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Research and Development Policy in the United States: Implications for Satellite Communications

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Innovation in electronic information technology has transformed U.S. telecommunications over the last decades. Research and development (R&D) in fields as diverse as microelectronics, space vehicles, and optics have transformed the basic technology of transmitting information. This transformation has also helped to profoundly affect both the structure of the communication and information services industry and the way in which government regulates those industries. Now these domestic changes are beginning to create serious strains in a world system that has, by and large, not adapted as drastically.

The resulting international policy debate blends together a vast array of issues, from technical standards and resources allocation to the free flow of information and First Amendment principles. Throughout, there is an unavoidable tension between the pragmatic desire to achieve a competitive position in the communications market, and concerns over maintaining cultural diversity and national sovereignty as well as perceived inequities in the consumption of scarce resources.[1]

Questions about technology, where it is and where it is going, weave through this debate. Technology is seen, at least in part, as the cause of some of these problems, and in other cases, as a possible solution. Hence, thoughtful policymakers in most countries look at research and development with a curious binocular perspective. They believe that it is in the national interest to pursue R&D in information technology aggressively. At the same time, they must also wonder what new problems technologies now in the laboratory hold for the future. Certainly that dual perspective exists in the area of satellite communications. This paper addresses aspects of the Federal policy role in technology, and touches on a few of the current concerns facing the U.S. Congress and such international bodies as the International Telecommunication Union, UNESCO, and the General Agreement on Tariffs and Trade (GATT).

To address some of these concerns, the Office of Technology Assessment was asked by the Congress to examine the state of R&D in information technology. The report of that assessment was released in February 1985.[2] In addition, OTA has released a report on cooperation and competition in space.[3] These reports will be the basis for much of the following discussion.

THE IMPORTANCE OF GOVERNMENT R&D FOR SATELLITES

An understanding of U.S. R&D policy as it relates to satellites is important for two reasons. First, the range of R&D that relates in some way to satellite communications is diverse. Improvements in future systems will depend on fundamental advances in a variety of such scientific and technical fields as microelectronics, antenna design, and the evolving mathematics of digital signal encoding, as well as on a more comprehensive understanding of radio wave propagation. The future of satellites will depend, in a reverse way, on how fast alternate technologies, such as fiber optics, advance. There are a number of application technologies that will affect the demand for satellite communication services. Will future demands for capacity be dominated simply by the need for more telephone channels or, as may be more likely, for more sophisticated services, such as videoconferencing, high definition broadcast television, mobile services, or some other application—such as interactive graphics? Answers to these questions depend on the results of research not only in hard science and engineering, but in such fields as social science, psychology, management, and the regulatory environment.

In addition, the Federal government has a history of involvement with R&D in the broad sense that reaches back nearly two centuries. How it perceives its responsibility with respect to the private sector to help advance satellite communication technology, and what action it takes, are deeply affected by this history and by firmly established science and technology policies. Although these policies do evolve over time, they are rarely altered drastically to serve the needs of just one technology.

We pause to note that, for obvious reasons, the Defense Department has a particularly keen interest in communications, including a continuing interest in satellite technology. But much of DOD R&D in this area is and always has been highly classified. This paper does not take that work into account except to acknowledge its existence and to suggest that there is probably a limited and slow, but also unidentifiable and thus incalculable, flow of technology from those defense efforts into the civilian sector.

INFORMATION TECHNOLOGY R&D

Science and technology policy in the United States generally distinguishes three broad groups of participants: government, industry, and nonprofit institutions—most notably, universities, although some new experimental forms are evolving. This section briefly focuses on industry and universities and then dwells at some greater length on government actions and policies.

Industry

Estimates of industry R&D levels are particularly hard to come by. Funding levels are often considered to be proprietary, definitions vary, and investments by small, entrepreneurial firms are hard to measure. We estimated that all U.S. industrial investments in information technology R&D amounted to approximately $10 billion in 1982. The industry is broadly based, in general, and sustains a relatively high level of R&D, ranging from new product development performed by the very small firms to a wide mixture of basic research and development performed in large industrial laboratories.

