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THE STATE AND TECHNOLOGY POLICY:
A Comparative Analysis of the
U.S. Strategic Defense Initiative, Informatics
Policy in Brazil, and Electronics Policy in China

Manuel Castells, Lisa Bornstein, Katharyne Mitchell,
Rebecca Skinner, and Jay Stowsky

June 1988

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GENERAL INTRODUCTION: GOVERNMENT POLICY AND MODELS OF TECHNOLOGICAL DEVELOPMENT

Manuel Castells

We live in the midst of a major technological revolution characterized by two main features:

a) Its raw material, as well as its outcome, is information. Although there are also major discoveries that are not information technologies (e.g., new materials, such as superconductors), the core of this technological revolution is in information technologies: microelectronics, computers, telecommunications, and genetic engineering (the decoding and reprogramming of the living matter).

b) As most technological revolutions in history, it is process oriented, rather than product oriented. To be sure, technological change does give rise to new products whose production and distribution dramatically affects economic processes. But the usefulness of most of these new products mainly relates to their application in all processes of production, consumption, and management.

These two features have important consequences on the impacts of new technologies on economic and social organization. On the one hand, because they are process oriented, their effects are pervasive, and take place in the entire realm of social activity and institutional organization. On the other hand, because they are based on information, that is on instrumental manipulation of symbols, their production and utilization appears more linked than ever to the cultural capacity of each society, ultimately expressed in its educational level.

This technological revolution has blossomed in a historical context characterized by a process of economic restructuring, in the aftermath of the crisis of the 1970s, and of accelerated integration of the world economy. Its development and characteristics have been deeply influenced by such processes. At the same time, these new technologies are fundamental instruments in fulfilling economic and organizational restructuring as well as achieving international competitiveness.

Furthermore, one of the most striking effects of these information technologies, and of the overall constellation of technological change they foster, is the transformation of the military means of exercising political power. New weapons systems are rapidly making obsolete the current armed forces, and redefining warfare, both strategic and tactical, nuclear and conventional, in entirely new terms.

Economic development and political-military power have come to rely increasingly on the technological capacity of nations and organizations. Therefore, States have become deeply involved in enhancing and guiding the process of technological development to fulfill the social, economic, and political interests they articulate, including the State apparatuses' specific interests. Technological policies are now crucial elements of power strategies, both domestic and international. However, these policies do not operate in a vacuum. They relate to the specific requirements of the processes of technological development, made up of the interaction between scientific discovery, technological innovation, economic competition, and organizational management.

From the interaction between specific models of technological development and the policy orientations of a given State result technological trajectories that shape the dynamics of countries, firms, and social groups, in an interdependent world currently undergoing a process of multidimensional restructuring.

Eight Models of Technological Development

There is a considerable literature on technological trajectories and models of technological innovation.[1] However, with some notable exceptions, particularly the work by Nathan Rosenberg,[2] most of these analyses excessively rely on abstract models of technological innovation without careful reference to empirical observation of historical experience. This is particularly troublesome when studying the current technological revolution, because of its historical originality, linked to the crucial role of science-based information technologies in its development. In addition, arguments put forward to analyze

1. For an informed discussion on the literature on technological innovation, see Peter Hall and Paschal Preston, The Carrier Wave: New Information Technology and the Geography of Innovation, 1846-2003, London: Unwin Hyman, 1988.
2. See, in particular, Nathan Rosenberg, Perspectives on Technology, Cambridge: Cambridge University Press, 1976.

the innovation process shift constantly from the level of the firm to the level of countries or even of the international economy without recognizing the specificity of each level.

This is why, rather than entering anew the inconclusive debate on the conditions of technological innovation and technological development, we will reflect on the recent historical experience of processes of technological development throughout the world, to generate some exploratory hypotheses that will guide our analysis of case studies of technological policy.[3]

At the risk of oversimplification, but for the sake of clarity, we can summarize recent experience of technological development in eight major models. Most countries exhibit more than one model in their technological development, although the more the State shapes the process, and the more a country tends to organize its development around a dominant model. We must warn that our analysis does not concern here the process of scientific discovery or technological innovation in itself, but technological development, namely the articulation between discovery, application, and diffusion in the overall economy and society.

1) The first model may be called Diversified Entrepreneurial Milieu of Innovation. It consists of networks of firms, connected to centers of knowledge-generation, and often supported by government markets, whose fundamental source of innovation and competitiveness resides in the synergetic capacity of the milieu itself. This model is often associated with some high technology spatial complexes, such as Silicon Valley (Santa Clara County), Route 128 (Boston), and Orange County (Los Angeles). However, although spatial articulation is an important factor in the functioning of the model, the key element in the developmental process concerns the existence and dynamics of the milieu itself, once it builds up a critical mass in terms of knowledge-generation and internal linkages.

2) The second model is represented by Corporate Innovation Systems, represented by large, multinational companies, that often integrate vertically markets and manufacturing for high technology products (e.g., computer makers, such as IBM producing their own integrated circuits). These Corporate Systems are able to generate technology by themselves, without using Universities and research centers, and articulate worldwide networks of

3. A useful, empirically-based analysis of technological policy is that of Richard E. Nelson, High-Technology Policies: A Five-Nation Comparison, Washington D.C.: American Enterprise Institute, 1984.

production and distribution around themselves. In addition, they have entered in the 1980s a new stage of strategic alliances and horizontal networking that reinforces their power to shape, through their interaction and initiatives, the pace of technological development in a variety of national contexts. These corporate systems have sometimes emerged on the basis of the support of national governments, either through reserved military markets (e.g., Texas Instruments or Motorola, in the U.S.), or through government's support in funding, research, and export strategies (as it is the case for the large Japanese companies: NEC, Toshiba, Hitachi, Fujitsu etc.). Yet, large firms tend to undertake the formation of their own research and development programs, and account for the largest stream of technological innovation going into the market place. This is certainly the case for IBM and ATT.

3) The third model, that some observers have labeled neo-mercantilist, is represented by processes of technological development that take place on the basis of State policies protecting a domestic market and helping national firms to win foreign markets' shares through subsidies and government-sponsored R&D programs aimed at gaining a competitive edge in the technological race in key commercial areas. This is, essentially, the Japanese Model, in which MITI targeted sequentially the industrial and technological development of Japan on industries such as steel, then automobile, then consumer electronics, then semiconductors and computers, now telecommunications and biotechnology. But this is also, by and large the case of Korea, the most technologically advanced of the NICs. In this model, the de facto closing of the domestic market assures to national firms a launching platform, allowing also bargaining power for technology transfer from corporate systems trying to enter that market, as it was the case with IBM in Japan. Both in Japan and in Korea, the linkage between the State and large national corporations is the key to the model, at the service of a shared goal of national development, on the basis of technological excellence able to enhance competitiveness in the world economy.

4) A fourth model also relies on the technological-economic intervention of the State, but performs as Statism in an Open Economy. It is particularly the case of France, whose technological policies focus, on the one hand on military and nuclear power programs, linked to the affirmation of French national power; on the other hand, on the support to large French firms to position themselves in the international economy with the financial, institutional, and

technological help of the French State. For instance, subsidizing research programs, helping Thomson to acquire U.S. firms such as Mostek, or using political leverage to achieve the agreement between Thomson and the Italian firm SGS to become one the world's largest semiconductors producers. In a similar vein, French Government support was crucial to enable Alcatel to acquire ITT-Europe, thus establishing its hegemony in the European telecommunications market, to be able to compete with Siemens.

5) A fifth model is a Nationalist Import Substitution Policy, in which the closing of the domestic market, at least in some segments of high technology industries, and the Government's systematic protection to the national industry is considered an indispensable phase for endogenous technological development on the basis of national interests and needs. Technology transfer is sought through licensing, reverse engineering, and the sending abroad of scientific and technical personnel to be trained. This is particularly the case of major Third World countries, with potentially large markets, and a relatively high level of human capacity in science and technology, as it is the case in Brazil and India. China's policy also follows this model, although it combines it with an opening to multinational companies, offering market shares in exchange of technology transfer.

6) A sixth model, emphasizes military superiority as a fundamental factor of technological development, organizing technology around the specific interests of the State as a political apparatus projecting itself into the world arena. Although many States do follow this model partially (both in the U.K. and in France the military component of technological policy is essential, as it is in the large Third World countries, China, India, and Brazil), it is naturally in the case of the two superpowers that this model is most influential. However, there is a substantial difference between the Soviet Union, where the State is not only the designer of the technological trajectory, but also the manufacturer and user of technological products, and the United States, where private firms play a major role in the implementation of the technological requirements of the military. In any case, military-induced technological programs, in all countries, with the exception of Japan (and even for Japan it may change),[4]

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4. See Wayne Sandholtz, Jay Stowsky, and Steven K. Vogel, "The Dilemmas of Technological Competition in A Comparative Perspective: Is It Guns vs. Butter?," Berkeley: University of California, Berkeley Roundtable on the International Economy, April 1988.

are a fundamental component of technological development, and their characteristics and orientation follow a political logic rather than an economic one.

7) A seventh model is represented by the articulation between governments and private firms cooperating at the international level, in order to generate economies of scale for technological development, mainly aimed at commercial applications. This is the case of the EUREKA Program in Europe, where 18 countries cooperate in areas of common interest, funding projects judged to be promising, on the basis of applications submitted by private firms of at least two member countries. This appears to be a flexible model that establishes public-private partnership and supersedes narrowly defined national interests. However, the actual technological yield of the EUREKA program in its first four years appears to be meager.

8) Finally, an eighth model is the one that aims primarily at technological diffusion, through Government-initiated programs that seek the proper use of new technologies in traditional products and processes by national firms and domestic organizations. In this model the objective is less to promote new technologies per se than to accelerate the diffusion and application of these new technologies in the entire realm of the economic and organizational activity. This is clearly the case of technological policies in Sweden and in West Germany, and to some extent in Italy. One of the main elements of this policy, that is also present in Japan, is the development of "Mechatronics," that its the merger of electronic devices and mechanical industries, as a key strategy to revitalize manufacturing.

There is no "good model" per se. The success of all of them depends on the socially defined goals for each process of technological development, and on the context in which they are implemented. However, recent experience provides some lessons on the potential assets and liabilities of each one of these models, underlying most of the technological policies being pursued at the world level.

Problems and Potential of the Different Models

Each one of the models I have presented appears to have some potential, but they all also reveal some significant problems, according to the lessons of the international experience.

The first model (the entrepreneurial milieu of innovation), has demonstrated its dynamism, thus acting as a role model for technological policies in many countries. However, it is probably the most difficult to reproduce in other contexts than those where it has taken place, such as Silicon Valley. This is because it relies on a concentrated scientific-technological milieu,[5] whose quantitative and qualitative elements are so rare that they are unlikely to be replicated in a different space and time. Besides, once launched the technological revolution, there is a cumulative process of concentration of knowledge and experience in the first centers of such revolution. On the other hand, these milieus are generally unable to achieve the economic or political power to guide and shape the effects of the technologies they invent and develop.[6] They become gradually integrated into the networks of multinational corporations and governments, as providers of technological services and specialty high technology manufacturing. Thus, this model is hardly reproducible and at the same time its outcome plays an increasingly subordinate role in the overall process of technological development, in spite of its entrepreneurial dynamism and the glamor of its saga.

The second model (organized around the strategies of large corporate systems) is probably the most influential at this point in time, and reinforces its domination by increasingly absorbing into its networks the most innovative firms and the leading non-profit research centers. In addition, these corporations are increasingly interconnected, forming a global network.[7] However, they do not constitute an oligopoly, unlike what some critics argue,[8] because their alliances change according to countries, products, and companies, so that in fact they keep competing against each other at the same time that they cooperate. Organizations operating on the basis of this model concentrate an increasing share of the world's technological potential. However, this model is quite vulnerable at two basic levels:

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5. For a presentation of the concept of technological milieu see my book, The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process, Oxford: Basil Blackwell, 1989.
6. Manuel Castells, "The Real Crisis of Silicon Valley" in Richard Gordon and Linda Kimball (eds), The Future of Silicon Valley, London: Unwin Hyman, forthcoming.
7. Dieter Ernst, Innovation, Industrial Structure, and Global Competition: The Changing Economics of Internationalization Frankfurt: Campus Verlag, forthcoming.
8. Ann Markusen, Profit Cycles, Oligopoly, and Regional Development Cambridge, MA: MIT Press, 1985.

a) Much of their technological potential is external to the corporations themselves, and depends upon innovative firms and research centers that should they become fully absorbed in the corporate system they may lose their innovative dynamism. Truly innovative large corporations, such as ATT, IBM, or Siemens, are the exception rather than the rule.

b) On the other hand, the size of the investments that large corporations have to assume to keep the pace of technological change grows exponentially. This implies that in order to be profitable, as they need to be, they have to anticipate a corresponding expansion of the markets for the high technology products resulting from such investments. However, the expansion of these markets requires an ability of societies and industrial structures to engage in a process of utilization of new technologies at a rate clearly superior to their current capacities. Since competition between corporations is to some extent based on stepping up innovation, it results a growing contradiction between the rate of growth of supply and the rate of growth of demand in high technology markets, undermining the overall dynamics of this model, that could result into a demand crisis, into the slowing down of technological innovation, or into both.

The neo-mercantilist model, best represented by Japan, is the one that has obtained the most spectacular successes in the last decade,[9] after the technological revolution had been launched by the entrepreneurial milieu of innovation. The linkage between the State and large corporations, on the basis of strategic planning fostering the national interests, has proven its superiority over the free-market policies in terms of the fulfillment of specific developmental goals. True, the formation of a world market economy and the liberalization of international trade have been a major stimulus for economic growth in the post World War II era. However, the countries that have benefitted most from such world economic dynamism have been those (Japan, and the Asian NICs) in which the State has guided the process of development establishing competitive advantages for the national firms and the national economies, while avoiding to suffocate the flexibility of market mechanisms. It is in

9. Michael G. Borrus, Competing for COntrol: America's Stake in Microelectronics, Cambridge, MA: Ballinger, 1988.

this combination of the developmental State and entrepreneurialism that resides the success of the economies of the Asian Pacific Basin.[10]

However, the neo-mercantilist model has also considerable limits that make impossible its continuation without changing the current conditions of its implementation. Its fundamental limit consists in the fact that it only works for a few countries on the condition that the other countries do not follow the same model, since once it is generalized, its comparative advantage is undermined. In fact, the protectionist reactions from the United States and the EEC toward Japan and the NICs will make increasingly difficult to maintain the model in its current parameters. At the same time, having reached the current technological frontier, Japan cannot rely any more, as in the past, on the strategy of successfully imitating and better fabricating technologically innovative products resulting from other countries' efforts. Now Japan is also a technological leader. But precisely because of this, the benefits of neo-mercantilism are largely exhausted. And yet, the transition to a new model will find serious obstacles built into the largely bureaucratized structure of the relationship between State and large corporations in Japan and Korea. The strong point of the neo-mercantilist model is the mobilization of national resources in support of targeted technological-industrial goals. But its main weakness is the lack of a sufficiently autonomous scientific and technological basis in the University system and in small, innovative firms.

The fourth model (Statism in an Open Economy, as in the case of France) has the fundamental flaw that it entirely depends on the quality and flexibility of the large, national firms. When these companies do not meet the level of expectations, this model becomes, in fact, the rationalization of sterile subsidization policies. This brand of statism could be a double loser: too statist to unleash the competitive dynamics of innovation, and too narrowly linked to a few companies to reach the national strategic goals.

The fifth model, of nationalist import substitution policy, as practiced by Brazil, China, or India, will have to respond to the challenge of developing new technologies from an endogenous process while creating some distance vis a vis the international companies and

10. Manuel Castells and Pei Hsiung Chin, "Four Asian Tigers with a Dragon Head: State Intervention and Economic Development in Singapore, South Korea, Taiwan, and Hong Kong," forthcoming.

governments that are the technology holders at this historical moment. On the other hand, it does address the question of the necessary adaptation between the type of technologies that must be produced and used, and the specific goals and interests of the national development process.[11] A major task for comparative research on technological policy is precisely to analyze on empirical grounds the potential and the contradictions of an autonomous path of development in a necessarily interdependent economic context.

The sixth model, the military-oriented model of technological development, has the fundamental capacity of mobilizing large resources, and has proven its ability to inspire major technological discoveries. Besides, being free from short term commercial considerations, it can provide breathing room for applied scientific research and experimental programs, something that private capital cannot afford very often. In this sense, regardless of the moral critique to the military applications of new technologies, it is too simplistic to dismiss the technological potential of this model without actually examining its implementation in different contexts. Yet, a number of studies suggest that excessive specification of the products, secrecy of the research conducted for military purposes, and discontinuity of the efforts, following the political evolution, both domestic and international, undermine the technological yields of this policy. The rapid progress of Japan concentrating for a long time on commercial uses of new technologies gives credit to the argument of the handicap that represents for a country to engage many of its resources in costly military programs. Yet, technological leapfrogging also needs the institutional capacity of resource mobilization, and a certain distance to short term commercial interests. Thus, under some circumstances, military programs could be a powerful instrument of technological development.

The seventh model, featuring international cooperation between governments and companies, as represented by EUREKA in Europe, appears as one of the most flexible formulas combining market mechanisms with government resources in a comprehensive view of the needs and possibilities of a whole region of the world economy. It is too early to judge EUREKA's results. However, in a first and superficial observation,[12] several shortcomings can be noted:there are still frequent rivalries between countries, remnants of nostalgic

11. See our analysis on the issue in Patrizio Bianchi, Martin Carnoy, and Manuel Castells, Economic Modernization and Technology Transfer in the People's Republic of China, Stanford: CERAS, 1988.
12. Based on inside information from the EUREKA Office. See also, Wayne Sandholtz et al., op. cit., 1988

nationalism in Europe, particularly in the case of France; the mechanism of allocating resources gives an excessive role to the market and does not take enough into consideration the strategic planning of technological trajectories; it takes place in excessive isolation from the most innovative public research centers, perhaps giving too much emphasis to the ideology of the small firm. These factors may explain the gap between the success of EUREKA in terms of the number of projects presented and approved, and the relative importance of the funds allocated, and the very few significant results obtained in terms of technological breakthroughs.

Finally, the model of industrial diffusion has the major merit of its pragmatic approach to technology, but suffers from the limits inherent to technological dependency. By institutionalizing the separation between the design of new technologies and their use, and by focusing everything on applications, it takes advantage of other countries' efforts in technological development, but becomes unable to generate technologies linked to the specific needs of the country. In addition, the intimate connection between the production and use of new technologies in the generation of knowledge, both for production and use, undermines the position of those economies and firms that place themselves exclusively at the user end of the technological continuum. Thus, for the emphasis on application to be successful, it has to combine with the development of some level of autonomous technological capacity in generating new technologies, along the lines proposed by anyone of the models presented here. In fact, Germany is successful in its experience of technological diffusion mainly because of the knowledge capacity installed in its leading industrial corporations and in its University research system.

Government policy appears to be an important element in the formation and implementation of each one of these models of technological development. But Government policies respond to different orientations whose characteristics interact with those of the models themselves to shape the actual process of technological innovation in each context.

A Framework for Analyzing Technological Policy

Models of technological development emerge through the interaction between economic forces, government policies, and social behavior in given national and international contexts. But once these models develop their own dynamics, governments still act upon them on the basis of their specific interests. These interests are linked to the governments' political strategies, as well as to the values and goals of the different social classes and groups that are present in the structure of the State and in the politics of each government.

Thus, government policies in the technological field are diverse and conjunctural. However, for our analytical purpose, they can be regrouped by introducing the useful typology proposed by Ergas[13] between Mission-Oriented policies, Diffusion-Oriented Policies, and Development-Oriented policies.

In Ergas terms "Mission-oriented research can be described as big science deployed to meet big problems . . . . It is of primary relevance to countries engaged in the search for international strategic leadership, and the countries in which it dominates are those where defense accounts for a high share of government expenditure on R&D. Though it has also been used in these countries to meet perceived technological needs in civilian markets, the link to national sovereignty provides its major rationale".[14]

Diffusion-oriented policies are those whose primary objective is to modernize the industrial and organizational structure for the sake of efficiency and rationalization, taking advantage of the latest technological tools within the limits of the country and for the specific needs of the country. Sweden and West Germany appear to the leading examples of these policies.

Development-oriented policies are those that combine mission and diffusion goals, to engage in an industrial and organizational transformation that will enable the country to achieve higher level collective goals on the basis of the enhanced technological capacity. It is, to some extent, diffusion-oriented strategies at the service of mission-oriented goals. Japan is, in Ergas' analysis the quintessential example of this type of technological policy.

On the basis of these considerations, a useful framework to study technological policies and their outcomes on technology, economy, and society, could be to examine the interaction between the eight models of technological development and the three types of

13. Henry Ergas, "Does Technology Policy Matter?" in Bruce R. Guile and Harvey Brooks (eds), Technology and Global Industry: Companies and Nations in the World Economy, Washington D.C.: National Academy Press, 1987, pp. 191-245.
14. See Ergas, op. cit., 1987, p. 192.

government policy as presented here. From this perspective we would distinguish between the process of development and the policy intervening in such process, assessing separately the effects of the two elements on different dimensions: technological, economic, social. The systematic presentation of such framework, in logical and theoretical terms, is unnecessarily complex for the limited purpose of this Research Report. It is sufficient to mention it to expose the analytical logic underlying the structure of our overall research project.

In the Chapters that will follow in this text, we will concentrate on the analysis of three Mission-oriented technological policies: SDI in the United States, Informatics Policy in Brazil, and Electronics Policy in China. In the three cases, the interests of the State are the determinant factor in designing a technological policy with far-reaching consequences for the technology and the economy of each country, and indeed of the world at large. In the three cases, the goals of ensuring military strength and national economic development were major factors in the process of policy-making, although with different emphases. In the three cases, the actual policy outcomes resulted from the interaction between the State, the international context, and the specific process of technological development in each country. By focusing on three major cases of Mission-oriented technological policies we aim at highlighting the crucial role of the State in current technological development, a role too often underestimated by the excessively abstract, market-biased models frequently used in analyzing technological innovation. While technology is not solely a product of State policies, as far as it bears the promise of power its development and characteristics will be inseparable of the process of power making acted and structured by the State.

THE STRATEGIC DEFENSE INITIATIVE AND THE NEW TECHNOLOGICAL FRONTIER OF THE AMERICAN STATE

Manuel Castells and Rebecca Skinner

The political controversy surrounding the Strategic Defense Initiative (SDI) has obscured its meaning and importance as a technological policy. Critics and advocates of the Reagan Administration's space-based defense program have concentrated on two issues that, while extremely relevant, do not address, in our opinion, the real significance of the program.

On the one hand, most of the debate has concentrated on examining the feasibility of the stated goal of SDI, namely the development of a space-based, efficient shield against attacking ICBMs.[1] On the other hand, a number of studies of SDI have criticized the program on the grounds of its negative effects on American economic competitiveness,[2] while SDI defenders increasingly shift their arguments away from the strictly military terrain to emphasize the program's capacity to create technological spin-offs with commercial applications.

Yet, as former Secretary of Defense Caspar Weinberger said:"Even if achieving the security needed for [peace with freedom] meant some dislocation in the economy—and it does not today—who would suggest any other course".[3] In other words, if SDI represents the creation of a new technological threshold assuring the United States strategic superiority over the Soviet Union and, more broadly, a qualitatively enhanced defense policy, arguments about competitiveness would come only second in the concerns and priorities of a State assuming its global political responsibility.

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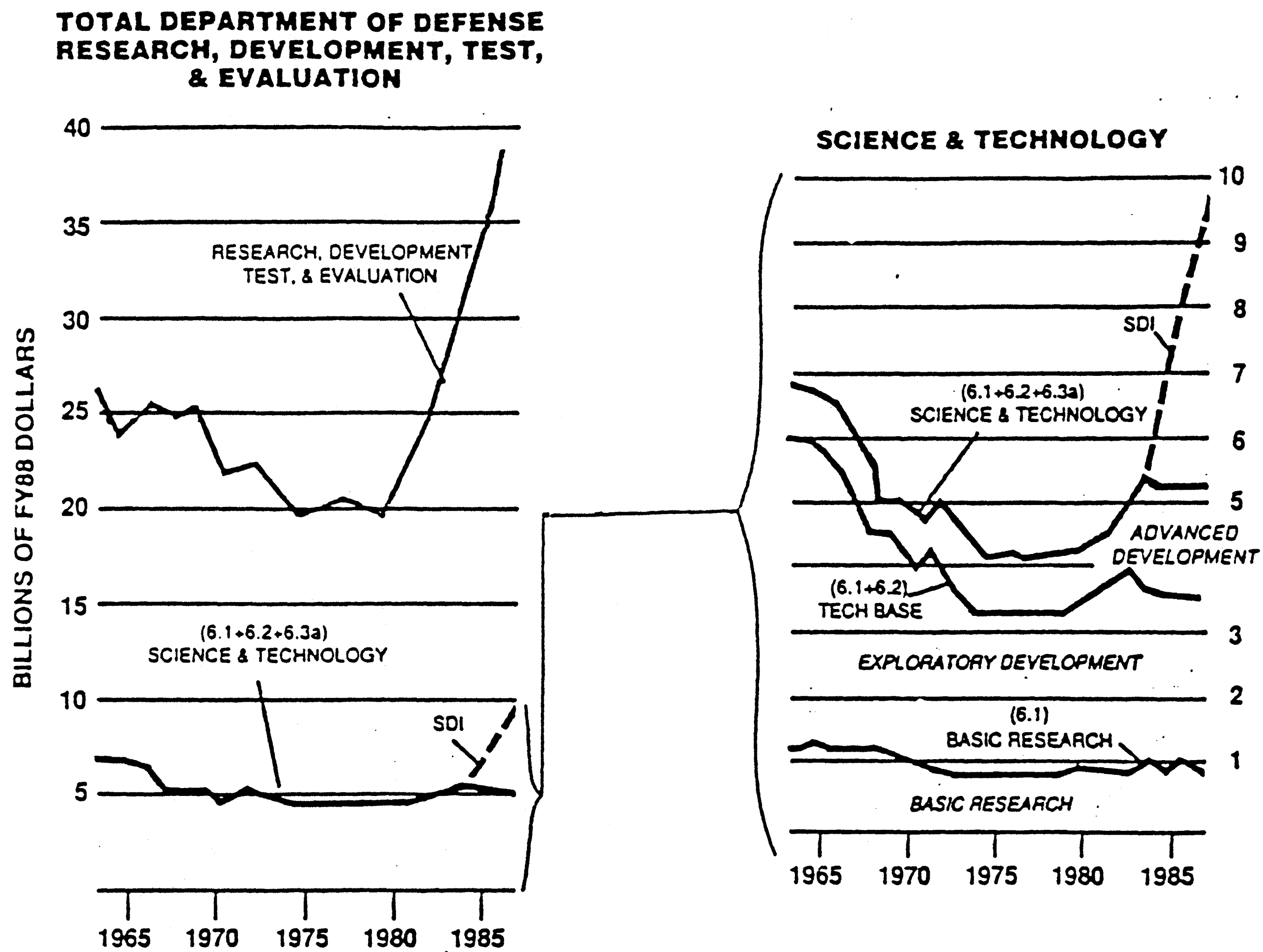
1. John Tirman (editor) and the Union of Concerned Scientists, Empty Promise: The Growing Case Against Star Wars, Boston: Beacon Press, 1986. H. Brown, "Is SDI technically feasible?" Foreign Affairs, n.1, January 1986. E.P. Thompson (editor), Star-Wars: Science-Fiction Fantasy or Serious Probability?, New York: Pantheon Books, 1985.
2. Rosy Nimrody (editor) and The Council on Economic Priorities, Star Wars: The Economic Fallout, Cambridge, MA: Ballinger, 1988. R. DeGrasse and S. Dagget, An Economic Analysis of the President's Strategic Defense Initiative: Cost and Cost Exchange Ratios, New York: Council on Economic Priorities, 1984.
3. Caspar Weinberger, Speech Before the Miami Chamber of Commerce, September 15, 1982.

The issue then becomes how SDI can be relevant if it appears to most scientists as a technological utopia. Without entering into the details of the debate (that are too technical to be reported here) we will try to synthesize in the following section of this Chapter the most likely hypotheses on the matter of SDI's feasibility. In any case, it appears certain that the Program will never provide a leak-proof shield, and it is unlikely to develop beyond a limited anti-ballistic system, and this only by the first decade of the twenty first century. Nevertheless, we argue that SDI's implications for military strategy go beyond its emphasis on an anti-ballistic system. It represents an unprecedented mobilization of scientific, financial, and institutional resources in the development of military-oriented technologies, with most of these technologies having a wide range of military applications, many of them in conventional warfare and intelligence gathering and processing operations. Figure 1 displays the dramatic turnaround of military-oriented research in the Reagan Administration and the predominant role of SDI in such new trend. It aims, in fact, at a technological leapfrogging that would make obsolete existing military technologies, thus assuring U.S. strategic superiority on the basis of the most important comparative advantage that the U.S. has over the Soviet Union, namely the superiority of American science and technology, particularly in the critical areas of information technology.[4] The reasons for the choice of a space-defense system as the articulating goal for such military technology effort are complex and will be presented in the following section. But what we formulate from the onset of this study as the guiding hypothesis of our analysis is that SDI's relevance has to be found less in the explicit goals of the program than in its exemplary role in fostering the systematic application of new technologies to military applications as both the technological policy and the new military strategy of the American State. This is why the policy represented by SDI(namely, the high technology emphasis on defense planning) is likely to continue in the future, regardless of the political fate on the program as such in future Administrations.

Thus, SDI as a specific program, aimed at a space-based anti-ballistic shield, may not last. But SDI as a new form of articulation between high technology and the State could be a pace-setting initiative. What SDI announces is the renewal of a close connection between

4. See "Soviet Strategic Defense Programs: A Decade Behind the United States" in R. Nimrody and The Council on Economic Priorities, op. cit., 1988, Chapter 9, pp. 145-197.

Figure 1
Total Department of Defense Expenditure on Research, Development, Test & Evaluation
and Portion for Science & Technology
(in US$ billion)



national security interests and technological policy under the guidance, funding, and organizational setting of the federal government and the scientific-industrial-military complex organized around its policies.

In this Chapter we explore the reasons underlying the formation of the SDI Program as a new military strategy orienting the technological policy of the American State. The implications of such policy for economic development and technological trajectories are presented in the following Chapter. Together the two Chapters call for the introduction into the analysis of the process of policy formation of the specificity of State's political interests as the overriding factor in shaping the direction and effects of technological innovation on economy and society.

SDI and the State

When on March 23, 1983, President Reagan wished upon a star, aiming at the obsolescence of strategic nuclear weapons through revolutionary technologies he surprised many observers, and even many in the Pentagon, yet he was expressing a deliberate, well grounded political strategy that responded to at least five layers of factors, all of them fundamental elements in the dynamics of the modern global State.

First of all, the major technological revolution we are living in has become a key factor in determining world power.[5] Of course, as we argued in the Introduction to this research monograph, technology has always been closely connected to the State and to the military. Yet, with the exception of the short period when the U.S. had the monopoly of the nuclear bomb, this is the first time in recent history in which technological superiority becomes the central factor in achieving military, thus political supremacy. The U.S. is aiming at a quantum leap in its warfare capabilities, taking the Soviet Union to the one area in which its capability to compete is seriously undermined by the very characteristics of its social system: the development of information technologies. Indeed, this is one of the main factors inciting Gorbachev to step up his "perestroika", and also one of the reasons why the generally conservative Soviet military has not opposed Gorbachev's daring reforms. This is also the major reason for the confrontation between the U.S. and the Soviet Union on the pursuit of

5. John Tirman (editor) The Militarization of High Technology, Cambridge, MA: Ballinger, 1984.

SDI, at the point of endangering the otherwise promising arms reduction process. It is not so much that the Soviet Union fears the U.S. space program's capabilities, since such program has fallen far behind the Soviet program, but that the Soviets are aware of their critical backwardness in microelectronics, computers, and communications, while SDI could become a major element in the military-oriented developments of these technologies. From the American perspective, by making strategic weapons less effective, and by ensuring a technological edge in its strengthened armed forces, the U.S. could succeed in stalling the deterioration of its power in the aftermath of the Vietnam War.[6]

Furthermore, the array of new technologies envisaged by SDI are not confined to strategic weapons. They will have a substantial impact on conventional weapons. The Defense Department's Commission on Integrated Long Term Strategy, in its Report issued in January 1988[7] identified four major areas in which weapons technology should concentrate the efforts of the U.S. to upgrade its defense capabilities:

a) The integration of "low-observables" (Stealth) systems into the U.S. strategic plan
b) "Smart" weapons, that is precision-guided munitions that combine long-range and high accuracy.
c) Ballistic missile defense
d) Space capabilities needed for wartime operations.

Technologies developed by the SDI Program are all key components to achieve superiority in these four fields, as we will present below when analyzing the technological content of SDI. Thus, SDI represents a new generation of military technology with potential dual military use, strategic and tactical, nuclear and conventional, although the explicit organization of the Program is built around the design of anti-ballistic defense. SDI cannot be understood in isolation of the renewed emphasis on high technology research and development by the Defense Department. In the last decade, under the impulse of new defense agencies, closely related to the scientific establishment, the Department of Defense has engaged in a bold program of mobilizing America's technological capacity to achieve military superiority in both strategic and conventional weapons. Furthermore, the Pentagon

6. Georges Skelton "U.S. Fears Soviet Leap in A-Arms," Los Angeles Times, 1-15-1985; Philip M. Boffrey "Many Questions Remain as Star Wars Advances," International Herald Tribune, 3-121985.
7. Fred Ikle and Albert Wohlstetter (co-Chairmen), Discriminate Deterrence, Report of the Commission on Integrated Long-Term Strategy to the Secretary of Defense, Washington D.C.: U.S. Government Printing Office, January 1988.

has become increasingly involved in fostering the development of science and technology per se, so that the U.S. will not have to rely on foreign supplies in the critical areas of microelectronics, computing, telecommunications, and aerospace. Mario Pianta has analyzed the development of such effort during the 1980s.[8] Tables 1 and 2, elaborated by Pianta, provide an overview of the objectives and characteristics of the main Defense-sponsored programs in key areas of technological development.

SDI is in fact but the most ambitious, and politically best supported expression of the new technological orientation of the Pentagon, that represents a new line of strategic thinking after the period of uncertainty in the aftermath of the Vietnam War.[9] In fact, in the mid-1970s, the greatest military power in the world found itself semi-paralyzed in its ability to react to perceived aggressions or encroachment to its sphere of influence because of the combination of two trends: on the one hand, Soviet nuclear power would deter any confrontation of major proportions at the global level (the reciprocal argument is, of course, also true); on the other hand, direct American involvement in military conflicts had become too costly, and generally unacceptable for the American public, after the unforgettable tragedy of Vietnam, as it was demonstrated by the strong opposition to the intervention in Central America. Under these circumstances, new options were sought for American power to be able to reach out. Emphasis was placed on low-intensity warfare, including intelligence, political intervention in different countries, and support to forces that would oppose regimes considered hostile to the U.S. interests.[10] According to the Report of the Commission we already cited, in 1988 there were about 500,000 insurgents mobilized against anti-American regimes around the world, that were being supported directly or indirectly by the U.S.[11] Yet, in many instances this support can only be effective if backed by the potential direct use of military power by the U.S. Symbolic actions such as the invasion of Grenada were effective, but limited. Covert operations or open support to insurgency (Nicaraguan contras) or to counter-insurgency (El Salvador) cannot solve by themselves regional military conflicts.

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8. Mario Pianta "High Technology Programmes: For the Military or for the Economy?" Bulletin of Peace Proposals, n.1, 1988.
9. See Ikle and Wohlstetter, op. cit., 1988.
10. Michael T. Klare and Peter Kornbluh (editors), Low-intensity Warfare, New York: Pantheon Books, 1988.
11. Ikle and Wohlstetter, op.cit., 1988.

Table 1
Major High Technology Programs in the United States
Defense Department Programs
(in US$ millions)

Country	United States	United States	United States
Programme	Strategic computing programme	Very High Speed Integrated Circuits (VHSIC)	Strategic Defense Initiative (SDI)
Institutions involved	Defense Department, DARPA	Defense Department, DARPA, other agencies	Defense Department, SDIO
Key decision power	DARPA	Defense Department	Defense Department, SDIO
Where R&D is done	US firms, laboratories, universities	US firms, laboratories, universities	US firms, laboratories, universities (1% is done in Europe)
Period and funding	Five years, 1984-1989, $600m	1980-1985, $300m 1980-1989, $700m	1984-1987, $ 9,000m 1984-1990, $ 33,000m 1984-1994, $ 90,000m
Areas of research	Microelectronics, artificial intelligence, expert systems, computers, software	Microelectronics, Gallium Arsenide chips	Space, lasers, electromagnetism, microelectronics, supercomputers, software
Type of research	Applied, development	Applied, development	Applied, development
Products developed or considered	Autonomous land vehicle, Pilot's associate, Battle management system: new military systems	Very fast, miniaturized microprocessors for new weapons and control systems: new military systems	Space and BMD weapons, control systems: new military systems
Objectives and likely outcome	Development of new military technologies in artificial intelligence and computers	Development of new military technologies in microelectronics	New generation of strategic weapons, first strike capability, new arms race in space

Source: Mario Pianta, 1988.

Table 2
Major High Technology Programs in the United States
Private Sector Programs
(in US$ millions)

Country	United States	United States	United States
Programme	Microelectronics and Computer Technology Corporation (MCC)	Semiconductor Research Corporation (SRC)	Semiconductor Manufacturing Technology Corporation (Sematech) (planned)
Institutions involved	21 US private firms in a cooperative project	13 US private firms in a cooperative project	US semiconductor firms in a project sponsored by the Defense Department
Key decision power	Firms	Firms	Defense Department, firms
Where R&D is done	MCC laboratories (400 scientists)	US universities	New plants and laboratories
Period and funding	Started in 1983, annual budget $75m	Started in 1982, annual budget $35-40m	To be started in 1987, funded with $1,000m by the Defense Department over five years
Areas of research	Microelectronics, systems architecture, software, VLSI superconductivity	Semiconductors, VLSI	Semiconductor production technology
Type of research	Applied, precompetitive development	Basic, applied	Applied, development
Products developed or considered	New advanced microelectronics: new means of production	New semiconductors: new means of production	New semiconductor production systems: new means of production
Objectives and likely outcome	Development of new technologies by US firms; more competitiviness	Advances in semiconductor technology; more competitiveness	US self-reliance in chip production; national security, more competitiveness

Source: Mario Pianta, 1988.

Political means are necessary. But these political ways of fostering American interests in the world will be more effective if they are able to keep open the military option should political strategies fail. Yet, given the domestic political obstacles to any prolonged, costly, military intervention, the new military strategy requires the means to intervene "surgically" in any area of the world it might be required, if anything else to make credible threats of military action that could reinforce the U.S. bargaining position in the lower level of conflicts, without necessarily escalating them. It is within this perspective that new technologies, and particularly communications, computers, and a new generation of aircraft and ships armed with precision-guided weapons, and protected by new radars and electronics-jamming devices, play a decisive role. To some extent, new technologies are making possible again conventional warfare at a low-cost, for the holder of superior technology. Advances in microelectronics, telecommunications, and computing, are not only required to counter Soviet ICBMs, but to overcome the threat posed by Soviet SA-7s or French Exocets in the hands of hostile Third World armed forces. By ensuring technological superiority in conventional weapons systems, the U.S. military would be able again to protect the interests of the Western World, as perceived by the U.S. Government, at a cost politically acceptable for the American public. Examples of such new military strategy based on surgical interventions were the precision bombing of Khadafy's residence in Tripoli, or the damage inflicted to the Iranian Navy in 1988, with very limited losses on the American side.

In sum, SDI-induced military technologies are not confined to the illusion of an anti-ballistic shield. They represent a fundamental breakthrough in warfare, because of the precision and the flexibility in their use. These new military technologies could allow for a greater adaptation of the use of force to the specific conditions under which a global power has to operate at different moments and in different areas, thus linking the military instrument to the new political strategy of restrained, but relentless intervention in the global arena.

Secondly, the political dimension of SDI is not limited to the military expression of State power. It also refers to the search for legitimacy, in one of the most paradoxical twists of world politics in the last decade. SDI was, at least in its origins, a political response from the Reagan Administration to the growing strength of the peace movement in the world in general, and in the U.S. in particular.[12] It embraced the ideals of eternal peace and of permanent banning of nuclear weapons, and provided a technological solution to the problem that, unlike political bilateral negotiations, needed to rely solely on America's ingenuity and resources. The utopian soundings of White House's proclamations were seeking new legitimacy among the peace-conscious, anti-nuclear "yuppie" voters, who are becoming a major factor in American elections. SDI's ideological ability consisted in playing on a very old, deep-rooted American utopian solution to all problems through a technological fix. As evidence of this original legitimation goal of SDI we can cite the insistence of both President Reagan and the Pentagon on the non-nuclear character of the program, going as far as not adopting some of the technical proposals by Edward Teller not to comply with his pro-nuclear orientation. In spite of the fact that some scenarios do contemplate the inclusion of some nuclear elements in the program, SDI officials systematically emphasized its defensive and non-nuclear characteristics, thus giving in, at least apparently, to the universal request for peace and nuclear disarmament. At first, the strategy seemed to work, since public opinion polls in 1984—86 showed simultaneously support for SDI and a majority opinion for nuclear disarmament.[13] However, when it became clear that SDI was in fact an offensive program, and one that endangered the process of negotiation with the Soviet Union to reduce nuclear weapons, its meaning has changed in the public opinion, and the elimination of SDI became a rallying banner for liberal forces in the United States during the 1988 Presidential campaign. Thus, while the legitimation purpose helped to create SDI, its subsequent development, and the debate that surrounded it, led to failure on this objective, in spite of the public relations ability of SDI officials, and would probably imply the phasing out of the Program as such, should a Democratic Administration come to power.

Thirdly, SDI represented a major effort of international cooperation between the U.S. and its Western allies in the building of a common technological-military complex. For the first time, the U.S. Defense Department sought to involve foreign governments, companies, and research centers, in top-secret, cutting edge technological research with direct military applications. The sharing of advanced American technology and abundant funding were key

12. E.P. Thompson, op. cit., 1985.
13. Peter Grier "U.S. Public Opinion Generally Favors "Star Wars," Christian Science Monitor, 21-11-1985.

arguments in attracting foreign cooperation. So doing, not only the Defense Department was mobilizing all Western scientific resources around its own agenda, but the predominantly military goals of the U.S. government technological policy could potentially shape the technological policies of the OECD countries.[14] Britain, West Germany, Israel, Japan, and Italy, accepted participation in SDI, authorizing several companies and research centers to accept contracts from the Department of Defense to conduct classified research on specific projects assigned directly to them by the SDI Office. However, as of 1988, the quantitative and qualitative importance of such cooperation has been very limited(foreign contracts account for less than 1% of all funds contracted by SDI in 1987),[15] and the secretive character of most of its projects has slowed down the initial enthusiasm of Japanese and European companies to engage in SDI contracting, given the difficulty to ensure commercial spin-offs from technologies developed through these programs.[16] Thus, while SDI represents an innovative approach to defense technological policy, going global for the first time, its actual impact on technological policies of other countries is falling short of the initial expectations. Yet, the objective of building technological cooperation of the Western Alliance under the organizational leadership of the U.S. Defense Department was an important element in fostering the construction of the new military-technological complex around SDI.

The analysis of SDI we have presented up to this point has focused on the structurally determined tendencies of the American State, as they express the interests of the social system in which it is rooted. Yet, State policies are also the result of strategies of individual actors defending their own specific interests, on the basis of their influence in the power networks to which they have access. It is this interplay between historical interests of the system and the particular interests of powerful social actors that renders most decisively the complexity of a political process, such as the one leading to the formulation and implementation of SDI.Thus, a fourth factor to be taken into consideration is the influence of the Defense lobby, or the so-

14. Pianta, op. cit., 1988.
15. Preliminary calculations by Rebecca Skinner on SDI contracts data basis, research in progress.
16. Walter Zegveld and Christien Enzing, SDI and Industrial Technology Policy: Threat or Opportunity, New York: St. Martin's Press, 1987.

called industrial-military complex.[17] It is unquestionable that Defense contracts, running out of steam, once the last programs were to be exhausted or cancelled (MX missile, Midgetman missile, B-1 Bomber), found in SDI a new driving force, able to help the defense build-up, and, down the line, to renew the entire military hardware through induced technological obsolescence. As the spearhead of a new effort in defense procurement, "Star Wars" could propel some of the most powerful companies in abundance. And it is a fact that the defense-electronics complexes in Silicon Valley, Route 128, and Los Angeles-Orange County, have greatly benefitted from SDI-related funding in the mid-1980s, at a moment when the 1984—86 slump was threatening the vitality of U.S. high technology industries.

Much of defense contracts are concentrated in a few companies, with long established ties to the Navy, Army, and Air Force. In the case of SDI this pattern seems to be reproduced. Thus, while the first $2 Billion in research contracts for SDI were spread in 1,500 companies, the top 10 contractors accounted for 60% of the funds distributed up to 1985. In 1987, the top contractors are generally the same large companies specialized in the production of missiles, aircraft, and related electronic equipment, with the addition of the major national laboratories.[18]

True, the amount of research money involved is relatively small by Pentagon standards: less than $10 Billion in 1984—87, maybe $39 Billion in 1988—92.[19] (See Table 3.) But should the system come to be deployed, even in a scaled-down version, it would be the most expensive military program in history (and therefore the largest market ever); estimates widely vary for figures between $400 Billion and $1.6 Trillion, since no one really knows what such a system would be. In any event, what is sure is the gigantic scale of such military markets, and its potential spin-offs in a wide range of industries: electronics, energy, laser, telecommunications, advanced materials, nuclear reactors, weapons procurement and ordnance etc. This is the reason why companies position themselves from the outset in the research stage of the program. Companies with inside knowledge of the technological options adopted for each part of the system, will have a decisive advantage in securing future

17. Ernest Conine "Star Wars and Economic Power," Los Angeles Times, 8-19-1985; W. Hartung et al., The Strategic Defense Initiative: Costs, Contractors, and Consequences, New York: Council on Economic Priorities, 1984.
18. Nimrody and The Council on Economic Priorities, op. cit., 1988, Chapters 4 and 5.
19. Wayne Biddle "Star Wars Defense Has a Future," The New York Times, 3-25-1984, p. 22.

Table 3
Strategic Defense Initiative Budget Authority
(in US $ million)

	Actual					*Requested*					
	1984	*1985*	*1986*	*1987*	*Total 1984-87*	*1988*	*1989*	*1990*	*1991*	*1992*	*Total 1988-92*
Surveillance, acquisition, and tracking	$ 367	$ 546	$ 847	$ 911	$2,671	$1,493	$1,859	–	–	–	
Directed energy	323	377	803	844	2,347	1,104	1,246	–	–	–	
Kinetic energy	196	256	596	729	1,777	1,075	1,200	–	–	–	
Systems analysis and battle management	83	100	211	387	781	627	787	–	–	–	
Support	23	118	230	358	729	922	1,190	–	–	–	
DOD Total	992	1,397	2,687	3,229	8,305	5,221	6,282	7,400	8,400	9,800	37,103
DOE Total	118	224	285	514	1,141	569	390	390	390	390	2,129
SDI Total	$1,110	$1,621	$2,972	$3,743	$9,446	$5,790	$6,672	$7,790	$8,790	$10,190	$39,232

Sources: RDT&E Programs (R-1), Department of Defense Budget for FY 1988 and 1989, january 5,1987. Data for FY 1989-92 from SDIO budget breakdown released February 25, 1987, and Congressional Budget Office, "Selected Weapons Costs From the President's 1988/89 Program," April 2, 1987. [Reproduced from Council on Economic Priorities, Star Wars: The Economic Fallout (Cambridge, MA: Ballinger, 1988), pp.28-29.]

contracts. Thus, given the high business stakes involved in the program, it is not surprising the full mobilization of the defense industry in assuring the success of SDI policy. This is particularly crucial regarding their influence on numerous Congressmen and Senators whose constituencies grow ever more dependent on military-induced funding to shift from traditional manufacturing to high technology industries.[20]

Yet, in spite of the importance of this factor, it is not the only one, nor the most important, in explaining the creation of SDI and the political priority given to the program by the Reagan Administration. And this is because the defense lobby is a permanent feature of the American political system.[21] Given the opportunity its influence greatly expands, and it becomes the driving force in increasing its share of the federal budget. But such opportunity is generated by forces and considerations much broader than the defense lobby's influence. True, it is likely that in the last decade, a new political elite, with Western and Southern roots, has consolidated its position, and reinforced the access of the defense-relate business to the higher circles of power. Yet, the military-industrial complex is an old feature of the system and there is no evidence that defense-oriented, pork-barrel policies vary considerably with the geographic or social origin of the governing elite: political decision-making is a somewhat more subtle process. The influence of the powerful defense lobby was a factor, but only one, in the development of SDI.

In fact, some analysts argue that in this case a more important factor was the influence of the scientific and research lobby.[22] By such, we understand an informal network of scientists and research managers, that connect U.S. leading Universities, national federal laboratories (that include 775 facilities, with total expenditures of over $15 Billion per year), research branches of large corporations, specialized private research firms, and federal government agencies, particularly the Pentagon and the Department of Energy. Most prominent institutions in this complex network are MIT's Lincoln Laboratory in Lexington, Mass.; University of California's operated national laboratories in Livermore, CA and Los Alamos, N.M., and the weapons-development research facility Sandia Laboratory in

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20. See Nimrody and The Council on Economic Priorities, op. cit., 1988, Chapter 7.
21. G. Adams, The Iron Triangle: The Politics of Defense Contracting, New York: Council on Economic Priorities, 1981.
22. Warren Davis, "The Pentagon and the Scientist" in John Tirman (editor), The Militarization of High Technology, Cambridge, MA: Ballinger, 1984.

