984.

Trouvat, M., and J.C. Pennanec'h. "France Rolls Out National ISDN," *Telecommunications*. April 1988, pp.100-102.

Ungerer, H. *Telecommunications in Europe*. Luxembourg: Office for Official Publications of the European Communities, 1988.

Uslaner, Selma. "International Report," *Solid State Technology*. December 1988, p.12.

U.S. Department of Commerce. *The Competitive Status of the U.S. Electronics Sector: From Silicon to Systems, Issues and Options*. Washington, D.C.: Science and Electronics Trade Development, International Trade Administration. April draft, 1989.

Valovic, T. "ISDN in the U.S.: An Assessment," *Telecommunications*. December 1987, p.8.

Wigand, R.T. "Integrated Services Digital Network," *Journal of Communication*. Vol. 38, No. 1, 1988, pp.29-49.