The most prominent example of a large laboratory is AT&T's Bell Laboratories, one of the nation's first industrial laboratories, and still one of the largest and, by many accounts, most productive. In fact, Bell Telephone Laboratories was the only industrial center able to invest in significant R&D in satellite communications during the early, high risk years when this technology was first being developed. Lately, many science policy experts have been expressing concern about the fate of Bell Labs in light of the divestiture of AT&T and the deregulation of the telephone industry. They argue that divestiture may deprive AT&T of the ready source of funds from the local operating companies for fundamental research, and that deregulation may pressure the labs to increase significantly its emphasis on short-term development at the expense of longer-term applied and basic research. OTA's investigation suggests that there is little evidence or economic theory that would support such a bleak scenario over the short term, but that longer-term prospects were less clear.

A new trend among firms in the information technology industry is the formation of joint research ventures. The best known of these is probably the Microelectronics and Computer Technology Corporation (MCC), conceived by Bill Norris of Control Data as a U.S. response to the challenge of joint technology programs promoted by the Japanese government. Other such centers include the Semiconductor Research Consortium (SRC), that principally offers basic research grants to investigators in university laboratories, and the Microelectronics Center of North Carolina (MCNC), that combines both industrial and state funding. Out of concern about possible antitrust violations, most of these ventures have been carefully designed to concentrate on nonappropriable basic or applied research. Many are associated with or provide support to university research projects.

Universities

Universities are another important institutional element in the U.S. R&D picture, principally as performers of basic research. Much of it is funded by the Federal government, but an increasing amount of private research funds are also being channeled to university labs.

The role that universities play in computer and communications research has shifted over the years. In computers, for example, university laboratories were the focus of much pioneering early research. Then, as the development of new generation computers became expensive and difficult to manage, industry took over computer and software design, leaving the university researchers to work on more theoretical problems. Lately, very large scale integrated circuit technology has allowed architecture research to move back on campus, funded by both Federal agencies and private industry. In the past few years, industry and the Federal and State governments have been strengthening their ties with university research centers across the nation, in recognition of the important contributions expected from these centers.

Government

Traditionally, when talking about R&D, the term "government" referred to the Federal government. Recently, however, some State and local governments, assuming a close link between high technology and economic development, have become more active in establishing new research centers and are promoting and funding R&D.[4] The following discussion focuses principally on Federal policy.

In establishing science and technology policies, the U.S. government is pursuing several goals, some of which may be in conflict. Many of these goals relate directly to support of R&D in satellite communications. For example, there is the clear goal of strengthening national defense. A modern military force is critically dependent on worldwide electronic communications for purposes including intelligence and surveillance, missile guidance, navigation, command and control, and so on. The implications for satellite communications, as well as for information technologies in general, is demonstrated by the fact that the Department of Defense accounts for nearly 80 percent of all R&D funding in these areas. The DOD provided the principal funding for the early development of satellite technology, and still provides significant support.

Moreover, advanced communications technology is of established and growing significance in providing for social needs. Communications is more than merely a set of services in the marketplace. U.S. policy reflects the view that communications is a fundamental infrastructure of society and that access to communications is a basic necessity. A major goal of U.S. communications regulation has always been "universal service." One of the motivations behind the formation of INTELSAT was to provide access to satellite telecommunications for the developing world. Communications technology will increasingly form the basis for the delivery of such important public services as education, agriculture, and public health with incalculable benefits to mankind. There are numerous and increasing examples of this in such countries as the United States, Canada, the United Kingdom, India, Indonesia, and Brazil.

The government's R&D is also aimed at stimulating economic growth. One of the key objectives of many NASA programs is to reduce the risks associated with commercializing technology and providing new services. Some examples include the NASA programs in fixed service satellite communications, remote sensing, broadcast satellites, and, for the past decade, mobile satellite communications.