Albuquerque, N.M., initially operated also by the University of California, later transferred to ATT's management. Altogether, they concentrate an impressive scientific potential, both in terms of personnel and equipment, in terms of a coordinated, targeted effort. DARPA, the prospective research agency of the Pentagon, has been crucial in creating bridges between the most advanced research and their potential defense applications, through generous funding, flexible procedures, and a generally good understanding of the specific dynamics of basic research, since DARPA high-level staff is itself composed by a majority of scientists.[23] This scientific network holds substantial power in an age in which science and technology are the key to both military and economic superiority. It also has its own specific interests, namely, the enhancement of the means provided by the government to their ever more ambitious scientific programs, that accelerate in scope and scale with the exponential expansion of knowledge during the current technological revolution. Of course, cozy living conditions, special privileges and honors, and, sometimes, participation in successful companies, are also part of the rewards of the defense-connected, scientific elite. (That, by no means, encompasses the majority of the scientific community of the U.S., as widespread academic and scientific opposition to SDI-related research strikingly shows. In fact, the majority of the leading scientists in the U.S. is opposed to SDI).[24] Yet, there is a substantial minority of scientists that focus much of their research effort in defense-related research, and through a number of informal networks they have come to represent an important lobby. The very fundamental interest of this scientific-military lobby, beyond the personal benefits of its members, is to increase the complex itself, namely, to obtain endlessly the vast resources they need to engage in the new frontiers of science, in a self-reinforcing spiral of scientific discovery, military power, and political influence.[25] Given these priorities, SDI was the dream program to achieve the interests of the scientific-military lobby, because it could win over the support of the top level of the Administration to a renewed, massive effort in cutting-edge research on key fields of science and technology, very much in the same way that the Soviet "Sputnik" triggered the massive expansion of research and higher education in the U.S.

23. See Jay Stowsky "Beating Our Plowshares into Double-Edged Swords: The Impact of Pentagon Policies on the Commercialization of Advanced Technologies," Berkeley: University of California, BRIE Working Papers, n. 17, April 1986.

24. F. Kaplan "4 of 5 Top US Scientists Oppose 'Star Wars' Poll Finds" The Boston Globe, October 31, 1986.

25. William J. Broad, Star Warriors, New York: Simon and Schuster, 1985.

during the 1960s. The origins of the scientific-military lobby can be traced back to the Manhattan Project and to the work of the Los Alamos team, whose most remarkable spin-off was the Lawrence Livermore Laboratory, probably the world's leading center in the design of advanced weapons.

The day-to-day story of the genesis of SDI provides some evidence about the role of the scientific lobby in inspiring the program and urging a favorable presidential decision.[26] A key figure in helping to convince the President was Dr. George A. Keyworth, appointed to the post of the President's science adviser in May 1981, a post in which he served until 1985. Dr. Keyworth was a nuclear physicist, closely associated with Edward Teller, the father of the H-Bomb, and the founder, and main supporter, of the Lawrence Livermore Laboratory. Dr. Teller himself appears to have played a major role in conceiving the SDI Program in its initial version, and in successfully arguing for it. As the story goes, in 1981 a group of influential scientists, industrialists, military men, and aerospace executives began to meet in Washington D.C. at the Heritage Foundation, a conservative "think tank". Their goal was to formulate a plan for creating a national system of defense. Among the participants to these meetings were Dr. Teller, Dr. Wood, and such members of the President's "kitchen cabinet" as Joseph Coors, the beer executive; Justin Dart, a businessman; and Jacqueline Hume, an industrialist. The group's top officer was Karl R. Bendetsen, once Under Secretary of the Army, later chairman of the board of the Champion International Corporation, and a member of the Board of the Hoover Institution. He was an acquaintance of Dr. Teller since the 1940s. Another prominent member of the group was retired Army Colonel Lieutenant Daniel O. Graham, formerly head of the Defense Intelligence Agency. All group members received security clearance in order to discuss classified information.

Soon the group divided into different opinions about the ways to achieve space-based strategic defense. While Colonel Graham argued in favor of building a "high frontier" system on the basis of existing technology, Bendetsen and Teller put forward the proposal of launching a grandiose research program that would discover new technological means to

26. See William J. Broad "Reagan's Star Wars Bid: Many Ideas Converging," The New York Times, 3-4-1985, p. 1.

achieve the goal of strategic defense. Also, Teller wanted to include a nuclear component into the program, as the main energy source for the space-based laser weapons systems.

The split in the group was significant because it opposed the military scientific lobby, represented by Teller, to the traditional defense contractors, arguing for an anti-ballistic program that would not require waiting for radically new technologies. For Graham and the defense industry, SDI should revive the defense effort in missiles and aerospace. For the scientific lobby, SDI should bring together for the first time, in an integrated approach, a number of innovative research programs that were transforming military technology on the basis of the information revolution, such as lasers and supercomputers at Livermore, or advanced radars and computer software at Lincoln Laboratory. The daring proposal of the scientific lobby won the President's favor.The first meeting between the group of SDI scientific advocates and the President took place in January 1982.

Then, enters the key actor in the "Star Wars" saga: President Reagan himself. His deep, personal conviction in both the need for military superiority and its achievement through American-grown technology, are fundamental elements to understand the scope, direction, and resources that were given to the program.[27] In the same way one cannot understand the origins of the French nuclear power policy, with its military dimension, without General De Gaulle's personal equation, we must consider Ronald Reagan's role as being crucial in the formulation and expansion of SDI. Not only the political elements of such program were explicitly contained in the Republican Party Electoral Platform of July 1980, but Reagan's commitment to technological military development dates back to his period as Governor of California, and to his personal interest in the work conducted at Livermore, and especially in Teller's ideas, as early as 1967. As soon as he had the opportunity he explored the feasibility of concepts that had been hovering over the California military research establishment for many years.[28] In 1981, under the President's instruction, Caspar Weinberger asked the Defense Science Board, in the Pentagon, to study the possibilities of anti-ICBM defense. In January 1982, Edward Teller held the first of four personal meetings with the President to advise him about the feasibility of such a program.

27. Aaron Wildavsky, "Reagan the Strategist," The Wall Street Journal, 1-3-1986, p. 10.
28. We have journalistic evidence that Lawrence Livermore Laboratory was working on key concepts of SDI in January 1980, before Reagan's election as President.

And when Reagan announced his decision to propose SDI, his call was primarily aimed at American scientists. The circle was closed. The "Great Communicator" had, this time, something of historic relevance to communicate: the dream of eternal peace in a US-dominated world won over by American ingenuity that would also provide technology, jobs, and markets for the nation's industries, as well as substantial rewards for their powerful lobbies. A new, more dynamic relationship between the State, Defense, and technology, would emerge as the reconstructed coalition of new social groups and old economic interests at the dawn of the informational society.

The "Star Wars" Program: The Technological Search for a Military El Dorado

In spite of its technological and economic implications, SDI is, above all, a military program. Given the media attention to its specific content and evolution, we do not think necessary to recall its characteristics, except when required to understand its impact on technological policy. Nevertheless, we have to consider briefly the subject that has dominated public debate concerning "Star Wars": its feasibility.

Scientists, political leaders, and the media have battled with fury to argue for or against the possibility of building such a non-nuclear shield.[29] The debate has generally oversimplified extremely complex technical matters that these authors have no competence for assessing. Besides, each time that SDI scientists have been pushed on the defensive, they hide behind the classified character of the technological answers that they affirm to hold for the gigantic problems posed to an effective space-based defensive system. Yet, informed opinion in both sides of the debate tends to converge towards a more realistic assessment of SDI possibilities in the following terms:[30]

a) The concept of a leak-proof seems to be out of the question, particularly because of the difficulty of the necessary software to such a system, and the inability to test it in real terms. Thus, as Carl Sagan said in one of the debates on the issue, even allowing for a 90% rate of success of SDI defenses against attacking ICBMs, the remaining 1,000 Soviet

29. See Thompson, op. cit., 1985; Office of Technology Assessment, The Strategic Defense Initiative, Washington D.C.: U.S. Congress, 1985.

30. Frank Barnaby, What on Earth is Star Wars? A Guide to the Strategic Defense Initiative, London: Fourth Estate, 1986.

warheads would be more than sufficient to obliterate the U.S.[31] Therefore, SDI is not truly a defensive system.

b) However, counting on the success and effective deployment of the Program, a somewhat effective anti-ICBM system could be deployed, protecting a limited number of specific locations (e.g. Washington D.C, strategic command and control centers, and some missile launching platforms). Combined with the uncertainty for the attackers about the rate of penetration of its missiles in a broader anti-ICBM system, SDI could add significantly to the deterrence of a nuclear exchange.

c) Consequently, since defense would only be effective as part of a deterrent strategy, offensive capabilities should be maintained at a significant level. SDI space-based weapons and communications systems could be essential in taking the high ground in the electronic communications warfare that could determine the fate of a global confrontation. To some extent, strategic superiority in communications, surveillance, and intelligence gathering and processing, could be equivalent to superiority in the strategic balance of military forces. Therefore, SDI is, in fact, an offensive system, and its potential impact on offensive capabilities explains the interest of the Pentagon in pursuing the effort in spite of the growing awareness of its limited defensive capabilities.

d) Although nuclear weapons would not necessarily be an integral part of the system, a major nuclear component would still be present in it (space-based nuclear reactors as energy sources; maybe nuclear bombs able to generate X-Ray lasers; and certainly the use, under the umbrella of the Program, of nuclear warheads in the case of a retaliatory attack).

e) The actual deployment of the system in space would face considerable difficulties linked to the deficiencies in the space launching program. In fact, experts appointed by the U.S. Congress estimate that there will be no launching capacity to put into orbit all the necessary payload for a simplified SDI system at least before the year 2000. Together with the technological difficulties in software, energy-directed weapons, and survivability potential of the communication satellites, it would seem that regardless of the political environment, SDI could not reach the stage of actual deployment before the end of the century.

31. See "SDI: Vision or Delusion?" Issues in Science and Technology, Winter 1988.

Given the widely acknowledged impossibility of the original objective of the Program, and the uncertainty and considerable lag of time for deploying more limited versions of it, one wonders about the reasons for the persistence of the Republican Administration, as well as of the Defense Department, in such project. In fact, the utopian concept of the anti-nuclear shield played a mobilizing role in bringing support for the Program, both among the political elites and in the public opinion, in the launching stage of the program. But once the program is underway its proponents and organizational agents are less concerned with the fulfillment of the stated ultimate goal than with the technological breakthroughs that they could attain in their search, particularly because most of these technological advances have an extraordinary importance for conventional warfare, unlike what is often stated by uninformed opinions, such as the ideological argument about the "baroque arsenal" presented by peace activist Mary Kaldor.[32] For instance, Table 3 and Figure 2 show the priority given to surveillance equipment (SATKA in SDI's terminology), especially sophisticated sensors, satellites, and communications. Such technologies are fundamental in short, precision strikes carried out by planes or ships in modern warfare; that is the type of action U.S. armed forces are being prepared for, following the Israeli model. Thus, strategically speaking, while most of the attention is being focused on the feasibility of the defensive capabilities of SDI, the actual goals of the program (that is, strategic nuclear offensive superiority on the basis of a limited anti-ICBM system, and decisive technological edge in conventional warfare) are well underway.

Besides, SDI represents a new form of operation within the Defense Department, whose flexibility and autonomy have attracted the hostility of the traditional Pentagon bureaucracy. Following the model established by DARPA, although actually undermining DARPA's power, SDI signals the institutional restructuring of military management to adapt its organization to the information age. The Program is managed by an independent defense agency, the Strategic Defense Initiative Organization (SDIO), whose director report directly to the Secretary of Defense. In February 1986 SDIO was issued a Charter establishing its organizational structure, as shown in Figure 3. One important innovation was the creation of two different structures, one for specific technology programs, another for issues and

32. Mary Kaldor, The Baroque Arsenal, London: Deutsch, 1981.

Figure 2
Growth in SDI Funding, FY 1984-88
(in US$ million)

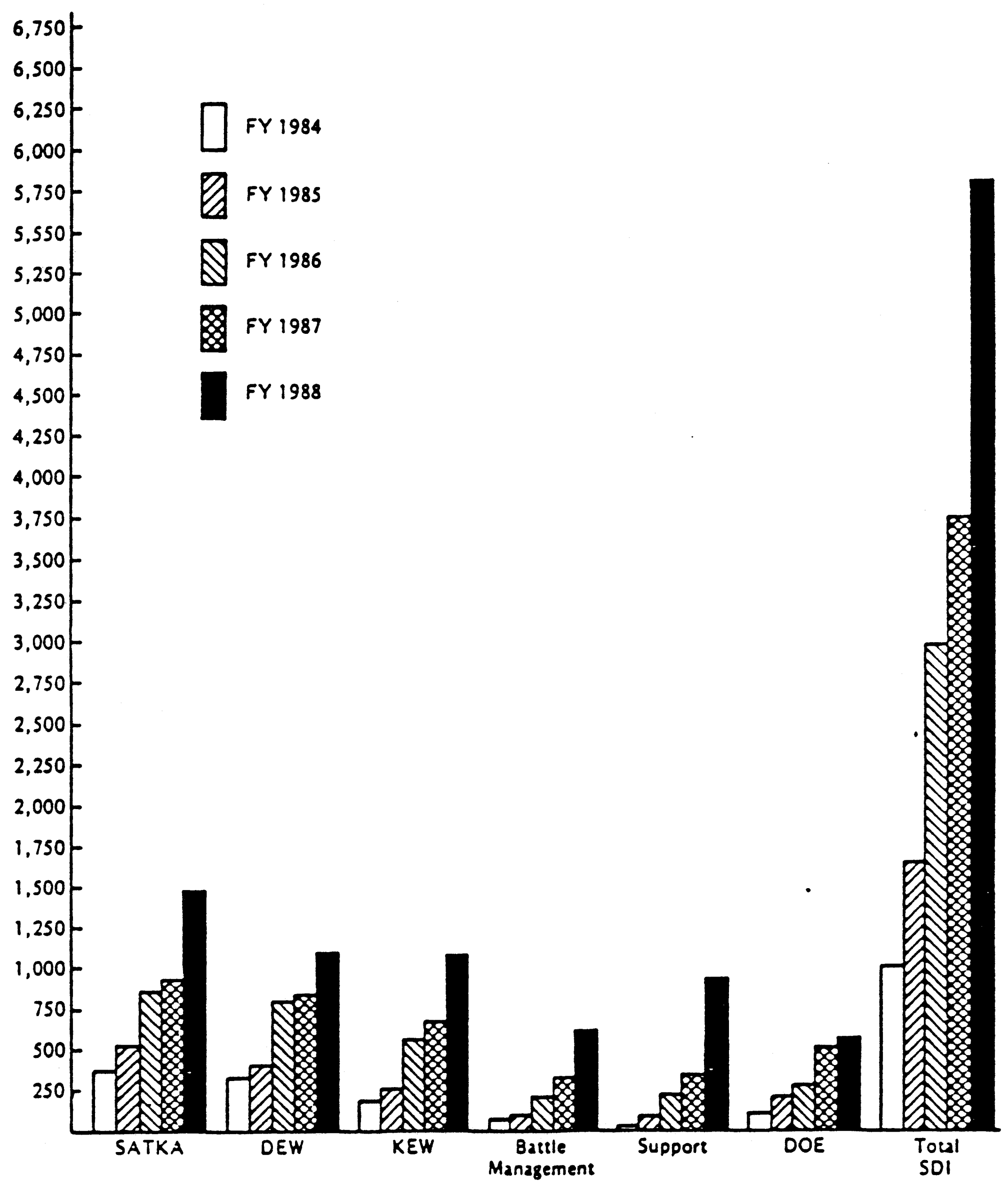
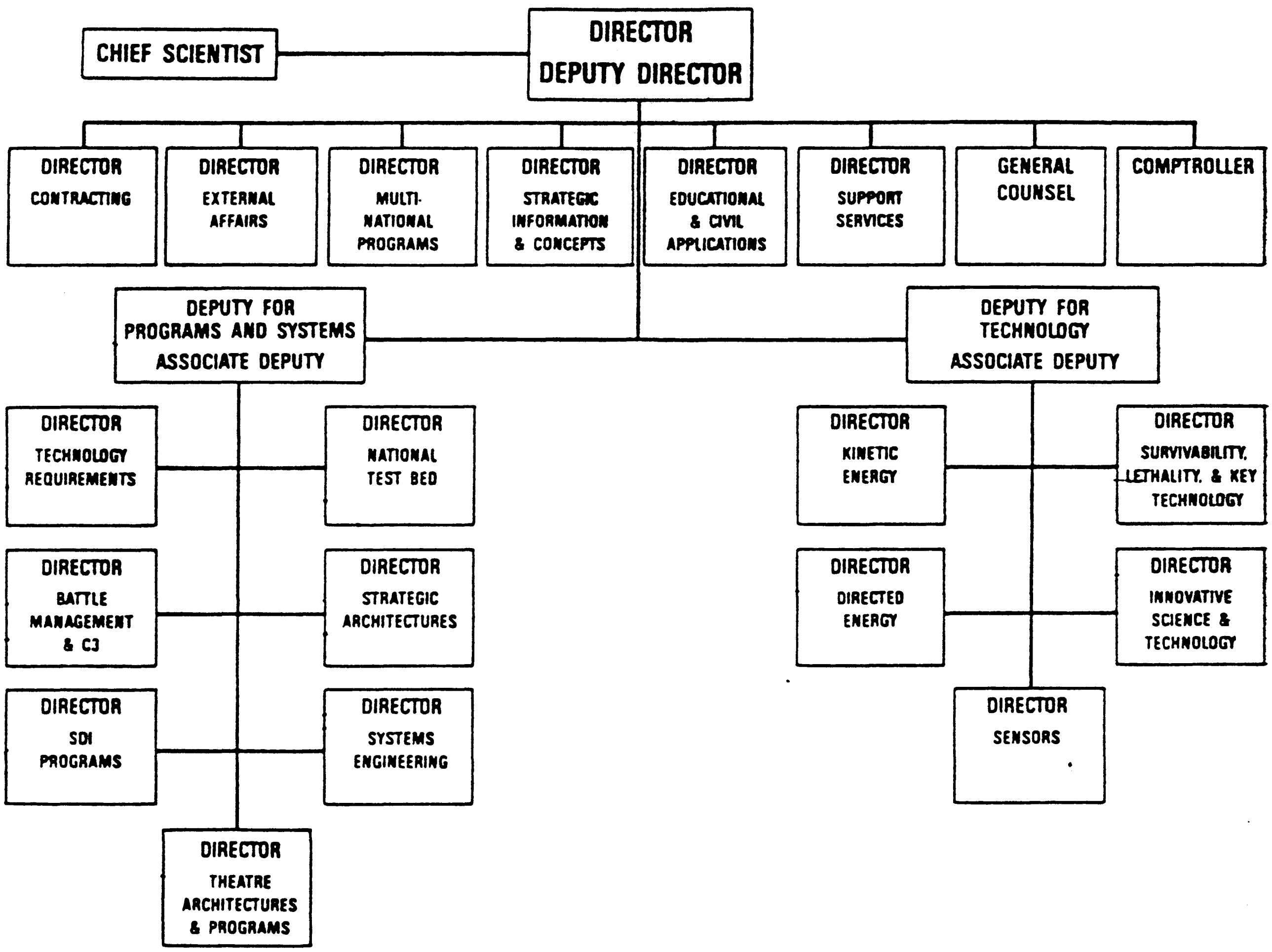


Figure 3
Current Organizational Structure of the SDIO



The SDI Executive Committee (EXCOM) is to provide DoD oversight for management of the SDI program. The EXCOM provides formal review of the program for the Secretary of Defense and is chaired by the Deputy Secretary of Defense. The SDIO Director serves as Executive Secretary of the EXCOM.

problems to be deal with in all of these programs. In addition, budgetary autonomy and administrative flexibility set SDIO in a class by itself, in terms of its managerial efficiency in comparison to the traditional lines of command of the Defense Department. A sign of the importance of building political support for the program as an organizational criterion was the appointment as Program Chief of James Abrahamson, an Air Force general with recognized public relations skills. SDIO contracts research with private corporations, universities, and national laboratories, on the basis of objectives and problems determined by SDIO's own technical staff.[33]

The technological fields targeted by SDIO as having priority include, as we stated, communications, supercomputers, and software, with emphasis on parallel architectures and artificial intelligence, in addition to energy weapons. Advanced materials are also an essential component of the program. Together with space manufacturing and the use of both solar and nuclear energy to power space-based activities, SDI is targeted toward all key technologies that matter for future industrial and economic development,[34] with the major exception of genetic engineering (and even in this field there are also a number of little-known, secret research programs.[35] Most of these technologies could be crucial for a wide range of applications. For instance, optical sensors, that are a fundamental element of SDI systems are the key element required to push robotization beyond its current primitive stage in manufacturing. The cost of global communication could be substantially lowered by enhanced satellite technology. Industrial applications of lasers are likely to revolutionize precision manufacturing. A new generation of "smart power" chips is on the making. And major breakthroughs in software development is the most critical need to unleash the productivity gap in information intensive services. In sum, SDI brings together in a system the most important new technologies and provides the economic and institutional support for their cumulative development. Thus, if pursued and funded for a number of years, SDI could overwhelm in resources and scope any of the Japanese or European technological programs, regardless of the success of its declared goals. A different matter is the commercial relevance

33. SDIO, "Report to the Congress on the Strategic Defense Initiative," Washington D.C.: Department of Defense, April 1987.

34. Mario Pianta "Star Wars Economics," Paper Presented at the Conference on "The State of Star Wars," Transnational Institute, Amsterdam, January 23-25, 1987.

35. Stewart Nozette "A Giant Step Forward in Technology," The New York Times, 12-8-1985.

and social usefulness of technologies developed under such parameters, a crucial question that will be examined in the following chapter of this Research Monograph. We do not imply that SDI or Defense oriented programs in general are the best way to mobilize resources for research in these key areas. In fact, a number of leading scientists argue that much talent is being wasted in dead-end research initiatives that are only of marginal interest to the advancement of knowledge, because of their too narrowly defined military application.[36] Yet, the fact that an alternative research program could yield much better results does not change the basic reality that SDI, regardless of its morality and in spite of its shortcomings, is indeed a grand-scale technological program.

Alike the Spanish conquerors exploring and colonizing the entire American continent in their vain search for the treasures of El-Dorado, "Star Wars" scientists and planners are dramatically expanding the frontier of technological innovation, and framing it into specific defense applications, while pursuing the military myth set up for them as a mobilizing goal.

SDI as Industrial Policy

Because of the decisive role of high technology in economic development, Defense-oriented technological programs are crucial in setting the agenda for America's industrial policy.[37] Given the fact that SDI is the largest, best organized, and more politically supported of these programs in recent years, it could actually shape American technological policy in a decisive moment and for a span of time longer than the existence of the program itself, because of the technological trajectories induced into the choices made under SDI directions.[38] Projected funding for SDI-related R&D is estimated to be at about $50 Billion for the 1984-93 period, although at least another $15 Billion should be added for programs that are connected to SDI but not managed by the SDIO, in particular those managed by the Department of Energy.[39] But, as we stated, the really important matter concerns the capacity of the first contractors to position themselves for the large potential contracts that will follow

36. Ben Thompson "What is Star Wars" in E.P. Thompson (ed.), op. cit., 1985.
37. Daniel S. Greenberg, "Defense, Father of Industry," Baltimore Sun, 11-11-1985.
38. See Zegveld and Enzing, op. cit., 1987.
39. See Nimrody and The Council on Economic Priorities, op. cit., 1988, Chapter 3.

the research stage, either to deploy an ABM system, or to develop a new generation of conventional weapons, or both.

The main beneficiaries of SDI contracts are the traditional large defense contractors, in aerospace, missiles, communications, and electronics, in addition to the national weapons laboratories, as shown in Table 4. Thus, SDI tightened anew the relationship between high technology industries and military programs, reversing the gradual disassociation between the two that occurred during the 1970s.[40] But there is a fundamental difference with the situation of the 1950s and early 1960s, when high technology was closer than ever to defense markets. And this is that while high technology industries were at that time a very small proportion of total manufacturing, they now represent its fundamental component, and the element that conditions the overall competitiveness of the U.S. economy. Therefore, the programming function of high technology played by SDI has far reaching consequences for overall industrial policy.

Besides, SDI extends its influence further beyond the traditional defense procurement activities. It creates a large market for information-processing and research firms, which represent the cutting-edge of a new form of industrial production in the informational economy.[41] These are companies specializing in computer simulations, system analyses, weapons performance assessment etc. Among these companies are Kaman Corp. (Bloomfield, Conn.), Rand (Santa Monica, CA), SRI (Stanford, CA), Sparta Inc., and the most prominent in this category, Science Applications International (SAIC) of La Jolla, CA. SAIC is a good illustration of the new type of military informational industry that SDI is fostering. Its 5,700 workers produce exclusively technical and strategic studies, for an annual revenue of $420 million in 1984 (90% from U.S. Government contracts). In fact, SAIC was very much involved itself in formulating some of the initial concepts of SDI since 1981. Its board of directors is also an expression of the intimate connection between the Defense establishment, the scientific community, and the intelligence agencies. It includes: former defense secretary Melvin R. Laird; former chief of National Security Agency admiral Robert R. Inman; former undersecretary of State Lucy W. Benson; MIT's Provost John M. Deutch;

40. Pianta, op. cit., 1987.
41. Fred Hiatt and Rick Atkinson, "Pentagon's Paper Warriors Find Market for SDI Advice," The Washington Post, 10-21-1985, p.1.

Table 4
Top 20 SDI Contractors, March 1987

Organization	Contracts Awarded (millions)
1. Lockheed	$1,024
2. General Motors (Hughes Aircraft)	734
3. TRW	567
4. Lawrence Livermore Lab	552
5. McDonnell Douglas	485
6. Boeing	475
7. EG&G	468
8. Los Alamos Lab	458
9. General Electric	420
10. Rockwell International	369
11. Massachusetts Institute of Technology (MIT)	353
12. Raytheon	248
13. LTV	227
14. Flúor	198
15. Grumman	193
16. Gencorp	191
17. Teledyne	189
18. Honeywell	151
19. Martin Marietta	134
20. Textron	118

source: Federation of American Scientists; reprinted in High Technology Business (December 1987)

Table 5
Number of Firms that have Created a New Division or Department for Dealing with SDI-Related Contracts

	Number of Respondents	Percent of Total
New Division/Department	13	9.6%
No New Division/Department	117	86.7%
no response	5	3.7%

source: High Technology Business (December 1987)
note: percentages may not total 100% because of rounding

General Welch, formerly with the National Security Agency; and Donald A. Hicks, from Northrop's Corporation, who resigned from SAIC to become the Pentagon's research director. This company, with some of the most sophisticated experts both in technology and in security analysis, is representative of the new breed of defense industry that is being spurred by SDI and related programs.

Another major development in information industries directly linked to SDI is the Pentagon's growing role in generating new software.[42] Particularly important is the creation and diffusion of ADA language, that allows different software systems to communicate. Many advanced software companies are now being directly funded by SDIO. In addition, the Defense Department has established a new office to provide venture capital for high technology start-up firms ready to work in areas of SDI's interest. It is estimated that such SDI funding could account for about 20% of all high-tech venture capital in the 1986-90 period.[43]

So, the extent of SDI inspired activity goes far beyond the traditional realm of the defense industry, to embrace the most advanced research fields, including basic analytical programs.[44] As a result, the personnel employed by SDI-related investment will be in the upper-tier of the technical ladder. According to a study by the Council of Economic Priorities, SDI-related production will employ 6 times as many scientists and engineers as the average industry.[45] Such development is dramatically affecting the high technology labor market, creating a shortage of skilled professionals in the civilian markets and concentrating some of the best talent in the military industrial sector by paying higher salaries, offering better equipment, and providing better working conditions. It will follow a gradual technological edge to the advantage of the defense industry.[46] Table 5 presents the Council on Economic Priorities' estimates on the substantial impact of SDI on scientific and technical employment in the United States.

42. Reuters, "Small Firms Capitalize on Pentagon Software," Los Angeles Times, 25-11-1985.
43. Rosy Nimrody and William Hartung, "Putting Industry Even Further Behind," New York Times, 12-8-1985.
44. Tim Carrington "Scramble in Space: Star Wars Plans Spur Defense Firms to Vie for Billions in Orders," The Wall Street Journal, 5-21-1985.
45. Nimrody and Hartung, op. cit., 1985.
46. See John Tirman, op. cit., 1984.

Table 6
Estimated Engineering, Scientific, and Technical SDI Employment, 1986 and 1991

Industry	*Scientists*			*Engineers*			*Technicians*			*Total Set Employment*		
	Share of Total (percent)	*Employment 1986*	*Employment 1991*	*Share of Total (percent)*	*Employment 1986*	*Employment 1991*	*Share of Total (percent)*	*Employment 1986*	*Employment 1991*	*Share of Total (percent)*	*Employment 1986*	*Employment 1991*
Radio and TV communication equipment	2.3	117	352	15.0	765	2,296	8.6	438	1,316	25.9	1,320	3,964
Management, consulting, and labs	5.3	382	1,333	3.4	245	855	4.6	332	1,157	13.3	959	3,345
Complete guided missiles	2.7	76	217	25.9	733	2,081	9.6	272	771	38.2	1,081	3,069
Nonprofit organizations and miscellaneous profit services	0.3	23	83	0.1	8	28	0.4	30	111	0.8	61	222
Electric measuring instruments	1.2	40	122	7.7	254	781	7.6	251	771	16.5	545	1,674
Electronic computing equipment	6.6	123	516	11.9	222	930	9.4	175	734	27.9	520	2,180
Wholesale trade	0.8	21	67	0.8	21	67	2.0	52	167	3.6	94	301
Aircraft	1.9	25	67	10.9	143	385	5.4	71	191	18.2	239	643
Real estate	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0
Measuring and control instruments	1.2	16	49	7.7	106	314	7.6	104	310	16.5	226	673
Hotels and lodging places	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0
Eating and drinking places	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0	0
Electronic components, NEC	1.4	13	46	7.2	68	237	7.7	73	253	16.3	154	536
Electric utilities	1.3	4	13	4.8	14	45	5.6	16	53	11.7	34	111
Inorganic and organic chemistry	4.1	14	43	5.6	19	58	5.9	20	61	15.6	53	162
Computer and data processing	4.0	53	185	12.2	162	564	16.4	218	758	32.6	433	1,507
Other motor vehicles	1.2	4	13	7.7	29	86	7.6	28	85	16.5	61	184
Gas utilities	1.3	2	5	4.8	6	18	5.6	7	21	11.7	15	44
Aircraft engines and engine parts	1.9	9	23	10.9	52	133	5.1	24	62	17.9	85	218
Engineering and scientific instruments	1.2	8	26	7.7	52	164	7.6	52	162	16.5	112	352
Twenty industry totals[a]	2.1/2.2	930	3,160	6.6/6.2	2,899	9,042	4.9/4.8	2,163	6,983	13.6/13.2	5,992	19,185
All other industries[a]	2.1/2.2	462	1,561	6.6/6.2	1,452	4,400	4.9/4.8	1,078	3,406	13.6/13.2	2,992	9,367
Total[a]	2.1/2.2%	1,392	4,721	6.6/6.2%	4,351	13,442	4.9/4.8%	3,241	10,389	13.6/13.2%	8,984	28,552

[a]Percentages are for 1986 and 1991, respectively.

Source: CEP estimates and U.S. Department of Labor, Bureau of Labor Statistics.

There is serious concern about such trends on the part of economic experts and leading industrialists. It is argued that secrecy involving much of the research will restrain its diffusion, undermining the commercial and civilian spin-offs of the program.[47] Given the slowness of diffusion from military-related innovation, critics argue that increasing dependency on defense-inspired technological change will considerably hamper U.S. competitiveness.[48] Jay Stowsky's analysis on the shortcomings of defense spending as a technological industrial policy[49] applies also to SDI-related initiatives. The channeling of much of the technological resources in the defense field will be likely to slow down the rate of innovation, and to decrease productive efficiency, to the benefit, for instance, of commercially oriented Japanese competition. The response of the Defense Department to such challenge is to try to universalize SDI, reaching out to foreign companies and opening potential markets that could lure into the U.S. defense spending much of the foreign technological potential.[50] However, as we stated, the participation of foreign governments and companies in SDI, as of 1988, is still negligible. Thus, most likely, foreign companies, and particularly Japanese firms, will keep most of their production targeted for civilian applications, with the potential result of global bifurcation of high-technology industries, with the U.S. electronics companies being overwhelmed in many commercial areas, by Japan and Western Europe, while the hard core of U.S. high technology finds refuge in the growing military market. This development could trigger a new economic restructuring within the high technology industries, as well as a recomposition of the international division of labor.

In sum, SDI and/or similar defense-related high technology programs are becoming the core of both defense policy and technological policy of the United States government, both because of its capacity to define the goals of technological innovation and because of its potential in creating markets and attracting the most skilled scientific labor force. On the other hand, because of the inherent shortcomings of defense production for civilian industrial development, SDI could trigger a profound restructuring of the international and national economies, from which the U.S. would probably emerge with a shrunk industrial structure,

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47. See Zegveld and Enzing, op. cit., 1987.
48. See Pianta, op. cit., 1987.
49. See Seymour Melman "Swords into Ploughshares," Technology Review, January 1986.
50. See M. Lucas "SDI and Europe," World Policy Journal, Spring 1986.

yet with a superior technological edge restrained to its own military, statist logic. SDI or similar programs could choke-off the market-driven entrepreneurialism that accompanied the birth and expansion of American high technology industries, to usher a new stage in which economic growth would be second to the technological exercise of global power. While State's technological policies have important economic consequences and motivations, their ultimate logic is fundamentally political.

THE EMPIRE'S NEW CLOTHES? SDI AND THE DIRECTION OF ECONOMIC AND TECHNOLOGICAL DEVELOPMENT

Jay S. Stowsky

Argument over the the economic impact of the Strategic Defense Initiative seems to constitute an ideological Rorschach test for both critics and proponents; analysts on either side of the issue tend to exaggerate the extent to which SDI will either initiate the technological milennium or jeapardize American competitiveness in the international economy. Because there is no way to wholly disprove either contention before the fact, both groups fall back on the historical case record to argue their points. These constant references to the past are essential to an informed debate, but they tend nevertheless to obscure much that is genuinely novel about SDI and its potential impact on the American economy. Underlying this debate, moreover, is a broader concern shared by many analysts on both sides of the so-called "spinoff" question. That concern is about how best to stop dependence on foreign sources of key commercial technologies from translating into over-dependence on foreign sources for state-of-the-art weapons systems and components.

In this paper I examine claims by SDI proponents that SDI can serve as a vehicle for strengthening America's civilian high-tech industries through the generation of technological spinoffs. The SDI Office of Education and Civil Applications has released a list of 18 putative technological spinoffs from SDI research, along with an estimate that $5 to $20 trillion in commercial sales can be expected to result from SDI-sponsored research over the next forty years. SDI now accounts for a substantial chunk of total U.S. government support for R&D, so it is especially important that we understand how SDI's specific mission is influencing the overall direction of technological development in the United States.

We will focus particular attention, in this paper, on the effects of SDI support on the research agendas of new small firms. Small, innovative firms have been a major focus of attention for SDI planners, who set up an Innovative Science and Technology Office (ISTO) in 1984 for the express purpose of stimulating the flow of ideas between small businesses and researchers in academia. Moreover, scores of fledgling firms have been granted SDI contracts under special federal set-asides like the Small Business Innovation Research (SBIR) program.

Of course Pentagon involvement with the civilian sector is nothing new. What is new is the Pentagon's evident willingness, through SDI and other recent research initiatives, to use its considerable powers of finance and coordination, not incidently but on purpose, to influence the strength and direction of the civilian industrial base. This is not to say that the Pentagon is interested in running a comprehensive industrial policy. Rather, the Pentagon wants to influence the development of the industrial structure that is now emerging to produce a particular set of advanced technologies, technologies that are seen as critical to the cost and performance of a full sprectrum of next-generation weapons systems. Nevertheless, in the absence of any other governmental agency charged with the development of a full-fledged industrial strategy for the United States, the Pentagon has always ended up improvising that role. The difference now is that at least one faction within the Pentagon seems ready to work with a script. As a result, a growing set of Pentagon initiatives explicitly links the achievement of a strengthened defense posture to an improvement in the long-term competitiveness of the nation's civilian economy, and projects are being structured in ways that suggest substantial institutional commitment behind the rhetoric.

The paper is organized as follows. First, I put forth some theoretical propositions about the nature of technological change. The consequences of increased military involvement in the evolution of the nation's technology base will become clearer when viewed from the perspective of a broader framework that takes into account the critical relationships between the direction of domestic technological development and future prospects for economic growth. Second, I describe the basic characteristics of SDI with respect to the overall direction of technological innovation and the diffusion of that innovation in the form of new products and production techniques. Third, I present some empirical data on the nature of private firm involvement in SDI-related research, followed by some brief case studies detailing the effects of SDI funding on the budding research agendas of two small firms. I conclude with some observations about the different implications of SDI-sponsored development of the nation's technology base for America's position in the world's military and civilian markets--particularly the increasing extent to which America's technological advantage in the former is coming to depend on its competitive performance in the latter.

Technological Trajectories and Path-Dependent Development

Technological change is a path-dependent process in which opportunities for future learning and innovation grow out of research and development programs pursued in the present and the past.[1] Thus today's patterns of resource allocation and production directly affect the technological opportunities that will be available tomorrow. Furthermore, technological knowledge is often "local" in the sense that what is learned incrementally over time through research and prototype production itself builds on skills, insights, and organizational search routines that may not be embodied in products or production equipment.[2] Such knowledge may be bottled up within particular firms or development networks and thus may be quite difficult to communicate across national borders. National, and sometimes even regional or sectoral, communities can generate distinct technological trajectories based on knowledge that has accumulated in the skills and experiences of the "local" workforce and the "local" institutions through which technologies diffuse.[3]

At a sectoral, regional or national level, different technological trajectories ultimately correspond to different opportunities for further technological development and long-term economic growth. The untraded, path-dependent nature of the learning associated with the development and use of new technologies makes it possible, in fact, to envision distinct alternative paths toward riches or ruin. "Virtuous" paths reflect the widespread diffusion of accumulated learning and associated dynamic advance; "vicious" paths refer to patterns of scattered learning and consequently slower growth. Because such paths are cumulative and

1. On the notion of path-dependence, see W. Brian Arthur, "Competing Technologies and Lock-In by Historical Events: The Dynamics of Allocation under Increasing Returns" CEPR Working Paper #43, Center for Economic Policy Research, Stanford University, November 1983, revised January 1985.
2. For an example of the effects of such "local" technological knowledge in the U.S. and Japanese semiconductor industries see Jay Stowsky, "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade" BRIE Working Paper #27, University of California, Berkeley (August 1987).
3. On the notion of national technological trajectories, see Giovanni Dosi "Some Notes on Patterns of Production, Industrial Organization, and International Competitiveness," unpublished paper, July 1987 (prepared for the meeting on "Production Reorganization and Skills," BRIE, University of California, Berkeley, September 10-12, 1987) and Giovanni Dosi, Laura D'Andrea Tyson and John Zysman, "Trade, Technologies, and Development: A Framework for Discussing Japan," unpublished BRIE manuscript, April 1988.

unpredictable, however, and because they embody externalities that cannot be captured by private actors, the entire array of choices that will send an economy down one path rather than the other cannot be signalled accurately through the market.[4]

In this context of imperfect markets and an unpredictable future, those who make choices about the direction of technological development and its diffusion today have the power to simultaneously open or foreclose future learning opportunities and the prospects for future development that those opportunities imply. The question of who actually develops, deploys, uses and controls access to new technologies thus becomes of paramount importance to understanding the pattern and pace of future economic growth.[5] It is that question, above all else, that generates our present concern about the possible implications of increased military control over the direction of technological development in the United States.

A Preliminary Overview of SDI: Particular Direction for Development and Diffusion

In order to assess the economic impact of a large military research program like the Strategic Defense Initiative, we want to know, first, the extent to which a distinct defense-driven technological trajectory is pervading the national technology base, as illustrated by the re-configuration of the nation's R&D investment patterns and the shifting activities of innovative firms, research institutions, and scientific and technical personnel. Second, we want to know whether the military "selection environment" has produced a significant divergence between the development trajectories being pursued by the military and civilian sectors with respect to the same underlying technologies.[6] Third, we want to know whether the military program is structured in such a way as to promote or to inhibit the diffusion of relevant technological knowledge between the military and civilian sectors.

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4. Dosi (1987) op. cit.
5. For an application of a similar logic to the development of a national integrated digital telecommunications services infrastructure, see Francois Bar and Michael Borrus, "From Public Access to Private Connections: Network Policy and National Advantage," BRIE Working Paper #28, University of California, Berkeley (September 1987).
6. The notion of a "selection environment" draws on the work of Richard Nelson and Sidney Winter. See, for example, "In Search of a Useful Theory of Innovation" Research Policy, Vol. 6, No. 1 (1977).

Table 1
Federal Outlays for Research and Development
(FY 1960 - FY 1987, in billions of 1985 $)

FY	Total R&D Outlays	Military R&D	Non-Mil R&D	Mil share of total
1960	30.2	24.5	5.7	81.1%
1961	35.7	28.1	7.6	78.7%
1962	39.6	28.5	11.1	72.0%
1963	43.9	27.6	16.3	62.9%
1964	52.5	29.9	22.6	57.0%
1965	51.8	26.5	25.3	51.2%
1966	53.5	25.5	28.0	47.7%
1967	55.4	28.0	27.4	50.5%
1968	53.4	28.2	25.2	52.8%
1969	48.6	25.8	22.8	53.1%
1970	44.2	23.4	20.8	52.9%
1971	41.8	22.0	19.8	52.6%
1972	41.7	22.6	19.1	54.2%
1973	40.9	21.9	19.0	53.5%
1974	38.3	20.7	17.6	54.0%
1975	36.6	19.2	17.4	52.5%
1976	36.6	18.0	18.6	49.2%
1977	36.5	18.5	18.0	50.7%
1978	39.0	19.2	19.8	49.2%
1979	38.6	17.8	20.8	46.1%
1980	40.0	19.4	20.6	48.5%
1981	40.9	20.3	20.6	49.6%
1982	38.8	22.2	16.6	57.2%
1983	38.6	24.0	14.6	62.2%
1984	42.5	26.7	15.8	62.8%
1985	47.3	30.4	16.9	64.3%
1986	51.0	34.9	16.1	68.4%
1987	52.3	35.8	16.5	68.5%
1988*	54.5	38.2	16.3	70.1%

Source: Office of Management and Budget, <u>Historical Tables, FY 1988</u>.

* administration request

The National Trajectory of Technological Development

As to the first point, substantial evidence exists to suggest that the nation's research and development efforts have been significantly re-militarized since the late 1970's.[7] The military share of federal R&D spending has risen from 48 percent in 1980 (55 percent if half of NASA R&D is counted as military) to 68.5 percent in 1987 (see Table 1).[8] The picture seems less dramatic when statistics are added to include non-Federal sources of R&D support, which surpassed Federal sources for the first time in 1980, but only if we assume that none of the non-Federal R&D was for military purposes. Making that assumption, the fraction of all U.S. R&D directed to military ends was 27 percent in 1980 and 30 percent in 1985, adjusting for space. Nevertheless, research conducted by Professor Lichtenberg at Columbia indicates that about 30 percent of industrial R&D expenditures in 1984 were induced by the prospect of attracting government contracts, most of which were defense-related. Lichtenberg suggests that this 30 percent figure actually represents a substantial increase over the late 70's, when only 20 percent of industrial R&D was tied to government-procurement contracts.[9] Holdren and Green at Berkeley calculated that, if one takes 15 percent and 25 percent as rough estimates of the fractions of corporate R&D that were actually defense-oriented in 1980 and 1985, then the fraction of all U.S. research and development spending directed toward military ends rose from 34 percent to 43 percent during the first five years of the decade.[10]

SDI clearly fueled much of the reorientation toward defense-driven technological exploration in the United States, although its influence served primarily to accelerate a trend already under way as the Reagan Administration came to power in January 1981. According to figures from the Council on Economic Priorities (CEP), SDI's share of the total national R&D budget grew from 3.1 percent in 1983 to 8.9 percent in 1987; that share would rise to just under 15 percent of all R&D done in the United States between 1988 and 1992 if the

7. This section draws heavily on the excellent work done by Professor John P. Holdren and F. Bailey Green of the Energy and Resources Group at the University of California, Berkeley. Holdren and Green have published their findings under the title "Military Spending, the SDI, and Government Support of Research and Development: Effects on the Economy and the Health of American Science" in the FAS (Federation of American Scientists) Public Interest Report, September 1986.

8. Figures on military R&D are taken from the official calculations of the Office of Management and Budget (OMB); figures on non-Federal sources derive from National Science Foundation data.

9. Frank Lichtenberg, "Private Investment in R&D to Signal Ability to Perform Government Contracts," draft report, Columbia University Graduate School of Business, June 1986.

10. Holdren and Green, op. cit., page 8.

Table 2
SDI as a Proportion of Total U.S. Research
and DOD RDT&E Spending
(1983 - 1987, in millions of dollars)

	1983	1984	1985	1986	1987	Total 84-87
Strategic Defense Initiative (SDI)						
DOD	912	992	1397	2687	3229	8305
DOE	54	118	224	285	514	1141
Total SDI	966	1110	1621	2972	3743	9446
DOD RDT&E	22,798	26,867	31,327	33,609	36,724	128,527
DOD SDI as % of DOD RDT&E	4.0%	3.7%	4.5%	8.0%	8.8%	6.5%
Total U.S. Research*	31,180	33,295	36,225	39,029	42,214	150,763
SDI as % of total U.S. research*	3.1%	3.3%	4.5%	7.6%	8.9%	6.3%

Source: Council on Economic Priorities, Star Wars: The Economic Fallout (Ballinger: Cambridge, MA., 1988), page 36.
* basic and applied research spending combined.

Administration's original budget requests were met (see Table 2).[11] SDI accounted for 6.5 percent of the Defense Department's actual budget authority for total RDT&E (Research, Development, Testing, and Evaluation) between 1984 and 1987.[12] Ashton Carter of Harvard's Kennedy School has calculated that, taking into account the substantial portion of SDI that actually represents the relabelling of already-existing projects, DOD's planned spending on SDI between FY 1984 and FY 1988 was about 22 percent higher than the

11. Council on Economic Priorities, Star Wars: The Economic Fallout (Ballinger: Cambridge, MA., 1988). Table 3-6, page 36.
12. ibid.

Table 3
SDI Growth as a Percentage of Growth of DOD RDT&E
and Growth in Total U.S. Research Spending
(in millions of constant 1987 dollars)

	1983	1984	1985	1986	1987	Total 84-87
Strategic Defense Initiative						
DOD	1051	1104	1501	2790	3229	8624
DOE	62	131	241	296	514	1182
Total SDI	1113	1235	1742	3086	3743	9806
SDI growth	-	10.9%	41.0%	77.2%	21.3%	37.6%
DOD RDT&E	26,271	29,889	33,660	34,900	36,724	135,173
DOD RDT&E growth	-	3618	3771	1240	1824	10,453
DOD SDI growth as % of DOD RDT&E growth	-	1.5%	10.5%	104.0%	24.1%	20.8%
Total U.S. research*	35,930	37,040	38,922	40,529	42,214	158,705
Total U.S. research growth	-	1110	1883	1606	1685	6284
SDI growth as % of total U.S. research growth		11.0%	26.9%	83.7%	39.0%	41.9%

Source: Council on Economic Priorities, Star Wars: The Economic Fallout (Ballinger: Cambridge, MA., 1988), page 36.
* basic and applied research combined.

Pentagon wanted to spend in any case, based on DOD budget projections made before President Reagan's SDI proposal in March 1983.[13] In order to gauge how fast SDI has grown compared to total Defense RDT&E and total national R&D, CEP calculated SDI growth as a percentage of growth in both defense RDT&E and national basic and applied research. They found that SDI accounted for almost 21 percent of defense RDT&E growth and nearly 42 percent of all the growth in U.S. research spending between 1984 and 1987 (see Table 3).[14]

Although SDI does not seem likely, by itself, to cause a substantial shortage of scientific and technical personnel in the United States, there are indications that it could divert some of the most talented minds away from commercial research, certainly in the short run, and perhaps permanently. SDI's impact on the labor market for scientific and technical personnel is difficult to gauge, but CEP has constructed a rough mathematical estimate indicating that SDI employment of engineers, scientists, and technicians would grow from about 9,000 in 1986 to 28,500 by 1991. For 1987 alone, SDI would employ 5 percent total employed by the Pentagon and just 0.5 of the total employed nationwide. (Between 25 and 30 percent of the nation's scientists and engineers are engaged in military activities, if one includes defense-related energy and space programs).[15] Nevertheless, SDI would be expected to create short-term bottlenecks in some areas. Moreover, a panel of the National Academy of Engineering found that engineers working in the defense sector tend to stay there throughout their professional careers, greatly reducing the opportunities for human-borne spinoffs from defense R&D to the commercial sector.[16]

Spinoffs

The typical list of potential commercial spinoffs cited by SDI proponents and the SDI Office of Educational and Civil Applications reads like a wholesale catalogue of next-generation dual-use technologies:

1. Electronic components that are lighter, smaller, more capable, and more energy efficient.

13. Research presented at the Kennedy School Research Conference on Dual-Use Technology, sponsored by the Dual Use Technology Project of the Science, Technology and Public Policy Program, John F. Kennedy School of Government, Harvard University, April 21-23, 1988.
14. Council on Economic Priorities, op. cit., Table 3-7, page 36.
15. Lloyd J. Dumas, The Overburdened Economy (University of California Press: Berkeley, 1986).
16. The Impact of Defense Spending on Nondefense Engineering Labor Markets: A Report ot the National Academy of Engineering (National Academy Press: Washington, D.C. 1986).

2. V.ry high speed integrated circuits and gallium arsenide IC's for superspeed communications and computing.
3. Optical computing that uses laser light instead of electronic circuits to transmit information near the speed of light.
4. Electrical system hardening techniques applicable to reduction or elimination of noise and other interference in communications systems.
5. "Artificial intelligence" or knowledge-based software aimed at enabling computers to learn from experience and to reason deductively based on stored knowledge.
6. New structural materials, design, and fabrication concepts being explored, such as fatigue-resistant metal composites and ceramic matrix composites with high fracture resistance, that may have widespread product potential in the automotive, maritime, and aerospace industries.
7. Free-electron lasers that can be used in non-invasive medical diagnosis, treatments, and surgical procedures.
8. Tomographic technologies that may enhance medical techniques by providing higher resolution for location and discrimination of soft tissue abnormalities.
9. Light-weight mirrors with computer-controlled adaptive alignment that can enhance laser applications in manufacturing.
10. Integration of laser technology, robotics, and computerized precision control techniques into applications that are also associated with a host of manufacturing processes--including microreplication and fabrication of microelectronic components--and bio-medical applications.
11. Ultra-precise sensing and measurement technology that may lead to new instrumentation for automated process control in manufacturing and medical research.
12. Cryogenic cooling systems that are lighter, smaller, and more efficient for use in food preparation and medical applications.
13. Space-based nuclear reactor technology (required to power electrically-driven weapons in space) that could ultimately make power in space relatively plentiful for commercial space factories.
14. Electrical power systems that are more efficient with respect to the ratio between task performance and orbit weights and volumes that will be less expensive to place in orbit and thus could translate into more economical access to space for industry.
15. Tracking and pointing technology developed for surveillance that could be used for commercial aircraft guidance and control as well as monitoring and scheduling of ground traffic.