Clearly, over the last two decades the computer and communication industries have grown in importance as components of the economy. These industries have been recognized increasingly by the OECD, the ITU, the World Bank, and other organizations as central to infrastructure development and economic growth. Moreover, they form the basis for a rapidly growing information services industry, and this leverage makes their economic importance to nations even greater. It is not surprising, then, to see national programs to stimulate and support these industries, including satellite communications, cropping up all over the world.

Research in computer and communication science has made major contributions to our understanding of the world around us. Examples range from contributions in artificial intelligence to cognitive psychology to the Nobel Prize winning work of Arno Penzias on the origins of the universe. NASA has always needed to balance its priorities between scientific research and other objectives of the space program.

Computers and high-speed data communication links between computers have also become a vital tool for the conduct of scientific research. The ARPANET has been indispensable to DOD and civil agency supported computer science researchers for many years. Key to the new supercomputer program at NSF will be the development of data communications networks to link the centers together and facilitate researcher access to them.

Certainly a major motivation for the space program has been one of national prestige. Similarly, investments of billions of dollars on such major research instruments as accelerators or telescopes are justified by the argument that international economic and political advantages accrue simply from the world perception of the United States as a technological and scientific leader. The pioneering work in satellite communications clearly has contributed to U.S. national prestige.

The U.S. government also supports R&D necessary to performing the missions of its agencies. One such mission, of course, is national defense, and that has already been discussed. However, many civilian agencies—such as the Social Security Administration and the Treasury Department—make extensive use of information technology. As the administration attempts to reduce Federal spending, and the appropriateness of some civilian agency programs is under question, one might expect civilian support of technology development (in contrast to basic research) to decrease, and such has been the case. One result is that many demonstration programs have been cut in recent years. Even so, for example, the Department of Energy, and to a limited extent

NASA, support development of advanced computer technology, and the Department of Education supports R&D in the educational use of an assortment of information technologies.

Finally, NASA's satellite communications programs have been helpful in promoting U.S. foreign relations. For example, the ATS-1, -3, and -6 satellites have been used extensively throughout portions of the world for applications in public health, safety, and education, and for experiments leading toward commercial applications. Some of the participants included more than a dozen island nations in the Pacific Basin and the Caribbean, as well as India and Canada.

THE PATTERN OF GOVERNMENT FUNDING OF R&D IN INFORMATION TECHNOLOGY

The Federal government has had a long history of funding R&D in information technology-related fields. It is currently the major sponsor of R&D in the kind of information technology in which it has special interests. It includes artificial intelligence, supercomputers, software engineering, and very large scale integrated circuits (VLSI), all areas in their technological infancy and with enormous potential for military as well as commercial applications. There is a long list of related technologies that have been stimulated by government—often defense or other mission agencies—sponsorship of R&D including radar, guidance system, and satellite communications.

There are some historic examples of intensive government sponsorship of technological development in areas where the potential benefit was expected to be great, but the risks and costs of research were high and therefore unattractive to industry, e.g., computers, aviation, and communications satellites. One of the classic illustrations of a successful, major government contribution to information technology R&D is in the field of satellite communications. The National Aeronautics and Space Administration (NASA) (which currently accounts for about 7 percent of the Federal R&D budget) had the leading role in pioneering technological progress toward commercial development, accelerating the time frame for the introduction of this technology, influencing the structure of the U.S. domestic and international telecommunications common carrier industries, and effecting significant cost savings over the long run.[5]

In these cases, the government, through the undertaking of a number of risky and expensive R&D programs and with extensive private sector involvement, developed a large pool of baseline technology that served to prove the feasibility of geostationary satellite communications. These R&D programs were for the purpose of proving the feasibility of various technological advances, such as geostationary orbiting satellites, electromagnetic propagation of signals from outer space, traveling wave tubes, automatic station keeping, and aircraft communications. The NASA programs initiated to undertake the extensive R&D included the SCORE, ECHO, and RELAY programs, the SYNCOM series of launches that paved the way for INTELSAT I, the first commercial communications satellite, and the Applications Technology Satellite series. The costs for the RELAY, ECHO, and SYNCOM programs alone through 1965 were over $128 million—an amount that few companies could—or would—commit, particularly considering that the feasibility of synchronous satellite operation was seriously questioned.