To argue, however, that many of SDI's constituent technologies have potential applications in the civilian sector is one thing; to assert that SDI by its very existence promotes the commercialization of those technologies is quite another. Even if SDI is pushing the state-of-the-art for military applications, the successful commercial introduction of new technologies is driven in many cases by market demand. For that reason, the technologies listed above that are the most promising in terms of potential commercial application are already under development in the commercial sector. With so much potential competition from civilian companies in the U.S. and abroad, speed is the key to successful commercialization of an SDI-generated technology, speed with regard to the time it takes for the technology to become available for commercial exploitation. But speed is precisely what is sacrificed due to the prior pursuit of specialized military applications and the cumbersome bureaucratic procedures firms must follow to transfer technology from defense to the civilian sector.

Indeed, it is already evident that SDI exhibits many of the characteristics that have been associated in the past with a marked divergence between military and civilian applications of the same underlying technologies. These are characteristics that are associated, historically, with military research programs that have not helped--and have in some cases hurt--the long-term competitiveness of U.S. civilian producers.[17] The main characteristics we have identified are as follows.

First, although the program is clearly aimed at advancing the general technological state-of-the-art--a characteristic that should make civilian spinoffs more likely--technological advances attributable to SDI itself will be geared instead to the development of a specific military system. As Harvey Brooks notes, most of SDI's more generic constituent technologies were under development for years before being collected under a single budget category called "SDI"; future expansion directly attributable to the project will entail "a great deal of testing and hardware with little <u>additional</u> potential spinoff."[18]

Good examples of this are SDI research into knowledge-based computing (sometimes referred to as AI or "artificial intelligence") and gallium arsenide semiconductors. DARPA-funded research into both technologies was already well underway before the creation of SDIO. For example, DARPA has plunged $600 million into a five-year Japanese-style Strategic Computing Initiative, aimed at creating a trio of intelligent systems for each of the

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17. For a more detailed argument along these lines, see Jay Stowsky, "Beating Our Plowshares Into Double-Edged Swords: The Impact of Pentagon Policies on the Commercialization of Advanced Technologies" BRIE Working Paper #17, University of California, Berkeley (April 1986).

18. Brooks, Harvey. 1986. "The Strategic Defense Initiative as Science Policy" <u>International Security</u> Vol. 11, No. 2 (Fall) pp. 177-84. Emphasis added.

armed services; SDI's funding is similarly mission specific, aimed at building a computer system smart enough to coordinate millions of discrete events and expert systems geared specifically for testing hardware and software in the SDI program. Although it continues to fund AI projects worth approximately $200 million annually, SDI's interest in knowledge-based computing has actually flagged a bit of late. A major slowdown in AI research was announced at the end of 1986 by Lt. Col. Charles Anderson, deputy of technology development for SDI at the Rome Air Development Center (RADC) where most SDI AI research for battle management takes place. Lt. General James Abrahamson, head of SDIO, announced in 1987 that AI would only be explored for relatively simple problems in distributed systems.[19]

Similarly, SDI funding for research into the feasiblility of gallium arsenide for integrated circuits replaces or extends research sponsored by DARPA. The single largest SDI-funded GaAs pilot production line is at Rockwell (which has subcontracted a substantial portion of GaAs work to Honeywell), with SDI-funded work going on also at Hughes Aircraft and McDonnell Douglas, Raytheon, the California Institute of Technology, and several start-ups, including Microwave Monolithics and Advanced Research & Applications. Military funding has no doubt accelerated work on this technology in the United States. Commercial activity was relatively nil in the U.S. before DARPA constructed its first pilot production lines in 1982; at about the same time, IBM abandoned Josephson junctions in favor of GaAs in its efforts to build possible alternatives to silicon. Several civilian start-ups have also spun off from this research; Vitesse, for example, is headed by the former head of DARPA's pilot GaAs line at Rockwell. Yet Vitesse is working not on exotic Pentagon projects, but on building strategic alliances with large commercial silicon chip producers like Advanced Micro Devices and commercial supercomputer producers like Cray and ETA. Like other firms that have tried to focus on commercial applications of GaAs, Vitesse finds it more beneficial to address the commercial market directly rather than through technological advances gleaned from Pentagon projects.[20]

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19. Joseph Corrado, "AI in the Military: Expectations Move Closer to Reality," The Spang Robinson Report--2, June 1987.
20. "A start-up that's stepping on the commercial GaAs" Electronic Business (March 1, 1988) pages 90-92.

Second, the development of civilian applications out of SDI's generic research is inhibited at the outset due to a set of built-in military specifications that diverge widely from anything civilian users are ever likely to deem either necessary or affordable. These include performance specifications and reliability criteria related especially to space-based operation, nuclear battlefield survivability, and redundancy that is needed to ensure component failure rates of much less than one in a million on the average.[21] For example, although gallium arsenide chips may one day have substantial commercial applications in communications and computing due to their blinding speed and capacity for optical switching, SDI research into GaAs chips derives in large part from the fact that SDI computers must be able to withstand nuclear explosions, so the GaAs chips being built for SDI are optimized in terms of their inherent resistance to radiation as well as their inherently faster speeds. Directed energy systems have clear potential uses in medicine and industry where they must be able to operate reliably at low power levels for months or years at a time; the directed energy systems being built for SDI must operate at millions of Watts for only a few minutes at a time. Similarly, though X-ray lasers present important opportunities for applications in medical research and sub-micron semiconductor production, SDI researchers are working on X-ray lasers powered by nuclear explosions. As FAS's John Pike put it in testimony before Congress, "no hospital or factory is going to detonate atomic bombs in its basement on a regular basis."[22]

The fact is that most of the technologies claimed by SDI proponents to have substantial commercial applications are already in development in the commercial sector. In many cases, in fact, civilian firms are technologically in the lead. For example, in its report on SDI computing requirements, The Defense Technology Study Team (the Fletcher Panel) indicated that the computing speeds required for ballistic missile defense would actually be available in civilian computers by the mid-1990's. In other markets, for example, the market for artificial intelligence software (particularly expert systems), civilian applications are simply growing more rapidly than their military counterparts.

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21. O'Keefe, Bernard J. (1986). "The SDI and American R&D" International Security Vol. 11, No. 2 (Fall) pp. 190-92.

22. Quotation and examples from testimony by John Pike, Associate Director for Space Policy of the Federation of American Scientists, before a hearing on the "Impact of SDI on the U.S. Industrial Base," held by the House Subcommittee on Economic Stabilization of the Committee on Banking, Finance, and Urban Affairs, December 1985.

Third, although most of the technologies that are targeted for SDI-related research are at a pre-commercial stage, the Pentagon-dominated selection environment appears to be focusing the attention of innovative firms and researchers on product applications of obvious significance to military users. This is crucial, because the successful commercialization of a new technology normally involves what Nathan Rosenberg calls "learning by using," the incremental, interactive modification of each new product or production technique by potential civilian users, prior to marketing.[23] Although the Innovative Science and Technology Office is attempting to increase such interaction between SDI contractors and inventors in the broader technical community, the R&D effort remains entirely segregated from potential civilian users. Exploratory paths directed toward more generic applications that might be ultimately adaptable for both military and civilian use are thus being neglected and perhaps prematurely foreclosed.

Fourth, and finally, there already exist for foreign competitors a number of parallel, government-orchestrated R&D projects explicitly aimed at advancing the commercial state-of-the-art with respect to the same technologies underlying SDI.

Thus, the correct question to ask about SDI is not whether there will be any spinoffs; even most of SDI's critics acknowledge that an exploratory research program of SDI's sheer size and expected duration will surely produce something that also has commercial applications. In the face of aggressive government-supported efforts by foreign competitors, however, the correct question to ask about SDI spinoffs is: "compared to what?"[24] Whatever one's view of SDI's spinoff potential, commercial spinoffs from commercial R&D are a priori more likely than commercial spinoffs from military R&D.

Technology Transfer

To the extent that SDI actually pushes the state of the art of technologies now believed amenable to commercialization or develops commercially-viable technologies that no one has even heard of yet, successful commercialization will depend on the development of new institutional mechanisms to promote the transfer of SDI-developed technology to the

23. See Nathan Rosenberg Inside the Black Box: Technology and Economics (Cambridge: Cambridge University Press, 1982).
24. Brooks, op. cit., page 182.

commercial sector. One such mechanism is the Technology Applications Information System (TAIS), established by the Strategic Defense Initiative Organization (SDIO) in October 1987. TAIS is a free electronic database filled with more than 200 technical abstracts, all of which contain unclassified technical information developed under SDI sponsorship. Still, institutional routines die hard at the Pentagon: although technologies contained in the TAIS database are not classified, access to the database is somewhat restricted. U.S. companies and citizens wishing to use it must be certified first by the Defense Logistics Agency.

TAIS officials foresee dozens of commercial spinoffs from information contained in the database; aside from the sorts of spinoffs already discussed, TAIS lists such things as high-capacity batteries, superconducting materials, and laser doppler technology for tracking the migration of "killer bees." Besides gaining access to the basic technical information contained in the abstract, TAIS users can employ the database to discover whether the technology-in-question is in the research, development, or mature stage. SDIO will also provide users with information on the researcher responsible for the abstract, while at the same time supplying the researcher with information about the user inquiries. SDIO's Office of Technology Applications has organized monthly meetings to review technology transfer issues relevant to TAIS, particularly as regards which abstracts to include in the TAIS database. These meetings are slated to include representatives of universities and major corporations, private research institutes, and professional associations, as well as representatives of the federal labs.

SDI contains other program elements aimed explicitly at facilitating two-way technology transfer between the military and civilian sectors. These program elements, particularly the Innovative Science and Technology Office (ISTO) and the Office of Educational and Civil Applications (OECA), extend the public purposes of the research and development networks built by SDIO since its inception in 1983. To be sure, there is an element of political constituency-building in the creation of these networks, but it would be a mistake to discount the potential impact of SDI's new technology transfer mechanisms on the nation's science and technology development efforts. Such mechanisms in part reflect a new commitment by some in the defense establishment to use the Pentagon's considerable financial and organizational resources in a conscious, coordinated effort to strengthen the civilian technology base, at least as far as is needed to ensure the timely development of state-of-the-art military applications.

These efforts stem from a series of reports issued at the end of 1980 that detailed growing problems in the U.S. defense industrial base.[25] Two interrelated problems dominated the reports: (1) the rapidly escalating cost of military weapons systems; and (2) the Pentagon's increased dependence on foreign sources (primarily Japanese) for critical materials and microelectronic components. Just when the revolution in information technology seemed to afford the United States with an opportunity to achieve politically decisive technological superiority over the Soviet Union, defense planners discovered that the Pentagon's habit of targeting R&D spending on a few major weapons systems was starving development efforts at the subsystem, component, materials, and base technology levels. Subsequently, groups within and around the Pentagon began to support a set of Defense Department initiatives aimed at strengthening the nation's civilian technology base, particularly in the areas of semiconductors and machine tools.

Thus both SDIO and DARPA fund and coordinate research and development efforts that bring together government, industry, and leading universities in ways that sometimes consciously parallel the Japanese developmental model, but with military applications as the primary goal. Recent public-private partnerships sponsored by DARPA or the Pentagon's Office of Science and Technology include the Very High Speed Integrated Circuit Program (VHSIC), the Strategic Computing Initiative (SCI), and the Monolithic Microwave Integrated Circuit Program (MMIC). The competitiveness of U.S. civilian producers has been an important aspect of the Pentagon's various ManTech programs, and a primary feature of DOD's subtantial involvement in the Semiconductor Research Consortium (SRC), the Microelectronics and Computer Technology Corporation (MCC), and the semiconductor industry's new manufacturing consortium (Sematech), for which DARPA will provide half the funding and most of the government oversight. The Pentagon has recently sponsored the creation of a Defense Manufacturing Board as a companion to the Defense Science Board and

25. House Armed Services Committee Industrial Base Panel Report, "The Ailing Defense Industrial Base; Unready for Crisis" (Chairman, Richard Ichord), December 31, 1980; Defense Science Board Task Force report on industrial competitiveness (Chairman, Robert Furhman), November 21, 1980; the Air Force Systems Command statement on defense industrial base issues (General Alton Slay), November 21, 1980; and Jacques S. Gansler, The Defense Industry (Cambridge, Mass., MIT Press, 1980).

has requested that the National Academy of Sciences set up a manufacturing advisory committee.

Together these efforts represent a new willingness among Pentagon planners to participate consciously in the strategic direction of certain "militarily critical" civilian industries, particularly semiconductors and machine tools. Moreover, as institutional forms, these mechanisms look increasingly likely to outlast both the Reagan Administration and SDI itself. Despite the utopian and apocalyptic consequences variously ascribed to it by proponents and critics, SDI is a very specific proposal bedevilled by uncertainties with regard to its technological and budgetary feasibility; its future seems increasingly tied to the short-term political fortunes of the Republican Party. However, institutional innovations such as SDI's Technology Applications Information System, the Innovative Science and Technology Office and the Office of Educational and Civil Applications represent a broader, more politically stable commitment by members of the defense establishment to purposefully promote the economic competitiveness of certain "militarily critical" civilian industries. Again, there is a large element of public relations and political constituency-building to these efforts. But as institutional innovations in and of themselves, they could ultimately create a new sort of organizational capacity in the United States. That would be the capacity to generate a constant stream of scientific and technological discoveries underwritten with tremendous government support, discoveries that would then be transferred, with government assistance, between the military and civilian sectors.

Such a system is not likely to be created overnight. TAIS is quite similar to the Department of Commerce's National Technology Information Service (NTIS), a database that includes all DOD technical publications that have been approved for public release as well as all other government-produced research, development, and engineering reports. Civilian firms have been slow to take advantage of this resource, however, and sometimes for good reason; the information is so "available" as to be virtually worthless to a firm that hopes to use proprietary technical know-how to gain a leg up on the competition. What is more, firms wanting to take advantage of this cheap resource must first make their way through a thicket of bureaucratic red tape. Access to all such information is governed by DOD Instruction 5200.21, "Dissemination of DOD Technical Information," which establishes certification procedures for potential users of the database; potential users must fill out DOD Form 1540, "Registration for Scientific and Technical Information Services" and must be included in the "Dissemination Authority List" published quarterly by the Defense Technical Information Center of the Defense Logistics Agency. Whether the information is ignored by firms on purpose (because it is too easily available or simply irrelevant to commercial pursuits) or simply bottled up by bureaucratic procedures in the federal labs, the result is the same: only about 4 percent of some 28,000 U.S. government patents have ever been licensed.[26]

In addition, many firms shy away from government-funded work to avoid running afoul of various technology export controls, all of which can be applied to unclassified work. DOD Directive 5230.25, "Withholding of Unclassified Technical Data from Public Disclosure" provides for a fine and/or imprisonment of any domestic contractor who continues to disseminate technical data with military or space application once that data has become subject to license requirements of the Export Administration Act or the Arms Export Control Act. Most transactions under the Export Administration Act involve agencies other than the Department of Defense. Under the Arms Export Control Act, however, the Defense Department must establish a "position" on each export license application of military significance. Significant items are typically those included on the Pentagon's list of "militarily critical technologies," (MCT's). The MCT list has been updated periodically since its enactment in 1979 and includes all of the advanced technologies under development for SDI.

SDI and the Private Sector: Some Overall Patterns of Firm Involvement

4,800 SDI contracts have been awarded to more than 500 for-profit companies, roughly 100 universities, and about 100 non-profit organizations during the program's first five years, 1983-1988.[27] SDIO funding has totalled $15 billion, although only $7.2 billion of that amount has actually been obligated. 78 percent or $12 billion of the total has been awarded to industry, 12 percent or $1.8 billion to the federal labs, 4 percent to other

26. Figure cited by D. Bruce Merrifield, the Reagan Administration's Assistant Secretary of Commerce for Productivity, Technology, and Innovation. See Stewert Nozette and Robert Lawrence Kuhn (eds.) Commercializing SDI Technologies (Praeger: New York, 1987), page 40.

27. Figures from the Federation of American Scientists. The FAS data base is compiled from Defense Department contract announcements, the SDIO contracting list, Freedom of Information Act requests, and news reports. Aviation Week & Space Technology, March 21, 1988, page 17.

government agencies, 3 percent to universities, 1 percent to non-profit organizations, and 2 percent to foreign entities. The top ten contractors, in terms of absolute dollars, are traditional defense contractors engaged primarily in the development of operational systems and prototypes--Lockheed, GM/Hughes, TRW, Boeing, Rockwell, McDonnell Douglas, General Electric, Martin Marietta, Teledyne, and EG&G. In terms of basic generic and applied research, however, a very large number of SDI contracts have been awarded to small innovative start-ups.

Late in 1987, High Technology Business surveyed the presidents of the 318 companies that have received more than $100,000 worth of SDI-related contracts.[28] Although contracts have been awarded to a large number of companies, the survey indicates that most of the contracts are fairly small; thus far, SDI work has consisted mainly of small laboratory experiments. Nearly half of the survey participants report deriving less than 20 percent of their income from SDI work (Table 4), and over one-third of the respondents report receiving annual contracts worth $50,000 or less (Table 5). In part, these results reflect the fact that the biggest SDI contracts (in absolute dollars) have gone to the biggest firms (Table 6), and so represent a relatively small percentage of total revenues; on the other hand, it is common for smaller companies, whose annual revenue typically falls between $50 million and $500 million, to report SDI-related income at between 10 and 40 percent of the total. It is not surprising in light of these findings that fewer than 10 percent of the respondents have bothered to set up a new division or department to deal with SDI-related contracts (Table 7). Only 3 percent of the company presidents reported having acquired other companies or divisions in order to increase their SDI capabilities and just over 5 percent had any plans to do so during 1988.

28. 135 usable surveys were returned, for a response rate of approximately 42 percent. Questionnaires were mailed to the companies' presidents and were followed by telephone calls to those who did not respond initially. High Technology Business (December 1987).

Table 4
Percentage of Annual Revenues Derived from SDI-related Work in Companies Receiving more than $100,000 worth of SDI-related Contracts

	Number of Respondents	Percent of Total
less than 1 percent	24	17.8%
1-10 percent	40	29.6%
10-20 percent	22	16.3%
20-30 percent	13	9.6%
30-40 percent	6	4.4%
40-50 percent	6	4.4%
50-60 percent	7	5.2%
60-70 percent	2	1.5%
70-80 percent	1	1.0%
more than 80 percent	6	4.4%
no response	8	5.9%

Source: <u>High Technology Business</u> (December 1987).
note: percentages may not total 100% because of rounding

Table 5
Annual Revenue Received from SDI-related Contracts

	Number of Respondents	Percent of Total
$0 - $50,000	47	34.8%
$50,000 - $100,000	12	8.9%
$100,000 - $250,000	14	10.4%
$250,000 - $500,000	10	7.4%
$500,000 - $1 million	12	8.9%
$1 million - $2 million	9	6.7%
$2 million - $5 million	6	4.4%
$5 million or more	8	5.9%
no response	17	12.6%

Source: <u>High Technology Business</u> (December 1987)
note: percentages may not total 100% because of rounding

Table 6
The Top 20 SDI Contractors as of March 1987

Organization	Contracts Awarded (millions)
1. Lockheed	$1,024
2. General Motors (Hughes Aircraft)	734
3. TRW	567
4. Lawrence Livermore Lab	552
5. McDonnell Douglas	485
6. Boeing	475
7. EG&G	468
8. Los Alamos Lab	458
9. General Electric	420
10. Rockwell International	369
11. Massachusetts Institute of Technology (MIT)	353
12. Raytheon	248
13. LTV	227
14. Fluor	198
15. Grumman	193
16. Gencorp	191
17. Teledyne	189
18. Honeywell	151
19. Martin Marietta	134
20. Textron	118

Source: Federation of American Scientists; reprinted in High Technology Business (December 1987)

Table 7
Number of Firms that have set up a New Division or Department to deal with SDI-related Contracts

	Number of Respondents	Percent of Total
New Division/Department	13	9.6%
No New Division/Department	117	86.7%
no response	5	3.7%

Source: High Technology Business (December 1987)
note: percentages may not total 100% because of rounding

Table 8
Company Presidents' Rating of the Potential for Commercialization of the SDI-related Technology in which their Company is Involved

	Number of Respondents	Percent of Total
Extremely High	24	17.8%
High	21	15.6%
Moderate	31	23.0%
Low	28	20.7%
Extremely Low	17	12.6%
no response	14	10.4%

Source: High Technology Business (December 1987)
note: percentages may not total 100% because of rounding

The survey results also indicate that, for the most part, firms participating in SDI have chosen to do so in order to receive the direct benefits of the program's contract dollars, rather than out of any great confidence in the program's ability to produce profitable commercial spinoffs in the future. Precisely a third of the respondents classified the potential for commercialization of the SDI-related technology in which they are involved as "high" or "extremely high." More than half view the potential for commercial spinoffs as moderate, low, or extremely low (Table 8). Moreover, whether it produces profitable spinoffs or not, many company presidents appear to view SDI as primarily a short-term funding opportunity; 40 percent expect the SDI budget to decrease after the Reagan Administration leaves office while only 11 percent expect an increase.

As for the nature of the government support that is being given to firms through SDI, indications are again mixed as to whether current defense-driven technological development efforts are likely to generate future civilian spinoffs. It is generally argued that the prospects for civilian spinoff from military R&D have been diminished by the preponderance of "development" as opposed to "basic research" in the Pentagon budget. If so, then SDI might be expected to contribute more civilian spinoffs than the typical Pentagon program. Whereas less than 3 percent of the Pentagon's annual R&D budget was devoted to basic research during the late 1980's, SDI planners have announced plans to devote approximately one-third of their total budget to work on the technology base. This is still less than the 37 percent usually devoted to basic research in civilian R&D projects sponsored by the federal government, but it represents a ten-fold increase in Pentagon efforts, nevertheless. Recent budget requests suggest, however, that SDI is already drifting away from this basic research orientation. According to the Federation of American Scientists, 49 percent of the FY 1987 budget request for SDI was for operational experiments; the bulk of SDI funding targets three program elements--lasers, kinetic energy weapons, and battlefield tracking and surveillance systems--all of which have emphasized hardware demonstrations and prototype development in their budget plans through 1991.[29]

Patterns of Influence: Brief Case Studies of Small Firms Participating in SDI Research

At the stage of basic research, before the direction of a technology's commercial development has been defined and confirmed by a pattern of private-sector investment, short-term government funding can have significant long-term consequences. For example, SDI has in many cases already provoked the first tentative steps toward commercialization of an emerging technology. Like other Pentagon agencies, however, SDI is a jealous parent. No sooner has the program fostered the development of an innovative firm, but that the firm is sequestered from interacting with the civilian marketplace. Geltech Inc., a 14-person start-up located in Alachua, Florida, is a fairly representative example.[30] The firm grew out of ISTO's strong interest in some pioneering research being carried out at the University of Florida into a new technology for making glass. Among SDI's many putative components is a set of large, lightweight mirrors that would be used, in theory, to bounce directed energy beams at incoming missiles. The Florida researchers claim to have found a way to mix silica-based solutions that harden into glass, which means that the glass can be poured to fit any mold the customer might like. In addition, the process supposedly produces glass that is

29. Council on Economic Priorities, Star Wars: The Economic Fallout (Cambridge, Mass.: Ballinger, 1988), page 138.
30. Much of the historical information on Geltech is drawn from Jay Finegan "Star Wars Inc." Inc. Magazine, April 1987.

purer, stronger, and more easily set into large pieces than anything produced by melting sand in the traditional way. These properties are quite attractive to SDI officials, as well as to medical researchers looking into the use of glass as a material to replace human bone during bone-graft operations, and other civilian companies interested in laser applications to manufacturing processes.

Given that there is already a potential market for the product, ISTO's involvement in Geltech works to promote the commercialization of the new technology in two important ways. First, government support serves as a sort of letter of credit, enabling the research group to gain credibility with the university and to raise private capital for its needs. (As part of the start-up deal, Geltech paid the University of Florida $380,000 for the right to license its 12 patent applications). Second, should Geltech succeed in its plan to eventually market its product to civilian users, SDI funding will have provided a substantial subsidy from defense to commercial development. That subsidy should help Geltech establish a competitive position in the marketplace since development costs will not have to be imputed to product price. At such an early stage in the product life cycle, SDI is a source of seed money, not profits. But SDI is a crucial benefactor. Geltech's initial $1.6 million, 16-month contract covers approximately half of the firm's costs for constructing a pilot plant in which to explore the physical properties of the glass while also effectively demonstrating its reliability.

Unfortunately for Geltech, however, the price for Pentagon parentage may be a lifetime of stunted growth. The successful commercialization of a new technology requires not only its embodiment in a saleable product, but also its widespread diffusion to a variety of potential users. The Defense Department is so impressed by the company's existing patents, however, that it has classified the Geltech process as a "critical technology." In effect, that classification prohibits widespread commercial diffusion; it forbids Geltech from disclosing its patents publicly.

In some cases, the inventor of a new technology "escapes" from a defense-sponsored R&D project before classification restrictions can impede further commercialization and diffusion of the invention. Nevertheless, on-going development of the technology may then bifurcate, with defense-directed projects holding a distinct advantage over civilian ventures in overall funding. Pentagon funding may still be said to have given commercialization a push, since civilian ventures are sometimes started with money earned when a defense-contractor buys one or more of the original partners out. But if parallel development in military and civilian settings leads to the creation of competing versions of the new technology, the one that wins out may be the one that benefitted earliest from a large launch market, even if it is not technically the "best" of the two.[31] In the case of a technology that is new, relatively untried, and therefore risky, the Pentagon is likely to provide that launch market sooner than a profit-oriented civilian firm. The military-relevant technology that then dominates U.S. product offerings may prove vulnerable in the long run to simpler, less expensive products offered by foreign firms, firms that have been targeted from the start on developing the technology to serve the needs of civilian users.

An example of this sort of process is the case of EERG (for "Energy/Environmental Research Group"), a small company now based in Melbourne, Florida.[32] EERG began in 1980 as a small consulting firm consisting of three colleagues associated with the astronomy department at the University of Arizona at Tuscon. Among their creations was a technique for improving the quality of electronic photography, which converts images into electronic impulses that can be bounced off satellite sensors to be read, stored, and transmitted by computer. Unlike traditional photography, which utilizes chemical processes for gathering light on film, electronic photographs depend on a medium, called a pixel, that will collect electronic impulses and emit light in response. An electronic picture is made up of thousands of responding pixels, themselves located on the faces of tiny integrated circuits. The problem is that the borders of the chips have persistently undermined the sharpness of the photographic images that can be picked up by satellite sensors.

In 1985, two members of EERG patented an optical technique which uses a series of geometrically exacting prisms to "trick" the computer chips into appearing borderless. The technique was patented under the name Rimstar and was of immediate interest to the officials ruuning SDI. Because of the "border" problem, satellite sensors typically have limited peripheral vision, which means that they have to continuously scan in order to monitor large amounts of territory. If the satellite is scanning in the wrong place at the wrong time, it is

31. See W. Brian Arthur "Competing Technologies: An Overview" CEPR Publication No. 98, Center for Economic Policy Research, Stanford University, July 1987.

32. For historical material see Finegan, op. cit.

liable to miss the launching of an enemy missile attack. For SDI proponents, Rimstar presages the development of a fixed, infrared electronic eye, capable of uninterrupted crystal-clear surveillance of large tracks of land. For the civilian market, Rimstar offers improved control and guidance of commercial aircraft (in the air and on the ground; at night and in bad weather) and a tremendous boost to high-definition image transmission, a key competitive advantage for firms looking to leverage the emerging global digital telecommunications infrastructure.

With respect to its impact on the trajectory of technological development, SDI appears to be diverting further development of Rimstar down a path largely relevant to applications of a military, as opposed to a commercial, nature. To be sure, Pentagon money has helped, indirectly, to launch a new Arizona firm that will be devoted, in part, to civilian applications of enhanced electronic photography; one of the technique's inventors disdained government work and was bought out by DBA Systems, Inc., a Melbourne, Florida defense firm. Nevertheless, the other inventor stayed with EERG, now Florida-based as well, and received a three-year, $4.5 million contract from SDI to adapt Rimstar to specifications that are irrelevant to the civilian market. In simplest terms, SDI officials want EERG to design an infrared optical sensor capable of operating in the harsh environment of space and the incomparably harsher environment of nuclear missile attack. If the company is successful, it will be in line to participate in the actual development of one of SDI's core systems (an early warning and missile-tracking system). Because of the sophisticated (and expensive) environmental operating specifications which will have been developed in the course of these projects, however, the first product spin-offs from this work are likely to be military as well--infrared cameras for use in tanks, helicopters, and TV-guided missiles.

Indeed, it is already clear that the quickest and most numerous "spinoffs" from SDI will occur in the area of conventional weapons systems, if only because the technological overlap among different military systems is typically greater than the overlap between any particular military system and its civilian analog. According to Gerold Yonas, SDI's former Chief Scientist, research into hardened sensors and other components needed to enhance the lethality and survivability of SDI systems will benefit a wide range of military systems that must also continue to operate under harsh battlefield conditions. Advances in radar, lasers, and battlefield communications management software can be employed to improve air defense capability in a variety of combat situations by providing more wide-ranging surveillance and real-time display of highly distilled information. Most important, perhaps, from a strategic viewpoint, is the fact that high-power directed and kinetic energy devices can be used for tactical defense, while advanced sensors, data processing, and programming methods greatly enhance the capabilities of high-leverage "smart" tactical weapons.[33]

Conclusions

We spoke of technological change, at the outset, as a path-dependent process in which choices made about the direction of technological development and its diffusion today simultaneously open and foreclose future learning opportunities and the prospects for future economic development that those opportunities imply. This is because much technological knowledge is "local," in the sense that it becomes embodied in particular people and sequestered in particular organizational networks that cannot be traded or easily communicated across national borders. We may speak, therefore, of different national technological trajectories that imply different opportunities for further technological development and long-term economic growth.

By directing much cutting-edge technological development toward the creation of a politically decisive technological advantage in weapons systems, SDI contributes-- along with a growing set of Pentagon-sponsored public-private partnerships--to the development of a particular type of national technological trajectory in the United States. That trajectory is directed primarily at sustaining American leadership in those sectors of civilian industry that are most closely involved with the development of key military-relevant technologies. Not coincidentally, that leadership will be reflected in the performance of America's <u>conventional</u> weapons systems, whether or not the fabled "peace shield" ever gets off the ground.

The contribution of these Pentagon-sponsored efforts to America's broader economic position is another matter. To the extent that military and civilian applications overlap, the Pentagon's tendency so far has been to segregate the technologies from civilian users or to prevent commercial diffusion outright. More importantly, however, massive public efforts

33. Yonas, Gerold. 1986. "Research and the Strategic Defense Initiative" <u>International Security</u> Vol. 11, No. 2 (Fall) pp. 185-89.

such as SDI may contribute to a national environment in which defense-relevant versions of new technologies gain a competitive advantage over their commercial counterparts simply by virtue of having a larger launch market. This advantage reflects what Arthur refers to as "increasing returns to adoption," economic returns that accrue as more and more users begin to favor one technology over other, otherwise acceptable technologies capable of meeting the same basic need.[34]

The problem is that such national-level economic advantages may prove irrelevant in an international market that is driven by the needs of civilian users. In that environment, American products spun off from military research have to compete on cost and quality with foreign products that were developed initially in an entirely commercially-driven environment. Those products may have already benefitted from increasing returns to adoption in their country of origin. Consequently, the price and performance requirements of early adopters in those other countries probably reflect the developing requirements of civilian customers in the international commercial market better than the more esoteric military requirements of early adopters in the United States. It is in that sense that SDI and other big Pentagon-sponsored R&D efforts "skew" the national technological trajectory in a direction that may ultimately undermine the ability of American firms to compete in international high tech markets.

The consequences may not remain confined to commercial markets, however, because of the extent to which today's state-of-the-art military applications depend on breakthroughs generated years earlier by the civilian technology base. Indeed, the Pentagon's concern over the nation's growing dependence on foreign sources for essential components involves components and sub-systems that were originally developed for civilian markets. It may be true, as Lester Thurow has argued, that no defense project can be justified or rejected solely on the basis of its economic impact. A defense project can surely be judged ill-advised, however, if its economic impact--in this case its impact on the civilian technology base--actually undermines the nation's capacity to defend itself. That is the prospect faced by the

34. Increasing returns to adoption may accrue in the form of network externalities (the advantages of belonging to a large network of users), learning by using, scale economies in production, the development of better information about the technology as it gains widespread use, and the development of other sub-technologies and products that become part of the new infrastructure dedicated to supporting that version of the technology. Arthur (1987) op. cit.

United States if commercial applications continue to drive further technological development in technologies crucial to the nation's defenses. The Pentagon may be getting more serious about finding ways to transfer relevant defense-developed technologies to the commercial sector, but it would also do well to consider the ways in which it could take better advantage of the potential spinoffs that are piling up in the opposite direction.

NATIONAL AUTONOMY AND DEVELOPMENT STRATEGY: INFORMATICS POLICY IN BRAZIL

Lisa Bornstein

Brazilian government policy towards science and technology development has become a focal point for economic and political trade discussions. Brazil's passage of the 1984 Informatics Law, which formalizes the Brazilian government's policy toward high-tech infant industries, led the U.S. to impose trade sanctions against Brazil, and led other Third World policy-makers to examine the replicability of the Brazilian strategy.

The central thrust of the Brazilian strategy has been to protect and support the growth of strategic industries. This has been accomplished by simultaneously developing the infrastructure needed for technological development and by protecting the market in targeted industries from foreign competition.

The Brazilians have been pursuing similar policies since the 1920s, with respect to a variety of industries, as part of an import substitution industrialization strategy. What differs with the recent events is, first, the extreme importance of Brazil's actions toward technological development for both national and international political and economic relations and, second, the particular mechanisms used to protect the industry.

As Renato Archer, the Brazilian Minister of Science and Technology, writes, "in our contemporary world we can only strive for national development on the basis and models chosen by those countries which hold the levers of scientific and technological progress which are today, as President Sarney stated, synonymous with sovereignty."[1] The Secretariat of Informatics (SEI) further explains, "the Government was convinced that informatics was strategically important to the nation and that, therefore, Brazil needed a policy which would enable it to acquire the technical capability necessary to reduce its dependence."[2]

1. Archer, Renato, "Brazil's Informatics Policy Achieves Success," Transnational Data and Communications Report 9:10 (October 1986), pp.19.
2. United Nations Centre on Transnational Corporations (UNCTC), Transborder Data Flows and Brazil, prepared by Special Secretariat of Informatics-SEI (New York: United Nations, 1984), p.63, #175.

The importance of Brazil's policy for international relations transcends political rhetoric. First, as presented in the introductory essay by Manuel Castells, technological change is an important force generating global economic restructuring. Not only do these new technologies provide the infrastructure for the global economic system, but the new "high-tech" industries are also among the most productive and fast-growing industrial sectors. Concretely, we have the examples of the Asian NICs--countries which have used the opening of new markets and new industries, and the growth of new skill requirements, to develop internationally competitive industries. These countries have grown in both economic and political importance as a consequence of their new competitiveness and prosperity.

A central thesis of this work is that there are two fundamental sources of national autonomy and power--they are steady economic development and military strength. A review of the new international economic powers suggests that access to sophisticated technologies and production capabilities in high-technology industries are important sources of both economic and military strength.[3] In addition to the direct financial implications of lessening technological dependence--which may include the reduction of payments for technology imports and the expansion of local production for domestic and export markets--technological development has immediate consequences for the power of the state. As Erber notes, it is a political characteristic of the state to have a "monopoly of the means of violence"; this necessarily entails the capacity to design and produce weaponry. He further writes that control of local economic activities from abroad weakens the political and economic cohesion of the nation, and thus "undermines the sovereignty of the state."[4]

Technology appears to be a critical factor in attaining national power; a belief in this link has motivated much of Brazilian policy, as a review of Brazil's technological development will demonstrate. To what extent the reality of Brazil's policies and actual technological achievements have contributed to national power is a central question of this report.

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3. Dosi, Giovanni and Luc Soete, "Technology Gaps and Cost-based Adjustment: Some Explorations on the Determinants of International Competitiveness," Metroeconomica 35:3 (October 1983), pp.197-222.
4. Erber, Fabio, "Science and Technology Policy: A View from the Periphery," in Joseph Szyliowicz (ed.), Technology in International Affairs (New York: Praeger, 1981), pp. 190-191.

Brazil, like many countries, has a long-tradition of aspiring for national greatness. From the 1920s to the present, national progress has been the rationale for the ISI strategy and other modernization programs: industrialization was portrayed as the road to modernization and power. Likewise, the founding of Brasilia was based on the image of nation-building, of starting anew. The modernization of the military, the acquisition of nuclear power plants, the development of an arms export industry, the construction of the Itaipu dam, and the protection of high-technology industries have all been described by Brazilian officials and analysts as "strategically" important to Brazil's national integrity.

The combination of this nationalist drive with the reality of an international economy in which latecomers may still get front-row seats, provides an explanation for both the U.S. reaction and Third World interest in Brazil's computer policy. If Brazilian support for infant industries (such as that of computers) can lead to the creation of new internationally competitive firms, then there is cause for retaliation by the established producing nations (such as the U.S.) and for emulation by aspiring producers. What remains uncertain is, first, whether entry into the international computer market is still possible for latecomers and, second, to what extent the Brazilian policies have succeeded in creating internationally competitive high-technology industries. Leaving aside the first question for time to resolve, we shall turn to the second--the nature and success of Brazil's informatics policy.

In addressing this topic, I first present, in Part 2, the technological policies of the Brazilian government since the 1940s; this allows the Brazilian computer policy to be viewed in light of other technology policies and highlights the inderdependence of technological advances. Part 3 turns to an analysis of the development of the Brazilian computer industry in which the role of the Brazilian government in providing the conditions necessary for the development of the computer industry is explored. The success of the policy for domestic production capacity is assessed and the likely consequences of the policy are examined in Part 4. Finally, in the conclusion, areas for further research are outlined.

This report attempts only to outline the current debates, present some plausible explanations of the relationship between technological development and political and economic change, and propose questions requiring additional research. The report relies on secondary data and library research, and draws heavily on the works of Emanuel Adler, Clelia

Piragibe, Ravi Ramamurti, Paulo Tigre, and the United Nations Centre on Transnational Corporations. The lack of recent data (in this rapidly changing field) necessarily limits the conclusiveness of the findings of this report. As such this report attempts more to incorporate existing findings into a broader analytical approach than to present original case study material.

Science and Technology Policy in Brazil

Technology policy in Brazil has gone through dramatic changes in the last thirty years. From a minor aspect of industrial policy, science and technology have moved to the forefront of Brazilian policy debates and have formed a central component of Brazil's political and economic development strategies.

First, economic and military strength are sources of national power in the international arena. The current techno-restructuring of the global economy leaves those countries without technological capabilities unable to participate [economically]. Technologies obtained abroad, through licensing, joint ventures or foreign direct investment, are problematic since the host country remains highly dependent on suppliers for training of local technicians, maintenance and repairs of the system, and further technological upgrading of the system. This is particularly troublesome in light of the rapid pace of technological innovation and obsolescence. Most apparent in the defense sector and the communications sector, such dependence undermines national autonomy, security, and integrity. The lack of technological capabilities virtually precludes the development of autonomous military strength; technological dependence necessarily entails strategic military weaknesses.

The growth in the importance of science and technology reflects, second, the increasing importance of technological infrastructure and skills to participation in the global economy. Telecommunication links are now essential to economic activity and confer competitive advantage on those countries and firms which are best able to access and use information. International markets are increasingly available, contested, and quality sensitive; economic success in these markets depends on information as to fluctuations in demand and preferences, and the ability to respond with production and distribution adjustments.

Third, technological and scientific know-how has been a springboard for the development of the Asian NICs (which have capitalized on the micro-electronic revolution). This has inevitably caused other Third World countries to examine whether they too can foster internationally competitive "high-technology" firms.

National governments have a critical role in providing both the infrastructure and the foundations for technological development in all three areas--defense, economic infrastructure, and production activities. Erber explains the technology programs of Third World countries by noting that, "in the present conditions of many markets, where technology is a critical competitive asset and where most national states (especially the more developed ones) support the technological development of local enterprises, if a specific state does not provide such support to national enterprises, the latter are automatically placed in a disadvantageous position in terms of international competition in such markets."

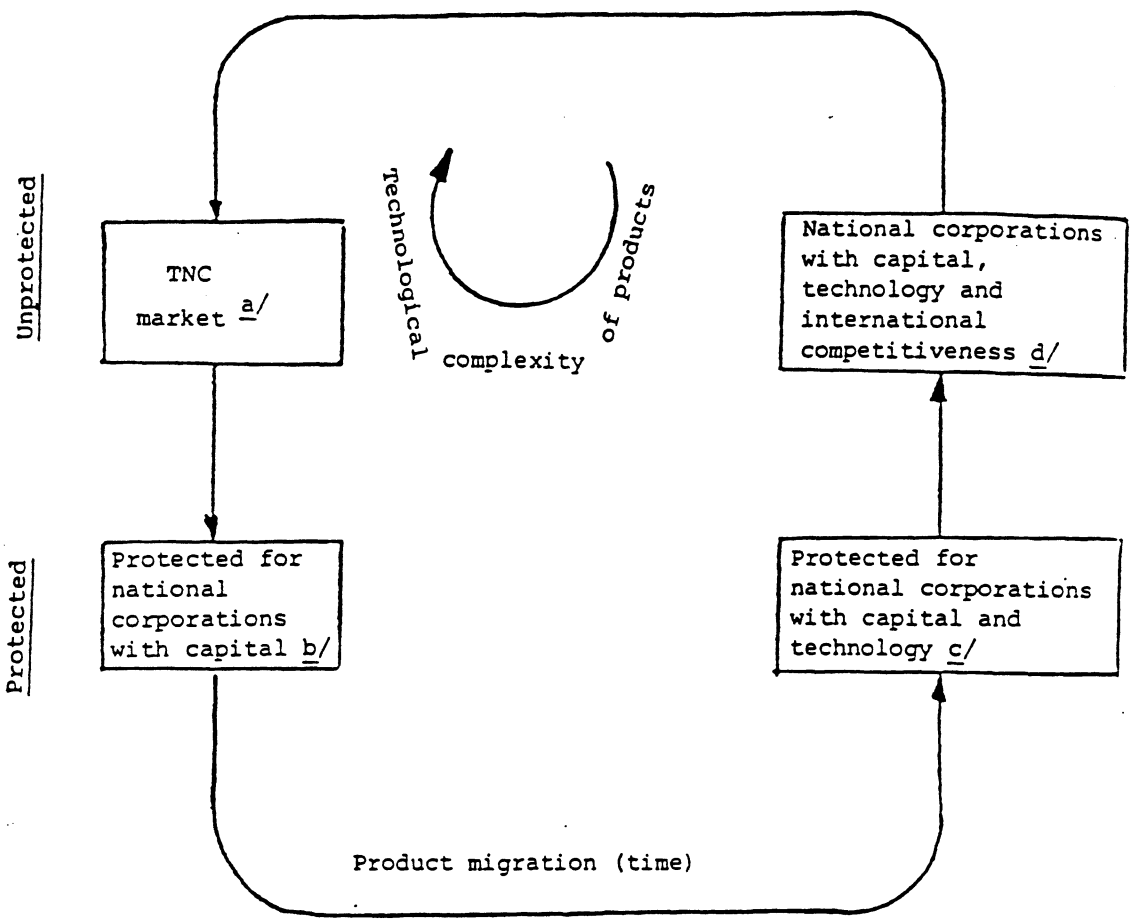
The centrality of science and technology policy to Brazil's national plans reflects these changes in the international techno-economic structure. Science and technology policy in Brazil also reflects changes in the domestic economy and society over the last thirty years. An examination of how both local and international conditions have shaped Brazil's technology policy attests both to great continuity in industrial policy and to strategic adjustments to the changing international context.

Current Status of Brazilian Information Technology Policy.

Technology policy in Brazil, as of 1988, rests in the offices of the Special Secretariat for Informatics (SEI). This agency, which up until 1986 was directly accountable to the National Security Council and the President, is responsible for policy in the areas of informatics, telecommunications, telematics (the connection of the first two), and transborder data flows (telematics extended to the international realm). As such, SEI has considerable power to recommend and implement policies regarding technology transfer, trade, infrastructure development, and industrial development.

The 1984 Informatics Law most clearly delineates the elements of Brazil's current computer policy. The Law formalizes the policies articulated in the late 1970s and early 1980s. It reaffirms the government's commitment to the protection of infant industries such

Figure 1
Brazil's Industrial Informatics Strategy



Source: Special Secretariat of Informatics.

a/ Not protected (transnational corporations are welcome if they export and use state-of-the-art technology) because national corporations are not yet able to enter production.

b/ Protected for national corporations (which can use foreign technologies) because they are able to invest, but do not yet have their own technology.

c/ Protected for those national corporations that have their own capital and technology, but are not yet fully competitive on the international market.

d/ Protected barriers are lowered because national corporations are competitive on the international market. Local technology is still required and preventive measures are being taken to maintain control of the national industry.

Source: UNCTC, 1984, p. 66.

as micro-computers and peripherals. It specifies when industries will be classified as internationally competitive and when they qualify for protection. It is this law that has sparked the U.S. claims of an unfair trade practice and has drawn additional international attention to the successes and failures of the Brazilian policy.

Figure 1 depicts the elements of the informatics policy. Four stages are identified. In the first stage, the technology is beyond the capabilities of Brazilian producers. Foreign producers are encouraged to supply the Brazilian market both with products and technology. The second stage is reached when Brazilian companies have the capability to produce technologically sophisticated goods but not the ability to generate the technologies domestically. In this case, the market is protected and these infant firms supported through subsidies and government assistance in obtaining technologies from abroad.

When firms have both domestic financial and technological foundations for production, they have reached the third stage. The government begins to introduce export incentives and encourage increased competitiveness. The market in this third stage is still protected form foreign competition. In the fourth stage, when the firms are internationally competitive as well as have indigenous capital and technology, market protection mechanisms are removed.

The Brazilian informatics policy assumes that the technological sophistication of firms at all stages of the process will increase. It is also understood that because of the relative lack of Brazilian experience with technologically sophisticated products, stages three and four will be more easily achieved with the low-end of high-technology products.

The Informatics Law additionally specifies that the market reserve will be enforces for at least 8 years, until 1992. It further defines that a Brazilian firm, one allowed to produce in Brazil under market reserve protection, is one where Brazilians have majority control over stock ownership, managerial decision-making, and technological development.

In one sense, informatics has been accorded a privileged position in Brazilian policy. The sector has been supported politically and financially throughout the recessions and crises of the last twenty years. The Brazilian government has continued support despite United States retaliatory trade policies. The informatics policy has further provided a model and rationale for similar protection and support of other technologically strategic sectors.

In another sense, however, the informatics policy is not a radical departure from past industrial practices. The Informatics Law has its foundation in laws dating back to the 1940s. The Brazilian government has repeatedly returned to an import substitution industrialization (ISI) strategy to spark economic growth. The Informatics Law, in many respects, is a variation on the model of ISI. Viewed from an historical perspective, the informatics law is but one part of Brazil's broader industrial policy.

Moreover, the Informatics Law draws upon a strong tradition of nationalism. Brazil's industrial policy reflects an on-going commitment to industrial growth and national security as the two foundations of national development. What differs throughout the years and political regimes is the choice of strategies and mechanisms used to encourage industrialization and military power. The following historical review highlights the dominant trends and guiding policy documents of Brazil's technology policy.

Technology Policy in Brazil

Brazil has given more explicit attention to the development of technological capabilities than the other Latin American countries. This attention has been based on the two objectives of insuring steady economic development and continued military strength.

Prior to 1960, technology policy was an implicit element of broader strategy of import substitution industrialization (ISI). ISI involved extensive reliance on foreign direct investment (FDI) and foreign borrowing. The government imposed import controls and offered subsidies to local manufacturers. These were, then, the primary mechanisms used to implement policy, and continue to be instruments of technology policy.

There were a number of important by-products of the early ISI strategy for the later informatics/computer industry. The fairly rapid rate of industrialization experienced between 1945 and 1962 (with average industrial growth of 8%) included the foundation of capital goods industries (autos, machinery, ships, etc). With foreign loans, the government invested in manufacturing infrastructure, especially in the Southern region of the country, including the development of transportation, communication, and energy networks, financial and service industries, and marketing distribution systems. Extensive borrowing in this period contributed to later debt crises, and has thus hampered Brazil's capacity to autonomously formulate policy and placed an immense strain on the domestic economy.

Nevertheless, the infrastructure and experience in manufacturing and management gained between 1945 and 1962 distinguishes Brazil from many other Third World nations. Lack of infrastructure and capitalist experience have been highlighted as conditions discouraging the foreign plants or investment. In Brazil, the availability of institutional and physical infrastructure, and professional, managerial, and skilled industrial workers would contribute to the growth of high-technology manufacturing in the 1970s and 1980s.

A second legacy from Brazil's early industrial policy was the Law of National Similars. Passed during the Novo Estado, the period of authoritarian control of Getulio Vargas (1937-45), the Law of Similars prohibited imports of goods similar to those being produced in Brazil. It is thus an early version of Brazil's market reserve policy. The law was first passed as part of Brazil's attempts at ISI and has remained an instrument of Brazilian industrial and technological policy.

While explicit technology policy was not articulated until 1968, important human resource and institutional development had taken place. Examples of early technology policy were the foundation of some R&D institutions and the government's tentative attention to human resource development prior to 1960. Between 1920 and 1960, the government sponsored the creation of six R&D institutions in the areas of engineering and sciences. The National Institute of Technology (INT), founded in 1921, would become a particularly important source of policy in the later period.

Additionally, in 1951, two organizations were founded to encourage the development of human resources for science and technology: the National Research Council (CNPq)[5] and Campaign for the Improvement of High-level Manpower (CAPES). These two organizations would play an active role in the formulation and implementation of Brazil's technology policy of the 1970s and 1980s. Additionally, this early attention to human resource and research development provided the foundation for later technological development through

5. Emanuel Adler reports that CNPq was created because of concerns that Argentina had developed the atomic bomb (The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil, Berkeley: University of California Press, 1987, p.311). He further quotes from a 1956 Congressional Inquiry Commission into the founding of CNPq: "it is impossible...to dissociate [sic] economic development from a military capacity, at least a latent one." (p.319.)

the provision of highly qualified workers and through the creation of scientific communities committed to scientific development.

As in the later period, the military also had a part in technological policy prior to 1960. Although initially defense and industrial technological policies were distinct, the technology policy implicit in defense policy proved a considerable stimulus to commercial technological development in the 1970s.

The military, like the commercial sector, established human resource, R&D centers, and technologically-intensive industries. World War II and the subsequent defense pacts with the U.S. provided a push to modernize the Brazilian military. The military founded a university, the National War College (ESG), and they encouraged the development of a defense industry, focusing on the production of light weaponry. They also imported equipment. With limited technology transfer, however, the military could not maintain the equipment or supply spare parts. Both dependence and debt increased, and many in the military recognized their vulnerability.

A further push for technological development was military concerns regarding atomic power and weaponry. By the 1950s, the establishment of an independent nuclear program was a clear priority for segments of the military and scientific community. The National Nuclear Energy Commission (CNEN) was thus founded in 1956. Many educational programs and research institutes were established to promote nuclear research, and keeping pace with the Argentinian nuclear program an explicit policy goal.[6]

Prior to 1960, science and technology policy in Brazil was a component of broader industrial policy. The emphasis throughout the 1930s, 1940s and 1950s was on the development of consumer goods industries based on an ISI strategy. The development of physical, financial and human resource infrastructure was justified on the basis that these were prerequisites to Brazil's development into a modern national power. Legacies of this period thus included strong nationalist sentiments as well as industrial growth, the foundation of R&D centers, and the establishment of a defense industry.

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6. The development of a nuclear program was slow; Brazil still has no atomic plant working at full capacity and has had difficulties with fuel enrichment. Adler explains that the failure of the nuclear program was due to internal political fragmentation regarding the policy, international pressure against the program, and technologically unrealistic programs. Adler, The Power of Ideology, Chapter 11.

1960-1964: Initial attention to technological development. The first half of the 1960s proved a transitional period in Brazilian political and economic history. Economic growth was constrained by the debts contracted by Kubitschek during his presidency, the expense of his large public projects, and the recessions of 1963 and 1964. Industrial growth slowed, with extensive under-utilization of manufacturing capacity. Social protests in the cities and countryside added social and political crises to the economic one facing the government.

In addition to the political and economic turmoil, there were two major advances in Brazil's technology policy between 1962 and 1964. First, it is in this period that policy begins to address the problems of technology transfer. The policies adopted in Laws 4131 and 4137 of 1962 attempted to examine and regulate the terms of technology transfer, and the relations between Brazilian affiliates and transnational corporations (TNCs). Law 4131 was concerned with foreign investment and technology transfer and restricted the remittance of earnings abroad in order to encourage the development of R&D capacity within the country. It further required that all payments in foreign currencies for technology transfer be registered with the Brazilian Central Bank (BNDE). Law 4137 created mechanisms to control abuses in technology transfer contracts with the aim of making the conditions of technology transfer more favorable to Brazilian firms and subsidiaries.

Second, the Telecommunication Law of 1962 was passed. This law defined general policies for the sector. It also specified the institutional and regulatory framework for the development and reorganization of Brazil's fragmented telephone system, thus guiding the sector's development for the next 15 years. The specific objectives of the law were to ensure both the rapid expansion and improvement of the telecommunications system and to encourage domestic technological self- sufficiency. Towards these ends, control of the telephone operating companies was transferred from foreign to Brazilian control.

1964-67: The Brazilian coup and economic stabilization. In 1964, in response to the political and economic crises, the military, with the backing of industrial and urban elites, took control of the government in 1964. Agrarian reform, educational reform, and basic democratic rights were abolished. The conditions for continued capital accumulation were assured by both repression and the implementation of economic stabilization programs which entailed lowered wages, increasd prices, and fiscal and monetary controls.

In contrast to the social and political spheres, there were few dramatic departures from earlier industrial policies.[7] While the government expressed increased interest in foreign direct investment and implemented some measures liberalizing imports, export incentives continued.

One change was the government's conversion of under-utilized manufacturing capacity to military purposes; the government here, through the development of defense industries, had a rationale for intervention in the production process itself, and not merely in providing the conditions for industrial capitalism. This conversion process meant that production could expand without high levels of fixed investment; it also meant government support for the consolidation of a defense industry.

This period marked an important transition in government approaches to technological development. The military leadership pursued an active and explicit science and technology policy in both commercial and defense sectors. There was a high level of government involvement in directing policy, providing credit, insuring qualified labor, and encouraging technology transfer. This increased intervention reflected the growing in the technological bases of both economic and defense activities.

Between 1964 and 1965, for example, the government focused on the creation of organizations for the financing of science and technology development. As these organizations were influential in later technology policy they are listed below:

> Fund for Scientific and Technical Development (FUNTEC): A subsidiary of the Brazilian National Development Bank (BNDE). Finances the purchase of nationally produced equipment in order to increase domestic supply of technology and demand by national enterprises;
>
> Fund for Financing the Acquisition of Industrial Machinery and Equipment (FINAME): Part of BNDE, founded in 1964;
> Fund for the Support of Technology (FUNAT): Established in 1967 under the Ministry of Industry and Commerce (MIC). Fund to train industrial technicians;
>
> Studies and Projects Financing Agency (FINEP): Initially under the Ministry of Planning and Coordination. In 1967, FINEP was transformed into a public enterprise. Responsible for funding feasibility studies and project development. It grew to power in the 1970s.

7. Adler explains that this was due in part to the retention of policy leaders in many sectors.

The military government followed a parallel strategy of increased support for universities, research, and graduate education in Brazil and abroad. Educational reforms were implemented in 1964 which included the opening of privately owned professional schools and the development of a national system of graduate studies. The Coordination of Graduate Programs in Engineering (COPPE) was created in 1965, a project of BNDE designed to promote graduate engineering training. R&D labs were established in state-owned companies. In 1967, the Project Return was adopted in order to encourage Brazilian scientists working abroad to return to Brazil; the plan reduced duties on personal imports and increased salaries for Brazilian researchers returning to Brazil.

Policies to assure "real" technology transfer and to aid industry in acquisition of foreign technology were implemented between 1964 and 1967. This occurred despite the government's avowed attempts to increase foreign direct investment and joint ventures. Law 4605, passed in 1964, regulated the capitalization of research costs. Law 4390 and Decree 55762, although repealing some earlier restrictions, maintained the registration of contracts, control of real transfer, and prohibition of remittances between TNCs and affiliates. SEI explains that these policies provided "incentives for foreign direct investors to encourage local production" by requiring domestic reinvestment of profits.[8] An additional technological support for industry was the creation of SUMOC (Superintendency of Money and Credit) in 1965, responsible for the regulation of machinery and equipment imports.

The military, meanwhile, pursued an explicit import substitution approach in building up the defense industry. The 1964-67 Plan of Industrial Mobilization was submitted by a group of Sao Paulo manufacturers and military leaders. It linked the national defense industry to national security, thereby justifying the following activities:

> the conversion of civilian industries to military production, using existing capacity in automobile, steel, and other heavy industries;
>
> the creation of research centers--including the Aerospace Technology Center, the Institute of Military Engineering, and the Naval Research Center;

8. UNCTC, Transborder Data Flows and Brazil, p.18, #55.

> government attempts to lower acquisition and licensing costs for military technology. These efforts included direct government purchase of know-how and subsidies to Brazilian producers.

As Adler points out, the technology policy which emerged in this period reflected the convergence of the interests of industrialists and the military; in light of the primacy of technological development to military strength and economic growth, and the importance of both of these aims to national power, the convergence of these interests is not surprising.

An additional area of policy elaboration was in telecom-munications. Two administrative agencies, EMBRATEL and CONTEL, were created between 1965 and 1967, and given the responsibility for long-distance (national and international) telecommunications corporations.

1968-74: .Initial formulation of technology policy. The period from 1968 through 1974 marked an expansion of government interest in and support for scientific and technological development.[9] The first explicit policies for technology and R&D were detailed in 1968. Numerous policy statements were issued, all affirming the importance of technological advancement to national autonomy.

The first explicit science and technology policy document was issued as the Strategic Development Program for 1968-70. This document described science and technology as critical to national autonomy and economic power, and focused policy on promoting real technology transfer and domestic innovative capabilities. These aims and policy approaches were reiterated in the first National Development Plan, and the First, Second and Third National Plans. The first National Development Plan, published in 1971, contained the Basic Plan of Scientific and Technology Development (PBDCT). This major policy instrument was followed by the First National Plan, issued in 1973 for the 1973-76 period; it focused on strengthening the financial basis of science and technology development.

The Brazilian government has relied on four approaches to support technology policy: subsidized financing to local firms; the development of physical and human R&D

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9. One indication of the growing importance of science and technology to national development is its increasing share of the national budget. In 1970, the share of the national budget pinpointed for science and technology was 0.84 percent. By 1982, this share had risen to 3.64 percent. See Claudio Frischtak, "Brazil," in Francis Rushing and Carole Ganz Brown (eds.), National Policies for Developing High Technology Industries (Boulder, CO: Westview Press, 1986), pp.31-70.

infrastructure; the regulation of contracts for acquisition of foreign technology; and the protection of the market for capital goods relying on Law of National Similars.

Of these four mechanisms, the government relied most heavily upon financing and regulation of technology transfer between 1968 and 1974. The government could then afford to do so. The economic stabilization policies of 1964-1967, supplemented by continued foreign borrowing, led to a boom in the economy starting in 1968. The increase in international liquidity, due both to recycled petro-dollars and U.S. balance-of-payments deficits, led to increased willingness on the part of international lenders to extend loans to Third World countries. The government was able to pursue expansionist policies.

Between 1968 and 1974, in addition to outlining technology policy, the government invested in the development of human resources and local technological capabilities. The government also encouraged the rationalization of science and technology institutions (see Table 1 and Figure 2). While the existing reliance on foreign technology was maintained, the terms of technology transfer were increasingly regulated.

In order to promote financial support of science and technology and human resource development, the government funneled subsidies through FUNTEC, FINEP and the National Science and Technology Development Fund (FNDCT). From 1964 to 1974, FUNTEC continued to fund post-grad training for scientists and engineers and finance graduate study abroad. FNDCT, created in 1969, meanwhile became the principal instrument for support of science and technology in Brazil.

In this period, the government systematically increased regulation of technology transfer in order to encourage "real" transfer. In 1970, the National Institute of Industrial Property (INPI) was created to administer the technology transfer, patents and trademarks systems. In 1971, the Industrial Property Code modified regulations of technology transfer with the dual objectives of speeding up "real" transfer, and increasing the bargaining power of the government vis-a-vis technology suppliers. The Industrial Technology Commission was founded in 1973 and given responsibility for review of technology transfer contracts. In order to open technological packages, Normative Act 15 of 1975 divided technical know-how into 5 categories and required separate agreements for each type of technology.

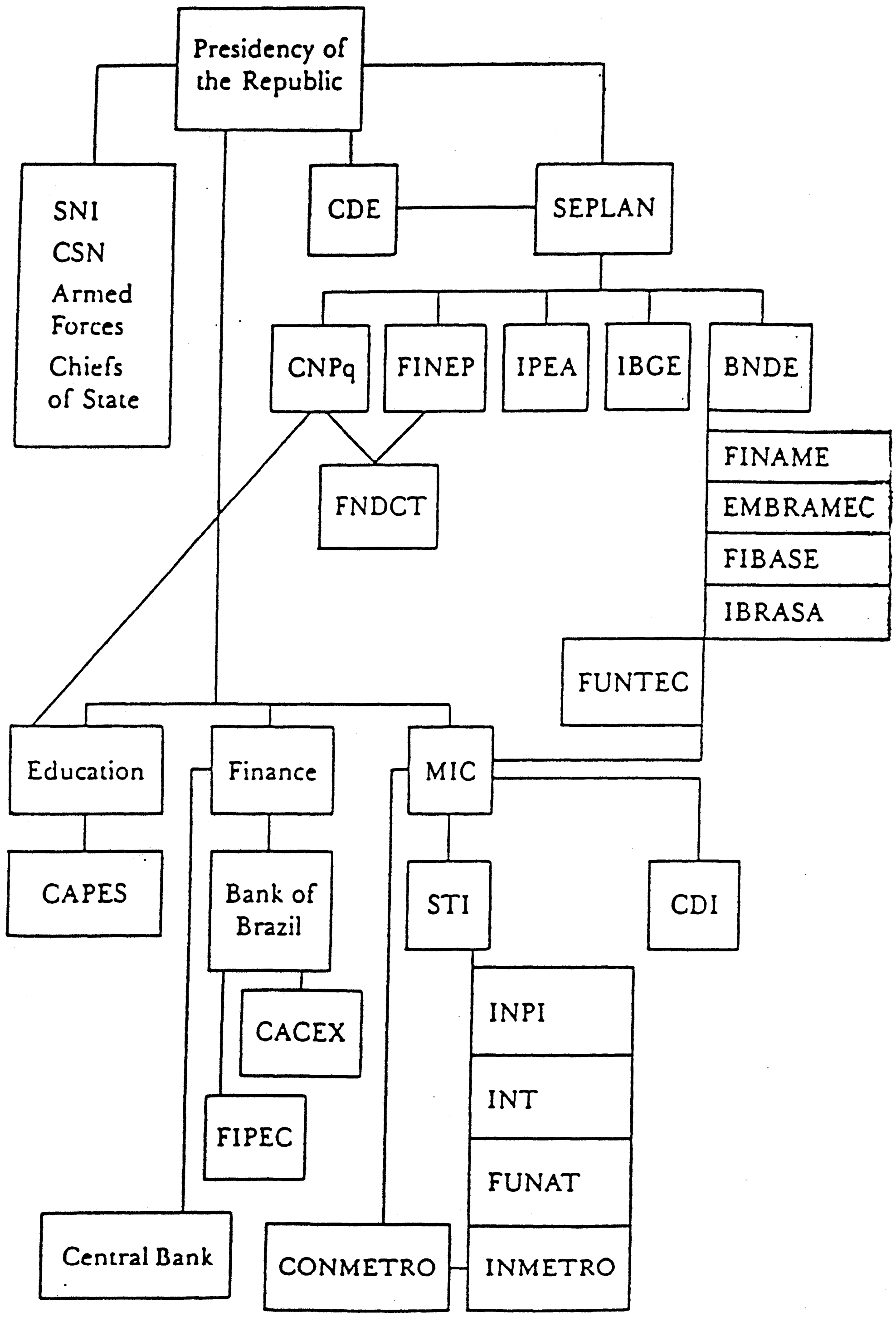
Table 1
Regulatory and Institutional Evolution in the Informatics Sector, 1972-1981

	Subject matter	Regulatory instrument
5 April 1972	Creation of CAPRE	Decree No. 70,370
3 December 1975	Import control	Resolution No. 104
9 February 1976	Restructuring of CAPRE	Decree No. 77,118
15 July 1976	Recommendation on national informatics policy	Resolution No. 01
1 June 1977	Invitation to national corporations to present microcomputers projects	Resolution No. 01/77
1 October 1979	Presidential Guidelines on national policy for informatics	
8 October 1979	Creation of SEI	Decree No. 84,067
5 December 1979	Structuring SEI	Decree No. 84,266
20 March 1980	Creation of the Special Commission on Software and Services	Directive No. 003
27 March 1980	Import control of finished products	Normative Act 001/80
12 May 1980	Data-processing equipment	Normative Act 002/80
24 June 1980	Government procurement	Normative Act 003/80
25 June 1980	Data-processing equipment	Normative Act 004/80
25 June 1980	Government procurement	Normative Act 005/80
15 July 1980	Creation of the Special Commission on Real-Time Control Systems	Directive No. 007/80
4 August 1980	Data-processing equipment	Normative Act 006/80
20 August 1980	Data-processing equipment	Normative Act 007/80
3 September 1980	Government procurement	Normative Act 008/80
15 October 1980	Government procurement	Normative Act 009/80
25 November 1980	Data-processing equipment	Normative Act 010/80
17 December 1980	Data-processing equipment	Normative Act 011/80
25 January 1981	Government procurement	Normative Act 012/81
12 February 1981	Technology transfer	Normative Act 013/81
6 March 1981	Microelectronics	Decree No. 85,790
18 March 1981	Real-time control systems	Normative Act 014/81
9 July 1981	Government procurement	Normative Act 015/81
10 July 1981	Import control of finished products	Normative Act 016/81
10 July 1981	Data-processing equipment	Normative Act 017/81
6 August 1981	Data-processing equipment	Normative Act 018/81
28 September 1981	Research and development	Normative Act 019/81
18 January 1982	Government procurement	Normative Act 020/82

Source: Special Secretariat of Informatics.

Source: UNCTC, 1984, p. 62.

Figure 2
Science and Technology Policy-Making System (to 1979)



Note: Abbreviations include CDE for Economic Development Council; CSN for National Security Council; SNI for National Intelligence Service; and FIPEC for Scientific and Technological Research Incentives Fund.

Source: Adler, 1987, p. 166.

Reorganization of technology development system was implemented in order to rationalize policies and centralize control. This was accompanied by the foundation of regional research centers. A central agency--the National System for the Development of Science and Technology (SNDCT)--was created in 1972, officially responsible for the formulation and implementation of technology policy. SNDCT also linked CNPq--in charge of scientific and technological matters-- with the ministry of planning and BNDE--in charge of financial matters. As Adler explains, "these actions formalize the relations that already exist[ed] between CNPq and the planning system".[10]

Furthermore, in 1971, FINAME was placed under the control of the National Development Bank (BNDE). In 1974, the Ministry of Planning was reorganized as the Planning Secretariat (SEPLAN) with broader powers and under the direct control of the president and military. SEPLAN retained the Ministry of Planning's advisory role in science and technology development (See Figure 2).

There were also attempts to foster local technological capacity during the 1968-74 period. In 1972, the Industrial Technology Secretariat (STI), an agency of the Ministry of Industry and Commerce (MIC), was created in order to develop and implement industrial technology policy. The INPI and National Institute of Technology (INT) were integrated under the new secretariat. In 1972 a National System of Science and Technology Information Network (SNICT) was also created. It provided databanks covering economic and social information and was primarily designed for government use.

1975-79: Industrial technology. The Second National Plan of 1974, for the 1975-79 period, reaffirmed past goals, but also outlined the reorganization and centralization of science and technology apparatus. Moreover, this plan shifted the policy emphasis from human resource and institutional development to industrial technological self-sufficiency. The plan called for improvements in the technological capabilities and sophistication of Brazilian industries--both national (governmental) and private firms. Support for high-technology industries was explicitly targeted, especially support for basic industries with high technology content such as computers, capital goods, petrochemicals, steel, and aeronautics.

10. Adler, The Power of Ideology, p.159.

Evidence of the transition to industrial rather than public [?] technological development appears in the development of new programs and modifications in existing ones. In 1974, the focus of FUNTEC's programs shifted from financing education to strengthening technological capabilities of local firms. Similarly, in 1973, FINEP was expanded to include programs to support local consulting firms and technological development of national enterprises. In 1973, the Program for the Support of Technological Development of the National Enterprise (ADTEN) began to provide funds for equipment purchases by national firms.

The year 1974 marked a transition to more aggressive bargaining with the TNCs, greater reliance on national firms, and a return to ISI policies (including import controls, and export incentives). This transition was, in part, fueled by the deceleration of overall growth and by crises in the global economy. By 1974, Brazil was faced with the economic repercussions of the first oil crisis, a worsening balance-of-payments, and recession and inflation in the global economy. Foreign borrowing no longer was an optional growth strategy, rather a necessity to avoid negative consequences of global recession. The government turned from government spending strategies to protection and market reserve mechanisms to support technological development.

The government increased support for national industries, and implemented requirements for local equity control and local technological capabilities. In 1974, BNDE subsidiaries were created for equity participation in national industries:

Embramec (Mecanica Brasileira S.A.)

Fibase (Financiametos e Participacoes)

Ibrase (Invementos Brasileiros)

In the computer industry, CAPRE called for increased participation by domestic firms in the development of new systems. Bargaining with the TNCs was pursued more aggressively, and in 1974 the IBM proposal to produce system 32 in Brazil was rejected. Instead, an open competition for approval for production of mini-computer was held, with tri-pe (domestic private firms, TNC, and Brazilian government cooperation) arrangements favored.

Military policy similarly reflected heightened vulnerability to economic and technological interdependence. The Vietnam War meant restrictions on military imports as U.S. weaponry was re-routed from Brazil to Southeast Asia; the Brazilians were forced to search for alternative weapons sources in Europe between 1967 and 1972. It also led to a parallel emphasis on development of Brazilian defense industries along ISI guidelines. In 1975, the Brazilian War Material Company was created (Petrobras of arms).

In 1977, Carter's Human Rights' Policy led to restrictions on military aid (which had continued from 1952 to 1976) due to Brazil's human rights violations. When the Brazilian president unilaterally canceled several military agreements with U.S., it ended the years of military cooperation and increased interest in development of a domestic arms production capacity.

The military responded with continued commitment to its ISI strategy and with attempts to fully nationalize the industry. Restrictions on imports continued as did subsidies to domestic producers. The military received increased funds for arms industry and military research, and expressed growing interest in the possibilities of nuclear and computer industries. A major contract was signed with the West Germans for the construction of atomic power plants in Brazil, and for the transfer of fuel enrichment know-how. The military also actively encouraged the foundation of an indigenous capability in computer technologies. The case of the computer industry will be explored in greater detail in the following section.

As in the commercial sector, access to foreign technologies were proclaimed a priority and the military pursued joint ventures with European and U.S. firms. A number of commercial successes punctuated the period--the production of internationally competitive weaponry, passenger aircraft, and single-engine planes--which appeared to confirm the wisdom of the ISI strategy.

Legacies of the 1968-1979 period include the publication of explicit technology policy documents, and the creation and reorganization of science and technology institutions. ISI approaches were re-emphasized, accompanied by continued interest in technologies from abroad. Official support continued for tri-pe agreements but with increased attention to local content, local control and real technology transfer; public sector and domestic private sector control over manufacturing increased. The oil crises and worsening balance-of-payments created additional pressure to reduce imports and increase national autonomy. It was a period of largely unsuccessful negotiation with TNCs, the beginnings of the market reserve policy in the computer industry, and the introduction of import controls for high-technology.

1979-88: the informatics policy. As mentioned earlier, in 1979, the Special Secretariat of Informatics (SEI) was founded and took over Capre's duties. SEI was located under the National Security Council and the Brazilian President. SEI was given responsibility for real-time control systems and microelectronics in general. It thus had five areas of responsibility: imports of finished products and components; entry and expansion of firms; government acquisition of informatics products and services; industrial electronic systems; and technology transfer.[11] SEI was instrumental in the ultimate formulation of the 1984 Informatics Law although the Law reflected the policy orientations of both SEI and its predecessor Capre.

The Third National Development Plan, for 1980-85, detailed a broad set of policies and priorities rather than specific programs and projects. These are the policies formalized in the Informatics Law, discussed earlier. The policies highlight present goals as gradual increases in industrial rather than governmental R&D, increases in the technological sophistication of R&D and industrial production processes, and decreases in protection of domestic production as competitiveness is achieved.

With the opening of the government in the early 1980s and the beginnings of democratization, the direct link between the military and SEI was altered. In 1984, CONIN, the National Informatics and Automation Council, was created and given supervisory control of SEI and equal footing with the National Security Council. CONIN is composed of non-governmental and governmental representatives, who generally have little knowledge or connection with the informatics sector. It is anticipated that SEI will remain the primary policy instrument in the sector. CONIN has formal responsibility for submitting a National Informatics and Automation Plan (PLANIN) to the President every three years.

11. Frischtak, "Brazil," 1986.

Recent policy developments include the adoption of the first National Informatics and Automation Plan in September, 1985. It calls for an increased commitment to human resource development. It additionally highlights the importance of strengthening R&D activities and proposes integrated R&D programs involving research centers, universities and firms. The plan also introduces fiscal incentives for R&D activities in national and private companies.[12] Foreign firms are further required to invest five percent of sales into R&D in areas dictated by the Council on Informatics and Automation.

Implications of the Informatics Plan for Other Sectors.

The informatics policy has become the model for other technologically driven sectors such as telecommunications, robotics, and genetic engineering. Distinct approaches exist, however, for the aeronautics, armaments, and nuclear sectors. The aeronautics and armaments industries have been closely linked since their initial development in the 1950s. The emphasis in these sectors has been to gain technologies through joint ventures and foreign licensing (as in informatics) but to immediately direct marketing efforts internationally rather than domestically.[13] The government has chosen to support one national firm in the case of aeronautics rather than implement a more internally competitive program. This national firm, EMBRAER, has had great success in international sales of light passenger aircraft and helicopters. The aeronautics industry is currently constructing a satellite launch site and expects to have a satellite in orbit by 1989. In contrast, the technological strategy for the nuclear sector has been largely unsuccessful.[14]

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12. The plan allows firms income tax deductions of up to two times R&D expenditures and accelerated depreciation of equipment used for R&D and production. From Frischtak, "Brazil," 1986.

13. Ravi Ramamurti, State-Owned Enterprises in High Technology Industries: Studies in India and Brazil (New York: Praeger, 1987), contains an excellent review of the development of the national aeronautics company EMBRAER.

14. The strategy has been to simultaneously develop local capabilities while purchasing entire systems from abroad. The 1976 purchase of entire fuel enrichment and nuclear power plants thus was unlike the incremental approach pursued in other sectors. Despite human resource development, financial investments in complete industrial packages, and existing capacity for supplying components, Brazil has been unable to operate any plant at full capacity.

Adler, The Power of Ideology, explains that the technology itself was not suitable to incremental improvements in technological capabilities; the jump from research to power reactors too great. Competition with Argentina in the development of nuclear capabilities as well as lack of consensus within the Brazilian government provide partial explanation for the lack of a pragmatic technological strategy in this area.

See Adler, The Power of Ideology, Chapter 11 for a comparison between the nuclear and computer policies, and for a comparison between Brazil's unsuccessful nuclear policy and Argentina's successful one.

Summary

In summary, technology policy in Brazil has struggled with a number of conflicting requirements since its emergence in the late 1960s. Technology policy has had the dual objective of promoting a rapid improvement in the goods and services produced and promoting domestic technological capabilities. There has necessarily been a tradeoff between these two objectives and variations in sectoral policies reflect differences in the weight placed on these two goals.

A second dilemma relates to the source of technology. Access to foreign technologies is necessary to the long-term technological and competitive needs of Brazil's industries. Reliance of foreign technologies can also undermine attempts to foster local capabilities and innovation. Brazilian policy has tried to strike a balance between these two constraints by addressing the terms of technology transfer and introducing market protection mechanisms.

The particular form of the technology policy adopted in a sector will have consequences for technology transfer, industrial development, indigenous technological capabilities, and national power. An analysis of the development of technology policy in the computer sector is provided in the next section. The implications of the policy are discussed in the following two sections.

Other areas of debate and tension relate to the social, regional, political and defense implications of technological development. These issues are discussed in Parts 4 and 5.

The Computer Industry and Government Policy

The development of the computer industry in Brazil has been highly shaped by Brazilian government policy. The policy approach to the computer industry has been to reserve the lower-end of the market--the micro-and mini-computer market--for local producers while permitting international producers to supply the more sophisticated end of the market. This policy has prompted claims of unfair trade practice by international governments and firms. The Brazilian government has responded by claiming that as a member of GATT, Brazil has the right to protect strategic infant industries. Indeed, many have argued that Brazil's approach to the computer industry is consistent with both Brazil's and other nations' treatment of infant industries.[15] This section describes the computer industry in Brazil and the development of the informatics policy. The section attempts to answer two questions: Why was the Brazilian governments policy towards the computer industry so nationalistic and protectionistic? To what extent has government policy succeeded in fostering an indigenous high-technology computer industry?

The Computer Industry.

The computer industry in Brazil got off to a relatively late start. It was non-existent to the end of the 1960s and when it did emerge in the early 1970s, the expansion was based on imports and accompanied by neither government regulations nor domestic production facilities. The only computer manufacturing to take place in Brazil was some final assembly of some equipment by an IBM affiliate. There were also minimal efforts to develop human resources or R&D activities.

The computer market grew quickly (see Table 2). Excluding micro-computers, the number of installed computers increased by 673 percent between 1973 and 1982. The primary consumer of electronic data processing equipment was, not surprisingly, the government which accounted for 45.6 percent of the market in 1980.[16] Micro-computers were introduced into the Brazilian market in 1973 and account for a growing share of the market.

While the micro- and mini-computer markets are growing rapidly, they account for a small proportion of the value of the computer market (See Table 2). It is this 7 percent of the market which has become fiercely contested by international micro producers--it accounted for over $2.5 billion in 1981 and has continued to grow.

There are five major minicomputer manufacturers--Cobra, Edisa, Labo, SID, and Sisco--and three major micro-computer manufacturers--Cobra, Sisco, and Polymax. Hewlett-Packard is the only foreign firm with local manufacturing of microcomputers and this is permitted only because HP specializes in scientific micro-computers. The 1980 mini-computer market (class 2) was divided as follows: Cobra, the national company controls 40

15. Botehlo, Jose, "Brazil's Independent Computer Strategy," Technology Review 90:4 (May/June 1987).
16. Tigre, Paulo Bastos, Technology and Competition in the Brazilian Computer Industry (New York: St. Martin's Press, 1983), p.46.

Table 2
Number and Value[a] of Comuters Installed by Class, 1970-83
(in millions of dollars)

Class	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981 b/	1982 b/	1983 b/
Class 1														
Number	-	-	-	586	1 514	2 143	3 131	3 846	4 290	4 791	4 722	6 420	12 420	18 000
Value	-	-	-	11.6	30.3	42.9	62.6	76.9	85.8	95.8	95.4	128.4	248.4	360
Class 2														
Number	-	-	-	19	81	173	265	356	656	1 015	1 675	...	...	...
Value	-	-	-	1.7	7.3	15.6	23.8	32.0	59.0	91.4	150.8	...	...	...
Class 3														
Number	378	403	454	639	775	1 057	1 309	1 296	1 378	1 494	1 688	...	...	...
Value	68.0	72.5	81.7	115.0	40.0	190.3	235.6	233.3	248.0	268.9	303.8	...	...	...
Sub-total Classes 2-3														
Number	378	403	454	658	856	1 230	1 574	1 652	2 034	2 509	3 363	4 204	5 255	6 568
Value	68.0	72.5	81.7	116.7	147.8	205.9	259.4	265.3	307.0	360.3	454.6	462.4	578.0	722.5
Class 4														
Number	122	163	184	250	288	327	388	353	370	377	388	...	...	...
Value	81.7	109.2	123.3	167.5	193.0	290.1	226.5	236.5	247.9	252.6	260.0	...	...	...
Class 5														
Number	2	2	10	45	72	82	99	122	166	226	248	...	...	...
Value	3.8	3.8	19.0	85.5	136.8	155.8	188.1	231.8	315.4	429.4	471.2	...	...	...
Class 6														
Number	4	10	19	33	42	61	72	87	93	97	123	...	...	...
Value	12.0	30.0	57.0	99.0	126.0	183.0	216.0	261.0	279.0	291.0	369.0	...	...	...
Sub-total Classes 4-6														
Number	128	175	213	328	402	470	509	562	629	700	759	835	918	1 010
Value	97.5	143.0	199.3	352.0	455.8	577.9	683.6	729.3	842.3	973.0	1 100.2	1 586.5	1 744.2	1 919
TOTAL														
Number	506	578	667	1 572	2 772	3 843	5 214	6 060	6 953	8 000	8 844	11 459	18 593	25 578
Value	165.5	215.5	281.0	480.4	632.9	806.7	952.6	1 071.5	1 235.1	1 429.1	1 649.2	2 177.3	2 570.6	3 001.5

Source: Special Secretariat of Informatics.

a/ In terms of 1980 average prices of a sample of equipment representing at least 80 per cent of the computer park of each class: class 1 = $20,000; class 2 = $90,000; class 3 = $180,000; class 4 = $670,000; class 5 = $1,900,000; class 6 = $3,000,000.

b/ Planned.

Source: UNCTC, 1984, p, 202.

percent of the market; Labo controls 20 percent; SID controls 15 percent; and Sisco and Medidata each control 2.2 percent. In 1980, the distribution of shares of micro-computer (class 1) production was: Cobra with 63.3 percent; Sisco with 2 percent; and Polymax controlling 34.7 percent.

Table 3 lists the number of firms and products in the Brazilian market as of 1984. Table 4 shows ownership patterns for the various firms, as well as provides estimates of the extent of dependence on foreign technology. As compared to the characteristics of the market in the early 1970s, the Brazilian policies have had some success.

In 1984, sales of computers and peripherals manufactured in Brazil totalled US$ 1,700 million. Of that total, national production accounted for $881 million. This was based on the sale of 1,082 mini-computers, 61,680 home micro-computers, 11,218 business micro-computers, 25,857 serial printers, 1,114 parallel printers, 10,267 video terminals, 35,273 financial terminals, 1,824 cartridge disk drives, 2,348 Winchester disk drives, 20,965 floppy disk units, 439 magnetic tape units, and 20,021 modems.[17]

Brazil now produces all the computers for the low-end of the market. Local content increased for many products (see Figures 3 and 4); the import content of total sales by national producers decreased from 28 percent to 7.5 percent between 1979 and 1982.[18] These accomplishments are completely a result of the market reserve established under Brazilian informatics policy.

The industry, moreover, seems dynamic. In 1977, only nine informatics companies operated in Brazil and six were foreign. By 1985, there were 274 registered companies in the sector and 247 were national. There are now a number of software and consulting companies in Brazil which account for both additional economic growth and employment.[19] Efforts to strengthen R&D infrastructure have had some success. By 1978, there were 208 scientists engaged in R&D per million population while in 1974 the corresponding number was 75 per million. There are now "an estimated twenty-five to thirty thousand scientific and industrial researchers and over one thousand graduate programs."[20]

17. Frischtak, "Brazil," p.41.
18. Frischtak, "Brazil," p.59.
19. Botelho, "Brazil's Independent Computer Strategy," 1987.
20. Frischtak, "Brazil," 1986, p. 34.

Table 3
Data-Processing Equipment Manufactured in Brazil, January 1982

Products	Number of corporations	Number of products
Microcomputers	14	16
Minicomputers	6	7
Medium computers	1	1
Large computers	2	3
Disk drives	9	16
Magnetic tape drives	3	8
Modems	8	31
Matrix printers	8	16
Line printers	2	4
CRT terminals	10	27
Financial terminals	6	6
Electronic accounting machines	6	12
Acoustic couplers	4	5
Word-processing machines	2	2
Cash registers	1	1
Others	33	36

Source: Special Secretariat of Informatics.

Source: UNCTC, 1984, p. 214.

Table 4
The 25 Largest Corporations in the Data Industry in Brazil, 1979-81

Rank	Name	Year of establishment	Major stockholders a/ Name	Share	Nationality	License agreement: Name of licenser	Nationality	Relative importance of foreign technology for production b/	Year	Sales (thousands of dollars) c/	Equity (thousands of dollars) c/	Employment
1	IBM do Brasil Ltda.	1960	IBM World Trade	99.9	United States	IBM	USA	Very important	1979	530 000	304 000	4 752
									1980	579 000	326 500	4 903
									1981	740 500	427 550	4 790
2	Burroughs Eletrônica Ltda.	1929	Burroughs Latin America Inc.	99.9	United States	Burroughs	USA	Very important	1979	168 500	...	3 123
									1980	138 000	64 500	2 523
									1981	160 000 d/	...	2 723
3	Cobra Computadores Brasileiros S.A.	1974	EDB	39	Brazil	Sycor	USA	Minor	1979	91 500	24 500	1 850
			Bank of Brazil	13		Ferranti	UK	Negligible	1980	91 500	6 000	1 998
			Caixa Econ Federal	13					1981	116 000 d/	...	1 990
			BNDES	11								
			SERPRO	13								
			Others	9								
4	Labo Eletrônica S.A.	1961	Forsa	79	Brazil	Nixdorf	Federal Republic of Germany	Important	1979	17 500	7 500	416
			Unibanco	13					1980	33 500	3 000	540
									1981	24 500 d/	...	613
5	Elebra Informatica	1979	Cia.Docas de Santos	100	Brazil	CDC	United States	Important	1979	500	1 000	52
						Honeywell	Italy	Important	1980	8 000	3 000	85
									1981	22 500 d/	...	96
6	SID - Sistemas de Informaçaoes Distribuidas S.A.	1978	Sharp	77	Brazil	Logabax	France	Important	1979	22 500	5 000	450
			Bradesco	18	Brazil				1980	40 000	8 000	783
									1981	22 500	...	500
7	Edisa Eletrônica Digital S.A.	1977	Iochpe Group	79	Brazil	Fujitsu	Japan	Important	1979	9 000	5 000	129
									1980	14 500	4 500	291
									1981	19 000 d/	...	355
8	Hewlett Packard do Brasil Ind. e Com. Ltda.	1967	Hewlett Packard	100	United States	Hewlett Packard	United States	Very important	1979	16 000	4 000	211
									1980	15 000	4 000	247
									1981	18 000	5 500	283
9	Microlab S.A.	1962	Individual	...	Brazil	Ampex	United States	Very important	1979	2 500 e/	2 000	221
									1980	9 000 e/	1 000	342
									1981	14 000 e/	...	451

Table 4 (continued)

Rank	Name	Year of establishment	Major stockholders a/ Name	Share	Nationality	License agreement Name of licensor	Nationality	Relative importance of foreign technology for production b/	Year	Sales (thousands of dollars) c/	Equity (thousands of dollars) c/	Employment
10	Sisco- Sistemas e Computadores Ltda.	1971	Individual	100	Brazil	-	-	-	1979	1 000	1 550	203
									1980	9 500	1 000	350
									1981	14 000 d/	...	381
11	Scopus Tècnologia Ind. e Com. Ltda.	1975	Individual	100	Brazil	-	-	-	1979	6 500	2 500	319
									1980	12 000	4 500	422
									1981	13 500 d/	...	454
12	Globus Digitais S.A.	1978	Individual	100	Brazil	Data Products	United States	Important	1979	1 000	... f/	50
									1980	10 500	...	118
						Pertec	United States	Important	1981	13 000	500	118
13	Racimec - Racionalizaçao e Mecanizaçao Ltda.	1966	Individual	100	Brazil	-	-	-	1979	3 500	1 000	54
									1980	4 500	1 500	85
									1981	3 500	155	81
14	Polymax	1977	Individual	100	Brazil	-	-	-	1979	500	500	31
									1980	5 000	1 000	193
									1981	12 000	1 500	282
15	Digilab Laboratório Digital S.A.	1979	Bradesco Metalúrgica Abramo Eberle	7	Brazil	Nec	Japan	Very important	1980	7 000	1 000	62
									1981	10 000 d/		
											...	120
16	Coencisa Ind. de Communicacoes S.A.	1976	Coencisa	51	Brazil	Raca	United States	Important	1979	8 000	6 000	186
			Racal Milgo	49	United States	Milgo			1980	6 500	14 500	178
									1981	9 000 d/	...	176
17	Prológica	1976	Individual	100	Brazil	-	-	-	1979	3 000	300	20
									1980	3 500	300	170
									1981	7 000 d/	...	226
18	Elebra Eletrônica	1970	Cia Docas de Santos	100	Brazil	Codex	United States	Important	1979	6 000 c/	3 500	577
									1980	9 000 c/	3 000	949
									1981	7 000 c/	...	857
19	Tecnodata	1979	Individual	100	Brazil	-	-	-	1980	1 000	...	...
									1981	7 000 d/	...	133

Table 4 (continued)

Rank	Name	Year of establishment	Major stockholders a/ Name	Share	Nationality	Licence agreement: Name of licenser	Nationality	Relative importance of foreign technology for production b/	Year	Sales (thousands of dollars c/)	Equity (thousands of dollars c/)	Employment
20	Compart	1980	Individual	100	Brazil	Pelkin-Elmer	United States	Very important	1980	2 500	1 000	53
									1981	6 000 d/	...	95
21	Multidigit	1978	Cia Forca e Luz Cataguases Leopoldina	64.7	Brazil	Pertec	United States	Very important	1979	500	...	9
									1980	8 500	500	9
									1981	4 500	1 000	19
			Digicon S.A.	32.8								
22	Moddata	1976	Individual	100	Brazil	Nec	Japan	Minor	1979	500	150	87
									1980	1 000	500	177
									1981	4 500 d/	...	153
23	Flexidisk	1979	Individual	100	Brazil	Shuggart	USA	Very important	1979	550	...	28
									1980	2 000	500	20
									1981	4 000	1 500	30
24	Digiponto Ind. e Com. Componentes Digital S.A.	1976	Individual	100	Brazil	-	-	-	1979	1 000	500	165
									1980	2 500	...	92
									1981	3 000 d/	...	135
25	Itaú Tecnologia S.A.	1979	Itausa	100	Brazil	-	-	-	1980	-	1 000	105
									1981	3 000	4 500	383

Source: Special Secretariat of Informatics.

a/ At least 10 per cent participation.

b/ Defined in terms of the importance of products produced with foreign technology. Negligible: 0-5 per cent; minor = 6-30 per cent; important 31-70 per cent; very important 71-100 per cent.

c/ Exchange rates: 1979: $1 = $Cr 26.101; 1980: $1 = $Cr 52.835; 1981: $1 = $Cr 93.774.

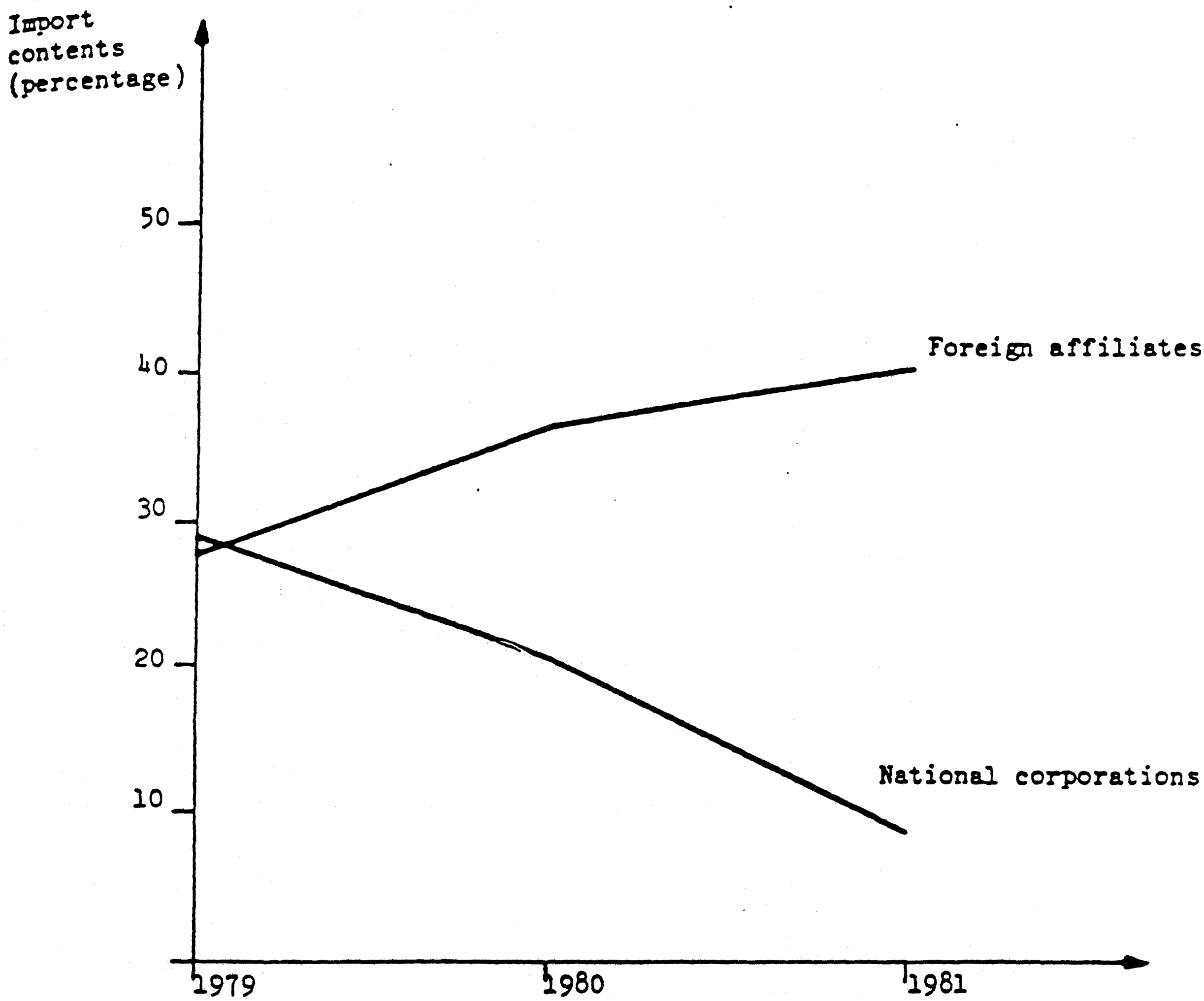
d/ Estimated.

e/ For informatics products only.

f/ Negative equity.

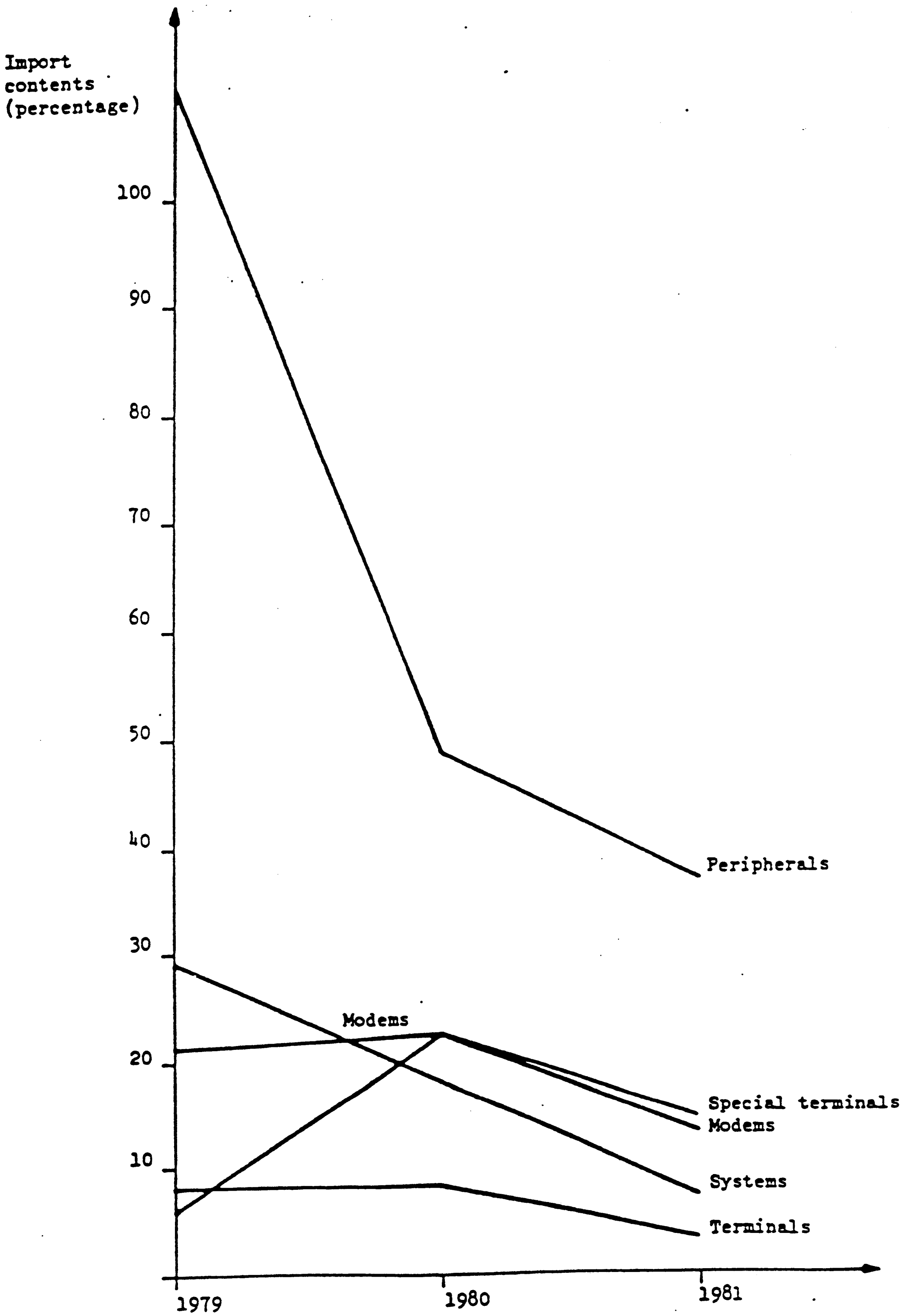
Source: UNCTC, 1984, pp. 211-213.

Figure 3
Import Contents of National Informatics Corporations and Foreign Affiliates, 1979-1981



Source: UNCTC, 1984, p. 99.

Figure 4
Import Contents of National Informatics Corporations, by Industry, 1979-1981



Source: UNCTC, 1984, p. 100.

Despite the successful technological and marketing advances of the Brazilian firms, domestic firms still control a small share of the overall computer market and rely heavily upon foreign technology. The challenges facing the further development of the computer industry will be discussed in Part 4.

Nationalism and Anti-dependency Ideology.

A description of the Brazilian computer industry does not, however, explain why the Brazilian government should have intervened when and in the manner it did. This section specifically addresses why the intervention was so nationalistic and why it targeted the lower end of the computer market. There are three forces which contributed to the form which the informatics policy eventually took. The first force was the tradition of nationalistic approaches to industrialization, modernization, and national security; nationalism, protectionism, and state intervention have characterized Brazilian industrial and economic development policy throughout the century. Second, there was a growing recognition throughout Brazilian society of the political and economic costs of technological dependency.

A third motivation was the actual events that transpired between 1972 and the present-- changes in the international economy, the global structure of the computer market, and the bargaining of TNCs and Brazil--which dramatically shaped the form of Brazilian policy. These three forces will be discussed below.

A number of factors contributed to the growth of support for nationalistic approaches to industrial development. The underlying reason for anti-dependency approaches was the growing recognition of the political and economic costs of technological dependency. In this sense the anti-dependency approach was pragmatically (materially) rather than ideologically motivated. The characteristics of different groups' anti-dependency motivations are outlined below.

National security and arms industry. A first factor contributing to nationalist sentiment was the military leadership's increasing sense of vulnerability to economic and technological interdependence. The Vietnam War reduction of military imports from the U.S. to Brazil, followed by the 1977 cutoff of U.S. military aid to Brazil (under Carter's Human Rights' Policy), forced the Brazilians to search for alternative weapons sources in Europe.