It is also interesting to note that these NASA programs likely had some important side effects on the structure of the U.S. international satellite communications industry. Because AT&T was the only private company to have heavily invested its own funds for satellite communications R&D—with focus on the nonsynchronous TELSTAR system—it is likely that AT&T would have dominated the new international and domestic satellite communications services industry. Instead, the NASA programs, through continuous transfer of technology to, and close interaction with, commercial firms stimulated the competition that followed the 1972 Federal Communications Commission's decision allowing open entry into the domestic satellite communications services industry.

The market for the supply of satellite communications equipment was also open to competition because of the expertise of contractors. In addition, the international satellite network that evolved is owned and operated by INTELSAT, an international consortium, with the U.S. portion owned and operated by COMSAT, a broadly based private public corporation.

Other Forms of Government

The Federal government has broad involvement in R&D, as a supporter of different programs, as a performer in government laboratories, and as a consumer of new technological products, for example, supercomputers, and, hence, is a force in stimulating innovation.

The picture over all science and technology is impressive. The Federal government is estimated to fund roughly 50 percent of all R&D carried out in the United States. This estimate does not include indirect incentives and subsidies such as tax credits for R&D.[6] Additionally, the government performs about $11 billion worth of R&D in its own laboratories, and supports over 65 percent of R&D performed on college campuses.

In the case of electronic equipment and communication technology, the proportion of overall Federal support rises to two-thirds. According to the National Science Foundation, Federal basic research support in computer science and electrical engineering was over $200 million in 1984, and applied research in the same fields amounted to over $700 million.[7]

The Department of Defense (DOD) is the principal source of this support. It accounts for about 60 percent of the overall Federal R&D budget. In comparison, NSF accounts for less than 3 percent. Of course, these numbers are skewed by the relatively heavy applied research and development emphasis of DOD expenditures compared to basic research in which NSF clearly plays a much more important role.

The government, through DOD and NASA, has played a major role in the development of satellite communications—particularly geostationary satellite technology.[8] Federally supported R&D through DOD and NASA created, in large part, the foundations of the domestic and international satellite communications industry.

While direct support of R&D is important, the government also affects R&D in several indirect ways, for example, through regulation. For many years, basic research at Bell Labs was supported through AT&T, Western Electric, and Bell Operating Companies. The pattern of research at the laboratories continues to be strongly influenced by FCC decisions deregulating the industry and by court decisions concerning the divestiture of AT&T. Some Bell labs research teams have been broken up and researchers have migrated to different organizations within AT&T or the Bell Operating Company structure. The guaranteed support of research by local companies has been eliminated. Although the effects, good or bad, of these changes are not yet understood, clearly vast changes have been wrought in the world's largest industrial laboratory by virtue of Federal deregulation and application of antitrust law by the Federal courts.

Another way in which the government affects R&D is through intellectual property law. Rooted in the Constitution, intellectual property law (e.g., patents, copyrights, and trademarks) is specifically intended to encourage technological invention and scientific and artistic creation. These days, new technology, particularly information technology, seems to be moving out beyond the reach of traditional intellectual property law.[9] Some in the industry argue that, without expanded protection for the results of R&D, incentives to innovate will erode.

Another intellectual property policy has been the assignment of patents on technology developed with government funds. Public Law 96-517 passed in 1980 was designed to ease the transfer of such patent rights to small business and universities. This policy has been further liberalized by executive order and revised Federal regulations.