These events also led to increased interest in the development of Brazilian defense industries. The Brazilian strategy generally conformed to import substitution industrialization guidelines; the post-1964 conversion of civilian industries to military production provided the physical infrastructure for the growth of the defense sector.

These events all contributed to the military leadership's recognition of their technological vulnerability in relying on foreign sources of weapons and technology. More recently, the importance of technological superiority to the British victory in the Falklands/Malvinas war further convinced military leaders that technological sophistication was strategically imperative.

The military also recognized the economic costs of global interdependence. The military leadership had been buffeted by the external shocks of the oil crises and global recessions of the early and mid-1970s. The military responded with attempts to fully nationalize the arms industry in order to reap the economic benefits of increasing arms sales. Restrictions on imports continued as did subsidies to domestic producers. The military increased funding for the arms industry and military research. Many were interested in the possibilities of a nuclear program, especially since Argentina was working in the nuclear sector. The Navy was particularly interested in a domestic computer industry since they needed to incorporate electronic guidance systems into their vessels in order to keep them internationally competitive.

The commercial success of a number of national enterprises--the production of internationally competitive weaponry, passenger aircraft, and single-engine planes--further appeared to confirm the necessity of developing advanced technological capabilities.

<u>Economic nationalism and industrial modernization</u>. There was continued sentiment among industrialists and middle-class that the country should have modern industries. In part this was a continuation of earlier nationalist sentiment--the image of a modern nation with modern industries. It was also a pragmatic reaction to the changing technological basis of production and commercial organization.

Many firms felt competitively vulnerable since the pace of technical advances in the production process of many traditional industries was increasing. There was also widespread recognition of the problems of dependence on foreign technologies and equipment (such as obtaining outdated equipment and processes, lacking spare parts or customized equipment) which was documented in UN and Brazilian reports. Furthermore, the importance of global communications to economic activities was growing throughout the late 1970s and early 1980s. Industrialists thus expressed interest in increasing technological capabilities, particularly in respect to human resource development, real-time systems, and communication networks.[21]

Political autonomy. There was support within the state for increased technological autonomy. The technology policy documents of the 1970s reflect an existing recognition that technological dependence reduced the autonomy of the state to make its own policies. Government agencies also required specialized data-processing systems and desired customized systems, not easily available from international suppliers.

Additionally, the size of the Brazilian market had been a source of leverage for the government vis-a-vis the TNCs. Experience in other industrial areas, such as in arms and petroleum, had demonstrated that local technical capabilities further strengthened the State's bargaining power, thereby strengthening national security.

Commercial and university interests. Another concern was expressed by university students and professors in the sciences. They were frustrated by the lack of professional options. Many had graduate training in Brazil or abroad and wanted the opportunity to implement their prototypes and designs but could not interest the TNCs in local R&D. They additionally desired the commercial opportunities such as characterize Silicon Valley. This group was particularly instrumental in the formulation of Brazil's technological policy, directing and participating in Capre and the many other agencies in the science and technology institutional network.[22]

Balance-of-payments and debt. National economic concerns provided an additional rationale for controlling imports and encouraging local production. First, payments for technology to TNCs by their subsidiaries was a major means of avoiding regulations on levels of profit remittances. For example, these payments were characteristically much higher than

21. House, Richard, "Counting the Cost of the Micro Boom," South 81 (July 1987), p.15.

22. See Adler, The Power of Ideology, and Peter Evans ("State, Capital, and the Transformation of Dependence: The Brazilian Computer Case," World Development 14:7, 1986, pp.791-808), for analyses of the role of these anti-dependency technocrats in the formulation of the Brazilian informatics policy.

the cost of technology were it purchased by an unaffiliated buyer.[23] TNCs could thus overcharge for the technology used by their affiliates.

Second, licensing, whether or not by affiliates, is a relatively expensive way of obtaining technical know-how and in many cases the subsequent use of the technology is limited. Despite the many regulations the Brazilian government had and has been imposing on technology transfer, the acquisition of technological capabilities is a lasting way of avoiding the problem.

Third, imports of technologically sophisticated equipment are increasing and comprise a large share of Brazilian outflow of foreign exchange. By 1976, the value of imported data-processing equipment was the fourth largest of all imported goods. Thus the economic costs of technological dependence were clearly felt by all who demanded a share of the national budget.

The confluence of national security, industrial, technological, commercial, economic, and political pressures towards technological autonomy meant that there was support for such policies among the military, the industrialists, the universities, the government agencies, and the middle-classes. While there were also concerns expressed by members of these groups that quality and diversity of goods would not be equivalent to international standards and that costs would be higher, recent improvement in price-quality tradeoffs suggest that the Brazilians are approaching international production standards.

Brazilian Science and Technology Policy and the Computer Industry

The development of government policy towards the computer industry demonstrates how the above described characteristics of the state, technological change, and the international economy interacted to push Brazil's policy into its present protectionist form. This section explores why the Brazilian government intervened when and in the manner it did. The tradition of nationalistic approaches to industrialization, modernization, and national security and the growing recognition throughout Brazilian society of the political and economic costs of technological dependency were two forces shaping the Brazilian policy. The rapid pace of technological change and the growing importance of microelectronics and

23. Erber, "Science and Technology Policy," 1981.

telecommunications to economic and political activities meant that these sectors became national priorities. Government intervention in some form was necessary for Brazil to create the infrastructure for technological development.

A third motivation behind Brazil's computer policy was the actual events that transpired between 1972 and the present--changes in the international economy, the global structure of the computer market, and the bargaining of TNCs and Brazil-- which dramatically shaped the form of Brazilian policy.

Early Computer Policy. In 1972, when computers were just entering the Brazilian market, the Brazilian government created Capre to coordinate the purchase and use of computers in government agencies. As the use and purchase of electronic data-processing equipment increased in the early 1970s, Capre grew in power and authority. It was the only official agency with responsibility for the review of computer purchases. Capre's explicit objectives were to achieve economies of scale, reduce imports, promote the development of a national industry, prolong the life of equipment, and help R&D centers obtain technology. These goals were consistent with general industrial policy and not especially nationalistic for Brazil's nationalistic economics.

Early interest in the development of computer technologies was expressed by the Navy and the Ministry of Planning.[24] In 1971 a contract was signed between the Navy and BNDE establishing Funtec 111, a project to encourage the development of minicomputers. The model pursued, although not explicitly, was to foster a national champion in the industry, like those that characterized the defense and aeronautics industries.

In 1972, a holding company was formed, the Electronica Digital Brasileira (EDB), through which the banks and government could found computer companies. The EDB sought to foster a **tri-pe** arrangement, a partnership of the state, private industry, and transnationals. A partnership with Ferranti Limited, a British firm already supplying computer-based ship and submarine systems to the Navy, was favored by the military. The BNDE preferred a partnership with Fujitsu.

24. The discussion of the early development of the computer industry draws heavily on Adler, The Power of Ideology, and Tigre, Technology and Competition .

The EDB decided to create two computer companies, one with military orientations and the other with civilian ones. The Brazilians civilian version did not materialize and consequently the **tri-pe** venture with Ferranti, called Cobra, was expanded to cover both military and civilian markets. EDB, meanwhile, was renamed Digibras and given responsibility for the national computer project. As described by Adler, "the [**tri-pe**] arrangement reflected a pragmatic position. Those involved thought that domestic technology would progress most rapidly if Cobra used foreign technology to develop the national computer, but only if the foreign firms committed to full technology transfer, with technology then to be absorbed by Cobra." He further contends that Ferranti was only chosen because it was receptive to Cobra's technology transfer requirements and not because of its product quality.[25]

Digibras indeed found that they could not easily obtain access to foreign technologies on Brazilian terms. Negotiations with DataGeneral, Fujitsu, and Nixdork for the development of a business computer stalemated on the Brazilian insistence that patents, blueprints, and other know-how be transferred to Cobra at the end of the license period. Digibras eventually contracted with a small American company, Sycor Inc., which was willing to accept the technology transfer terms. The license resulted in the production of two series of business and accounting minicomputers.

In both cases, that of Sycor and Ferranti, the chosen foreign partner was selected because of its willingness to accede to Brazilian technology transfer requirements and not because of the sophistication or suitability of the technology.

With the deficit problems of 1974 and 1975, Capre was given additional power to control imports since government purchases of electronic dataprocessors accounted for a major outflow of foreign exchange. Once they had the power to review and control imports, the individuals in Capre began to formulate a general Brazilian policy for the informatics sector.

The next critical moment for Brazil's policy development occurred in 1976 when IBM announced plans to manufacture a mini-computer--the system 32--in Brazil. Rather than accept IBM's proposal, Capre, and then the National Economic Development Council (CDE),

25. Adler, The Power of Ideology, p.246.

countered with a new policy regarding computer imports and production. The policy detailed by Capre in July 1976 subdivided the computer market--large computer systems were to be imported, while national production of smaller computers was to be encouraged (although without market reserve or state intervention). CDE also outlined the criteria for fiscal incentives: degree of nationalization, export potential, extent of technology transfer, viability of enterprises in market, and domestic capital majority.

Although formulated by the strongly nationalistic anti-dependency members of Capre, the policy also reflected the concerns of the Navy. The Navy, and thus others in the military leadership, had continued their involvement in Cobra and had pinpointed the computer industry as an area for local technological and industrial development due to the need for computerized guidance systems.

Capre was made up of engineers and computer scientists who recognized that much of the computer industry was beyond the reach of Brazilian technological capabilities. The lower end of the computer market (then the mini-computers) was consequently targeted for governmental support and encouragement. Due to the growing recognition within the government of the costs of technological dependence, the needs of the Navy, and the existing (albeit low) technological capacity in microelectronics in Brazil, the government supported the Capre computer policy.

When Capre announced an open-bid for minicomputer production in 1977, fourteen proposals were submitted, seven MNCs submitted independent proposals, two were joint ventures, and eight were independent proposals by Brazilian consortiums. Apparently the MNCs were relying on the greater sophistication of their products in the bid competition and did not propose joint ventures entailing real technology transfer. Capre responded by approving four Brazilian proposals--Cobra and three domestic consortiums--and rejecting the independent MNC bids and the joint ventures. Capre later approved the entry of a fifth domestic company.

Policy Modifications and Elaborations. In the years that followed, Brazil bargained with the MNCs about what could and had to be produced in Brazil, what would be an acceptable degree of nationalization, and what would be the export/domestic market sales balance. The size of the Brazilian government, the consistency of the policy, the power of the government to implement the policy, and the growing domestic production capabilities all served to strengthen the Brazilian government's bargaining power vis-a-vis the TNCs. Furthermore, the initial rejection of the Brazilian government's priorities by the MNCs led to a super-nationalistic policy, in which the level of confrontation between the parties was heightened and the conditions for production much debated.

A number of these developments within the policy approach should be noted. One of the major debates with the TNCs revolved around what computers fell under the market reserve policy. This particularly affected the importation of medium-sized computers since they could compete with mini-computers. In 1978, Capre approved the manufacture of the medium sized IBM 370/148 and the Burroughs B-6800. Later the same year, Capre rejected additional proposals from IBM and Burroughs; the IBM 4331, the IBM System 38, and the Burroughs 2800, while classified internationally as medium sized computers, were considerable threats to the Brazilian mini-computer producers. Capre explained that these 1978 proposals "did not provide for either sufficient national content of effective technology transfer."[26]

This policy has been further adjusted under the Special Secretariat for Informatics (SEI), the agency which replaced Capre in 1979. In 1980 IBM was given permission to produce a medium-sized computer, the 4331 MG2. This production was strictly regulated; the minimum memory capacity was held to two megabytes, the minimum national content limited to 85 percent, and the number sold on the Brazilian market limited to two for every three units exported with a maximum of 242 units sold domestically by 1983. IBM was also allowed to manufacture magnetic disks, for export only, which generated income for both the Brazilians and IBM.

Burroughs was similarly allowed to manufacture computers in Brazil only if subject to export/domestic market requirements. The domestic manufacture and sale of the B6900, a large computer, was approved at 1,950 units with the requirement that an additional 6,020 units be manufactured in Brazil and exported.

These agreements highlight the change in the relationship between Brazil and the TNCs. The size and potential value of the Brazilian market, coupled with the possibility of

26. Cited in Adler, The Power of Ideology, p.254.

exclusion from the market entirely, forced the TNCs into accepting conditions that five years previously they had rejected. Brazil, faced with a worsening balance-of trade, was also forced to grant concessions, foregoing some long-term self-sufficiency for the income of TNC subsidiaries' exports.

The increased strength of Brazil's bargaining position did not obviate the difficulties with obtaining technology. In 1984, for example, the market reserve policy was expanded to allow Brazilian companies to produce "super-minis." Eight Brazilian firms submitted proposals. Three proposals planned to develop these computers with domestic technology while another five companies proposed to rely on imported technology. SEI approved the three proposals-- submitted by Labo, SID and Cobra--relying on domestically developed technologies and hoped that some of the other five firms would merge. This did not occur and progress in supermini technologies developed slowly. In June 1984, SEI approved all the supermini projects relying on foreign technology. In order to remain competitive, Cobra, Labo and SID were forced to abandon their indigenous efforts and purchase foreign technologies. Thus, the tradeoff between technological diffusion and indigenous technological development in this case seemed too costly; competitiveness ranked above self-sufficiency.

Another area of the policy's evolution is the place of the computer secretariat in the government's structure. Initially, when Capre was responsible for the policy, Capre was a separate, insulated agency. In 1979, SEI replaced Capre, with direct links to the National Security Council and the President; this development reflected the growing importance of the sector to national security interests. In 1984, with the opening of the government and the first moves towards re-establishing a civilian government, the government passed the National Informatics Law (reaffirming past policy) and created CONIN, which is on "equal footing" with the National Security Council instead of under its control. Despite these changes in institutional structure, the informatics policy has remained largely consistent. This suggests that the policy is not the result of the isolated influence of dogmatic anti-dependency bureaucrats but rather the product of a widespread recognition of the costs of technological and economic dependence.

An additional example of the interactions of national goals, international pressures, market mechanisms, and technological developments is that of Brazilian policy towards software. Under the original formulation of the market reserve policy, software was not regulated or banned. Software imports are difficult to control; disks can easily be copied and programs can be carried on diskettes or cassettes.

Technological developments, particularly the decreasing costs of CPUs (the computer hardware), meant that the contribution of software to the total cost of a system began to increase. In 1981, SEI introduced a Software Registry and required the registration of all domestic and foreign programs available in Brazil. SEI used its power to approve imports and projects to implement sanctions against companies which did not register their software.

Pirated software still became the norm. Between 50 and 70 percent of the software in use in Brazil in 1986 was pirated.[27] One manager at a Brazilian computer firm, Itaupec, recently stated "all this piracy has damaged us internationally; no one wants to transfer technology to Brazil."[28] Moreover, Brazil did not officially recognize international copyright regulations for the industry.

Imports of operating systems have been discouraged. AT&T has been discouraged from permitting transfer of the software matrix for Unix (for superminis) and there is an on-going battle regarding the MS-DOS operating system.

The larger Brazilian computer manufacturers and national companies have developed their own software systems. Cobra has developed its version of Unix, Sox, which it will sell to Scopus and other supermini producers. Scopus has developed its own operating system for its IBM-PC clones. Itautec has developed its own "multilevel DOS" and simple text editing, spreadsheet and database programs. Itautec representatives say that Multi-DOS is faster than Microsoft's MS-DOS but anticipate competitive difficulties due to domestic name recognition and familiarity with MS-DOS.

In 1987, six Brazilian hardware manufacturers sought a software license to use MS-DOS.[29] Microsoft meanwhile threatened legal action against the Brazilian companies

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27. House, Richard, "Hard Fight for a Soft Option," South 81 (July 1987), p.15.
28. Ivany Cavalcanti, quoted in House, "Hard Fight for a Soft Option," p.15.
29. New York Times, "Reagan Imposes Punitive Tariffs Against Brazil," November 14, 1987, pp.1,38.

(including Itautec) for copyright infringement of its operating system.[30] The conflict heightened as SEI considered the license proposal. SEI decided that it would not allow the import of Microsoft MS-DOS unless there was no comparable product available in Brazil. This decision constituted an expansion of the market reserve informatics policy into software development. The U.S. government entered the fray as the interests of Microsoft and other U.S. firms were challenged; "the US made it clear that it was opposed to such an expansion" of the policy and threatened retaliatory trade sanctions.[31]

Microsoft claimed that the operating systems available in Brazil are inferior copies of the MS-DOS original. US trade negotiators attempted to demonstrate how the MS-DOS system differed from the Brazilian versions. SEI announced, however, that the import of MS-DOS would not be permitted and the US imposed trade sanctions. Brazil did concede that the government would consider legislation to adopt copyright protection for software and to extend the period in which technology remained proprietary after licensing. Botelho reports that indeed Brazil has recently adopted both of these proposals.[32]

The Brazilian experience with copyrights and software demonstrates the level of commitment to the informatics policy, most particularly in areas where access to technologies are not endangered. Brazilians can obtain much new software and can then duplicate and improve on the programs; protection of the Brazilian operating systems outweighed even trade relations. Disregard for international copyright conventions, in contrast, did threaten access to state-of-the-art technologies and the adoption of these conventions was a politically astute maneuver, especially since such regulations are, in practice, difficult to enforce.

In summary, the lack of initial success in bargaining with the TNCs led in part to the implementation of a market reserve policy as opposed to a more traditional ISI strategy. The case of the computer industry largely followed the government's broader approach to technology transfer and local managerial and equity control when the policy was originally formulated in the early 1970s. The refusal by the TNCs to include local firms in the 1977

30. House, "Hard Fight for a Soft Option," p.14.

31. Christian Science Monitor, "White House answers Brazil's software ban with tough tariffs," Ron Scherer, November 16, 1987, p.3.

32. Proprietary technology restrictions entail a period of time after the licensing of technology in which that know-how cannot be disseminated. In 1983, the period of licensing and confidentiality was extended. Botelho, "Brazil's Independent Computer Strategy."

bids was a complete rejection of the priorities expressed by the Brazilian government in all industrial areas. The Brazilian reaction was to leave them out of the future market, especially when the local firms had alternative sources of technology.

More recently, the Brazilian government has made some concessions to international producers. The necessity of keeping channels open for continued technology transfer required that Brazil adopt some conventions of the industry such as copyright laws and the number of years, after licensing or purchase, that technology would remain proprietary. The need to remain competitive, as in the case of super-minicomputers, has also pushed the government to modify the policy. When continued access to technology was threatened through the actions of either Brazilian or transnational firms, the Brazilian policy has consistently been to modify nationalistic demands. Whenever the structure of the technology and the industry made it feasible, the Brazilian government has maintained its commitment to local industry and technological development. The Brazilian policy, in this light, appears both dynamic and pragmatic.

Structure of the Global Computer Industry.

There are also a number of characteristics of the computer market that contributed to the feasibility of the Brazilian strategy. First, the Brazilian policy-makers concentrated on the low- end of the computer market because it required the least technological sophistication to enter the market. The subsequent development of micro-computers proved fortuitous for the Brazilians. As a new product, micro-computers had no established producers or importers supplying the Brazilian market. The micro-computers involved an even lower technological level to assemble and the global micro-computer market was characterized by the relatively "unpackaged" quality of micro-computer production. In contrast to the larger computers, where the technology and components had to be purchased together, micro-computer components could be purchased independently; Brazil still relies on imports of standard components and thus can more easily achieve international production standards for final goods. Moreover, in addition to soaring sales world-wide, micro-computers have become integral components of the leading edge of communication systems; ironically it the lowest end of the computer market which is critical to the development of the most sophisticated technological systems.

Characteristics of Brazil's industrial structure and computer market also contributed to the ability of the Brazilian government to implement policy. The large share of purchases of computer equipment by government agencies meant that policy was easier to implement and that the government had a strong case for intervening in the market. The availability of skilled engineers and managers meant that the production process itself was feasible. The focus on the lower-end of the market, requiring less technological sophistication, fell within the skill level of the available work force. Likewise, when the industry began to achieve profits and expand, private capital was available to complement government support for the sector.

Summary

Through an examination of the historical evolution of Brazil's technology policy, it appears that the computer case is similar to many of Brazil's other industrial sectors. An ISI strategy, complete with import controls and support for domestic industries, largely describes the Brazilian government's approach to the computer industry. However, the importance of the computer industry specifically, and technological advancement generally, militates for a more nationalistic and protectionist strategy. The costs of not gaining technological sophistication, and the difficulties in establishing the infrastructure for technological advancement provide two explanations for Brazil's commitment to its computer strategy. Moreover, government policy appears to be as much a consequence of the attitude of the TNCs to fostering local Brazilian production as to nationalist sentiment within Brazil; the two have been mutually reinforcing. It is the confluence of numerous factors, local support for technological autonomy and local production, the general logic of the state, strategic bargaining with the TNCs, and of the structure of the international computer market, which provides an explanation for the emergence of the Brazilian policy. To the extent that the policy has had some success, it is likely that it will prove the model for other high-technology sectors.

The Impact of the Informatics Policy on the Diffusion of Technology.

Brazilian technological policy has been most recently and most publicly formulated in the 1984 Informatics Law. This law reserves the Brazilian market for domestic producers of minicomputers, microcomputers, and peripherals. The law also establishes an overall policy for development of high-technology industries and technologies. In addition to prompting an international response--the U.S. retaliatory trade measures of November 1987--it has generated immediate controversy.

Critics claim that Brazil's market-reserve policies have resulted in higher costs, lower quality and decreased diversity of computer goods for the Brazilian consumers. Others claim that Brazil's industry is "little more than an assembly line for...imported components"[33] and that limited technology transfer has occurred. More general criticisms from have been voiced by U.S. policymakers and firms, such as Data General and Microsoft--that the policy violates principles of international free trade, constitutes an unfair trade practice, and sets a dangerous precedent for other Third World countries.

Brazilian governmental and industry spokespeople have countered that the Brazilian government, under GATT provisions, has the right to protect strategic and infant industries and that the informatics industry qualifies as both. In apparent refutation of international critiques, the Brazilian government has pointed to the growth of Brazilian informatics companies.[34]

The data presented suggests that the policies have led to the creation of a strong domestic computer industry. Yet while sales and industry data point to some commercial success through the Brazilian protectionist strategy, it does little to clarify other aspects of the controversy. The dual objectives of the informatics policy have been to foster local technological self-sufficiency and to insure the spread of technological infrastructure and services throughout society. To what extent has the Brazilian policy succeeded in transferring technological know-how and providing the foundations for future indigenous technological development? To what extent has the policy influenced the operations and competitiveness of firms within the sector and in other sectors? To what extent have the Brazilians managed to

33. "South Survey: Brazil," South 81 (July 1987), pp.49-63.
34. For example, see Archer, "Brazil's Informatics Policy Achieves Success."

balance the two objectives of technological diffusion and self-sufficiency? What have been the tradeoffs of this balancing act?

A central thesis of this work has been that the Brazilian government has used technological development to strengthen national power. Has the informatics policy, as developed over the last twenty years, in fact strengthened the national economy, the military, or national autonomy?

More generally, there are a number of theoretical questions which this research cannot answer but can address, indicating directions for future Brazilian and comparative research.[35] The pace of technological change globally may have implications for the international division of labor. How have technological changes affected Brazil's position in the international economy? How has Brazilian government policy influenced this position?

What limits do technology itself, the industrial organization of industry, the international economy, and domestic politics place upon national strategies? How can governments simultaneously obtain access to advanced technologies and avoid dependence? Additionally, how has technological change affected the structure of labor markets within Brazil?

The Impact of the Informatics Policy on the Diffusion of Technology

In addressing these numerous questions, this chapter examines the accomplishments and barriers to further growth of the informatics sector. It then turns to the implications of the Brazilian experience with informatics and technology policy for an understanding of the relationships among government policy, nationalism, economic development, and technology.

> To what extent has the policy influenced the operations and competitiveness of firms within the sector and in other sectors? To what extent have the Brazilians managed to balance the two objectives of technological diffusion and self-sufficiency? What have been the tradeoffs of this balancing act?

The Brazilian policy has had some success in transferring technological know-how and providing the foundations for future indigenous technological development. The

35. Many of these questions were prompted by Kenneth Flamm's exploratory essay, "Latin America's Role in the International Computer Industry: A Framework for Discussion," paper presented at the Workshop on The Impact of High Technology on Economic Development and International Competitiveness in Industrialized and Newly Industrializing Countries, Rio de Janeiro, January 26-28, 1987.

government policy has encouraged the development of human resources, educational and research facilities, national and domestically controlled computer industries, and real technology transfer.[36] Yet there are also barriers to the further development of the sector. The extent of these accomplishments and barriers are reviewed below.

Human Resources/Research and Development (R&D). In the area of human resource development, the Brazilian policy has been largely successful. There are over 30,000 researchers and scientists in the informatics sector. There are five institutions providing doctoral degrees in computer science for approximately 10 people each year. The total number of researchers with Ph.D.s in computer science and engineering is 108. There are 15 institutions offering Masters degrees. Estimates of the total number of Brazilian researchers engaged in R&D range from 750 to 1,100.[37] Frischtak estimates that approximately two-thirds, or 500 people, are working on software development.

Brazil has additionally been "unusually successful" in ensuring the availability of an industrial work force. There is a network of industrial vocational schools--the SENAI system-- which in 1984, had 723,000 trainees enrolled in 673 schools and training centers.[38]

The development of these institutions and human resources does not mean that Brazil's has established the necessary basis for further growth. As in the rest of the world, the skills of the labor force may not match those required by the new industries. Castro writes, "the typical training profile offered by SENAI will be inadequate for the new wave of automation. It is not obsolete now, but it caters to occupational profiles that are bound to grow at a much slower rate....the new worker needs more of what Brazil has less to offer: good formal schooling."[39] He additionally suggests that the educational tradition in Brazil may not encourage innovative or hands on work, both necessary for the new technology driven industries.

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36. The successes of the informatics policy were presented in the previous section.

37. Frischtak, "Brazil," p.64, estimates that there are 750 researchers. Claudio de Moura Castro and Ruy de Quadros Carvalho ("Automation in Brazil: Who's Afraid of Digital Circuits," paper presented at the Workshop on the Impact of High Technology on Economic Development and International Competitiveness in Industrialized and Newly Industrialized Countries, Rio de Janeiro, January 26-28, 1987), estimate the higher figure.

38. Castro and Carvalho, "Automation in Brazil."

39. Castro and Carvalho, "Automation in Brazil," p.13.

Others have expressed concern that the innovative potential of basic university research is threatened by the government policy. Schwartzman, for instance, suspects that the nation will lose innovative capacity with increasing control of R&D by industry and with the profit motive permeating universities.[40] He has questioned the wisdom of having the bulk of government R&D funds go to private industry; he suggests that there is both too little financial support to university research and too much regulation of internal university activities.

More immediately problematic are the existing financial constraints within the sector. The Brazilian market may not be large enough to support the levels of R&D required keep the technological gap at its present level, let alone to decrease the gap. In the national firms, R&D expenditures were 9.8 percent of total sales in 1983. The average for the period from 1979 to 1982 was 11 percent. In this same period, R&D expenditures increased 78.3 percent per annum in real terms. The manufacturing sector, in contrast, spent only 0.6 percent of sales in R&D activities. Continued government financing of R&D is a clear necessity.

Average Brazilian investment in R&D compares favorably with that of the U.S. In 1980 Brazilian firms spent 8.7 percent of total sales on R&D.[41] American computer and peripheral companies spent an average of 6.1 percent of total sales that same year. R&D expenditures per employee were $4730 for the Brazilian firms and $3265 for the U.S. firms.

In absolute terms, however, the limitations of Brazil's R&D approach are striking. Brazilian public and private R&D spending is low in comparison to the global leaders in the informatics industry. This may be a further area of concern for the Brazilian industry. Nationally, only 0.54 percent of Brazil's GNP is invested in R&D of new technologies.[42] Between 1979 and 1982, Brazilian national and private computer firms spent US$160 million on R&D.[43] IBM, in comparison, spent more than US$2 billion, equivalent to 6% of IBM's global sales, on R&D in 1982 alone. Burroughs spent US$221 million and Hewlett-Packard

40. Schwartzman, Simon, "Coming Full Circle: A Reappraisal of University Research in Latin America," Minerva 24:4 (Winter 1986), pp.456-475.

41. Tigre, Technology and Competition, p.93.

42. House, "Hard Fight for a Soft Option," pp.15-16.

43. Piragibe, Clelia, Industria da informatica: Desenvolvimento Brasileiro e Mundial (Rio de Janeiro: Editora Campus Ltda., 1985), p.197.

US$ 424 million that same year.[44] Data General spent US$ 84 million and Apple US$ 38 million on microcomputer development in 1982. The Brazilian computer firms spent US$ 69 million in 1982. The difference in the financial resources available to the international industry leaders and those available to the Brazilian firms highlights their difficulty in maintaining the existing technological gap.

An additional indication of the differences in scale are the human resources available to Brazilian and international firms. As mentioned above, there are an estimated 30,000 researchers and scientists in the Brazilian informatics sector. IBM alone employs approximately 2,500 professionals in basic research and 50,000 professionals in the development of new products. There are over 700 Ph.D.s working in IBM's research center in Yorktown. There are fewer than 200 researchers with doctorates working in Brazil's entire computer industry.

These comparisons suggest that Brazil has considerable barriers to further technological development. They do not mean, however, that the Brazilian industry cannot continue to gain in market size and technological capabilities. Instead, the differences in financial and human capital resources suggest that Brazil's strategy must not be to compete directly with the TNCs for either markets or products, nor to strive for state-of-the-art technological capabilities in many product areas. Instead, these differences suggests that Brazilian policy must focus on enlarging the market for Brazilian firms (by promoting exports as well as the growth of a domestic market), encouraging cooperative R&D among Brazilian firms, ensuring continued financing of R&D and human resource development, and promoting the development of specialized product niches.

Industrial Growth and Competitiveness. By 1986, the nascent computer industry had a domestic market of over 2.5 million U.S. dollars. The most rapidly growing part of the informatics market is that of data-processing peripherals--monitors, printers and disk-drives. Brazilian exports of peripherals grew from $41 million to $106 million between 1978 and 1982.[45]

44. From Business Week, "R&D Scoreboard-1982," June 20, 1983, cited in Piragibe, Industria da informatica, p.202.

45. The growth of this sector internationally meant, however, that Brazil's share of the world market remained at 1 percent. Raphael Kaplinsky, "The Electronics Industry in Developing Countries," viertejahresberichte 103 (March 1986), p.22.

The dynamism which has characterized the electronics sector in the U.S. appears also to characterize the Brazilian industry. Early spin-off companies emerged, for example, out of an effort between the University of Sao Paulo and Rio de Janeiro Catholic University to produced the G-10 minicomputer, the Federal Data Processing Service's development of a keyboard concentrator, and Rio de Janeiro Federal University's (UFRJ) development of an intelligent terminal. Spin-off companies include: Scopus, founded in 1975 by engineers from USP; Globus, founded in 1978 by two ex-directors of Cobra, and producing peripherals; Compart, founded by two more ex-directors of Cobra, and producing magnetic tape drives; and Embracomp, founded in 1977 by 69 people from UFRJ.

An example of a recently formed spin-off company is Humana Informatica, a one-product company, headed by a former Sao Paulo Polytechnic professor. He has created a universal communications program, the Programme Z. It is more advanced than its slightly less expensive U.S. competitor Crosstalk and Humana Informatica sells about 300 programs per month. By 1987 there were 1,500 programs in use in Brazil and increasing number of overseas users.[46]

In addition to spin-off companies from the universities, there have been spin-offs from manufacturing firms such as Dismac from Elgin Maquinas and Kuhn Engenharia from two modem manufacturing firms. Informatics firms have also been established by entrepreneurs in non-electronics industries, by electronics firms not formerly engaged in data-processing equipment manufacture, and by individual electronic engineers. Larger industries' efforts at diversification have resulted in the creation of firms such as Polymax, a systems manufacturer set up by food-processing industry, and Elebra, Labo, and Micolab established by firms with previous electronics experience. Firms created by electronic engineers tend to be small and innovative and include Exata, Digirede, and Medidata, among others.

By 1986, there were over 250 registered informatics firms in Brazil. In 1980 there were 88 independent software suppliers--firms that supply software packages for local mini-computer manufacturers--and this number has grown dramatically since then.[47]

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46. House, "Hard Fight for a Soft Option," p.15.
47. Tigre, Technology and Competition, p.63.

As the example of Humana Informatica suggests, Brazil is beginning to achieve international competitiveness for certain technologies and products. Brazilian computer producers have exported to West Germany, Portugal, Italy, Israel, Argentina, Turkey and Hungary. It is expected that Brazil will achieve international competitiveness soon in on-line banking equipment.[48] Brazilian firms have exported goods to IBM under original equipment manufacture (OEM) agreements. Original equipment manufacture (OEM) arrangements are when exports are sold under a different name. For example, Japan's Kyosera exports portable computers to Tandy which sells it under Radio Shack brand. Frischtak explains that OEM agreements are becoming increasingly common. In Brazil, "IBM export-oriented OEM purchases from Brazilian manufacturers have increased fairly rapidly from $5 million in 1984 to $15 million in 1985, and are expected to reach $30 million in 1986."[49] Additionally, a number of individuals have licensed software to international computer firms.[50]

Despite these achievements, the discussion presented in the previous section suggested that Brazilian firms rely heavily on foreign technologies (See Table 4). While the informatics policy outlines increasing self-sufficiency in technological innovation, patterns of R&D expenditure in Brazil, changes in electronic products and the increasing pace of technological change suggest that Brazilian firms will find it difficult to maintain the technological gap at its present status unless they continue to depend on foreign technology.

The last few years have noted a technological shift towards closed architecture in micro- computers (those using 16 and 32 bit micro-chips) rather than open architecture. Closed- architecture systems require customized semi-conductors and proprietary operating systems, and are more difficult to copy or reverse engineer. There has also been a global shift to automation and vertical disintegration in the electronics industry. Larger production volumes and shortened product cycles now characterize the industry.

The combination of shortened product cycles, automation, and closed architecture, means that, as Frischtak notes, "efforts...to design, manufacture as well as copy...newer generations of machines becomes increasingly expensive."[51] Brazil may have great difficulty

48. House, "Hard Fight for a Soft Option," p.16.
49. Frischtak, "Brazil," p.67.
50. Botelho, "Brazil's Independent Computer Strategy."
51. Frischtak, "Brazil," p.55.

in achieving international competitiveness as well as technological state-of-the-art. The growing production volumes, and the resulting economies of scale reached, means that it is more difficult for the Brazilian firms to be price competitive.

There has been a shift in the importance of software to the cost of computer systems. Software is a growing portion of the final cost of a computer package. Brazilian policy has only recently begun to emphasize software development. Furthermore, it is difficult to prevent the importation of software. According to SEI, three-quarters of the software programmes used in Brazil are developed elsewhere. Although the overall software market for micro-computers totalled US $1-billion in 1985, "local companies have a tiny slice, with the biggest chunk going to pirated US imports sold on street corners for about US$17 a diskette."[52]

One of the domestic barriers faced by Brazilian firms in lowering their prices is the size of the Brazilian market. By international standards, the Brazilian market is relatively small; its size may not permit the Brazilian companies to achieve economies of scale.

Frischtak compared the markets and economies of scale achieved by foreign and Brazilian manufacturers. He found that Brazilian producers of 16-bit IBM clones manufacture on average 200 units per month or 2,400 per year. In contrast, Apple shipped 250-300,000 units of MacIntosh, Compaq over 130,000 units, and IBM over two million PCs (presumably this production was spread out over numerous plants). The South Korean plants produce 50-10,000 units of micro-computers each year. Frischtak estimates that this is the minimum production capacity required to realize economies of scale.

The inability of the Brazilian firms to increase production is thus a consequence both of unrestricted entry of domestic firms into the market and limited domestic demand. This barrier could be eliminated; it is likely that the firms now operating in the Brazilian market will consolidate and, if exports are encouraged, have access to a larger market.

An additional difficulty derives from Brazil's continued dependence on importation of components. The extent of links and communication between component and final product manufacturers are becoming an increasingly critical determinant of international

52. House, "Hard Fight for a Soft Option."

competitiveness.[53] Leading computer manufacturers increasingly rely on in-house production of components.[54] Control over the design and manufacture of components seems necessary to the development of the customized systems which now characterize the global computer industry. As Tigre explains,

> A high degree of dependence on foreign supply of components can inhibit the future development of the local industry. If Brazil does not develop semiconductor design and production capability the local computer industry would have little control over supply and costs or the major computer hardware component and would be reduced to a passive role with respect technical change, This can constrain the long-term competitiveness of local computer products.[55]

The technological requirements for semiconductor manufacture are much higher than for the manufacture and assembly of other computer products. Brazil has very limited capabilities in high precision mechanical components (used in computer peripheral equipment) and microelectronic components (for integrated circuits). Tigre examined semiconductor production in Brazil and found that there were 13 manufacturers of semiconductors in 1981, and only one, Transit, was nationally owned.[56] The foreign firms merely assembled imported chips. Transit had a more integrated production system but halted its operations in 1981 due to financial and technical problems.

The Brazilian government thus faces a dilemma not unlike that faced in 1976 with respect to minicomputer manufacture. Even if the government were to invest heavily in the foundation of R&D and manufacturing facilities for semiconductor production, the quality and reliability would be lower than current imports. The use of domestically produced semiconductors would harm domestic producers of micro- and mini-computers. On the positive side, the investment in semiconductor production capabilities would benefit the long-term autonomy of the Brazilian informatics industry.

53. See Jay Stowsky, "Beating Our Plowshares into Double-Edged Swords: The Impact of Pentagon Policies on the Commercialization of Advanced Technologies" (Berkeley: University of California, BRIE Working Papers #17, 1986), and "The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade" (Berkeley: University of California, BRIE Working Papers #27, 1987).

54. Tigre, Technology and Competition, p.119.

55. Tigre, Technology and Competition, p.118.

56. Tigre, Technology and Competition, pp.116-118.

Meanwhile, the existing policy has had some success in decreasing imports of components (see Figure 3 and 4). There are strict government controls over the import of components. Firms are allocated a fixed annual quota for imports. This quota varies for the different product lines, depending on feasible minimum domestic sources of components. The import content of national informatics firms' production declined dramatically from 1979 to 1981--from 29 percent to 8 percent. In contrast, the import content rose during the same period for foreign affiliates, from 28 percent to 40 percent. Tigre found, however, that there was growing interest among foreign producers in product nationalization; this was due to both the government controls and to the bureaucratic problems associated with those regulations.[57]

Terms of technology transfer. The existing policy has also had success in improving the terms of technology transfer, as discussed in section 3, and the extent of level of local content in production. In addition to regulating the terms of technology transfer, as discussed previously, the development of local firms has placed pressure on foreign affiliates to contract with Brazilian suppliers. For example, the minimum level of nationalization required for a product line is based on what the Brazilian market can realistically supply. In one case, that of electronic accounting machines, three proposals were submitted to Capre, two by foreign affiliates and one by a Brazilian firm, Exata. The Brazilian firm, using local designs and inputs, requested a low import quota of $260 per unit. The two other proposals proposed to use foreign technologies and inputs; they were required to conform to the product nationalization level employed by Exata.[58]

The local content, or nationalization index, of Brazilian production has improved. In 1979, the share of the total data-equipment production manufactured with local technology was 31 percent. By 1981, reliance on local technology had increased to 53 percent.[59] The reliance on imported technology for systems and modems has decreased by over 30 percent (see Figure 4). The production of computer systems by national firms doubled its production with local technology, from 28 percent to 60 percent, between 1979 and 1981. The modems industry has succeeded in developing its own low- and medium-velocity modem technologies

57. Tigre, Technology and Competition, p.119-120.
58. Example from Tigre, Technology and Competition, pp.120-121.
59. UNCTC, Transborder Data Flows and Brazil, p.94, #266.

but still relies on foreign technology for the production of high-velocity modems; the reliance on national technologies has thus improved from 10 to 50 percent between 1979 and 1981.[60] Heavy dependence on foreign technologies has continued for the production of peripherals (see Figures 3 and 4).

Case Studies in Technological Diffusion

A discussion of the challenges currently facing Brazilian firms--challenges emerging from the structure of the informatics industry, technological changes, and domestic politics--suggests that Brazilian policy will need to be modified if Brazil is to ensure the further growth of a domestic computer industry. An examination of two dimensions of technological diffusion, that of product/price ratios and industrial use of microelectronic technologies, further illuminates both the successes of and challenges to the Brazilian informatics policy.

Prices of Informatics Products in Brazil. The pattern of price differentials between the products available on the Brazilian and U.S. market highlights both the successes and potential failures of the Brazilian policy. Two studies have examined the evolution of prices for computer and peripherals in Brazil--one by Tigre and Perine, the other by Piragibe.[61] Tigre and Perine examined the evolution of prices for Apple-IIs, HP-85 A and B, TRS-80 and their Brazilian clones. The study concluded that the Brazilian copies are competitive in terms of CPUs but not for the entire system (CPU, disk drives, and monitor). For example, in 1984, the Apple II CPU was 8.2 percent more expensive in Brazil than in the U.S. The entire system was 36.6% more expensive. Similarly, the TRS-80 CPU was two percent less expensive in Brazil, while the system cost 18 percent more in Brazil than in the U.S. For the HP85A and B, the Brazilian prices were, respectively, 37.5 percent and 48.8 percent more expensive.

Frischtak comments on the higher prices of HP and observes that unlike the IBM and Apple clones, HPs are manufactured in Brazil by a TNC (Hewlett-Packard) subsidiary. Consequently there is no competition to drive the price down. In contrast, there are six producers of the TRS clone and 12 producers of the Apple clone.

Tigre and Perine note that the Brazilian prices for the systems they studied were initially two or three times more expensive, but had dropped considerably in a two year

60. UNCTC, Transborder Data Flows and Brazil, p.94, #267.
61. These studies are compared in Frischtak, "Brazil."

period. The evolution of prices for the 16-bit IBM PC clone exemplifies the rapid drop in costs. In mid- 1984, the basic configuration sold for $10,500. By mid-1985 the price had fallen to $6,650 and was expected to drop to $5,600 by 1986. The unit cost of production expected to reach $3000 but was not expected to further decrease since further economies of scale were not likely to be achieved. Meanwhile, intense competition in the U.S. was driving prices down there. Price ratios between the American and Brazilian market for the clone thus had decreased, from 4 to 3, but were not expected to fall further.

Piragibe studied the prices of serial printers. She found that some prices fell while others remained well above U.S. prices. Average price-ratios between Brazilian products and those available in the U.S. ranged in June 1984 from 2.073 (for 200 CPS printers) to 5.96 (for daisy wheels). Frischtak explains that the high cost of daisy wheels may be due to a scarcity of skills in precision mechanics, leading to higher production costs, and lower competition in the market for printers than CPUs.

The variation in price ratios appears largely a function of the extent of competition among producers of that product. Thus there was only one producer of daisy wheels in Brazil while there were four producers of CPS printers (see Table 3). The overall average price ratio for printers in the two countries was 3.072 more expensive in Brazil. Piragibe notes that these figures exaggerate the price differential since, in the case of printers, there are quality differences; the Brazilian manufacture more durable printers. Higher taxes in Brazil also contribute to higher costs, but she concludes that there has still been little overall reduction in price differentials over time.

There is an additional difficulty in using price differentials to indicate the competitiveness of the Brazilian products and the impact of the informatics policy on increased costs to Brazilian consumers. The TNCs do not sell their products abroad at the same prices as in their home countries. TNCs tend to charge higher prices in the Brazilian market than in the U.S. one. For example, in mid-1984 the IBM 4341 system, with a typical configuration, was between 2.4 (according to IBM) and 3.02 (according to the Association of National Computer Producers-- Abicomp) times more expensive in Brazil than in the U.S. Prices for Brazilian manufactured computers and peripherals are thus comparable to the prices that Brazilian consumers would have to pay for imports.

A further area of international controversy is the impact of the informatics policy on the rate of diffusion of technological advance. Frischtak examined the rate at which innovations by international electronics firms reached the Brazilian market. He found that for most products there was a lag of approximately one year in introducing innovations. More recent innovations, however, such as ink-jet, thermal and laser non-impact printers, are expected to be introduced in the Brazilian market with a three to five year lag.[62] The lag in introducing international innovations to the Brazilian market appears to be growing as the complexity of new products, the pace of innovation, and the incorporation of software into hardware (firmware) increases.

In summary, costs appear to be decreasing for the products currently produced in Brazil. Cost differentials between the U.S. and Brazil have also dropped for most products. The exception is for products, such as daisy wheels, where a monopoly exists in Brazil. Cost differentials between the U.S. and Brazil are not expected to drop lower than three due to Brazil's inability to achieve economies of scale and intense competition for the U.S. market. The pace of diffusion of international innovations is about one year for most products but there are some indications that this pace is slowing.

Diffusion of Industrial Technologies[63] Another example of the impact of the Brazilian policy on the diffusion of high- technologies is that of industrial applications of microelectronics. Numerically controlled machine tools are beginning to be produced within Brazil by both national and foreign firms.[64] In 1985, there were 1,711 numerically-controlled machines installed in Brazilian industries. Of this number, 534 were imports, predominately imported in the early 1980s. The reliance on imports has more recently declined; only 60 of the 473 machines installed in 1985 were imported. Presently 14 Brazilian firms produce numerical control machines.

Robotics are also being introduced into Brazilian industry. By 1985 there were 25 robots installed in four major automobile factories. There were plans to install 40 additional robots in early 1986 and the implementation of 200 more was anticipated by 1989. There are

62. Frischtak, "Brazil," p.54.
63. This section relies on the study of automation in Brazil conducted in Castro and Carvalho, "Automation in Brazil."
64. Tauile, 1984 work, cited in Hubert Schmitz, "Microelectronics Based Automation and Labour Utilisation in Developing Countries," viertejahresberichte 103 (March 1986), p.34.

four firms currently developing their own industrial robots and 12 additional firms intend to license foreign technology.

There were 43 CAD/CAM systems installed by 1985, all imported. There are, however, numerous projects to produce these systems in Brazil. Twenty projects had been approved by SEI by 1985.

Some firms in the heavy industries are also developing their own software and hardware, and marketing them within Brazil. Similarly, the development of office and bank automation systems is being backed by financial conglomerates, with participation by traditional banks, and being marketed throughout Brazil.

Moura Castro explains that initial diffusion has been modest and cautious; he claims that a the cautious approach was necessary as firms learned to use the new technologies and the management and work force adapted. The informatics policy may also have slowed the process of diffusion by imposing barriers (both tariff and non-tariff). Last, the business cycle itself may account for the relatively slow diffusion of automation in production and services; the negative growth rates experienced in the early 1980s led to a "severe slowdown in industrial investment."[65] The improvement in the economy in 1985 and 1986 may lead to increased investment, and an increased pace of diffusion of high-tech industrial systems.

The implementation of flexible automation and other industrial technologies has the potential to improve the competitiveness of Brazilian firms. Problems may also be experienced, as in the First World economies, as new technologies are introduced into the workplace. A loss of jobs as a consequence of introducing labor-saving technologies is one anticipated problem. While the number of electronic industrial systems installed in Brazil is still small, the question remains whether the pace has affected the competitiveness of Brazilian firms or, alternatively, employment levels in Brazil?

Automation has the potential of improving competitiveness of industrial manufacturers. For example, product testing machines for the electronics industry test product quality with 95 percent accuracy while manual methods realized only 65 percent accuracy). The machines are costly, however, and only three Brazilian firms use them.

65. Castro and Carvalho, "Automation in Brazil," p.3.

Most of Brazilian industry has not implemented fixed automation, instead relying on the flexibility of stand-alone machines. This means that there is the possibility of technological leap-frogging, jumping the intermediate technology of fixed automation and implementing flexible automation.

Because there has been limited automation in Brazil, the impacts of automation on labor are thus far largely speculative. Some decrease in the size of a required labor force is expected. A study of employment consequences of automation in Brazil found that in the automated automotive factory studied, automation only reduced the factory's work force by 1.5 percent.[66]

Summary

The above review of the impact of the Brazilian policy with respect to human resources, R&D, industrial growth, industrial dynamism, technological parity, indigenous technological and industrial capabilities, price performance ratios and technological diffusion suggests only partial answers to the questions presented at the opening of the section. The Brazilian policy has had some success in establishing the foundations for further growth in the industry yet the Brazilian firms lack the technological and industrial basis for semiconductor manufacture, one of the key inputs in the sector and of increasing strategic importance. While the domestic market for local products has grown, it is still too small to support internationally competitive levels of R&D investment or scales of production. The policy appears to slow the pace of diffusion of industrial applications but the scale of such applications is still too small, and other barriers to diffusion too great, to reach definitive conclusions regarding the policy's impact on industrial competitiveness. In summary, the Brazilian policy, based on largely traditional approaches to industrial development, has succeeded in achieving the explicit policy goals regarding human resources, R%D infrastructure, increased output and quality, and decreased costs. The requirements of the international informatics sector, however, mean that these traditional strategies are inadequate; the resources and mechanisms of traditional development policies cannot begin to

66. Castro and Carvalho, "Automation in Brazil," p.6.

cope with the pace of technological change, the costs of technological advances, and the dynamics of implementing the technologies.

The political implication of the informatics policy are also inconclusive. The policy has succeeded in strengthening Brazil's bargaining position vis-a-vis the transnationals, as their concessions indicate. Dependence, with respect to required imports of components as well as technologies, appears to have simultaneously increased. Domestically, the industries' growth represents a consolidation of some military, financial and industrial interests, although the recent political and economic crises--resulting from the Cruzado Plan's [implementation] prior to a major election and from political jockeying accompanying the democratization process--may reduce the legitimacy of both those who govern and their economic plans.[67]

Conclusions

Although Brazil's policy has succeeded in creating the basis for an informatics industry, there are indications, as summarized above, that Brazilian firms may have difficulties in reaching stages three (technological self-sufficiency) and four (international competitiveness) of the informatics policy program. Alternatively, there is the promise held out by Brazil's success in other technologically sophisticated industries such as petroleum exploration, aeronautics, and weaponry. One of the critical questions at this juncture is whether Brazil will maintain its current balance between autonomous development and dependence, will move towards technological self-sufficiency, or will become increasingly reliant on foreign technologies and components.

Alternatives to the Informatics Policy

The case of the informatics suggests that the Brazilian policy objectives of achieving technological diffusion and fostering a national industry have to some extent both been met. There are, however, significant barriers to the further consolidation of the Brazilian industry, barriers arising from changes in the global technological frontier as well from the structure of

67. Julia Michaels writes, "[International] pressures, plus doubts about foreign debt negotiations, the return of high inflation, and increased social conflict, have led many Brazilians to conclude that the government is losing control of the situation." (Christian Science Monitor, "US trade curbs stir Brazil's troubled political waters," Julia Michaels, November 16, 1987, pp.9-10.) Recently a congressional committee limited the presidential term to 4 years instead of eight and this was seen as a further indication of growing dissatisfaction. Also see South 81 (July 1987), pp.51-2, in which John Barham describes the measures of and political response to the Cruzado Plan.

both the international and Brazilian informatics industry. While the development of the computer industry suggests that the Brazilian informatics policy could prove a model for other technologically-dependent sectors, there have been successes in other sectors based on other policy approaches.