Taxes are another way the Federal government influences investments in R&D. The R&D investment tax credit and R&D limited partnerships are policies specifically designed to provide incentives for investment in R&D. The investment credits program will terminate in 1986 unless renewed by Congress, and debate has already started over whether they have been effective.

Export controls are another Federal policy with a potentially significant impact on R&D, particularly in areas like satellite communications that are considered to be sensitive because they have military applications. They affect private sector R&D in two ways. First, controls over the publication and transfer of technical information, while possibly depriving foreign governments access, also can impede its flow within the U.S. technical community. Second, the possibility of limitations of exports can lessen incentives for firms to develop new technology by limiting potential international markets for their products.

SOME POLICY ISSUES

The Federal involvement in R&D in satellite communications raises a number of policy issues, almost all of which are international in character, and present serious challenges to the United States and other countries.

Private Versus Public Investment

NASA's early investment in the development of satellite communications was made when market prospects for the industry were highly uncertain and costs of R&D greater than virtually any private firms could bear.

Now, however, we have an established market for fixed and maritime satellite services that has proved itself successful. To serve that market, we now have a viable domestic satellite industry—manufacturers and service providers. And soon we will have broadcast satellites that send signals directly to residences, and satellites for mobile communications.

To what extent should the government continue to directly fund development of advanced satellite technology? The answer to that question depends, not only on political values and on an assessment of potential markets, but also on the growing threat from foreign nations whose governments do not engage in such political introspection. There has been a U.S. national space policy since 1982 committing the Federal government to encouraging private sector development of space for commercial applications. The government's role, through NASA, is to help reduce some of the technical, financial, and other deterrents to private sector investment.

Developing World

Third World countries have become more demanding of guarantees that the limited natural resources, e.g., electromagnetic spectrum and satellite orbit positions, will be available for their eventual use. There are also continuing concerns about sovereignty issues in international organizations such as the ITU and UNESCO. Developing countries are trying to find ways to deal with these perceived needs and fears, and at the same time to continue the rapid implementation of new applications. These types of issues are likely to continue to emerge as the technology evolves and as demands grow for using the limited natural resources.

Competition for INTELSAT Services

The role of INTELSAT, as initially envisioned, has been eroded by competition in recent years and is threatened further. One source of the erosion is that the number of regional and national satellite communications systems continues to grow worldwide, with each representing foregone traffic for INTELSAT. And now there is the prospect of new businesses vying for a share of the heavy traffic North Atlantic route. Questions are raised concerning how goals of economic efficiency, open competition, and deregulation can be attained while assuring a stable, future role for INTELSAT. The White House recently announced its decision to permit private satellite carriers to provide limited competitive services (video and digital data communications), but not to compete for public switched network services. A second source of erosion to INTELSAT's position is in the form of prospective competition from another technology—fiber optic cable—for transoceanic routes.

International Trade in Equipment and Services

The U.S. trade balance in telecommunications equipment—a field in which the United States has had a tradition of technological leadership—shifted from a $39 million deficit in

1983 to an estimated deficit of $500 million in 1984.[10] The main causes are seen as the growing imports into a unilaterally open U.S. market and much slower growth in U.S. exports, because other countries follow restrictive trade policies. Anticipation of the magnitude of the trade deficit prompted the last Congress to consider legislation that would authorize the President to take unilateral action against countries with restrictive import policies.[11] Executive branch efforts are underway to open foreign markets and to expand the terms of the GATT negotiations to include services and government procurement of telecommunications equipment.

The foregoing attempts to illustrate a number of points. One is that a number of factors are closely intertwined and are helping to shape the current menu of policy issues, including rapidly advancing technology and Federal regulation of industry and its direct and indirect support of R&D. A second point is that domestic policy can have significant implications internationally. And, finally, growing demands for scarce natural resources are causing tensions in international forums.

NOTES

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11. "Telecommunications Trade Act of 1984," S. 2618.