For instance, Brazil's three international high-technology successes have been in petrochemical exploration, aircraft, and armaments. Petrochemical exploration is a result of finding and developing a niche in the world market; created comparative advantage. This is unlike the computer industry which has been largely emulative of technological changes by the international leaders. Still, this represents a relatively small market and accounts for a much more limited economic and technological impact than microelectronics.

Aircraft is the result of a second strategy in which a national firm, EMBRAER, became the "national champion." The orientation from the industry' foundation was towards the export market with internal consumption simultaneously assured by military purchasing policies. As there was no internal competition, economies of scale could be achieves.

There were significant economic and political costs associated with the aeronautics industry. First, there was the financial burden of founding and supporting the growth of the industry. This burden was transferred to society in general through the conversion of civilian industrial facilities to military uses and through the military's unrestricted control over the national budget. The second consequence of the industry's development was the militarization of the society and economy, a militarization which has outlasted that of its military leaders.[68]

Similarly, the armaments industry is internationally competitive and exports to both Third and First World nations. This competitive success has been achieved through the licensing of technologies, joint ventures and tri-pe arrangements, an early export orientation, and heavy investment by the Brazilian government. Both of these industries have also had the security of a captive, although limited, domestic market--the Brazilian military. Technological innovation has tended to be incremental, improving technologies licensed from abroad. Additionally, as noted by Gerd Junne, "given the intensive competition between

68. Brigagao, Clovis, "The Brazilian Arms Industry," Journal of International Affairs 40:1 (Summer 1986), pp.101-114.

weapons producers in the industrialized countries, it is often less difficult to get access to advanced military technology than it is to get civil technology.[69]

Why have neither of these approaches been used to support the computer and other high-technology communications sectors? First, the rapid pace of technological innovation and the shortened product cycles of the informatics industries required high-levels of R&D and continual access to the technological advances made internationally.

Second, in the case of the computer industry, the potential national champion, Cobra, was neither able to raise the necessary capital nor manage the technical production of minicomputers.[70] Tri-pe arrangements were similarly precluded since local capital was not yet interested in microelectronics ventures and transnational corporations resistant to such cooperation.[71]

Third, while armaments and aeronautics are strategically important, the products of these industries are largely confined to the industry itself (the exception being the recent applications of missile launching to satellite launching capabilities). Informatics, in contrast, affect all sectors of the economy. The initial interest in a computer project, moreover, came from both civilian and military groups. Thus, while the Brazilian aircraft and armaments industries focused on particular market niches and products, the aim in the informatics sector was to produce a wide range of technologies and products. As Frischtak states,

> The point of departure is that the possession and capacity to utilize information resources are increasingly becoming a form of national power, and require, therefore, the adoption of national policies that stimulate the emergence of national data industries and markets for hardware, software and services.[72]

Areas for Further Research

Just as the problems now faced by the informatics sector cannot be resolved through an adoption of past strategies of other sectors, the successes of the policy will also be difficult to reproduce. One of the central concerns of those examining Brazil's policy is to determine

69. Junne, Gerd, "New Technologies and Third World Development," viertejahresberichte 103 (March 1986), p.10.
70. See Adler, The Power of Ideology, and Ramamurti, State-Owned Enterprises.
71. See Evans, "State, Capital, and the Transformation of Dependence."
72. Frischtak, "Brazil," p.39.

to what extent the Brazilian protectionist strategy can provide a model for the development of high-technology industries in other Third World countries. Although the informatics law has focused international attention on the microcomputer market, Brazil's high-technology policy actually encompasses the computer industry, an arms/munitions industry and a nuclear industry. The consolidation of these three industries, and the political, technological, and cultural consequences of their development, has dramatically marked the past 20 years of Brazilian industrialization. The close relationship between computer policy and defense policy, and between computer policy and nationalism is discussed in Sections 2 and 3. Defense concerns and nationalism characterize many Third World nations and further accounts for their interest in Brazil's successes and failures.

Brazil's protectionist strategy is of limited use as a blueprint for the development of other Third World countries. First, the market reserve policy is but one of many factors contributing to the growth of the mini-and micro-computer industry. An understanding of the other factors-- political, institutional, economic, and ideological--suggests that many government mechanisms/policies, as well as the characteristics of the global computer market, contributed to the emergence of Brazil's computer industry.

For instance, Brazil's previous manufacturing and engineering experience contributed to the feasibility of the computer sector's development. More important, perhaps, was the coalescence of various interests--the previous alignments of military and class interests allowed the financing and political backing of the Guaranys, Cobra, and Capre programs. The size of the Brazilian market also allowed Brazil greater bargaining power with TNCs in obtaining technology. These details suggest that Brazil's policy cannot act as a blueprint. The policy experience may, however, suggest the utility of particular policy measures. An assessment of just how applicable different measures could be is one question for further comparative study.

Advocates of Brazil's computer policy have praised the development of a national industry, especially a high-technology industry. They focus on expected decreases in technological dependence, improvements in the skill level of the workforce, technological and commercial spinoffs, and the improved bargaining position of the country. They look to the policies which have promoted the industry--the development of human resources, the promotion of R&D promotion, the regulation of technology transfer and capital flows, and the protection of the market--to assess the adequacy of each measure, and the applicability to other sectors and countries.

While important, such analyses have downplayed the connections between Brazil's informatics policy and military interests. If informatics is viewed as an integral part of Brazil's defense policy, then a focus on the on the contribution of the defense industry to national research and development capacity and of the informatics sector to national defense becomes necessary. This then is a second area requiring further research.

The challenges that are facing the Brazilian industry do not preclude its further development. Opportunites for further consolidation of the informatics industry do exist. Hobday writes,

> [there] may be new opportunities for local manufacture of digital equipment for developing countries with relatively large internal markets. The shift from analogue, electro-mechanical to fully digital technology, has produced a trend towards smaller scale systems, and a greater degree of "technological divisibility" in the development of larger systems. Thus in spite of the economic and technological barriers to entry in large scale switching there may be prospects for selective market entry by [developing country] firms.[73]

Indeed, it is these opportunities for industrial and technological development, created by the new changes in technology, on which Brazil has attempted to capitalize. The policy measures needed to resolve current dilemmas and surpass present barriers are an area for further investigations.

Changes in the structure of high-technology production will also change the potential strategies which Brazil can employ. How will increased customization and software and firmware development affect the Brazilian strategy? Will the industry vertically integrate globally? domestically? How will this affect the possibilities of further Brazilian development?

Other areas for further research would assess the impact on society of the development of high-technology industries and the introduction of high-technology processes. These

73. Hobday, Mike, "Telecommunications—A 'Leading Edge' in the Accumulation of Digital Technology? Evidence from the Case of Brazil," vierteiahresberichte 103 (March 1986), p.69.

include issues such as the consequences for regional development (and underdevelopment) within Brazil and for the Latin American economy as a whole.

The extension of informatics to telecommunications and telematics also requires further investigation. Can the policy applied to computer and software production be successfully applied to the telecommunications sector, as currently planned? Are there technological requirements of such systems that demand other policy measures? Does the current distribution of knowledge regarding telecommunication, or other advanced technologies such as biotechnology, require special policy measures to foster local industrial and technological capabilities?

Summary of Findings

Technology policy in Brazil has struggled with a number of conflicting requirements since its emergence in the late 1960s. Technology policy has had explicit dual objective of promoting a rapid improvement in the goods and services available in Brazil and promoting domestic technological capabilities. The diffusion of the technologies themselves were seen as critical to the competitive functioning of diverse industries, military and civilian, manufacturing and service. The acquisition of technological capabilities was portrayed as critical to continued economic growth and to military power. The two distinct, and often contradictory, goals were linked through the promotion of nationalist programs, such as the informatics policy.

A second dilemma relates to the source of technology. Access to foreign technologies is necessary to the long-term technological and competitive needs of Brazil's industries. Reliance of foreign technologies can also undermine attempts to foster local capabilities and innovation. Brazilian policy has tried to strike a balance between these two constraints by addressing the terms of technology transfer and introducing market protection mechanisms. It has tried to resolve the political contradictions of such a policy through pragmatic bargaining with the TNCs and the implementation of increasingly nationalistic policy. The rhetoric of nationalism, the ideology of anti-dependency, and the resulting regulation of technology transfer, foreign direct investment, capital remittances and market production levels (domestic versus export) allowed the Brazilian government to create new areas for negotiating with the suppliers of technology.

The analysis of the development of technology policy in the computer sector demonstrated that the computer case is similar to many of Brazil's other industrial sectors. However, the importance of the computer industry specifically, and technological advancement generally, militates for a more nationalistic and protectionist strategy. The costs of not gaining technological sophistication, and the difficulties in establishing the infrastructure for technological advancement provide two explanations for Brazil's commitment to its computer strategy. The convergence of military defense requirements and civilian economic priorities provides a further basis for the policies' emergence.

The particulars of the policy, moreover, appear to be as much a consequence of the attitude of the TNCs to fostering local Brazilian production as to nationalist sentiment within Brazil; the two have been mutually reinforcing. It is the confluence of numerous factors, local support for technological autonomy and local production, the general logic of the state, strategic bargaining with the TNCs, and of the structure of the international computer market, which provides an explanation for the emergence of the Brazilian policy.

The review of the impact of the Brazilian policy with respect to human resources, R&D, industrial growth, industrial dynamism, technological parity, indigenous technological and industrial capabilities, price performance ratios and technological diffusion suggests that the Brazilian policy, has succeeded in achieving its explicit policy goals regarding these issues. The requirements of the international informatics sector, however, mean that these goals are insufficient to ensure, first, further technological development in Brazil and, second, the corollary objectives of national power, economic growth, and military strength. The resources and mechanisms of traditional development policies, while producing some significant results, are inadequate to respond to the pace of technological change, the costs of technological advances, and the dynamics of implementing the technologies.

One of the significant results that the policy has achieved is strengthening Brazil's bargaining position vis-a-vis the transnationals. Nevertheless, dependence, especially with respect to required imports of components and technologies, appears to have simultaneously increased. This dependence on continued access to technological advances has thus forced

Brazil to make some concessions to international firms. Brazil's nationalistic computer policy, in light of the strategic bargaining in which Brazil and the TNCs are currently engaged, appears to have kept Brazil in the game but not ensured participation in further rounds.

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THE TECHNOLOGICAL IMPERATIVE IN THE OPEN DOOR POLICY: TECHNOLOGICAL POLICY IN THE PEOPLE'S REPUBLIC OF CHINA

Katharyne Mitchell

The goal of this paper is to analyze the relationship between politics and technology in China since 1978. It is our contention that government policies regarding technology have had a great impact on the development and transfer of technology in China, and that these policies are fundamentally connected to the use of technology as an instrument of political power. How this power is wielded has far-reaching implications for China's economic development, as the utilization of new technologies affects both military capabilities and industrial development. As the new technology is becoming increasingly crucial in industrial renovation and modernization, the efficacy of the diffusion of new technology into industry will play a major role in the nation's ability to enter the international markets, as well as to meet domestic demands.

As in most developing countries, technology in China is perceived in its dual dimensions of military capability and national economic development. The relative weight given to either of these spheres determines to a great extent the priorities and the goals of those controlling State policy at any given point in time. These priorities have shifted often since 1949, and the government's directives concerning the best uses for technology have usually shifted with them. The questions to be addressed concern the economic and political reasons for these priority and policy shifts, and their ramifications for China's modernization drive.

The body of this paper will be focused on the changes that have occurred in China since 1978, with particular emphasis on the impact of government policy on the diffusion of technology into industry. The industry that is currently the most fundamental to China's economic development is the electronics industry, as it has the potential to aid in the automation and upgrading of other industries, as well as to process information needed in international business dealings. The electronics industry will thus serve as the central case study within a more general analysis of technology policy in China since the Open Door period.

The specific questions related to the electronics industry concern the major subsectors in the industry: computers, microelectronics, telecommunications, and consumer electronics. How are the government's political needs related to each of these subsectors and why? How big a role has the State played in guiding the development of each branch of the industry? What is the role of the military for the electronics industry as a whole, as well as for each subsector of the industry? How has the electronics industry been manipulated to fulfil the needs of the State during the drive toward modernization?

In order to address these questions in a comprehensive manner, it is necessary to provide a brief historical background of China's technology policy, in addition to the current political and economic analysis. This history finds five major technology periods. The second half of this study focuses mainly on the growth of the most important subsectors within the electronics industry, particularly the computer industry, between 1978 and 1988.

The research for this report has been conducted almost entirely at the libraries of the University of California at Berkeley. The Chinese newspapers and the FBIS and JPRS reports are located in the library at the Center for Chinese Studies at 2223 Fulton Street in Berkeley. Additional information was collected during a summer of study at the University of International Business and Economics in Beijing. Personal observation of technology transfer and the problems inherent in the industrial diffusion of technology in China was conducted during the summers of 1986 and 1987, when I worked as a quality control supervisor at a fish processing plant in Heilongjiang, China.

Technology Policy Themes

Self-Reliance

China's commitment to self-reliance has been a major theme affecting technology transfer and the development of electronics technology since the Soviet withdrawal in 1960. Historically, the Chinese nation has long been concerned with maintaining a strong, independent, autonomous state. The early reliance on the Soviet Union by the leaders of the People's Republic led to near disaster, and convinced many government officials to revert to the more traditional premise of self-reliance. Since that time, the two cardinal principles of technological development have become those of military self-sufficiency and national economic development based on the ideology of self-reliance. These two principles have probably been emphasized in China as a result of its socialist system and the isolation imposed on it for two decades by the international powers. The needs of the military during this time led China to concentrate on aviation and aerospace (including missiles), and on nuclear power. The needs of national economic development led to the concentration of efforts in technologies related to heavy industry and basic industrial infrastructure, specifically energy, steel, and transportation.

Steel vs. Electronics

Undoubtedly the Soviet Union's model of development played an important role in China's decision to emphasize heavy industry over light industry and agriculture in the 1950s. Even after the Soviet withdrawal, however, the emphasis on heavy industry continued. In an important ongoing debate concerning the role of steel vs. that of electronics as the foundation of economic development, steel emerged victorious throughout the sixties and seventies. Not only did the disagreement of several high-level government leaders have an effect on the outcome of the debate, (most notably Liu Shaoqi and Mao), but the fundamental intransigence of a vast bureaucracy based on heavy industry and modeled on the U.S.S.R. was probably also a decisive factor.

The New Technology and the Need for a More Complete Infrastructure

In the mid-1970s, the rapid innovation and development of new technologies in the world led to a crisis in China's fundamental principle of self-reliance. The technology of the 1970s was based on the processing and transmission of information by computer and telecommunications that demanded an infrastructure and a network of international contacts. This new information technology was thus basically incompatible with the ideology of self-reliance as practiced by China in the past.

At the same time as these rapid technological changes were occurring, an accelerated internationalization of the economy made it increasingly difficult to avoid joining in the competition for the world markets. A decision by a major developing country such as China to avoid the international marketplace at this time would undoubtedly have precluded the possibility of becoming a major political power at any point in the near future. The potential for political might and prestige was important for government leaders, as it accorded with their projection of the nation as a future political and economic power in Asia.

China was thus confronted by a conjuncture in time of a major technological revolution, with ramifications for every area of industry and the military, and a quickening and strengthening of global economic ties and international networking. In order to compete in the international markets, as well as to preclude the domination of foreign products in the domestic markets, China was forced to end its period of self-reliance and to join the world technology race. The only alternative was to face technological obsolescence and eventual industrial decline.

China's decision to join in the technology competition was not a casual decision, and was not without great social, political and economic implications. It is apparent to the leaders of most developing countries that the choice to join the technology race is largely a choice to buy and import technology from foreign countries. The domestic research and industrial capability for the production of the new information technologies takes time and capital to develop, and is largely impractical without the provision of an adequate infrastructure. Like most developing countries, China's infrastructure was incomplete or nonexistent in areas of education, trained personnel, modern management techniques, horizontal and vertical communication between sectors, transportation, industrial diffusion, marketing know-how, and a host of other areas. In order to join the technology race, China thus had no choice but to accept an entire system that was largely imported from foreign countries.

Political Aspirations

The imperative to integrate into the world system was two-fold. The rapid transformation of information technologies around the globe occurred at the same time as China's initial attempts to establish itself as a modern nation. The timing of China's new economic and political goals for modernization accorded well with the changes called for by the new information technologies, and set the stage for vast, sweeping reforms in nearly all of

China's bureaucratic and organizational structures and much of its previously rigid ideologies.

The Role of the Military

Throughout the first three decades of the People's Republic, military capability was considered as the highest priority for the security of the nation and for political legitimacy. The development of technology in industries related to the military was years ahead of research and development in the civilian sector. The top scientists and engineers were often selected to work on special military-related projects that were completely unrelated to civilian needs and were rarely copied or diffused into civilian industry. These projects were organized in a 'mission-oriented' fashion that had a much higher success rate than plans that had no potential military applications.

Since the Open Door Policy, however, the demands of the military are often considered in tandem with the demands of national economic development. Government policy has changed from an overwhelming support of all military developments, to one that seeks to combine the needs of the military with the needs of the nation in its drive to modernize. Although the trend is relatively recent, and data is difficult to find, it is clear that in the past four years, there has been a strong push to diffuse technological innovations that have appeared in the military industries into the civilian sector. The extent to which this diffusion has been successful is still undetermined, but will be analyzed in greater depth in the second half of this chapter.

The changes that have taken place in China since the Open Door Policy are due to the confluence of internal and external motivating factors. The most important perhaps, has been China's own insistence on entering and becoming a vital force in the world economy. The second has undoubtedly been the rise of a new technological challenge that has forced China, along with many governments, to make the choice between either accepting a widening technology gap and the economic and political dependency which that might entail, or mobilizing resources to adapt the old, adopt the new, and buy into the mainstream of technological progress.

There is no question of catching up--the differences in technological progress are already too large. The imperative, rather, is to keep the gap from growing in such a way that it will become historically irreversible. With the advent of Deng Xiaoping's new policy of openness and co-operation with outside partners, China has accepted this challenge, and has stated goals of achieving, by the 1990s, a technological level equivalent to the U.S. in the 1970s. China's leaders have, however, instituted widely varying and often rapidly changing types of policy measures in order to reach this goal. This vacillation might manifest confusion as to the best method of implementing these goals. At the same time, I believe it also demonstrates an ever-changing dynamic related to the shifting political needs and goals of the Chinese government at particular historical moments. The demands on the State since 1949 have changed dramatically, and it is our contention that these demands have played a central role in the formation of technology policy. In order to fully understand these demands and their probable policy results for the modern period, it is helpful to examine the evolution of technology policy since 1949.

Technology Policy in China: 1949 to 1988

Period 1: 1949-1960

For the first decade following the revolution, much of the State's technology policy was focused on technology transfer with the Soviet Union. Technology transfer included four possible procedures: 1) importing advanced equipment such as production lines; 2) importing know-how on the basis of licenses and of Chinese experts trained abroad; 3) importing advanced foreign factories and personnel capable of upgrading the technological level of the country by their presence in China's productive structure; 4) training Chinese scientists, technicians and workers so that know-how could be transferred to the productive system under the control of the Chinese government.

In the period from 1949 to 1960, all four of these procedures of technology transfer were implemented. This time period was characterized by rapid industrialization, following, to a large extent, the model of the U.S.S.R. Heavy industry was emphasized over light industry and agriculture, and science academies and other institutional structures were set up under a rigidly planned and centrally controlled system. As a result of these emphases, China was able to establish a strong and viable academic foundation for basic scientific research, but completely lacked any regional or local coordinating mechanisms that would enable these advanced research centers to link up to the rapidly expanding industrial sector. The early desire for extensive growth in GNP arising from the Soviet model's emphasis on heavy industry, thus precluded intensive growth arising from potential technological innovations emerging from the research labs.[1] The results of this early policy have had major repercussions for the nature of China's industrial growth and for the low level diffusion of technology through the present day.

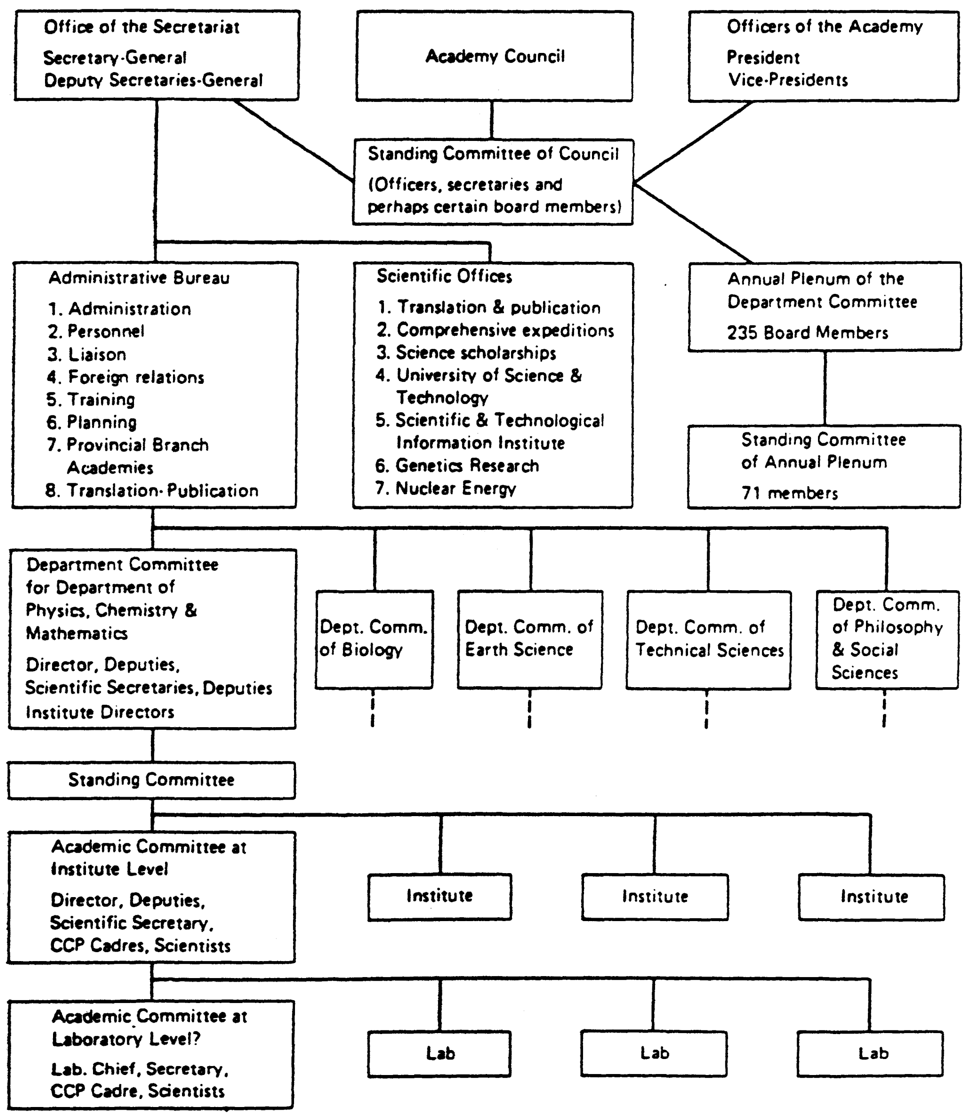
In terms of the growth in quantity and quality of academic institutions and scientific manpower, the early period was an undeniable success. From 1949 to 1955 the number of scientific institutions rose from 30 to 400, and the number of academic researchers rose from 500 to approximately 400,000 in various disciplines.[2] Several science institutions were founded, including the Academy of Sciences (CAS), which was formed from the older Academia Sinica and Peking Academy. This institution had two primary functions: it was a research establishment that was committed to the national goals of economic development and the military; it was also the agency of government in charge of most branches of science. For the first five years following the Revolution, almost all policy pronouncements relating to science came from the Academy. Research plans were formulated in consultation with the government departments, and implemented and coordinated through CAS.

CAS' general inefficacy in promoting China's first Five Year Plan (FFYP) led to some reorganization, including the establishment of a Soviet-style Secretariat in 1954. This Secretariat was far more political in nature than the Academy, and wielded considerable influence on research and planning decisions in science. Control over CAS became evenly divided between the administrative and the political branches, of which the Secretariat and the Administrative Council were the representative organizations. (See Figure 1).

In 1956, Zhou Enlai gave priority to technological development in the nation's modernization plans and, with the coordination of the State Council, set up a new State

1. For a more complete economic assessment of intensive vs. extensive growth in Chinese industry, see Reynolds, in China: A Reassessment of the Economy, Joint Economic Committee Congress of the U.S., July 10, 1975.
2. Bianchi, Patrizio Martin Carnoy, and Manuel Castells, Economic Modernization and Technology Transfer in the PRC, Stanford: Stanford University, CERAS, 1988.

Figure 1
CAS Organization for Leadership and Administration



Source: Suttmeier, Research and Revolution, p.57.

Science Planning Commission. This Commission produced the Twelve Year Plan for scientific and technological development in the same year. The plan was an important first step in the articulation of science priorities and in the initial attempts to coordinate science theory with practice. Priority projects of the plan manifested a concern for advancing sophisticated military technology, and for exploring the current "hot" scientific fields from around the world. The twelve categories for priority research included the peaceful uses of atomic energy, radio electronics, jet propulsion, automation and remote control, petroleum and scarce mineral exploration, metallurgy, fuel technology, power equipment and heavy machinery, problems relating to harnessing the Yellow and Yangtze Rivers, chemical fertilizers and the mechanization of agriculture, prevention and eradication of detrimental diseases, and problems of basic theory in natural science.[3]

Two other important science institutes that were set up in 1956 were the Science Planning Commission and the State Technological Commission. These two organizations merged in 1958 to form the State Scientific and Technological Commission (SSTC). The main purpose of these new institutes was to carry out the twelve priority research goals from the Twelve Year Plan, and to provide some central leadership for international scientific contacts and cooperation. It was also hoped that the institutes would mitigate the problem of communication between sectors by providing a link between scientific research and industrial enterprises.[4]

Much of the progress that was made in both technological development and in industrial growth, however, was the result of massive Soviet assistance. It is estimated that 10,000 Soviet engineers and technicians worked in China, while about 15,000 Chinese technicians were trained in the Soviet Union during this period. At the same time, industrial development was aided by the U.S.S.R through a variety of measures, most prominently through the importation of 256 complete plants and 50%-70% of the equipment needed for industrial construction.[5]

3. New China News Agency (NCNA), Dec. 30, 1956; reprinted in Survey of China Mainland Press (SCMP) 1442.
4. NCNA, Dec. 29, 1956; reprinted in SCMP 1453
5. Bianchi et al., Economic Modernization.

The policy of nearly complete reliance on technology transfer, and almost entirely from a single source, was disastrous for China's technological development after the Soviet Union's departure in 1960. The abrupt end of assistance, coupled with the political instability engendered by the Great Leap Forward and the Anti-Rightist Campaign, left much of the technological foundations of the Chinese economy in ruins.

Internal State policy on science and technology during the Great Leap Forward years (1958-1961) was equally devastating for technological development. This period of mobilization was characterized by a major shift in the preferred model of scientific and industrial management from one of "professionalism" to one of "bureaucratism."[6] The effects of this ideological shift on scientific research, on management, and eventually on industrial output, were quite large. The practice of one-man management and individual responsibility was reformed to a practice of consensus management, where decisions were made collectively. The prestige of Party cadres grew as they were allowed more important decision-making powers concerning future research topics than the scientists themselves. At the same time, the status of the "expert" dropped perceptibly and was replaced by an emphasis on being "red."[7] Scientists and technicians soon found themselves under the influence of politicians and bureaucrats rather than other scientists. In addition, since science was supposed to be led by the workers as well as by the scientists, it had to be decentralized on a large scale. By mid-1958 there was a proliferation of new administrative organizations in every sector of science and industry even to the level of the village factory.

In addition to the disruption of management structure on the provincial and local levels of science and industry, the mobilization policies of 1957 caused changes in the political hierarchy of the Party itself. Not only was technology used as an instrument of political power in its own right, but the ideology of the role of technology in socialist

6. The terms "professionalism" and "bureaucratism" are used in sociology to differentiate different styles of management. According to Richard P. Suttmeier, Research and Revolution (Lexington Books, 1974), the professional method of management in China is one governed by the rational choice of professionals operating in a hierarchical system. The bureaucratic method, by contrast, is a type of management based on the primacy of the Party rather than on professional choice, where decisions are made by administrative consensus. See Suttmeier's model, p. 83.

7. The "expert" in China is considered to be the man or woman with superior technical expertise and specialized training. The "red" is the person who has committed him or herself wholeheartedly to the socialist ideology and the goals of the Communist Party. The importance of "expert" vs. "red" has been an ongoing debate since 1949. For a more complete discussion of this topic, see Franz Schurmann, Ideology and Organization in Communist China (M.I.T. Press, 1958).

construction was also used as a political weapon. The control over technology was felt by State leaders to be too important to be left to the technicians, (or worse yet, to the intellectuals). An increased reliance on non-material incentives, along with lower-level decentralization of industry, worker participation, and cadre control, greatly added to the politicization of the economy and the aggrandizement of the State during the last two years of the decade.

This early period was thus characterized positively by great progress in the formation of academic research institutes and in the successful development of heavy industry, and negatively by the institutionalization of a rigid central bureaucracy that confounded communication between these two sectors. It was also notable for a nearly disastrous three year period of social and ideological chaos, and for an abrupt Soviet withdrawal which presented the State with serious problems for its future technological development. These final problems were undoubtedly responsible for initiating China's nearly two decades of isolationism and firm commitment to self-sufficiency. At this time, technology transfer was conducted on a less immediate level than in the past, and was perceived more as a means of bolstering the domestic industries (particularly those related to the military) than as the complete panacea that it had been during the years of partnership with the Soviet Union.

Period 2: 1960-1966

Owing to the painful lesson of the Soviet withdrawal, China's leaders began to rely more on the internal development of technology during the second period. There was a concerted effort to mobilize the country's own scientific resources and manpower, particularly in areas of strategic military importance. At the same time, technology transfer was not abandoned, as China negotiated successfully with both Japan and Western Europe for the importation of 50 industrial plants, and more than US$200 million of technologically advanced electronics products. Between 1962 and 1965, the practice of purchasing entire production lines, which could later be reproduced and adapted through a process of reverse engineering, was China's main procedure for technological upgrading. At this time, China's technology policy was largely geared toward the protection and improvement of the fledgling military industry, and Zhou Enlai was a leading figure in promoting technological advancement in that area.

In 1962, the members of the National Working Conference on Science and Technology met to reaffirm the nation's commitment to scientific research and development, and to stress the complementary role of scientific investigation in the construction of socialism. After the chaotic interlude of the Great Leap Forward and the Anti-Rightist Campaign, where science was treated with suspicion and distrust, this reaffirmation of the important position of science was crucial for the continuation of technological innovation and development.

The two goals of military capability and national economic development continued to be stressed during this period, as can be seen in the State Science and Technology Commission Program for 1963-1972. The program listed 374 major research projects, of which 333 were directly linked to defense and national economic goals.[8] The Chinese government's commitment to defense was manifested to the world with the explosion of its first nuclear bomb in 1964. The explosion of this bomb signified a long-term commitment to nuclear research, as well as other types of military-related research, that would continue through the chaotic period of the Cultural Revolution. The relative isolation and autonomy enjoyed by these defense-related projects during the Cultural Revolution was largely owing to the work of Zhou Enlai. Through personal and political power, he was able to protect the fledgling nuclear and military aerospace programs that might otherwise have been swept into the destructive tide of domestic confrontations that occurred over the next decade.

The development of these military industries thus remained a priority for the nation, despite the bitter feuds between high-ranking members of the government as to the best overall utilization of science and technology on the road to socialist construction. Various political battles took place on many levels, and a conflicting ideology associated with science and technology was often at the center of the controversy. Aside from the protected military technology, every other area of technology research and development was affected by the second "mobilization" campaign, the Cultural Revolution.

8. Bianchi et al., Economic Modernization.

Period 3: 1966-1972

Although the Cultural Revolution was not aimed at technology directly, many of the policy decisions made during this time had serious implications for both science and technology. Just as the policies of the Great Leap Forward had involved major changes in the structure of scientific organization and industrial management, the policies of the Cultural Revolution introduced similarly monumental paradigmatic shifts in the conception of how science and technology should be perceived and organized. The Maoist vision of the role of science as a group activity resulting in advances for socialist construction was fundamentally incompatible with new technological developments and the social hierarchies which they engendered. As a result, the scientific institutes were challenged, education was discontinued, CAS was disrupted, and the SSTC came under attack.

With the exception of the nuclear, aviation, and missile launching programs and their related computer and electronic components, all forms of technological innovation and application were severely retarded. As in the Great Leap years, technology policy was again used within the Politburo itself as a political weapon. Those who favored technological proficiency and a measure of autonomy for scientists and scientific research, such as Liu Shaoqi, were attacked and removed from positions of power. Perhaps the most detrimental long-term effect of this period, however, was the closing of the universities and specialized technical institutions. As a result of this educational disruption, an entire generation of scientists and engineers was lost. This gap is particularly noticeable in China today, as the Soviet-trained generation retires and replacements are few.

Period 4: 1972-1978

The fourth period is often analyzed in conjunction with the Cultural Revolution period, owing to the continuing control of political power by the ultra-left. Despite chaos on many fronts, however, there were some major investments and progress in technological programs. In domestic production, the electronics industry and other fields connected with the military were largely cushioned from the full impact of the Cultural Revolution's most destructive forces. Internationally, the China Technical Import Corporation (TECHIMPORT) was restored in 1972 to ensure the continuation of some vital imports. And in 1973, the State

Council approved the 4.3 Program, a big-budget spending measure designed to facilitate the importation of advanced equipment. Unfortunately, much of the investment was wasted because of insufficient infrastructure and poor intersectoral connections. (The 1.7 metre steel rolling mill at Wuhan is one of the most publicized examples of excessive waste in investments made during this period).

Period 5: 1978-1985

The Technology Imperative. The Open Door Policy has been the key State policy in China's current drive to modernization. Economic and technological development have been accorded highest priority, and technology transfer has assumed the primary position within that hierarchy. Since 1978 there have been several significant State policy pronouncements concerning technology. In 1978, the SSTC drafted an Outline Program for National Scientific and Technological Development. (The program continued through 1985). The main purpose of this program was to reaffirm the government's commitment to furthering scientific research and development as well as to identify and criticize the setbacks experienced during the Cultural Revolution. A similar meeting of the Scientific Council of CAS was convened in 1981. Here, top political and scientific leaders met to decide on the future direction of China's scientific development. A new Constitution was created that guaranteed the power and autonomy of the Scientific Council for making final decisions in CAS. The new Constitution heralded the incipient demise of the overwhelming political control of science that had characterized both the Cultural Revolution and the Great Leap Forward.

A return to professionalism over the previous decade of bureaucratic controls was further encouraged by a variety of financial and academic incentives for individual entrepreneurialism and research creativity. Financial and institutional aid for research and for education was provided on a large scale, and the number of science and engineering graduates grew rapidly from the lows of the Cultural Revolution. (See Table 1). In addition, management and organizational structures were reformed to allow for greater responsibility and autonomy. These structures were divorced, in some measure, from the political and bureaucratic strangleholds of the previous decade.

Table 1
College Graduates, 1976-85 (projection)

Year	All Fields	Science and Engineering
1976	107,100*	74,970
1977	116,900*	81,830
1978	120,000	84,000
1979	125,000	87,500
1980	140,000	98,000
1981	175,000	122,500
1982	278,000	194,600
1983	290,000	203,000
1984	319,000	223,300
1985	350,900	245,630
Total	2,021,900	1,415,330

*Based on figures on new entrants for 1973-74 and 1974-75 cited by Marianne Bastid-Bruguiere, "Higher Education in the People's Republic of China," in Organization for Economic Cooperation and Development, ed., *Science and Technology in the People's Republic of China* (Paris: OECD, 1977), p. 121, and assuming an attrition rate of 30 percent for those classes only.

Source: Richard P. Suttmeier, Science, Technology and China's Drive for Modernization, Stanford: Hoover Institution Press, 1980, p. 55.

Bureaucratic Intransigence. Despite the massive changes in organization, management, educational goals, political ideology, and perspective on opening to the world, the fundamental nature of the Chinese State did not radically alter. Political struggles continued at the highest level of government, and ideological lines were often drawn between those leaders who saw technological development and technology transfer as the key to modernization, (the reformers) and those who felt that the Socialist ideology was seriously compromised by the extent of reforms called for under Deng's Four Modernizations campaign, (the leftists).

The ongoing political battle had serious implications for the development of technology, as it caused numerous minor policy shifts and considerable vacillation as to the best methods of policy implementation. These vagaries had great consequences for both domestic production and for foreign companies engaged in technology transfer. Businessmen working in China often expressed considerable frustration at the number of changes in taxation policy and joint venture laws during the first few years of their business partnerships. In addition, the Chinese leaders' general lack of knowledge of how to join the international economy and buy and assimilate the right technology, was another fundamental stumbling block.

It appears now that the early ignorance of some basic practices of international business, coupled with the ongoing political debate associated with economic reform, often forced the reformist leaders to shift rapidly from one policy approach to the next, seeking the perfect solution. If a reform was not immediately effective, it was politically preferable for the reformist leaders to experiment with something else rather than to persevere with the initial policy measure in the long term. These policy shifts never countermanded the imperative to reform or to speed up technological development, but they did have some deleterious repercussions for management and the foundation of a complete infrastructure. The specific effects of these policy shifts will be addressed as they relate to the electronics industry, below.

The most important consequence of the political battles between the reformists (Deng Xiaoping et al) and the leftists, (Chen Yun et al), was undoubtedly the lack of any major structural change within the bureaucracy. Although the ideological shift from an emphasis on class struggle to one on economic development was a major change in 1978, there was actually little alteration of the overall structure of the Party or the State apparatus. The State bureaucracy, which consisted mainly of personnel from the revolution years, was resistant to sweeping change, particularly as it affected the basis of socialist ideology. Since technology is fundamentally connected with change, and has been historically associated with ideology in the mobilization campaigns of 1958 and 1966, it has always been a target of leftist intransigents, who still control large segments of the bureaucracy.

The fear of opening to the outside, of bringing in Western and Japanese technology and the ideas and values associated with them, was largely a fear of undermining socialist ideology. This fear was exacerbated by the example of other developing countries that had sunk rapidly into irreversible debts and dependency positions as a result of their relationships with developed nations. Not only were various individuals wary and disinclined to reverse their positions on opening to the outside, but the cumbersome and stagnant bureaucracy itself was fundamentally unyielding. In addition, the Chinese characteristic of reluctance to make quick changes--of a reliance on the weight and value of a long and successful tradition--has made many leftists confront the science and technology policy of the reformers with skepticism and antagonism.

Political Compromise. The compromise that was reached at the beginning of the Open Door Policy seems to have been a grudging acceptance of the need to participate in the international economy and to compete in the technology race, but a refusal to make any major systemic changes in the basic organization of the Party. Technology equipment was imported in huge quantities, but the overarching system that was needed to orchestrate and assimilate it was not in place. Evidently the acceptance of the need for major technology transfer did not extend far enough to accommodate the need for widespread systemic change, particularly in the bureaucratic hierarchy. The result was several years of the importation of valuable and expensive hardware that was often wasted or used inefficiently.[9]

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9. There are countless examples of the inefficient transfer of technology and equipment between 1978 and 1985. The transfer of Spey engine technology has never led to effective utilization in Chinese production. The Baoshan steel complex has been plagued with problems. There are serious difficulties associated with Volkswagon's Shanghai Santana venture and the AMC-Beijing Jeep operation, to name just a few. See the Office of Technology Assessment (OTA) report, Technology Transfer to China (U.S. Conress, July 1987), for a more complete list.

Technology Transfer. In the sixth Five-Year Plan period, China opted to spend a considerable percentage of its resources on importing technology. During this period, U.S. $9.7 billion, or 15 percent of the investment funds provided for in the plan, were spent on foreign technology.[10] During this first major technology transfer period of the Open Door years, emphasis was placed on the purchase of hardware rather than on software. Hardware was characterized as the actual equipment and machinery needed to renovate and upgrade factories. Software was a more varied package combining actual computer software, management know-how, engineering experience, maintenance and service abilities, and other types of knowledge related to the use and repair of the equipment itself.

Software importation was neglected for a variety of reasons, probably partially connected to the feeling that China's young scientists and engineers were capable of developing software on their own, given the advances they had already made in many areas of basic science. It was not until the second period of the Open Door years that China's leaders realized that the learning curve for many areas of computer science and other electronic technologies was too far behind to allow the nation's own scientists to catch up or to assimilate the new imported technology at a rapid enough rate. As a result, it appears that much of the first wave of imported technology was not diffused efficiently into industry.

Another problem related to technology transfer in the first five years of the Open Door Policy, occurred because of the nation's incomplete infrastructure. Owing to the lack of any fundamental systemic changes in the bureaucracy that controlled the new technology, it could not be coordinated or managed in any kind of complete system, and thus could never be completely assimilated. Government policy on management reform was so uneven and imprecise in the first few years, that it was often unclear exactly who had the authority to import technology, and where and how it could be used. Factory managers were not always consulted as to what kind of equipment they wanted, and when they were, they often were not familiar with the new types of technology offered by foreign firms.[11]

Problems with Horizontal Communication. The early emphasis on vertical coordination between sectors dating back to the Soviet years, has had tremendous

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10. OTA, Technology Transfer to China.

11. An interesting analysis of the factory manager's dilemmas can be found in the Far Eastern Economic Review, Feb. 11, 1988.

consequences for the current period. Horizontal communication between research and industry and between different industries is so poor that it alone has caused a plethora of problems relating to both technology development and technology transfer. In the importation of technology, owing to the lack of communication between different sectors and between different regions in the nation, the equipment that was purchased by one industry for another was often not what was needed or desired by the end-user.

In domestic production, there were similar problems stemming from the lack of communication between sectors. In the past, a central administration had always controlled the research programs, allocation of resources and funds, the marketing of the research discoveries to industry, and the dissemination of information from sector to sector. After the economic reforms of the Open Door period, however, some elements of the controlling central bureaucracy were dismantled, and individual responsibility was granted to various research institutes and enterprises. This interim period was particularly difficult, as many institutes and factory managers were ignorant of the means by which they could contact other sectors or market their products.

One of the main ramifications of the problem was the duplication of research. Owing to the lack of communication between research institutes, many scientists found themselves working completely alone on projects that they later discovered were being examined at other institutes. Another problem was the poor diffusion of scientific results into industry. Again the lack of communication between sectors resulted in a low percentage of technological discoveries making their way into actual use in the factories. (Specific data on the diffusion of technology into the electronics industry is presented below.)

Finally, owing to the size of the country and to some sharply divided geographical and ethnic loyalties, regional biases and demands often began to take precedence over national policy objectives. Duplication of production lines in different regions, particularly for consumer products such as televisions, became a major problem.

The government's response to the problem of intersectoral communication was to set up a number of coordinating "leading groups". These groups were established in several industries, including the electronics industry, and also even to the level of subsectors within those industries, such as computers. The purpose of the leading groups was to improve communication between sectors, cut through bureaucratic entanglements, and facilitate international business dealings. Specific international trade groups were also founded to function as intermediaries between international companies and domestic enterprises.

Although Deng and other leaders kept their more conservative opponents on the defensive by rapidly changing policies, economic adjustments, directional shifts, and periods of retrenchment, the general problems in the Chinese economy that had developed by 1985 could not be ignored. As a result, the government called for a reassessment of technology policy, and some new directions were outlined for technology transfer and domestic development for the period 1986-1990. These plans were published in the White Paper No. 1 on Science and Technology in 1986.

Period 6: 1986-1990

The White Paper, formulated under the auspices of the SSTC and the State Council, was important in establishing a clearly-defined policy for technology in China's current development strategy. Although it is, by its nature, somewhat overly optimistic and self-serving, it does provide a useful overview of the Chinese Government's main policy concerns relating to technology. As in the past, science and technology were still perceived as profoundly linked to economic development in the construction of the socialist state. In the current period, however, the modernization of science and technology is considered to be the most important element in the four modernizations, assuming ascendancy over agriculture, industry and defense for the first time. It is perceived by government leaders as the key to achieving the economic goal of quadrupling the production level of 1980 by the year 2000. In hopes that, if carefully monitored, technology might yet prove to be a panacea for the modernization problems of the nation, the government has laid out some recent policy guidelines for technological development and application, and for technology transfer:

1. The coordination of science and technology with economic development and social change.
2. An emphasis on production technology R&D rather than necessarily on the most advanced technologies.
3. A direct connection between research and agricultural and industrial production, with the intersectoral and interregional transfer of technology from the laboratory to production, from advanced regions to backward regions, from coastal areas to inland areas, and from military to civilian sectors.

4. A gradual development of basic research on the basis of strong, dynamic academic institutions.
5. The learning, adaptation, and assimilation of foreign science and technology.

The Emphasis on Domestic Production. The most important shift in the policy goals of the 1986-1990 period has undoubtedly been the greater emphasis on the introduction and development of technologies that can be used in domestic production. These policies have had an impact on both technology transfer, wherein the concern for renovation of traditional production industries has affected the types of technology that have been imported, and technology development, which has been promulgated on a much more selective basis than in the past, aimed at the formation of new production sectors.

This strategy differs from the first five years of the Open Door Policy in the acknowledgement of the limited supply of foreign exchange and the growing foreign trade deficit. These factors make it imperative to produce goods for export, and to concentrate on an adaptive reuse and renovation strategy for existing production facilities. To facilitate the development of production industries, the State has given research priority to three areas, the first being production technology. The other two fields are the utilization of natural resources, and scientific fields where it is felt that China can make a distinctive contribution at the world level. In addition, the State has given large sums of money for the renovation of traditional industries. During the sixth Five Year Plan, the total investment made by the state on the technical renovation of existing enterprises was RMB 150 billion, a 70 percent increase over similar investment during the fifth Five Year Plan. In the 1986-1990 period, RMB 276 billion will be spent on technical renovation. This is an increase of 87 percent over the sixth Five Year Plan.[12]

The Creation of Township Enterprises. Another significant development strategy of the seventh Five Year Plan was the development and diffusion of appropriate technologies to the countryside. This program was initiated in order to support the development of local economies. The largest embodiment of this strategy is evident in the "Spark" program. This plan addresses the issue of revitalizing the productive structure of rural areas. In order to mitigate the shock of modernization, the Spark program has been designed to create village

12. The China Investment Guide, 3rd Edition, China International Economic Consultants, Inc. (Longman Group Limited, 1986), p. 283.

and township enterprises near farming communities. The aim is to employ farmers in small enterprise activities in rural areas, and thus to keep the migration of unemployed farmers into the cities at a minimum.

The estimates for the rural labor force that might be phased out by mechanization and improved productivity within the next 20 years is approximately 2/3 of the current 360 million people.[13] If a significant number of these unemployed rural laborers drifted into the already overcrowded major cities, the impact on the urban economy would be disastrous. The employment of 50 million workers (by government calculation) in the "Spark"-initiated rural enterprises is thus of crucial importance for regional balance and national policy objectives.

The Spark program aims at reinforcing the development of village and township enterprises during 1986-1990 by the following strategies: the development and mass production of 100 categories of equipment sets especially designed for village and township enterprises; the establishment of 500 pilot plants to demonstrate production and management processes, product design and quality control techniques; the training of one million young employees with secondary education in modern techniques appropriate for local application; the regional development programs in 12 mountain areas, swamp areas, and areas with low yield levels of production; and the establishment of a number of export production bases.

To implement this program, the SSTC, in cooperation with different levels of government, set up a number of plans, using bank credits, government appropriations, and small amounts of foreign exchange, to support 736 national projects and 51 training centers in the fields of animal husbandry, on-site processing, storage, and transportation of agricultural and forestry produce, production of rural building materials, primary processing of coal products, new production equipment for agricultural, food, and beverage production, and applications of biotechnology, microelectronics and new materials technology for agricultural-related industries.

In 1987 China asked for loans and funding from the World Bank and other foreign sources of development aid. According to government reports, the success of the program has been great. It was written in the China Daily in 1987, that the rural enterprise output for

13. White Paper on Science and Technology No. 1, State Science and Technology Commission of the People's Republic of China, 1986, pp. 217-219.

that year had been 330 billion yuan. In addition, the number of Chinese rural laborers that had transferred into rural industry enterprises had supposedly jumped to 70 million by the end of 1987.[14] As of yet, however, the potentially large problems of inadequate infrastructure (including a largely obsolete telecommunications system) and poor transportation have not been seriously addressed, and represent a major threat to the future success of the program.

Upgrading and Renovation. In the adaptation and renovation of low and mid-level industrial technologies in rural areas, the Spark program demonstrates a key priority for technological policy in China today. The top priority is the utilization and renovation of existing production facilities and existing technologies rather than the wholesale construction of newer, fancier models. In order to best achieve this plan, the State has attempted to remove the internal blockages between research institutions and industry, and to purchase foreign technology that is specific to the particular needs of the end-user. Major problems have arisen, however, as a result of various difficulties associated with regional biases and with an anachronistic management style. Regional differences have exacerbated problems of communication between individual enterprises and from research institutes to enterprises. Technology purchasing and renovation plans have often been confounded by a generally poor understanding of modern technology needs and modern management techniques by enterprise leaders.

The Reformation of Management. The reformation of management and infrastructure has thus become one of the most important and most difficult processes that China is undertaking today. Without a restructuring of the management system, the various technology policies mandated by the government are unlikely to be implemented in an efficacious manner. A general reform of the infrastructure, particularly the management policies relating to technology policy, was promoted by the Central Committee of the Communist Party in March, 1985. The reform included four measures:

1. The restructuring of the funds appropriation system along two new lines:

    a. Contract research, in which institutes establish their own programs in direct relationship with enterprises and institutions.

    b. Competition, in which different institutes vie for research funds and awards from the state based on the quality of the proposed project.

14. China Daily, November, 1987.

2. The development of a technology market, in which scientific institutions are allowed to directly sell or license the technology that they have developed.
3. The encouragement of research and development institutes set up in conjunction with industrial enterprises.
4. The reform of the scientific personnel management system, ensuring greater mobility, easier promotion for researchers, and better incentives in the wage system.

These policy measures manifest the importance that the government attaches to the reformation of the management system in China. The manipulation of the development and transfer of technology through government policy measures is incomplete if the technology is not utilized properly afterwards. The efficient or inefficient management of technology is thus a key issue for the government in determining the success or failure of the use of technology as a political tool. Control of management reforms has also become a central issue in the battle between the political reformers and the leftists. The leftists rightly perceive that the purchase or development of technology per se in no way threatens the established order. It is the infrastructure in which the technology must be placed, including management reform, that presents a threat to the bureaucratic hierarchy, and potentially to socialist ideology itself.

The current conflict between the reformers and the leftists centers around differing perceptions of the meaning of socialism and how it should be embodied in the institutional structure. Opposing concepts of management have became an important element within that structure, since, depending on the management style chosen, different values are emphasized. A group, or "human" concept of management, rather than a "professional" style of one-man management, has long been the preferred style for members of the Politburo who believe that class struggle is the most important element in the development of the Chinese socialist state. The reformers, by contrast, have desired to replace class struggle with economic modernization as the most important factor in the development of the new Chinese nation. This has led the conservative leaders to fear that the "counter-revolutionary" virtues of an emphasis on pure research and basic science, a belief in the inherent good of technological progress and the importance of the intellectual, might take precedence over "revolutionary" values of group decision-making, the necessity of all research being connected to economic development, and the inherent power of the Party.[15]

The recurring fear of some government leaders (which continues to have repercussions in the Open Door period), has been that the return to a more "professional" style of management will undermine some of the key socialist values associated with the "human" style of management as practiced in the Great Leap Forward and Cultural Revolution years. This fear, coupled with the intransigence of the bureaucracy, and the weight of an over-centralized and poorly coordinated system itself, has created a profusion of management difficulties. These include a centralization of decision-making, inflexibility of enterprise research and manpower exchanges, bureaucratic controls, lack of incentives in productivity and profitability, a double system of management (political and economic), and gross mismatching in input and output planning for any given production process.

Problems of Economic and Political Integration. The double system of economic and political management is a particularly insidious problem because it exacerbates the poor coordination between policy and implementation. When policy directives are given at rapid rates and occasionally in contradiction with other policy measures, the implementation of these changes at the enterprise level are often uneven and confused. Political decisions have often been made at different times than economic decisions, causing confusion and disorder for the individual factory. For example, economic incentives for factory managers are sometimes determined by continuing price controls on the products of their industry. These price controls may have remained in place long after the introduction of free market elements in other industries. The political directive to install the latest technology in production is thus often countermanded by the fact that it is not economically advantageous for individual enterprises to do so, as the price of their products is still controlled by the planned economy, and they can not earn any benefits from improving the quality of their goods.

In addition to the occasional economic vagaries, there was a series of conflicting policy decisions from 1985 through March of 1988, which reflected the on-going ambivalence of the Politburo as to the best course for science and technology management.

15. For a more detailed discussion of the ideology of management in China, see Franz Schurmann, Ideology and Organization in Communist China (University of California Press, 1966), pp. 221-308.

On January 11, 1987, the central authorities promulgated three sets of regulations limiting the factory responsibility system while, at the same time, giving a lot of power to the worker's congresses. The following year, after four meetings of the National People's Congress on the same issue, an enterprise law was passed that increased the power of the factory responsibility system by a large factor. This kind of vacillation has made it difficult for managers to maintain authority on a long term basis.[16]

It has been this kind of yearly vacillation that has characterized policy decisions related to management since the Open Door Policy. And although management failure is a general problem, and not specific to technological development, it has undoubtedly been greatly exacerbated by the recent need for rapid changes in production equipment resulting from technological modernization. The purchase of the right technology and its efficient use in production are management responsibilities that are related not only to economic and political measures, but also to the access to more general sources of knowledge. This kind of knowledge can be categorized as the ability to gain access to the various sources of technology, (both domestic and foreign), to the know-how associated with the use of that technology, and to the access to necessary technology support and maintenance facilities. For many factory managers, these "secondary" features of technology are still unclear. In order to facilitate the transmission of this kind of knowledge to managers and the enterprises, the State has passed a number of policy measures and guidelines related to these technology features. This knowledge is related mostly to aspects of technology transfer, and will be discussed in the following section.

Technology Transfer. As was noted in the introduction, a developing country's decision to join in the technology race is largely a decision to purchase technology from outside sources. Without adequate management of the newly imported technology, however, it is destined to be mishandled and wasted. After the first five years of the Open Door years,

16. The new enterprise law gave a considerable amount of freedom to management. "In effect, the enterprise law makes it mandatory for the state sector to adopt many of the managerial techniques now common in profitable firms in the private and cooperative sectors. Once the law is passed, all state-owned industrial enterprises will become independent accounting units. As a legal entity, the enterprise is given a fair degree of leeway in its operations. For example, it may operate by leasing or contract. It has the right to set its own personnel system and wage scale and to hire and fire workers. It has the right to use its capital to buy shares and invest in other enterprises and to issue bonds. It may, in line with state regulations, use its foreign-exchange income. It is free to determine its own suppliers and set prices, except for products which are price-controlled." Far Eastern Economic Review, 11 Feb. 1988).

when technology was often utilized inefficiently, the government made some important new guidelines that were meant to address this problem. The guidelines for the purchase and assimilation of technology since 1985 can be summarized in three main areas: the management of machinery import, the acquisition by enterprises of advanced technological know-how, and the management of the system of industrial exchanges under the conditions of technological enhancement.

a) The import of advanced equipment: The system for the importation of advanced equipment is still totally centralized, with primary control in the hands of the State Commission of Machinery Industry. The Commission, formed in 1987, combines the Ministry of Machinery and the Ministry of Equipment, and supervises all equipment imports to ensure that they are necessary, compatible, and useful for the enterprises. The Commission is also responsible for determining the priorities for imports of machinery, and for the development and production of machinery in China. It directly controls 10,000 factories that produce equipment, dozens of R&D centers, and 20 Colleges of Management.[17]

Although the Commission is mainly concerned with the domestic production of machinery in China, it may also respond to requests by companies for new types of machinery that may only be found outside the country. Here a procedure to import can be initiated, with approval necessary at different levels of government according to the financial scale of the project. Once the petition is approved, the Commission establishes the technical plan for the machines' importation. The technical plan includes a feasibility study and an analysis of the impact of the import on the economy of China. When imports involve several Ministries, the Commission acts in consultation with the Ministries. Final approval of import projects often still rests with the Minister of Foreign Economic Relations.

b) The acquisition of know-how: In order to reverse the previous trend of poor vertical and horizontal communication between sectors, academic institutions are now encouraged to contract their services directly to companies or to local and provincial governments. In some cases, the government has reduced or entirely cut the funding for research institutes in order to force them to market their skills and research findings. If the institutes do not come up with useful results, or are unable to successfully market their research skills and products, they will eventually fold. As a result of the new bankruptcy law of 1985, with its important corollary in the enterprise law of 1988, bankruptcy is now a conceivable alternative for failing companies. As a positive incentive for the shift in allocation funding, the government has allowed enterprises to keep part of their profits and to allocate productivity bonuses to their employees. This particular policy, in combination with the important bankruptcy law, has had a major influence on the proliferation of technology enterprises (particularly those related to the electronics industry), around Beijing. In Beijing, the Institute of Electronics of Academia Sinica, one of the leading research institutions in the country, now draws over 50% of its funding from direct contracts with enterprises all over the country. This will be discussed at greater length below.

17. Bianchi et al., Economic Modernization.

Another major source of the direct acquisition of technology know-how by a company is through a joint venture with a foreign partner. Although this type of technology transfer does not necessarily lead to the transfer of the ability to generate new technologies, it does promote a greater understanding and familiarity with new technologies by the presence of the new equipment. The successful diffusion and use of these new technologies in industry, however, is another problem.

c) The industrial assimilation of new technology: Technology must be assimilated in order to be useful, and this has been a major stumbling block for China in the past decade. Problems with assimilation have been related not only to imported technology, but even to developments within the nation. Between 1978 and 1984, developments that had been made by research institutes alone (not affiliated with any industry) had a particularly low rate of application within industry, averaging only a 15 to 30 percent utilization rate. Technology developments that had been made in collaboration with industry averaged a higher 55 to 65 percent rate of utilization by industry. Statistics show that of 693 scientific research results made by industry with or without collaboration with research departments, only 97, or 14 percent were concerned with research and development of new products; the remainder were aimed at the lowering of costs and the improvement of already existing products. By contrast, 254, or 77.6 percent of the 327 achievements made by researchers independently of industry were concerned with the development of new products and techniques.[18] See Table below.

Research Diffusion into Industry

	Percentage of total advances	Utilization rate (light industry & handicrafts)	Percentage of advances related to new products and technology
Developed by industry, with or without the cooperation of research depts.	40%	55-65%	14%
Developed by researchers independently of industry	60%	15-20%	77.6%

(Source: Beijing Ziran Bianzhengfa Tonxun, 10 June, 1984)

18. Beijing Ziran Bianzhengfa Tonxun, June 10, 1984, pp. 38-42.

Problems Related to the Diffusion of Imported Technology. In the assimilation of foreign technology into industry, there are even more fundamental problems than with domestic assimilation. The foreign technology imported into China has often required a higher level of technological expertise to run efficiently, and has often led to initial problems of implementation and later problems of repair and maintenance. The number of factory workers and technicians familiar with the technology or able to use the equipment to its best potential is usually quite limited. Equipment that requires skilled labor and skilled maintenance is liable to remain underutilized or even unrepaired if purchased without a consideration of available personnel over time. In addition, the complete infrastructure necessary for a useful diffusion of imported technology into industry requires a broader base than is usually generated by importing a quantity of high technology product lines into a few areas. Islands of high-tech industrial production are only useful on a very small scale, as they bear little relation to current markets or to the inter-regional development concerns of the nation.

State Policies Aimed at Facilitating Technology Transfer. State policy decisions that are aimed at reducing some of the management difficulties outlined above, have generally focused on two areas: the improvement of coordination between sectors and between enterprises, and the gradual increase of responsibility for managers and scientists. Responsibility has also been increased with the rapidly growing decentralization of decision-making from the central authorities. One overarching policy that has been designed to aid both the new responsibility system and the improvement of intersectoral connections has been the promotion of the contract system. In this system, binding partnerships are formed between enterprises and between research institutes and enterprises in a manner similar to those of private firms. By the summer of 1987, 75% of large and medium State enterprises were working under this system, and according to government sources, quite successfully. In 1986, a sample survey showed that the application rate for 26 research institutes in Guangzhou was up 80 percent as a result of better marketing and identification of end user needs. In that survey, 57.5 percent of all projects researched that year were under contract to specific markets.[19]

19. China Economic News, Sept. 14, 1987.

Despite the greater autonomy and flexibility allowed factory managers in 1987 and in 1988, however, the final decision-making regarding the purchase of expensive technology is still under the jurisdiction of the State. This is why, in spite of all the difficulties involved in joint ventures, Chinese companies and local governments still hope to join with foreign partners--not so much because of the hope of technology transfer, but because their joint venture status will win them access to priority status in the import quotas of the State government. Priority is given to companies involved with foreign partners in the allocation of human resources as well. Owing to the generally inflexible labor system, where the transfer of highly trained personnel from one enterprise to another can be quite difficult, this priority is very important for Chinese companies. Thus, one of the main incentives for Chinese companies to join with foreign capital is to obtain a favored position with their own national government in terms of both technology and human capital.

Manpower and Education. The inflexibility of the labor force is a vital concern for enterprises because of the overall dearth of qualified scientific and engineering personnel. This problem derives, in part, from the effects of the Cultural Revolution, and also from an ongoing problem with an underutilization of trained manpower. The inflexibility of the movement of skilled personnel has been an ongoing problem for China, probably as a result of the early siphoning off of the best scientists for work on the mission-oriented military programs. As a result of the early State control of human resources, the market mechanisms for a rational flow of scientific and engineering talent has never been fully developed.

A sample survey by the People's Daily taken in Shanghai in 1986, indicated that two-thirds of Shanghai's scientists and technicians were under-utilized and their professional skills wasted. The survey showed that scientists and technicians were often misplaced in their jobs, so that their specific talents were not being used efficiently. Ninety percent of those surveyed wished for greater job flexibility, but only 40 percent of the work units investigated allowed for exchanges of their technical staff.[20]

To combat the inherent checks and blocks on the flow of talent in science and industry, the State Council issued a "Notice Concerning Promotion of the Rational Mobility

20. Xinhua (in English), Foreign Broadcast Information Service (FBIS) report, Dec. 2, 1986.

of Talent" in 1987.[21] This policy was intended to encourage more flexibility among enterprises, but it was insufficiently backed with economic incentives, and did not have much of an impact. The dearth of highly educated personnel has caused many enterprises to jealously guard their engineering talent and refuse to allow individuals to transfer.

The other major problem resulting in a low volume of skilled labor results from inadequacies in the educational system. These inadequacies have been addressed by the State in recent years, with an improvement of higher education as a number one priority for the nation. Deng Xiaoping was one of the first government leaders to recognize the need for a highly educated class, and was a leading agent in the rehabilitation of the intellectuals as early as 1977.[22] The early government plans for improving education focused on the expansion and improvement of undergraduate and postgraduate university education through the establishment of several new universities (26 in the first phase and 43 in the second); the rapid expansion of technical and vocational education through pilot projects and community colleges; and the improvement of teacher training.[23] These priorities have led to a great increase in student enrollment in higher education since the Open Door Policy. (See Table 2).

Despite the measures already taken, the Chinese government is well aware of the major constraints that the education and training system will face in meeting the need for high and medium-level manpower and skilled labor in every sector of China's development plans for the future. (See Tables 3 and 4 for an indication of projected manpower needs in the next decade.) To combat these constraints, China has focused recently on the establishment of several types of nonformal education, most importantly the TV University. In this area, the Ministry of Education is currently focusing on the further expansion of technical secondary and higher education for adults. Projections for the total enrollment in technical secondary education schools for adults would amount to 7 million in 1990, almost tripling the 2.6 million in 1979. In higher education, the increase in enrollment would be from 860,000 (280,000 of them in the TV universities) to 4 million, with half in the TV universities. (See Table 5).

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21. Science of Science and Management of Science and Technology (in Chinese) No. 2, Feb 1987, p. 55; from JPRS-CST-031, July 14, 1987.
22. Far Eastern Economic Review, Feb. 9, 1984.
23. China, Socialist Economic Development, The World Bank, 1983, Vol. 3, Appx. V, p. 230.

Table 2
Student Enrolllment of Adult Schools by Level and Type
(in 10,000 persons)

Type	1981	1982	1983	1984	1985
Schools of higher education for adults ①	**56.2**	**66.2**	**92.6**	**129.3**	**172.5**
Radio and TV universities	17.0	25.8	41.4	59.9	67.4
Universities for staff and workers and universities for peasants	10.5	14.4	17.4	19.3	26.1
Correspondence and evening universities	24.1	20.8	27.3	32.2	50.3
Colleges for management cadres			0.2	1.5	4.0
Pedagogical colleges	4.6	5.2	6.3	16.4	24.7
Schools of secondary education for adults②	**820.7**	**1,080.4**	**974.8**	**598.7**	**547.0**
Secondary technical schools	444.1	445.4	330.3	82.7	134.7
Middle schools	376.6	635.0	644.5	516.0	412.3
Schools of primary education for adults	**973.6**	**756.6**	**817.2**	**932.2**	**833.8**
Courses for primary education	352.3	360.6	288.5	323.4	314.8
Literacy courses	621.3	396.0	528.7	608.8	519.0

Source: <u>China Statistical Yearbook</u>, 1986.

Table 3
Projected Demand of Industrial and Agricultural Skilled Manpower, 1990

	Stock Exist. 1979	Stock Required 1990	Annual additional need /a	Current output /b per annum
Scientists, engineers	900,000	1,650,000	106,000	30,000
Middle-level technicians	1,600,000	2,900,000	190,000	50,000
Skilled workers	16,000,000	23,000,000	1,200,000	400,000

/a For economic growth and attrition.

/b Full-time schools only.

Source: Estimates based on data from State Commission on Science and Technology and State Planning Commission.
From World Bank, 1983.

Table 4
Requirement and Supply of New Scientific and Technical Manpower in Shanghai, 1979

Field	Requirement	Supply	Supply as % of requirement
Automatic control	251	20	8.0
Electronic computers	176	15	8.5
Industrial & civil engineering	480	47	9.8
Hydraulic drive	97	10	10.3
Radio communication	115	12	10.4
Industrial automation (electronic)	250	30	12.0
Architecture	107	13	12.1
Program design	241	31	12.9
Radio technology	104	14	13.5
Boilers	162	23	14.2
Industrial automatic dials	123	20	16.3
Computing mathematics	90	15	16.7
Chemistry	585	104	17.8
Motors	168	34	20.2
Machining methods & equipment	111	24	21.6
Physics	552	124	22.5
Chemical engineering	89	21	23.6
Biology	319	80	25.1
Total	4,020	637	16.0

Source: Municipal Planning Commission, Shanghai.

Table 5
TV University Enrollment Targets, 1980-90

	1980	1985	1990
Total enrollments ('000) (full-time and part-time)	420	1,200	2,000
Number of year-long courses offered	18	50	100
Central Broadcasting and TV University (Beijing)			
(i) staff		700	2,000
(ii) space (sq m)		40,000	130,000
(iii) foreign exchange requirements ($ millions)	3.3	6.3	12.6
Total staff /a of central and provincial TV universities		20,000 +	40,000

/a Estimated at one teaching staff member per 50 students and one administrative staff member per 100 students.

Source: World Bank, 1986.

The Emphasis on the Military. The final policy issue to be addressed in relation to the changes initiated by the Open Door Policy is the importance given to the military. As was discussed in the introductory remarks, the relative amount of time and money that is invested in either of the two main elements of technology policy--military capability or national economic development--manifests the needs and goals of the State at that particular time. Since 1980, it appears that the reconstruction and reinvigoration of the economy has taken precedence over pure military research and development, although of course these have continued simultaneously.

Nuclear Technology. In nuclear research, China's initial policy of founding a nuclear industry in the fifties, developing nuclear weapons in the sixties, and rapidly expanding its nuclear arsenal in the early seventies, has shifted considerably in recent years. Since the Open Door Policy, the Chinese leadership has decided to reduce armaments on a wide scale, and has formulated a strategic policy of turning a large part of military industry, including the nuclear industry, into civilian industry. This policy has taken some time to develop. In 1978, China refused to sign the American nuclear non-proliferation act and was placed on the list of 63 countries that require specific authorization for either dual-use equipment or military technology. In 1982 China was still considered "something of a nuclear outlaw" and most U.S. officials felt that it was unsafe to conduct business deals without extensive precautions.[24] At this time China had no commercial nuclear power reactors, but had 10 experimental reactors and about 4,000 nuclear engineers. The sites for China's first two nuclear plants had been pinpointed, and included one at Daiya Bay. Despite the U.S. government's worries, American nuclear-industry sources such as Westinghouse, General Electric, and Bechtel were all eager to become involved in possible technology transfers.

It was not until 1985, however, that the long-awaited US-PRC nuclear agreement was finally signed, and it was after French and British firms had already won a large business concession. The agreement covered transfers of information and technology as well as nuclear materials, facilities, and components.[25] The agreement has been one more incentive for Chinese leaders to shift the primarily military-related nuclear technology to other

24. Far Eastern Economic Review, Nov. 26, 1982.
25. Business China, Jan. 3, 1986.

industries, in order to work legally with U.S. firms committed to their country's principle of non-proliferation. At a work conference in 1986, the CPC Central Secretariat and the State Council met with ten nuclear experts and decided to entrust the task of building and developing nuclear power stations to the Ministry of Nuclear Industry. Vice-Premier Li Peng reiterated that the civilian sector of the Ministry of Nuclear Industry would concentrate on the development of nuclear power generation and not on arms production.[26]

Military Diffusion. The same theme of strengthening the civilian sector through cooperation with the defense industries have arisen in other military sectors as well. Countless editorials in the newspapers have stressed the importance of gearing the military-industrial enterprises to society. The end result of the cooperation is expected to be a positive growth for both military capability and socialist construction. "Our defense production enterprises are now strengthening cooperation with civilian industries. This is of particular significance for raising industrial technological levels, speeding technological transformation, invigorating the national economy, promoting export trade, and achieving socialist modernization in our country."[27]

The special emphasis on combining the efforts of the defense industries and the civilian industries began in 1978 with a general policy from the Third Plenum in December, but really gained momentum with Deng's ascendancy to the chairmanship of the Central Military Commission in June, 1981. In 1983, the number of defence-industry establishments involved in producing civilian goods such as bicycles and washing machines jumped to 20% of production, more than double the proportion of 1979. Many of these new products were relatively sophisticated and in high demand from domestic consumers and for export. Although some defence industries such as the China North Industries Corporation are active exporters of civilian products, most Chinese planners concur that internal technology transfer is the optimum use for China. The plan is modelled on the Western integrated structure of military and civilian production, and is motivated by the observation that many products which Chinese enterprises had been importing, were actually available within the Chinese defence establishment. It is estimated that the internal transfer of these technologically

26. Zhongguo Xinwen She, March 18, 1986; from FBIS reports, 20 March, 1986; K-6.
27. Beijing Guoji Shangbao, March 27, 1986; from FBIS reports, 15 April, 1986; K-10.

sophisticated processes and products would save the country millions of dollars of foreign currency exchange.[28]

In November of 1984, a month after the adoption of the Central Committee's decision on how to restructure the economy, Defence Minister Zhang Aiping further emphasized the connection between the defense industries and the civilian sector, clearly locating military development in a secondary position to the development of the economy. He said, "All arsenals and war-production facilities should gear production to the national economy" that is, "subordinate itself to state construction and contribute to national economic construction...turn war-industry enterprises into joint army-civilian enterprises capable of producing both military and civilian goods."[29] Deng also was quoted as saying that all elements of the national defense industry must devote themselves fully to civilian goods research and production. And Zhao Ziyang stated in 1986, that "converting military industrial technology to civilian uses is extremely important."[30]

It is clear that the modernization of the military through technological upgrading and innovations from research have become linked in recent years with modernizations and reforms in civilian industry. The rigidly isolated, mission-oriented nature of military technology research that was evident in the first four periods of the People's Republic, has shifted to a more joint, cooperative venture with the civilian sector. The cooperation of military research labs in developing dual-purpose technology or technology expressly designed for the civilian sector, represents a major change in State priorities. In the realm of technological development, the formerly dominant and isolated sphere of military capability has been called on to share the responsibility for the economic modernization of the nation. This shift has far-reaching implications for the structure of technology research and development in China, and for the potential diffusion of research results into industry.

For the present, the impact of the use of military technologies in civilian production is difficult to determine exactly, although Chinese sources have lauded it as a great success. According to the Ministry of Ordnance Industry, the military has set up more than 200

28. Far Eastern Economic Review, Aug. 25, 1983.
29. Far Eastern Economic Review, Feb. 21, 1985.
30. Aviation Production Engineering, Sept. 1, 1985; from JPRS-CST-86-023, June 12, 1986.

assembly lines for civilian use, with an increase in the number of civilian products from 64 different kinds in 1980, to more than 400 in 60 major categories in 1986. In 1985, the output value of civilian goods by the Ministry was 2.2 billion yuan, a 225.7 percent increase over 1980.[31]

Whatever the exact percentages of military diffusion into the civilian sector have been in the last few years, (and there are many figures in the Chinese press), the numbers themselves are less significant than the implications of the policy shift that has encouraged this diffusion. Since 1985, China's leaders have manifested a concern for the modernization of civilian industry and the diffusion of new technology into industry to a far greater extent than in the past. The previous emphasis on military capability and the development of technology related solely to the military, has shifted to a more balanced concern for national economic development and the development of technology related to the civilian sector. The vastly increased production of civilian goods, particularly consumer electronics, that has occurred as a result of this shift is an important phenomenon that demonstrates a new concern for the Chinese people's needs and wants. The implications of this new concern for the most important utilization of technology will be addressed in the sections that follow.

The Electronics Industry

Electronics technology is considered by China's leaders to be the fundamental building block for China's modernization and entrance into the world economy. Electronics technology, particularly the information technologies of the computer and telecommunications systems, is essential for both upgrading industry and for participating in international networks. Knowledge of electronics technology is also necessary for the production of consumer electronics such as televisions and VCRs.

Understanding the sources of electronics technology in China, including both domestic development and technology transfer, is the key to understanding technology policy in the 1980s. The early and ongoing debate between steel and electronics as the core industry for China's modernization has finally been decided in favor of electronics. This decision manifests an important policy shift toward a more global and less self-reliant perspective, as

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31. Renmin Ribao, April 23, 1986.

well as toward a greater understanding of the nature and importance of the new information technologies for the modernization efforts of a rapidly developing country. An emphasis on national economic development and gratification of the nation's consumers has also been a recent policy shift, as demonstrated by the greater attempt at the diffusion of electronics technology from the military to the civilian sector, and the production of large quantities of consumer electronics for the domestic market. Finally, the policy decision to favor electronics also shows a willingness to work with foreign partners, since the gap in knowledge related to electronics technology is large, and outside aid is imperative.

The electronics industry operates under the same general policy controls and guidelines as other industries, yet since 1978, it has also been infused with an importance and urgency that makes it a unique and excellent case study. The current government leaders have invested the electronics industry with the power and imperative to take the lead in China's modernization drive, and to aid in the economic transformation of the country. In both the sixth Five-Year Plan and the seventh, the electronics industry was specifically mentioned as an important leading force that was to be actively developed and encouraged.

The importance of the electronics industry for China's current modernization efforts and imperative to join the international economy results from the nature of electronics technology. The new information technologies are revolutionizing the manner in which business is conducted around the world, and thus are an integral element in the attempt to join in the global networks. Computers and telecommunication systems feature a great processing speed, a tremendous generation of information, and an ability to connect rapidly with other systems on a worldwide basis. Nations seeking to compete in the international marketplace without these facilities operate at an impossible disadvantage.

The new technology is essentially different from other technologies in that its key feature is the processing of information rather than the manufacturing of a product. The successful creation of a processing network requires an inter-connected system of relationships and a complete infrastructure that takes time and capital to develop. A viable infrastructure must include a complementary institutional and organizational structure, education and manpower priorities, speedy and effective coordination between sectors, priorities for research and development, an effective management and labor structure, and a balanced import-export network.

In China, this infrastructure is far from complete, and, in some areas, is still fairly rudimentary. Since the Open Door Policy, Deng and the other reformers have methodically attempted to complete this infrastructure, at least to the point where the transfer of technology from abroad can be utilized efficiently in the Chinese system. The problems have arisen partly as a result of the imperative to modernize as rapidly as possible, and partly owing to the intransigence of Party and local bureaucracies, which have succeeded in sabotaging or deflecting some of the more overarching systemic reforms. Unfortunately, because of the nature of the new technology, the partial adoption of systemic change is often not sufficient to allow for the technology's most efficient use. Without a well-coordinated and fairly comprehensive system, the introduction of sophisticated technology, or the development of advanced basic research is often not effectively diffused into or assimilated by industry. This has been an ongoing problem for China, despite the commitment of most leaders toward the successful guidance and control of electronics technology through state policy.

The power of the state in guiding general technology policy has been discussed at greater length above. To recapitulate, it is our contention that the state is instrumental in directing the development of technology in China through several measures: general policy pronouncements, national and local Party leadership, funding, the reformation of the organization and management system, and the orientation of basic research and development. There is, however, an occasional gulf in directives between the articulated policy goals of the state, and what is actually encouraged through various political and economic measures promoted independently of the official policy line. In order to determine the impact of officially encouraged developments as opposed to those that have been unofficially sanctioned, it is necessary to look at what has happened in industry itself.

Although data is often erratic and insufficient, there is enough evidence to allow some conclusions regarding state policy and the development of the electronics industry from 1949 to 1988. First, there has been an ongoing conflict between the two choices of domestic development and technology transfer. This conflict has recurred in successive periods of both self-reliance and openness, and manifests a fundamental ambivalence by government leaders.

The negative implications of technology transfer involve a concern about dependency and trade deficits; the worrisome aspects of domestic production involve the potential for the technology gap to grow to an irreversible level. In addition, there has been an overriding conviction that self-reliance is, in the final analysis, the best policy for China whenever possible. These concerns have led to some policy vacillation between the energetic promotion of technology transfer, and a more conservative and protectionist strategy benefiting the fledgling domestic industries. Secondly, there has been a notable effort to increase the production of consumer electronics in the past four years. This emphasis has had some negative repercussions for industry that will be discussed below.

The following half of this paper is divided into four sections. Major policy themes examined are similar to the themes of general technology policy discussed above, but include specific reference to the electronics industry. Then follows a discussion of the general development and organization of the electronics industry since 1949, with a major subsection on recent government emphases, including consumer electronics. This is followed by examinations of important subsectors of the electronics industry, particularly those affecting the computer industry--namely telecommunications and microelectronics. A final discussion focuses on technology transfer and the role of foreign firms in electronics development.

Electronics Policy Themes

On the whole, the electronics industry during the period of 1949 to 1958 was characterized by a more mission-oriented approach than many other areas of science and industry. Although the entire industry, which was never very large, had been decimated during the war, the Chinese communists were able to consolidate some small remaining plants in efficient enterprises. They borrowed considerably from the Soviet Union in terms of both new equipment and organizational know-how, and used their new knowledge in setting up prototypes for domestic production. From 1956 to 1960, China established eight major electronics factories from among the 156 Soviet key projects that were implemented during that time. In addition, by 1960, sixty major plants with automatic and semiautomatic production machinery purchased from the Soviet Union and Eastern Europe were established for Chinese production.[32]

The Role of the Military

The uninterrupted, mission-oriented approach to the electronics industry at that time was undoubtedly the result of the military significance of the new technologies being developed. The strategic uses of various branches of electronics for the military sector led to both an increased interest and awareness of the dual uses of electronics technology transferred from the Soviet Union, and also the proliferation of small indigenous factories. Despite great backwardness in most other industries at this time, China was able to make advances in the fields of telecommunications, electronic components, simple electronic instruments, and military electronics.

Although there was considerable turmoil in many other sectors, in the electronics industry the Great Leap Forward did not cause any fiscal crises, as the state continued to make large increases in electronics investment. From 1958 to 1965, the State invested 1.306 billion yuan in the electronics industry. This figure was up from the 0.555 billion invested between 1953 and 1957.[33] In terms of production, the gap between China and industrially advanced countries may even have diminished in the fields of electronic and calculation technology. The exploding of the atom bomb in 1964, and the development and operation of the DJS-1 and DJS-2 vacuum tube computers are examples of great progress in some sectors. It can be noted again that the more mission-oriented approach to electronics resulting from its military importance, was undoubtedly the reason for this relative lack of disruption.

As in the Great Leap Forward period, the second mobilization campaign, the Cultural Revolution, was not as devastating for the electronics industry as for other sectors of industry. Between 1964 and 1978, the number of electronics workers actually rose from 294,000 to 1,165,000, of which 95,700 were engineers. In terms of output value, the growth rate never

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32. Reichers, Philip D., "The Electronics Industry of China," from The People's Republic of China: An Economic Assessment, a compendium of papers submitted to the U.S. Congress, Joint Economic Committee (US GPO, 1972), p. 87.
33. Development of Electronics and Employment in China with Special Emphasis on Application, prepared for the Maastricht conference on 'Technology and Employment', December 9-11, 1986, p. 12.

stopped expanding, rising from a 33 million yuan value in 1952 to 28.6 billion yuan in 1986. The number of plants rose from 60 in 1960, to 200 in 1971.[34]

Steel vs. Electronics

One theme that emerged in the early 1960s and continued through the seventies, was the battle over the promotion of steel vs. the promotion of electronics as the best focus for Chinese industrialization. This battle became a major political struggle, as Liu Shaoqi and Deng Xiaoping aligned in opposition to Mao during the years following the Great Leap Forward. Liu favored electronics over steel, and also promoted a research-intensive strategy for the electronics industry, with a distinctly hierarchical organization subordinate to the center. During this period of reorganization and emphasis on the electronics industry, several important advances were made in electronics technology. In 1962 and 1963, discoveries in the computer industry were made, including the development of the silicon transistor and ICs. This allowed the manufacturing of miniaturized radios, computers, and electronic equipment.[35] In 1963, the Ministry of Electronics Industry was founded. With the advent of the Cultural Revolution in 1966, however, the emphasis on steel rather than electronics technology was resumed for the next few years.

In the early 1970s, the importance of electronics for modernizing industry was recognized and the theme of electronics vs. steel was raised once again. Several major articles in the newspapers questioned whether or not the industrial foundation favoring steel should be changed to one favoring electronic development. One editorial from the People's Daily on May 25, 1971 answered this question in the negative, although at the same time affirming the importance of electronics for industry as a whole.

> Should we take steel as the 'key link' or take electronics as the 'center'? These are two diametrically opposite policies. The role of the iron and steel industry in pushing forward industrial construction as a whole cannot be replaced by any other industry. Electronic technique is the eye and ear of science; adoption of electronic technique may raise the level of automation, construction and the development of national defense. But it is not the basic sector of industry as a whole and cannot be the 'center' in pushing forward the development of the industry as a whole.[36]

34. Reichers, "The Electronics Industry of China," p. 88.
35. Development of Electronics, p. 25.
36. Renmin Ribao, May 25, 1971.

Despite the importance of electronics for the military, it was felt at that time that the premature development of the industry may have had deleterious effects for the development and dispersal of small and medium enterprises in China. In the early 1970s, Chinese planners were stressing local industrialization and rural development (as a precursor to the later "Spark" plans), and the introduction of sophisticated electronic machinery and data processing was felt to be incompatible with the level of the developing industries at that time. Evidently it was believed that an early emphasis on electronics technology would have led to specialized, automated, high-capacity plants that would necessarily be located in advanced urban centers. These new centers would be incompatible with the incipient "Spark" plans as they would preclude the possibility of development in outlying rural areas.

The choice of favoring steel production over the electronics industry was thus largely a political choice, as the decision to aid in rural development and the dispersal of resources to underdeveloped agricultural areas was in line with the tenets of the Cultural Revolution. At the same time, a criticism of the idea of making electronics the core industry was a very direct attack on the beliefs of Liu Shaoqi, who was Mao's main political opponent at that time. See for example, the article in the Guangmin Ribao of December 13, 1971, entitled, "Line struggle in industry--a criticism of Liu Shaoqi's and other political swindlers' theory of 'electronics as the core.'"[37]

The discussion of electronics vs. steel as the key link in China's modernization drive was raised again in 1977. By this time, electronics was perceived by most of China's leaders as the foundation and cornerstone of economic development and industrial modernization. The media ran many editorials exhorting the enterprises to pay attention to the new technology. In a People's Daily editorial in 1977, it was announced that "all branches of the national economy must be equipped with the technology of electronics before they can advance at high speed."[38]

At the same time as the importance of electronics in China's development was fully understood, China's backwardness in relation to the West was also perceived by most

37. SCMP No. 5045, January 3, 1972.
38. Renmin Ribao, December 5, 1977.

political leaders. Wang Zheng, Minister in the Fourth Ministry of Machine-Building, and one of the leaders most responsible for the electronics industry, said in an interview:

> . . . within the realm of the national economy, our electronics industry is a relatively weak link, the technical level of its products is not high, its production efficiency is low, and it still cannot meet the needs of national defence and the building of the national economy. There is still a considerable gap between the level of our electronic technology and advanced-world levels.[39]

Hua Guofeng and Deng Xiaoping also both stressed the importance of the electronics industry in 1978, particularly the development of semiconductor and LSI technology. These two subsectors are critical in computer development and thus also in information processing and military capability.

Self-Reliance

An important factor in the early decision to favor steel over electronics may have been the fundamental desire to remain self-reliant as much as possible. After the Soviet withdrawal, and in the early growth years of the nation, government leaders were hesitant about relying once again on the munificence of foreigners. With steel as the core industry, China was able to maintain a relatively high degree of independence. If electronics had been favored as the central industry for modernization, the connections to the outside must have been much greater, as China's abilities and expertise in electronics technology were insufficient for the operation of a successful closed system.

Regional Dispersion of Industry

The government policy favoring steel shifted to an emphasis on electronics in the late 1970s. At the 1977 Electronics Conference it was apparent by the size of the delegation and the number of institutes represented, that electronics had already been given a boost by government policy. It was also evident that the earlier fears of urban centralization and big-city monopoly were well founded, as the vast majority of both research and production centers were located in Shanghai and Beijing.

Shanghai's already vast network of research centers and industry made it economically viable to locate electronics industry there, although Beijing seemed to attract

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39. Quoted in Sigurdson, Jon, Technology and Science in the People's Republic of China (Pergamon Press, Oxford, 1980), p. 27.

the greater portion of research. To counteract this tendency, there has been a major policy directive to locate electronics industries in the interior provinces. As a consequence, by 1986, two-thirds of the 4,000 electronics enterprises were located in the interior.[40] It appears, however, that the policy of locating in the interior has not been very successful to date. Actual production levels of electronics goods and the employment of scientific manpower have been far greater in the four major electronics centers in the east: Beijing, Shanghai, Jiangsu, and Guangdong. These four cities outproduced all of the interior industries combined, with 52.9 percent of the total production and a high percentage of the skilled labor.[41] (See Table 6). Productivity in the interior enterprises has been chronically low as a result of its poor infrastructure, dearth of manpower, and lack of markets and coordinating agencies.

The major reasons for the establishment of the electronics enterprises in the interior included a military strategy favoring regional self-reliance, and a concern about unemployment and the important success or failure of the Spark programs. The electronics industries located in the interior currently employ two-thirds of the workers of the industry as a whole.[42] If these small industries were compressed into larger aggregates, and moved to urban centers, the policy of encouraging employment through small-scale enterprises in rural areas would be undermined.

Management

There have been numerous policy measures designed to encourage individuals and enterprises to follow the economic reforms of the Four Modernizations. In 1985, experiments were conducted with a new personnel appointment system, in which the granting of titles, bonuses, and other incentives was common. The new system was meant to motivate scientists and engineers to follow the Open Door Policy measures. In 1986, the emphasis on the restructuring of science and technology management was placed on the reform of the funding system, and the implementation of the new appointment system on a national scale.[43]

40. Development of Electronics, p. 20.
41. Ibid.
42. Ibid, p. 54.
43. White Paper, p. 14.

Table 6
Labor Force Employed, by Sector and Province, End of 1985

Province	Real estate administration, public utilities residential services and consultancy service	Public health, sports & social welfare	Education, culture, art, radio and television broadcasting	Scientific research, comprehensive technical service	Banking & insurance	Governments, parties and organizations	Others
Total	**436.6**	**466.7**	**1,273.1**	**143.7**	**137.7**	**799.0**	**1,319.1**
Beijing	26.6	11.4	35.3	21.8	2.8	29.5	22.4
Tianjin	13.4	7.6	19.0	4.0	1.9	10.9	9.3
Hebei	16.6	20.8	58.5	4.3	8.1	44.5	70.0
Shanxi	10.2	13.1	39.2	3.0	4.7	26.6	60.3
Inner Mongolia	7.6	9.8	31.1	2.6	3.7	22.9	9.0
Liaoning	37.5	22.0	54.2	7.8	6.8	41.1	43.4
Jilin	14.1	12.7	36.8	3.4	4.3	20.1	6.7
Heilongjiang	22.6	17.4	45.9	4.0	5.1	31.1	11.5
Shanghai	22.6	15.2	30.5	9.6	2.5	13.4	22.6
Jiangsu	32.3	30.2	90.1	7.9	7.3	37.2	132.2
Zhejiang	36.6	16.5	38.7	3.4	5.2	24.4	102.2
Anhui	12.9	18.5	53.7	3.5	4.8	26.2	41.2
Fujian	8.2	11.4	31.2	1.8	3.6	21.1	45.5
Jiangxi	18.1	13.9	40.0	3.9	4.1	23.7	50.8
Shandong	16.4	34.8	83.8	4.6	8.1	45.3	140.0
Henan	16.1	33.0	87.8	5.9	8.4	46.3	48.7
Hubei	17.8	25.4	63.7	5.3	6.7	41.3	74.1
Hunan	9.5	20.2	57.5	4.2	6.2	37.3	54.5
Guangdong	27.0	29.0	66.3	6.5	10.0	55.8	123.6
Guangxi	8.5	12.0	39.6	2.7	3.6	21.4	20.0
Sichuan	25.8	38.2	103.2	13.0	10.7	57.8	76.8
Guizhou	4.9	9.1	28.7	2.0	3.0	19.8	11.7
Yunnan	6.1	10.9	36.7	3.0	4.3	31.0	26.2
Tibet	0.7	1.1	1.9	0.3	0.4	3.3	1.1
Shaanxi	10.5	14.3	43.6	9.1	4.7	26.3	11.8
Gansu	6.1	7.3	22.6	2.5	2.4	17.0	97.2
Qinghai	1.7	2.3	5.3	0.7	0.8	4.9	2.3
Ningxia	1.6	2.0	5.7	0.5	0.7	3.8	2.4
Xinjiang	4.6	6.6	22.5	2.4	2.8	15.0	1.6

Source: China Statistical Yearbook, 1986.

All of these reforms were particularly relevant to the electronics industry, as they encouraged innovation by granting funding and wage reforms on the basis of technological discovery and development. The incentive, however, was largely geared toward the basic research of individual scientists and engineers rather than the application of that research or its successful diffusion into industry.

Electronics Development and Organization

Government Strategy Since 1978

The first five years of the Open Door Policy were characterized by the strategy of buying as much sophisticated technology as possible in order to speed modernization and reduce the technology gap. Technology that was purchased was aimed at increasing the potential for domestic development, and often included entire production lines and complete sets of equipment. Hardware was purchased in great quantity, but there was little interest in software or in the knowledge associated with the development or adaptation of the imported technology. In general, the new equipment was installed into a changing but fundamentally intransigent infrastructure, where the reorganization of institutions and management was uneven and incomplete depending on the region and on local leaders and local needs.

As a result of some of the problems associated with this first strategy, the government made some policy changes concerning the electronics industry in 1984 and 1985. The main thrust of the new policies was toward less foreign technology purchase, a greater attempt to renovate old industries and upgrade them, and toward a more fundamental reorganization of the system, including the provision of a more complete and regionally coordinated infrastructure. Tables 7 and 8 show the relative importance given to technical updating in the electronics industry in 1985. Table 9 shows the comparative weight given to the expansion and reconstruction of pre-existing facilities rather than the new construction of electronics and telecommunications equipment in 1985. These figures point to a strong effort to upgrade and renovate rather than to purchase new technology from the outside. The large investment in capital construction and scientific research in that year (see Tables 10-12) also demonstrates a concern for encouraging domestic industry rather than relying on technology transfer for technological development.

Table 7
Investment in Technical Updating and Transformation: Number of Construction Projects and Newly Increased Fixed Assets, by Industry, 1985

Branch	Projects under construction	Projects completed	Completion rate (%)	Newly increased fixed assets (Rmb 100 million)	Rate of fixed assets turned over to use (%)
Power supply	1,655	948	57.3	5.20	76.0
Production and supply of steam and hot water	28	13	46.4	0.11	41.4
24. Petroleum processing	672	398	59.2	4.29	74.4
Production of artificial crude oil	4	1	25.0	0.02	78.7
Crude oil processing	668	397	59.4	4.27	74.4
25. Coking, gas and coal-related products	447	187	41.8	1.78	60.0
Coking	128	56	43.8	0.28	31.2
Gas production and supply	168	47	28.0	1.30	72.0
Gas production	80	6	7.5	0.71	79.4
Gas supply	88	41	46.6	0.59	64.7
Coal-related products	151	84	55.6	0.20	74.8
26. Chemical industry	5,452	3,012	55.2	19.22	72.2
Of which: Basic chemical materials	1,075	588	54.7	4.58	79.8
Chemical fertilizers	1,833	992	54.1	7.14	74.4
Chemical pesticides	243	150	61.7	0.71	68.3
27. Medical and pharmaceutical products	1,108	531	47.9	3.40	66.4
28. Chemical fibres	446	246	55.2	3.50	69.2
Artificial fibres	69	35	50.7	0.25	36.6
Synthetic fibres	377	211	56.0	3.25	74.2
29. Rubber manufactured goods	667	339	50.8	3.18	76.1
30. Plastics manufactured goods	389	214	55.0	2.80	61.5
31. Building materials and other non-metal mineral products	4,299	2,246	52.2	16.03	67.1
Of which: Cement	1,856	928	50.0	7.96	68.8
Cement and asbestos products	251	129	51.4	0.79	63.2
Brick, tile, lime and light-weight building materials	676	405	59.9	1.87	67.6
Glass and manufactured goods	576	297	51.6	2.76	62.1
Ceramica products	578	308	53.3	1.59	73.3
Fireproof materials	144	73	50.7	0.44	92.0
32. Smelting and pressing of ferrous metals	3,977	2,310	58.1	18.58	62.6
Of which: Iron smelting	547	290	53.0	2.97	69.0
Steel making	2,294	1,388	60.5	11.19	61.9
33. Smelting and pressing of non-ferrous metals	1,709	943	55.2	6.02	52.8
34. Metal products	840	496	59.0	2.70	62.2
35. Machine building	6,771	3,333	49.2	23.70	69.9
36. Transportation equipment	1,977	909	46.0	7.24	62.7
Railway transport equipment	186	96	51.6	0.46	81.0
Motor vehicles	668	272	40.7	4.05	58.3
Trolley buses					
Shipbuilding	293	140	47.8	0.73	66.4
Aircrafts	342	167	48.8	1.02	76.5
37. Electric equipment and machinery	1,418	621	43.8	6.38	60.9
38. Electronic and telecommunications equipment	1,334	629	47.2	10.59	59.3
39. Instruments, metres and other measuring equipment	456	209	45.8	1.52	50.8
40. Others	144	81	56.3	0.42	79.5

Source: China Statistical Yearbook, 1986.

Table 8
Investment in Technical Updating and Transformation, by Industry and Province, 1985

Province	33. Smelting and pressing of non-ferrous metals	34. Metal products	35. Machine building	36. Transportation equipment	37. Electric equipment and machinery	38. Electronic and telecommunication equipment	39. Instruments, metres and other measuring equipment	40. Others
National total..	**11.41**	**4.34**	**33.91**	**11.55**	**10.48**	**17.87**	**3.00**	**0.53**
Beijing	2.16	0.18	1.08	0.83	0.49	1.71	0.20	
Tianjin	0.23	0.69	1.27	0.67	1.34	1.03	0.23	0.01
Hebei	0.17	0.10	1.20	0.20	0.23	0.27	0.03	0.04
Shanxi	0.02	0.05	1.39	0.10	0.22	0.27	0.02	
Inner Mongolia	0.11	0.03	0.62	0.02	0.15	0.04	0.04	...
Liaoning ...	1.18	0.32	3.42	1.53	1.22	1.79	0.24	0.11
Jilin	0.43	0.06	0.71	0.66	0.20	0.44	0.10	0.01
Heilongjiang .	0.47	0.14	1.30	0.29	0.21	0.24	0.16	0.01
Shanghai ...	0.44	0.72	3.47	0.93	1.01	2.59	0.44	0.01
Jiangsu	0.46	0.10	2.14	0.65	0.52	2.14	0.29	0.01
Zhejiang ...	0.08	0.07	0.93	0.19	0.26	0.29	0.12	0.02
Anhui	0.14	0.08	0.76	0.22	0.41	0.29	0.07	0.01
Fujian	0.12	0.04	0.47	0.16	0.40	0.22	0.03	0.03
Jiangxi	0.23	0.01	0.76	0.39	0.21	0.24	0.05	0.02
Shandong ...	0.28	0.08	1.86	0.49	0.29	0.60	0.11	0.01
Henan	0.65	0.12	1.90	0.14	0.30	0.27	0.02	...
Hubei	0.62	0.17	1.33	1.22	0.24	0.52	0.07	0.01
Hunan	0.52	0.07	1.46	0.62	0.71	0.95	0.03	0.03
Guangdong .	0.35	0.76	1.13	0.25	0.56	1.21	0.20	0.07
Guangxi ...	0.21	0.01	0.38	0.27	0.17	0.20	0.01	0.01
Sichuan	0.59	0.29	2.84	0.50	0.62	1.34	0.20	0.01
Guizhou ...	0.21	0.08	0.32	0.41	0.08	0.40	0.04	...
Yunnan	0.37	0.02	0.55	0.16	0.13	0.17	0.01	0.01
Tibet			0.01	0.02				
Shaanxi	0.18	0.04	1.44	0.36	0.29	0.56	0.20	0.01
Gansu	1.03	0.05	0.57	0.08	0.12	0.08	0.06	0.10
Qinghai	0.02	0.01	0.15	0.02	0.01	...		
Ningxia	0.04	0.04	0.26		0.03	0.01	0.03	
Xinjiang ...	0.13	...	0.21	0.18	0.05	0.02		

Source: <u>China Statistical Yearbook</u>, 1986.

Table 9
Investment in Technical Updating and Transformation, by Nature of Construction and Industry, 1985

Branch	Investment (Rmb 100 million)	New construction	Expansion	Reconstruction	Construction of living facilities	Removal	Restoration
Power supply	6.84	0.64	2.63	3.41	0.05	0.06	
Production and supply of steam and hot water	0.27	0.04	0.07	0.15			
24. Petroleum processing	5.76	0.02	1.95	3.69	0.06	...	
Production of artificial crude oil	0.03		0.03	...			
Crude oil processing	5.73	0.02	1.92	3.69	0.06	...	
25. Coking, gas and coal-related products	2.96	1.21	1.26	0.42	0.01	0.01	
Coking	0.89	0.02	0.70	0.17			
Gas production and supply	1.80	1.15	0.41	0.19	...	...	
Gas production	0.89	0.78	0.05	0.06			
Gas supply	0.91	0.37	0.36	0.13	...	...	
Coal-related products	0.27	0.04	0.15	0.06		0.01	
26. Chemical industry	26.60	0.60	11.65	13.30	0.28	0.46	0.06
Of which: Basic chemical materials	5.74	0.34	2.62	2.67	0.01	0.08	...
Chemical fertilizers	9.60	0.03	4.20	5.03	0.13	0.02	0.06
Chemical pesticides	1.04	...	0.69	0.33	0.01	0.01	
27. Medical and pharmaceutical products	5.11	0.37	2.53	1.99	0.01	0.16	...
28. Chemical fibres	5.06	0.14	2.83	2.03	...	0.01	
Artificial fibres	0.67	0.04	0.47	0.16			
Synthetic fibres	4.39	0.10	2.36	1.86	...	0.01	
29. Rubber manufactured goods	4.18	0.02	2.12	1.75	0.02	0.20	
30. Plastics manufactured goods	4.55	0.34	2.73	1.07	0.02	0.20	
31. Building materials and other non-metal mineral products	23.90	0.89	13.88	8.03	0.12	0.55	0.08
Of which: Cement	11.57	0.23	7.75	3.32	0.06	0.12	
Cement and asbestos products	1.26	0.12	0.54	0.42	0.01	0.11	
Brick, tile, lime and light-weight building materials	2.77	0.28	1.42	0.74	0.01	0.22	
Glass and manufactured goods	4.44	0.14	2.60	1.58	0.01	0.06	0.03
Ceramics products	2.17	0.08	0.93	1.01	0.02	0.02	
Fireproof materials	0.47	0.01	0.21	0.25			
32. Smelting and pressing of ferrous metals	29.70	1.03	11.05	17.47	0.02	0.02	0.07
Of which: Iron smelting	4.31	0.15	1.88	2.22			0.05
Steel making	18.07	0.39	5.21	12.42	0.01	0.02	0.02
33. Smelting and pressing of non-ferrous metals	11.41	0.21	7.61	3.52	0.01	0.03	0.02
34. Metal products	4.34	0.20	2.34	1.53	0.01	0.01	
35. Machine building	33.91	0.23	15.37	15.64	0.33	0.57	0.04
36. Transportation equipment	11.55	0.25	5.60	5.12	0.04	0.27	0.01
Railway transport equipment	0.56		0.13	0.39			
Motor vehicles	6.95	0.10	4.19	2.36	0.01	0.21	
Trolley buses							
Shipbuilding	1.09		0.32	0.75			0.01
Aircrafts	1.33	0.01	0.57	0.69			
37. Electric equipment and machinery	10.48	0.37	5.70	3.57	0.07	0.16	
38. Electronic and telecommunications equipment	17.87	0.33	10.93	5.04	0.06	0.15	
39. Instruments, metres and other measuring equipment	3.00	0.06	1.35	1.15	0.02	0.06	
40. Others	0.53	0.06	0.21	0.21	0.01	0.02	

Source: China Statistical Yearbook, 1986.

Table 10
Investment in Capital Construction, by Industry and Province, 1985

Province Province	32. Smelting and pressing of ferrous metals	33. Smelting and pressing of non-ferrous metals	34. Metal products	35. Machine building	36. Transport-ation equipment	37. Electric equipment and machinery	38. Electronic and tele-communi-cation equipment	39. Instruments, metres and other measuring equipment	40. Others
National total..	**31.79**	**11.41**	**1.46**	**18.89**	**12.78**	**3.52**	**9.05**	**1.79**	**2.78**
Beijing	0.59	0.02	0.05	0.71	0.57	0.19	0.74	0.18	
Tianjin	0.22		0.02	0.32	0.15	0.03	1.41	0.02	0.10
Hebei	0.64	0.43	0.11	0.52	0.76	0.04	0.04	0.02	0.01
Shanxi	0.82	2.06	0.02	1.00	0.25	0.02	0.12	0.03	...
Inner Mongolia	0.79	0.77		0.17	0.01	0.03	0.02		...
Liaoning ...	1.47	0.16	0.17	1.96	1.12	0.47	0.17	0.09	0.01
Jilin	0.25		0.04	0.52	1.91	0.04	0.14	0.08	...
Heilongjiang .	0.12	0.12	0.03	1.86	0.47	0.19	0.03	0.05	0.01
Shanghai ...	18.70	0.04	0.12	0.91	1.01	0.32	0.51	0.18	
Jiangsu	0.22	...	0.10	0.80	0.40	0.10	0.79	0.18	0.01
Zhejiang ...	0.04	0.02	0.06	0.34	0.11	0.11	0.28	0.02	0.01
Anhui	0.15		0.01	0.28	0.14	0.02	0.04	0.02	0.01
Fujian	0.16	0.18		0.09	0.06	0.11	0.18	0.05	0.05
Jiangxi	0.85	0.79	0.01	0.15	0.25	0.01	0.21	0.02	...
Shandong ...	0.18	0.19	0.02	0.82	0.43	0.16	0.06	...	
Henan	0.79	0.48	0.08	1.17	0.13	0.08	0.04	0.01	...
Hubei	1.59	0.08	0.07	1.40	1.73	0.05	0.18	0.05	0.01
Hunan	0.12	0.04	0.01	0.56	0.57	0.16	0.12	0.03	...
Guangdong .	0.18	0.35	0.43	0.76	0.24	0.76	1.71	0.06	2.49
Guangxi ...	0.13	0.01	0.01	0.23	0.18	0.08	0.04	0.01	...
Sichuan	1.76	0.85	0.06	2.07	0.96	0.11	1.79	0.23	...
Guizhou ...	0.20	1.00	...	0.16	0.26	0.02	0.07	0.03	
Yunnan	0.08	0.04	0.01	0.26	0.02	0.01	0.02	0.01	
Tibet									
Shaanxi	0.33	0.40	0.01	1.10	0.86	0.35	0.26	0.38	
Gansu	0.84	1.92	...	0.25	0.11	0.03	0.07	0.02	0.04
Qinghai	0.04	0.94	...	0.20	0.06	0.01	0.01	...	...
Ningxia	0.07	0.52	...	0.09		0.03		0.02	...
Xinjiang ...	0.45	0.01	...	0.17	0.04	...	0.01	...	

Source: China Statistical Yearbook, 1986.

Table 11
Investment in Technical Updating, Transformation, and Other Measures (in Rmb 100 million)

Year	Total investment[1]	By source of funds: State budget	Funds raised by localities, departments and enterprises	Bank loans
1953-1957	23.11	12.30	10.81	
1958-1962	100.91	12.53	88.38	
1963-1965	77.56	53.06	21.20	3.30
1966-1970	233.06	52.58	167.08	13.40
1971-1975	512.42	64.57	425.99	21.86
1976-1980	844.05	135.45	612.73	95.87
Of which: 1978	167.73	26.48	129.97	11.28
1979	175.88	43.64	112.38	19.86
1980	187.01	32.98	108.20	45.83
1981-1985	1,920.38	188.58	1,212.28	495.14
1981	224.60	34.88	142.43	46.02
1982	289.78	32.95	190.09	64.03
1983	357.83	40.83	232.44	81.98
1984	442.03	58.10	277.25	103.90
1985	606.14	21.82	370.07	199.21

Note: ① Including foreign investment of Rmb127 million in 1981, Rmb271 million in 1982, Rmb258 million in 1983, Rmb278 million in 1984 and Rmb1,504 million in 1985.

Table 12
Investment in Technical Updating, Transformation, and Other Measures, by Sector

Sector	1981	1982	1983	1984	1985
National total	**195.30**	**250.37**	**291.13**	**309.28**	**449.14**
Agriculture, forestry, animal husbandry, fishery and water conservancy	5.04	8.40	6.13	5.24	6.07
Industry	142.97	170.84	207.46	225.43	351.05
Geological survey and prospecting	0.28	0.23	0.17	0.32	0.28
Construction	2.22	4.35	4.29	4.88	6.97
Transports, posts and telecommunications	21.88	30.42	32.58	34.93	40.42
Commerce, public catering, material supply and marketing and storage	7.46	12.95	14.08	11.31	11.14
Estate management, public utilities, resident services and consultation service	6.63	9.29	9.97	12.79	20.46
Public health, sports and social welfare	0.73	1.38	1.72	1.90	1.78
Education, culture and arts, radio and television broadcasting	1.85	3.26	3.60	3.89	2.91
Scientific research and polytechnical services	1.13	1.17	1.34	1.69	2.36
Banking and insurance	0.65	1.37	2.07	1.37	0.97
State organs, political parties and social organizations	2.60	3.84	4.28	3.14	3.24
Others	1.86	2.87	3.44	2.39	1.49

Source: China Statistical Yearbook, 1986.

Recent Emphases

To promote the domestic development of the electronics industry, the Seventh Five-Year Plan (1986-1990) proposed five new major projects: TV color tubes, VCRs, integrated circuits, computers, and switching systems. It appears, however, that in the past two years three main areas have actually been given priority: consumer electronics, microcomputers, and mainframe computers. The rationale for this recent policy shift is clearly political, and is best understood by analyzing each area of priority separately.

Why consumer electronics?. In the past, in the area of consumer electronics, there had been little emphasis on producing a supply of consumer goods. In 1960, only nine of the major communications studios were producing television sets. Although the number of television stations in China increased from a total of seven in 1966 to 37 by 1976, with 123 relay stations, the overall amount of programming and hours on the air was quite small considering actual demand and the size of the country. At the same time, the stock of television sets available for purchase during these years was never adequate to meet the demand. By 1976, the stock was a mere 500,000 and was growing at a rate of just 100,000 sets per year. In addition, these sets varied greatly in size and type, and often were criticized for being of poor quality.[44]

Recently, however, and in stark contrast with the first three decades of the People's Republic, China's leaders have made a concerted effort to encourage the domestic production and consumption of consumer electronics. From 1984 to 1985 the production of color TV sets increased by 222.4 percent. (See Table 13). China currently produces about 15 million TV sets per year, including 4 million color television sets. The projection for the future shows an equally great increase. By 1990 the volume of commodity retail sales will be 646 billion yuan, 50 percent greater than in 1985. Of this total, sales of consumer goods will be 574 billion yuan, an increase of 51.5 percent over 1985.[45]

Many small provinces import electronics products and production lines on their own. Because of the general decentralization policy, the provinces have enjoyed more freedom in pursuing their own interests, and many regions have acted independently of national policy

44. Craig, p. 31.
45. White Paper, p. 79.

Table 13
Gross value of Output of Major Products, 1982-85

Item	Unit	1982	1983	1984	1985	% increase over 1984
Coal	million tonnes	666.00	715.00	789.00	872.00	10.5
Crude oil	million tonnes	102.12	106.07	114.61	124.90	9.0
Electricity	billion kWh	327.70	351.40	377.00	410.70	8.9
Rolled steel	million tonnes	29.09	30.72	33.72	36.93	9.5
Chemical fertiliser	million tonnes	12.78	13.99	14.62	13.35	−8.6
Sulphuric acid	million tonnes	3.18	8.70	8.17	6.76	−17.3
Caustic soda	million tonnes	2.073	2.123	2.222	2.353	5.9
Cement	million tonnes	95.20	108.25	123.02	144.59	18.6
Timber	million m^3	50.41	52.32	63.85	63.23	−1.0
Plate glass	million crates	31.54	36.47	41.90	49.42	17.9
Machine tools	10 thousand	9.98	12.10	13.35	15.45	15.7
Generating equipment	million kW	1.645	2.74	4.764	5.63	20.5
Walking tractors	10 thousand	29.83	49.80	68.90	82.30	19.4
Yarn	million tonnes	3.354	3.271	3.219	3.535	9.8
Cloth of which:	billion m	15.35	14.88	13.70	14.67	7.1
Chemical-fibre cloth	billion m	5.17	5.36	5.83	6.07	4.1
TV sets of which:	million	5.92	6.84	10.04	16.65	65.8
Colour TV sets	10 thousand	28.80	53.10	134	432	222.4
Cameras	10 thousand	74.20	92.60	126.20	179	41.8
Tape-recorders	million	3.471	4.977	7.764	12.71	63.7
Washing machines for household use	million	2.533	3.659	5.781	8.872	53.5

Source: China Investment Guide, p.53.

guidelines. One of the most conspicuous results of this approach has been the importation duplication of electronics production lines in consumer goods. Between mid-1984 and the end of 1985, over 100 color TV production lines, 40 refrigerator production lines, and dozens of radio cassette recorder production lines were imported into various provinces in China. At the same time, there was a marked increase in the purchase of consumer goods. The purchase of electronic consumer goods in 1984 and 1985 represented more than a 10-fold increase over the past, and was the main factor behind a 73 percent rise in the overall value of imports from Japan in 1985. The resulting trade gap in Japan's favor of U.S. $5.9 billion in 1985 was more than twice that of the previous year.[46]

This obvious emphasis on the production of consumer electronics represents a fundamental difference from the earlier emphasis on military capability and national economic development, and manifests an important policy shift by the Chinese government. The reasons for this shift are probably in line with the following argument: there is a mass market in China, with an extraordinary potential demand for consumer electronics. By developing electronics in this area, the industry becomes profitable immediately and generates its own capital. With new capital, China may be able to upgrade the quality of the easiest electronics technology, and, in combination with low labor and low production costs, could conceivably compete in consumer electronics in the world market. At the same time, by becoming a market for electronic components, the industry creates demand for other electronics industries and thus stimulates overall electronics production.

By pursuing this strategy, China may be attempting to follow the lead of Japan and the Asian NICS of the past two decades. The problems with these tactics for China relate to time and actual competitiveness. Automation technology and the learning curve of the NICS in consumer electronics make it unlikely that China could compete on the basis of lower labor and production costs. Secondly, the potential benefit of stimulating the production of components is illusory, as most key components and spare parts have been imported and continue to be imported, mainly from Japan.

In the past, the emphasis on the growth of the electronics industry was almost completely tied to the concerns of military development, vital international communications,

46. Far Eastern Economic Review, April 24, 1986.

and political legitimacy; consumer goods and services were given the lowest priority. The changes in government policy that have occurred in the past three years demonstrate a new concern, however. The new concern has evolved in light of the economic changes and ideological shifts of the past decade. The real emphasis of the second part of the Open Door Policy has been one of political reinvigoration. One of the main issues in today's China is how to make a smooth transition of political legitimation from an ideological basis to something else. With the shattering of much of the people's ideological motivation during the Cultural Revolution, it was necessary to find a new system of gratification and legitimation for the Chinese people. The provision of consumer goods seems to provide this gratification, and is especially important in light of the growing personal income of most of the populace.

A final added bonus of the government emphasis on consumer electronics, particularly television sets, relates to the special properties of television itself. Through specially designed TV programming, the government has the ability to instill modern ideas into the society, and dispel some of the traditional superstitions. By upgrading and emphasizing the usefulness of a nonformal education, (as it has done) the government can also provide a more than adequate education through the TV University program.

Why microcomputers? The second area of priority, in practice, is microcomputers. The decision to go small and focus on microcomputers was part of a more general strategy to pay greater attention to meeting domestic needs, and to popularize computer use in industry and around the nation. Starting as early as 1980, the State Administration of Computer Industry encouraged the development and implementation of computers in four key areas: factory production, research and testing, economic management, and designing. In factory production, the emphasis was to be on the use of microcomputers to automatically position machine tools and control production processes. In designing, the aim was the use of computers to design electronic equipment and capital construction projects.

In the first few years of the Open Door Policy, the overall domestic production and application of microcomputers had been slow and erratic. During the early 1980s, many of the microcomputers used in factory production were made domestically, but were made almost entirely with imported components. After 1979, the immediate great demand for computers in the civilian sector had put China's leadership in the difficult position of deciding whether to promote domestic development of the computer industry through protectionist trade sanctions, or to import large quantities of microcomputers to speed up the process of automation and data-basing. Probably owing to the time imperative, the leadership opted for the latter choice, and the ensuing massive importation of large quantities of computers flooded the market. In 1983, 4,500 microcomputers were imported. Just one year later this number had jumped to 70,000.

To counter the loss of foreign currency brought about by this massive importation rate, and to improve its own computer industry, China has recently concentrated on the domestic development of microcomputers, and currently produces about 40,000 per year.[47] In order to protect the fledgling computer industry, the government has also started following a more protectionist strategy. Vice Premier Li Peng said in a Conference for Leading Cadres in the Electronics Industry, "Beginning with 1986, China's electronics industry will pursue an appropriate protectionist policy regarding its microcomputer and electronic parts products. All that can be produced in China which meet the requirements should be supplied domestically in the main."[48]

To add some bite to the protectionist policies, China reduced foreign exchange spending considerably, raised import duties 100 percent, and cut domestic computer prices by 23 percent in 1985.[49] In addition, after 1986, China ceased importing complete microcomputers except for those of over 32 bytes.

Why mainframes? The third priority in recent years has been the development of the mainframes, with obvious applications in the strategic field. China has developed a 100 Mips computer, the Galaxy, and is interested in purchasing even more powerful "supercomputers" from the U.S. (these are still in the red area of U.S. Defense Department list of exports control). The continued emphasis on military capability is evident in the desire for this sophisticated piece of equipment, although it can be argued that the supercomputers are also useful for oil exploration and other economic priorities.

47. Bianchi et al., Economic Modernization.
48. JPRS-CST-86-023, June 12, 1986.
49. China Facts and Figures Annual, edited by John Scherer (Academic International Press, 1986), p. 131.

Subsector Analyses

The Computer Subsector

Owing to the Soviet Union's poor level of computer research and the block on exportation of equipment from the West, China's computer development was very slow during the early years of the People's Republic. The development of computers began with the establishment of the Academy of Science's Institute of Computation Technology in 1956, but little progress was made through 1958, outside of some experimental work in reproducing Soviet digital and analog computers.[50] With the Soviet withdrawal in 1960, the Chinese experienced a severe setback in electronics crucial for the military, particularly the emerging nuclear and missile programs. Because of the government desire for a strong military system, the mission-oriented approach to scientific and industrial development in military electronics was intensified at this time.

By 1964, China was producing its own version of the Soviet M-20. Between 1960 and 1971, China produced 300 digital computers and several hundred analog computers. (See Tables 14 and 15). It is estimated that at least half of these computers were used in military applications. For a list of computers produced under the state administration through 1981, see Table 16. For a production list through 1984 of 8-bit and 16-bit computers, see Table 17.

Diffusion into Industry. As a result of the main emphasis on the production of consumer electronics in the past few years, the industrial diffusion of computers has been disappointingly slow. In 1983, China was just beginning to implement computer automation in factories, starting with the most important machine-making industries and textile factories. In addition to the emphasis on consumer goods, the cost of automation, management reticence, and lack of manpower have all worked to slow down the automation process. In the China Facts and Figures Annual for 1986, it was noted that only 10,000 factories and other civilian organizations use computers for management, storage, banking, transportation and quality control. With approximately 400,000 enterprises operating in China, this means that only 2.5 percent use computers.[51] A distressing article from the Transnational Data and Communications Report Conference Report of February of 1987, reported that as much as 80

50. Reichers, "The Electronics Industry of China," p. 96.
51. China Facts and Figures Annual, p. 130.

Table 14
Chronology of Development of Digital Computers

Initial year of serial manufacture and model and manufacturer	Arithmetic speeds (operations per second)	Storage	Input-output	Comments
1962: DJS-1, Peking Wire Communications Plant	1,800	Ferrite core, 1,000 words; magnetic drum, 2,048 words.	Punched paper tape, numeric printer	Vacuum tube, production version of model 103. Advertised in 1964.
1963: DJS-2, Peking Wire Communications Plant	10,000	Ferrite core, 2,048 to 4,096 words; 2 magnetic drums, 6,144 words each, magnetic tape.	do	Vacuum tube, production version of model 104. Advertised in 1964.
1964: Unknown, Peking Wire Communications Plant	50,000	Ferrite core, 4,096 to 16,384 words; 4 magnetic drums, 16,384 words each, magnetic tape.	Punched paper tape, printer	Vacuum tube, solid state diode.
1965: Unknown, Peking Radio Plant No. 3	10,000	Ferrite core, 1,024 to 2,048 words	do	Vacuum tube, designed in early 1960's.
Do	6,000	Ferrite core	Unknown	Solid state.
1966: DJS-21, Peking Wire Communications Plant	60,000	Ferrite core, 4,096 words; 2 magnetic drums, 16,384 words each, magnetic tape.	Magnetic tape, teletypewriter, paper tape, printer.	Solid state. Exhibited at Peking in the spring of 1966 and at the 1969 fall Canton Trade Fair.
1968: DJS-7, Peking Wire Communications Plant	2,700	Ferrite core, 4,096 words; 2 magnetic drums, 12,000 words each.	Punched paper tape, elctric typewriter	Solid state. Exhibited at 1968 fall Canton Trade Fair and 1969 spring Canton Trade Fair.
1970: DJS-6, Peking Wire Communications Plant	100,000	Ferrite core, 16,000 to 32,000 words; magnetic drums.	Punched paper tape, numeric printer, 1,200 lines per minute; electric typewriter.	Solid state. Exhibited at 1970 spring Canton Trade Fair.

Table 15
Chronology of Development of Analog Computers

Initial Year of Serial Manufacture	Model	Manufacturer	Specifications	Comments
Analog computers:				
1960	DMJ-16B	Peking Radio Plant No. 1.	Capable of solving differential equations up to the 6th order.	Vacuum tube, network analyser, in production by 1960. Displayed in Paris in 1965.
1964	FM-8	Tientsin Electronics Instrument Plant.	30 operational amplifiers capable of solving differential equations up to the 9th order. Accuracy 1.0%-5.0%.	Vacuum tube, in serial production since 1964.
1964	M-9	do	Capable of solving differential equations up to the 9th order.	Vacuum tube. Production began 1964.
1965	M-24	do	Capable of solving differential equations up to the 24th order.	Vacuum tube. Production began 1965. Major use reported to be flight simulation and part of surface-to-air missile system.
1966	DMJ-3	Peking Radio Plant No. 1.	98 operational amplifiers; including 20 integrating amplifiers; two units may be connected to permit solution of differential equations up to the 40th order. Accuracy 1.5%	Vacuum tube and solid state Reported cost of 200,000 yuan each.
1966	SJ-1	Shanghai Electric Relay Plant.	24 integrating amplifiers. Accuracy 0.1%.	Vacuum tube. Model that most closely resembles Western type of analog computers.
1968	DMJ-2	Peking Radio Plant No. 1.	30 operational amplifiers. Solves differential equations up to the 8th order.	Solid state. First exhibited at 1968 Spring Canton Trade Fair.

Source: Reicher, pp. 98-99.

Table 16
Computers Produced by Factories under the State Administration of Computer Industry

Model	Word length (bits)	Major Technical Characteristics	Factory
Microcomputers based on US models			
Microcomputers using Intel 8080 computer chips developed through reverse engineering:			
DJS-051 B,C	8	4k–6k RAM, 2k EPROM, takes 78 instructions	Shanghai Changjiang Computer Factory
DJS-052	8	8k–48k RAM, 2k–16k EPROM, takes 78 instructions	Anhui Radio Factory, Jiangsu Radio Factory
DJS-054	8	8k–64k RAM, 2k–4k EPROM, takes 78 instructions	No. 6 Institute, Yentai (Shandong Province) No. 2 Radio Factory, and Shanghai Computer Factory
DJS-050	8	Single board computer	No. 6 Institute, No. 830 Factory, and Shenzhen Electronic Assembly Plant
Utilizes imported Motorola 6800 computer chips:			
DJS-061	8	2k–8k RAM, 2k–8k ROM	No. 1447 Institute
DJS-062	8	8k–64k RAM, 1k ROM, 1k EPROM, takes 72 instructions	Hunan Radio Factory, No. 1447 Institute, and Jinzhou (Liaoning Province) Computer Factory (Sells for ¥20,000)
DJS-063	8	16k–48k, 1MH, takes 72 instructions	Shaanxi Electronics Institute
DJS-064	8	11k–64k RAM, 7k ROM, takes 72 instructions	No. 6 Institute, No. 4500 Factory
DJS-060	8	Single board computer	No. 6 Institute, No. 4500 Factory
Utilizes imported Zilog 80 computer chips and components:			
ZSS	8	1k–2k RAM, 2k–4k EPROM, takes 158 instructions	Shanghai Computer Factory (sells for ¥16,000).
DJS-045	NA	Single board computer	No. 735 Factory
Based on Rockwell International's AIM-65 microcomputer:			
DJS-035	NA	Single board computer	No. 734 Factory
New trial-produced Chinese computers			
DJS-140 high speed computer		64k–128k, 800,000 ops (operations/second) with memory cycle time of 1.1–1.4 microseconds	Produced jointly by Beijing No. 3 Computer Factory and Qinghua University. Will be produced at Jinzhou Computer Factory and sell for ¥150,000.
BCM-2 microcomputer		64k RAM, utilizing Zilog 80 computer chips and other imported components. Designed as a Chinese character processing system, can generate 5,000 characters.	Beijing No. 2 Computer Factory
TP-801		Single board microcomputer	Produced jointly by Beijing Engineering University and Jingye Company (HK).
DJM-330		China's first general purpose hybrid (digital/analog) computer capable of calculating linear equations to the 24th order	Semiconductor Research Institute of the Chinese Academy of Sciences
Computer laser editing typesetting system		Can store 600,000 Chinese characters of 500,000 bytes and produce 60 characters/second by laser scanning. Takes 140,000 software instructions. One of the projects of the 1978 science and technology plan. Required ¥3 million investment.	Beijing University with six other units
DYL-1300		Microcomputer based on DJS-130	Semiconductor Research Institute of the Chinese Academy of Sciences
24 beam Chinese character laser printer		Incorporates advanced acoustical optics; prints 1,000 characters/second.	Laser Laboratory of Applied Physics, and Beijing Engineering University
Computer memory		China's first 16k MOS dynamic RAM memory	Semiconductor Institute of Chinese Academy of Sciences
DJS-300		Reported as comparable to IBM 4341	NA
Portable calculators			
Great Wall 204		4k RAM, 3k ROM, utilizes Zilog 80 computer chips, performs 8 kinds of formulas	Nantong (Jiangsu Province) Computer Factory
Simplified liquid crystal type		Does 7 operations up to 12 digits	Factory Nos. 750, 8460, 4509, and 4292
Liquid crystal function type		Calculates 7 functions up to 12 digits	Beijing No. 5 Computer Factory, and Factory Nos. 8460, and 602
Numerical simplified		Does 7 operations up to 12 digits	Dalian Radio Factory, and Shaoyang (Hunan Province) Radio Factory, and No. 750 Factory
Numerical function type		Calculates 7 functions up to 12 digits	Yentai No. 3 Radio Factory, Beidaihe No. 1 Radio Factory, Dalian Radio Factory, No. 750 Factory
Storage and printer type		Does 10 operations up to 12 digits	No. 4292 Factory

SOURCE: State Administration of Computer Industry, Beijing, July 1981. SACI publications translated by I-chuan Chen and Karen Berney. Material obtained by the National Council's Beijing office from a Chinese computer exhibition held at the Beijing Exhibition Hall during September–October, where 200 computers and peripheral devices built by 86 Chinese factories and research institutes were displayed.

Table 16 (cont.)

Model Computers	Major Technical Characteristics: Word length (bits)	Memory size (words)	Speed (operations/ second)	Factory
DJS-101	16	8–32	400,000	East China Normal University Scientific Instrument Factory
DJS-110	16	4–12	90,000	Changzhou (Jiangsu Province) No. 2 Radio Factory
DJS-112	16	4–32 MOS	150,000	Changzhou No. 2 Radio Factory, and Shaoguang (Guangdong Province) Radio Factory
DJS-130	16	32	500,000	Suzhou Computer Factory, Weifang (Shandong Province) Computer Factory, Beijing No. 3 Computer Factory, Tianjin Electronic Instrument Factory and Tianjin No. 2 Radio Factory
	(China's highest production volume computer)			
DJS-131	16	32	500,000	Shanghai Computer Factory (formerly Shanghai No. 13 Radio Factory)
DJS-132	(Upgraded DJS-131 with cover protection)			Tianjin Radio Technical Institute, Tianjin Electronic Instrument Factory, and Suzhou Computer Factory
DJS-135	(Same as DJS-130, temperature resistant -15C°–45°C)			Tianjin No. 2 Radio Factory, and Yunnan Electric Equipment Factory
DJS-153	16	32–128 MOS	1.0–1.4 million	Tianjin Radio Technical Institute, No. 785 Factory, Suzhou Computer Factory, Weifang Computer Factory, and Tianjin Electronic Instrument Factory
DJS-154	16	32	200,000	No. 738 Factory, and Dalian Radio Factory
DJS-183	16	28	500,000	No. 830 Factory
DJS-183 guided navigation computer	16	(Comparable to the DJS-183)		Hubei Radio Factory
DJS-184	16	32–128	400,000–500,000	No. 1915 Institute
DJS-185	16	32–124	500,000	Shanghai Computer Factory
	(Comparable to the DEC PDP-11/35)			
DJS-186	16	16–128 MOS	1.0 million	No. 1915 Institute
DJS-210	32	32	50,000–70,000	Changzhou No. 2 Radio Factory
DJS-220	32	32	100,000–150,000	No. 734 Factory, No. 738 Factory, Shanghai Computer Factory, Harbin No. 3 Radio Factory
	(Comparable to the IBM 36/50)			
DJS-240	64	64	400,000–500,000	No. 830 Factory and No. 15 Institute
	(Comparable to the IBM 360)			
DJS-260	64	128	1.0–1.5 million	No. 1915 Institute
JD-101	12	4	100,000	Jiamusi (Heilongjiang Province) Electronic Instrument Factory
DJS-6	24	32–128	250,000	No. 738 Factory, Hunan Radio Factory, and Harbin No. 3 Radio Factory
DJS-18	48	64	120,000	Beijing University Electronics Instrument Factory, Jiamusi Electronics Instrument Factory, and Zibo (Shandong Province) No. 4 Radio Factory
DJS-19	12	4–32	200,000	Beijing Computer Factory
DJS-22	16	16	100,000	Xi'an Computer Factory
DJS-24 and DJS-25	(8k–32k RAM, 12k–96k ROM, scientific calculation computer with an analog/digital converter, outputs Chinese characters)			No. 734 Factory
DJS-310	(Simulator, calculates linear equations to the 8th order, can combine equations of the 4th or 12th order)			Beijing No. 1 Computer Factory
CJ-709	48	32	125,000	Shanghai Changjiang Computer Factory
CJ-1001	32	64	500,000	Shanghai Changjiang Computer Factory
TQ-16	48	32–64	150,000	Shanghai Computer Factory
TQ-6 equivalent to model 655	48	128	1.0 million	Shanghai Computer Factory
W91-III	16	8–64	500,000	Hubei Radio Factory
	(Small process control computer)			
HDS-801	32	64–256	300,000–500,000	No. 1932 Institute

Source: <u>China Business Review</u>, Nov-Dec 1981, pp.17-18.

Table 17
China's 8-bit and 16-bit Computers

Roughly 20,000 micros have been produced in the PRC since prototype production of the first DJS micro series began in April 1977

Microsystem	Word length (bits)	Type microprocessor	Random access memory (bytes)	Manufacturer
BCM 2[1]	8	Z-80	64K	Beijing Computer Technology Research Institute and Beijing No. 2 Computer Factory
BCM 3[1]	16	-	64K	Beijing Computer Technology Research Institute
CS 2115C	8	-	-	Beijing No. 5 Computer Factory
DJS 035[2]	8	AIM-65	-	No. 734 Factory
DJS 045[2 3]	8	Z-80	-	No. 735 Factory
DJS 050[2]	8	8080	-	Qinghua University Electronics Engineering Dept., Anhui Radio Factory, Electronics Ministry No. 6 Institute, and Shenzhen Electronics Assembly Plant
DJS 051[4]	8	8080	4-6K	Shanghai Changjiang Computer Factory
DJS 052	8	8080	8-48K	Anhui Radio Factory
DJS 054	8	8080	8-64K	Yantai No. 6 Institute, Yantai No. 2 Radio Factory, and Shanghai Computer Factory
DJS 060[2 5]	8	6800	-	No. 6 Institute and No. 4500 Factory
DJS 061	8	6800	2-8K	No. 1447 Institute
DJS 062	8	6800	8-64K	Liaoning Jinzhou Computer Factory, No. 1447, Institute and Hunan Radio Factory
DJS 063	8	6800	16-48K	Shaanxi Electronics Institute
DJS 064	8	6800	11-64K	Ministry of Electronics No. 6 Institute and No. 4500 Factory
DJS 101[6]	16	-	8-32K	East China Teacher's University and Scientific Instruments Factory
DJS 110	16	-	4-12K	No. 2 Changzhou Radio Factory
DJS 112	16	-	4-32K	No. 2 Changzhou Radio Factory and Shaoguan Radio Factory
DJS 130	16	-	32K	Suzhou Computer Factory, Beijing No. 3 Computer Factory, and Weifang Computer Factory
DJS 131	16	-	32K	Shanghai Computer Factory
DJS 132[7]	-	-	-	Tianjin Radio Technology Institute
DJS 135[8]	-	-	-	Yunnan Electric Equipment Factory
DJS 140	16	-	64-128K	Qinghua University, Beijing No. 3 Computer Factory and Liaoning Jinzhou Computer Factory
DJS 142	16	-	.5M	Liaoning Jinzhou Computer Factory
DJS 153	16	-	32-128K	No. 785 Factory and Tianjin Radio Technology Institute
DJS 154	16	-	32K	No. 738 Factory and Dalian Radio Factory
DJS 183	16	-	28K	No. 830 Factory and Hubei Radio Factory
DJS 184	16	-	32-128K	No. 1915 Institute
DJS 185	16	-	32-128K	Shanghai Computer Factory
DJS 186	16	-	16-128K	No. 1915 Institute
DYL 1300[8]	16	-	-	Chinese Academy of Sciences Semi Conductor Research Institute
Great Wall 100[1 9]	16	8088	64-512K	Beijing Research Institute of Electronics Application, and Beijing Wire Communications Factory
KD 4	-	280A	16K	Science and Technology University
MIC 68K	16	68000	32K	Jiao Tong University Microcomputer Laboratory
MIC 48C[1]	8	Z-80	64K	Jiao Tong University Computer Center
MIC 8K2	16	28002	-	
Model 7711[1]	16	-	-	Beijing Lishan Micro Electronics Corp.
TP 801[2]	-	-	-	Beijing Engineering University and Jingye Co. (Hong Kong)
TQ 15	16	-	32K	Shanghai Radio Factory
TQH 100[10]	8	Z-80	32K	Shanghai Computer Factory
WSJ 2	8	-	64K	
X 1200	8	-	-	Tianjin Electronic Computer Factory
Z SS	8	Z-80	1-2K	Shanghai Computer Factory
ZD 065	16	-	-	Zhongshan University Physics Dept. and Guangdong Nanhai Radio Factory
ZD 2000	8	-	16-32K	Yanshan Computer Center
-[1 11]	16	-	-	Guangdong Computer Factory

[1]Equipped with Chinese character processing capability. [2]Single board microcomputer. [3]The DJS 040 series reportedly accounted for 73 percent of China's microcomputer production in 1982, but has falled substantially since then. [4]China's first microcomputer, an early version of the DJS 051, came with a maximum memory of 2 Kbytes RAM. [5]The DJS 060 series reportedly accounted for 8 percent of China's total microcomputer production in 1982, and a larger share in 1983. [6]DJS 100 series computers are originally conceived as software compatible 16-bit magnetic core machines based on Nova 1200 architecture licensed to China by the Nippon Computer Company, while the DJS 200 series machines closely replicated the IBM 370 and CDC 6600 designs. [7]Upgraded DJS 131. [8]Based on DJS 130. [9]The Great Wall 100 is reportedly "IBM compatible" and comes with 64K RAM, 40K ROM, two 5 ¼-inch floppy disk drives, and runs on MS DOS, CP/M 86, and UCSD p-System operating system, in addition to Chinese character DOS (CCDOS). Its Chinese word processing software contains 7,000 characters. As of January 1984, only 1,000 units had been produced, and sold for ¥30,000 ($15,000) each. [10]Chinese character intelligent terminal. [11]UNIX-based Chinese and Japanese word processor. Sources: *China Computer World; China Daily; Computer World; Electrical Market; Asian Computer Monthly; China Business Review; Info World; Nanfang Ribao;* US industry representatives; and National Council computer files.

percent of the computers in China were believed to be sitting in warehouses, unused. A more common figure, however is closer to 30 to 40 percent.[52]

In 1984, after a computer planning conference in which members of China's Computer Leading Group expressed concern over China's slow rate of domestic development and diffusion, several incentives were planned to encourage faster growth. The People's Daily ran editorials calling for managers and enterprises to install the new technology as soon as possible, and the State Economic Commission announced nationwide computer courses for factory managers. One article at the time stated plainly: "The new technology is superior to the old. If you do not want your enterprise to be left behind, please pay attention to computers."[53]

Material incentives for the installation of computer automation included the granting of interest-free loans to all factories buying microcomputers in some provinces. There were also numerous small fees paid for travel assistance, patents, and licensing problems related to computer automation. Professional associations were revived, allowing greater contact between scientists and engineers in different industries and fields. And managers of some enterprises were allowed to recruit and hire technical advisory staff through advertisements.[54]

Despite these numerous policy measures by the government, the fundamental emphasis on consumer electronics in the past five or six years has precluded any serious efforts at diffusion into industry and automation of the factories. Using as an indicator the proportion of employed workers in specific subsectors over total electronics employment, in 1982, 43% were in consumer electronics, 37% in components and devices, and only 20% were in industrial electronics (including computers and communications).[55] This represents a far lower emphasis on industrial electronics than in the U.S., Japan, or West Germany. (See Table 18). In Shanghai, the most advanced and sophisticated city in the nation, only 7.19 percent of the 25,828 enterprises surveyed by "China's Computerworld" in 1986 were

52. The difficulties of determining an exact figure for the warehousing of computers are easily apparent. Most figures that I have come across run between 25 and 45 percent, with Roche report the highest by far, at 80 percent (Roche, Edward, Transnational Data and Communications Report, February 1987, pp. 14-16). An article in the Chinese media quoted a number of 40,000 computers stocked in warehouses in 1985. (From JPRS-CST-86-012, May 12, 1986).

53. Quoted in the China Business Review, May-June, 1984.

54. Tidrick, Gene, Productivity Growth and Technological Change in Chinese Industry, World Bank Staff Working Papers, No. 761 (1986), p. 60.

55. Development of Electronics, p. 18.

Table 18
International Comparison of Electronics Industry Structure, 1982
(in percent)

	U.S.A.	Japan	West Germany	China
Industrial electronics	65.9	35.0	56.7	20.0
Consumer goods	10.6	34.0	24.9	43.0
Conponents and devices	23.5	31.0	18.4	37.0

Note: Industrial electronics consist of the computers, communicatins and instruments

Source: Research report, 1986 Huang Jiashu

Table 19
Distribution of Installed Mainframes and Minicomputers

Department	Quantity installed
Oil	164
Chemical engineering	51
Water conservancy and power	174
Metallurgy	249
Railway	114
Traffic	43
Coal	43
Agriculture and forestry	21
Light industry	73
Textile	109
Posts and telecommunications	83
Architecture and architectural material	45
Machine	271
Nuclear industry	81
Aviation industry	179
Electronics industry	347
Meteorology	18
Conventional weapons	31
Shipbuilding	169
Space	111
Commercial Bank	95
Academy of science	219
Planning and statistics	28
Medicine and health	111
Colleges and universities	465
Geology	45
Earthquake	37
Computer centres	61
Culture and publishing	17
Ocean	24
Mapping	12
Others	329
TOTAL	3,819

Source: South China Morning Post, Nov. 25, 1986.

Table 20
National Microcomputer Application, 1985
(total quantity installed — 217,900)

Scope of application	Quantity of projects	Percentage
Instrument and measurement	984	2.1 [as published]
Process control	662	21.6
Management	306	10.0
CAD, CAE, CAM	267	8.7
Software development	264	8.6
Medicine and health	173	5.6
Chinese character information processing	78	2.5
Optimisation and policy decision	42	1.3
Others	296	9.6
TOTAL	3,072	

Source: South China Morning Post, Nov. 25, 1986.

equipped with at least one computer.[56] (See Tables 19 and 20 for a list of computers installed in industry, and the application of microcomputers by project).

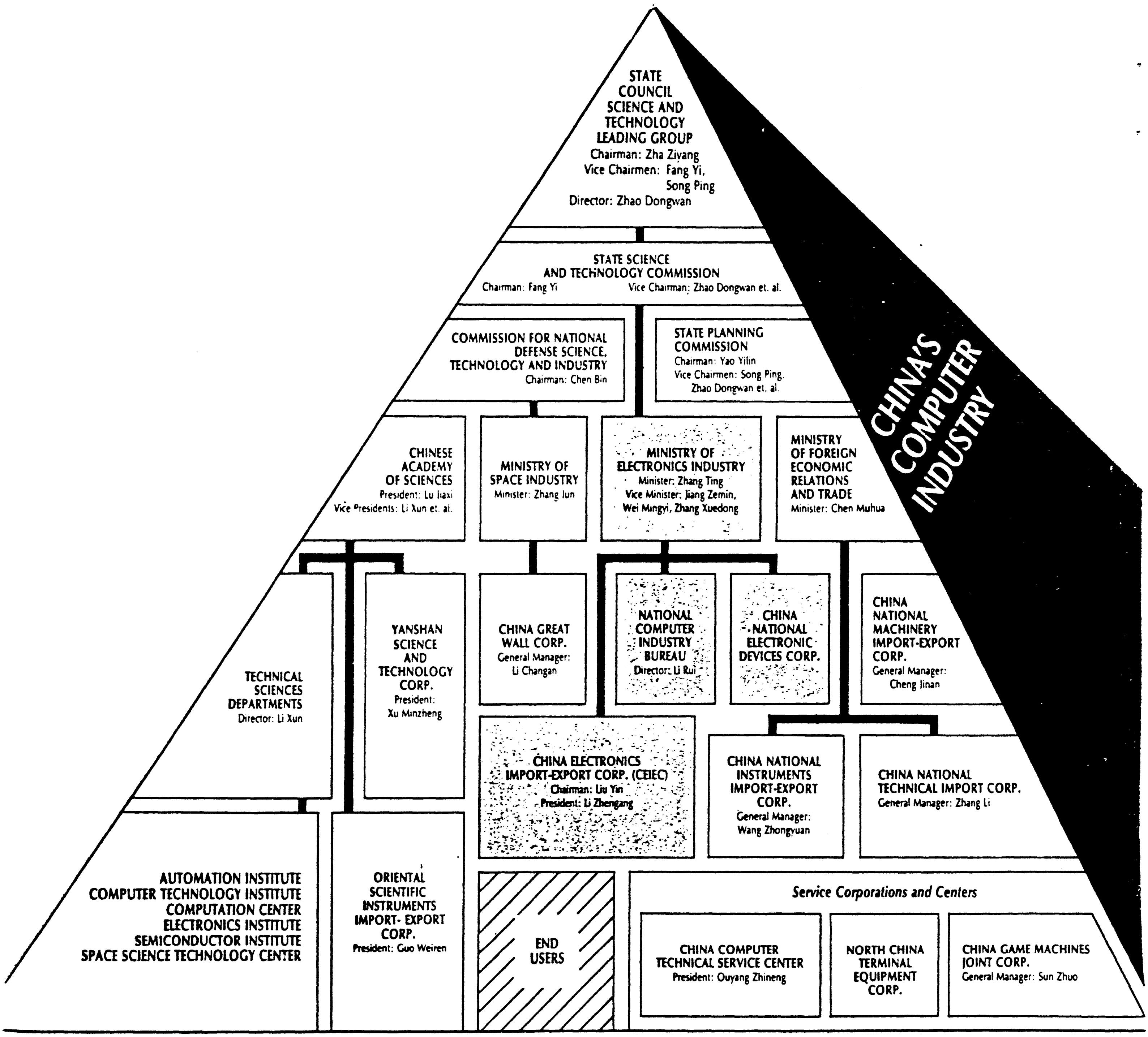
These figures show the outcome of the basic conflict between the Chinese goals of completing the infrastructure necessary for the assimilation and diffusion of imported and domestically produced technology, and of producing enough consumer electronics to satisfy the market. From 1979 to 1984, China's leaders had strongly advocated industrial diffusion and computer automation in policy pronouncements, but rather than encourage it, they had actually emphasized consumer electronics and strategic military programs by their actions. The diffusion of computer technologies into industry was also slowed by the historically weak ties between research institutes and enterprises dating back to the early 1950s.

Poor Horizontal Coordination. In the computer industry, as in most electronics industries, the coordination between the designer of a sophisticated system and the end-user is particularly important, as success in microprocessor and other advanced technology designs is based largely on the quality of the understanding between the two. When the end user is divorced from the design and manufacturing center, specific needs are often not met. Instead, products are researched and designed that must then be redesigned by in-house engineers after purchase of the technology by the factory. The dearth of in-house engineers that are able to make the adjustments can then become another major problem for the enterprise.

The lack of coordination between computer designers and their institutes, and industrial end-users has been a chronic problem for the successful development and diffusion of computer innovations into industry. The problems have been particularly severe in enterprises which fall under the jurisdiction of different bureaus or ministries. (See Figure 2) The government has attempted to correct this problem through the formation of coordinating groups such as the China Computer Development Corporation (CCDC), and the Great-Wall Computer Group Corporation (GCG), which can cut through bureaucratic red tape and speed up the coordination between ministries. In addition, it has sought to loosen the vertical ties that had bound together various projects in the past, and to strengthen horizontal mobility and interconnectedness. In 1987, the Central Committee and the State Council repeatedly advocated and encouraged horizontal economic integration for all sectors of the electronics

56. Bianchi et al., Economic Modernization.

Figure 2
China's Computer Industry



Source: China Business Review, Mar-Apr 1983, p.33.

industry. In March of that year, a national meeting was held pertaining solely to the question of integration between sectors. From this meeting came the "Regulations Concerning Certain Problems in Promoting Horizontal Economic Integration."[57]

One feature of these regulations was the establishment of more direct involvement of research units with the enterprises. In the first type of direct involvement, the centers maintained their economic independence, but were more integrally connected with the specific needs of the large enterprises. Another form of direct linkage was through joint enterprises in the development of new technologies. A third type of linkage was the association of research institutes and enterprises to form companies undertaking complete technical or engineering projects. A final type of linkage was in the formation of civilian companies where science and technology personnel joined to offer new technologies and technological services for sale. This form has been manifested most in the proliferation of computer companies in the Haidian District of Beijing.

One problem associated with the economic independence of institutes, and their responsibility for making their own horizontal connections and marketing contracts, has been the inability to read the market or to generate an income fast enough to keep pace with the reduction of operating funds from the government. One computer firm in Tianjin experienced severe cutbacks in funding as a result of the new policy and was unable to plan for its own future development.[58] To allow for this possibility, the government has recently promulgated a new bankruptcy law, which deflects some of the costs of failure from the individuals involved. This law has special consequences for the computer and microelectronics industries where the rapid growth and stimulation of small, high-tech enterprises could be instrumental in producing research innovations and improvements. These small companies are often risky concerns, and the government's 'guarantee' of a limitation of possible loss is extremely important. The law also gives a measure of legitimacy to these small civilian companies that is important in quelling the fears of another policy swing against private business.

Science Cities. The research-production combination for high technology has perhaps worked best in the concentrated high technology areas known as science parks or science

57. Science of Science and the Management of Science and Technoloy, from JPRS-CST-87-031, July 14, 1987.
58. Ibid, July 7, 1987.

cities. The features of these centralized technology centers are a wide education and knowledge base, a concentration of high-technology authorities or production bases, and a high output value of products. In addition, "advanced technology is used to guide production, the very latest research results are quickly transferred, and the annual output is often several times that of ordinary areas in value."[59] China's incipient high technology areas are currently forming in Zhongshan Village in Beijing, the Wushan Science City at Guangzhou, Shanghai's Jiangwan Wujiaochang, the Donghu Developmental Center at Wuhan, and Wuxi's Microelectronic Base.

The infrastructure of these science cities is already vastly superior to any other region, and the numbers of universities and educated personnel far outnumber outlying areas. Government policies promote these cities by encouraging pilot projects and experimental management, so that the production and innovation levels of these major centers are significantly higher than those of the smaller or more rural enterprises. In areas of marketing and international networking, the sophistication of the populace from the cities is notably higher.

Although government leaders have seemed wary of the "big city" domination of electronics technology, it is apparent that the existing structure, combined with the tenets of the experimental reforms and the desperate need for closer coordination between sectors, will probably lead to an increasing number of high technology centers in China. According to many editorials, the relaxation of controls on science and technology personnel and on research institutes in these science centers is essential for the growth of high-technology research-production combinations in electronics development. These combinations are crucial for innovation as well as diffusion, as risk-taking and flexibility are an important element in scientific discovery, and they are allowed more latitude in independent technology centers.

The ability to accede to rapid change and to be flexible in the light of innovation and new marketing needs is crucial for the computer industry to function properly. A large and cumbersome bureaucratic structure not only retards the speed at which decisions can be made, but also leads to localization of interests, competition, and thus to duplication and lack of

59. Ibid, October 29, 1987.

standardization. In 1983, China had more than 150 models of computer equipment that were being produced by scores of different factories and research institutes. The three institutes that were in chief competition in the area of computer production were the Ministry of Electronics Industry's Bureau of National Computer Industry, the Chinese Academy of Science's Department of Technical Sciences, and the Commission for National Defense Science, Technology, and Industry.[60] The result of this type of competition was a lack of standardization that was devastating for China's industries. Often even the specifications of the same model of computer, such as the DJS-130 minicomputer, varied from one unit to another. This lack of standardization was also a problem in matching system components, in designing software, and in providing maintenance services.

Current Policy and Strategies for the Future. From 1984 through the present, China's leaders have been attempting to coordinate a more fundamental reorganization of the basic infrastructure needed to utilize the new information technology more efficiently. This infrastructure requires institutional and organizational revamping with particular emphasis on the establishment of new "leading group" or coordinating agencies, a new priority for research and development allowing scientists greater creative leeway but also harnessing developments in the institutes more firmly to industrial use, a firm commitment to the provision of a good education on a widespread basis, and a one-man management system with worker bonuses and other material incentives for labor.

A new, intensified software program is also receiving great support in the seventh Five Year Plan. The key projects in software development will include the development of software industrial production and its management techniques, the development of system software and supporting software, Chinese character information processing techniques and its application, and other fields.[61] According to Jetro's China Newsletter of August, 1987, the percentage of software technology transferred to China, rose from 1.3 percent in 1978 to 35 percent by 1987.

In an attempt to provide a computer group similar to the Leading Group for the Invigoration of the Electronics Industry, the Chinese Ministry of Electronics formed the

60. China Business Review, March-April, 1983.
61. White Paper, p. 196.

China Computer Development Corporation in December, 1986. This corporation was established for the purpose of merging many of China's smaller data processing firms into one giant corporation. The size of the concern would enable it to handle a number of activities, such as research and production, education and training, and national sales and service. The establishment of CCDC was timed to coincide with the government policy of fostering the development of the data processing industry. This policy was given weight through the following concrete incentives: tax exemptions for firms importing software, authorization to issue shares, and greater freedom to recruit technicians, including foreigners.[62]

Another computer group was established in 1987 to develop the nation's data industry. The Great-Wall Computer Group Corporation (GCG), based in Beijing, was set up with a trained technical staff of 15,000 people and a union of 67 existing enterprises and institutions. The purpose of this group is to aid in the coordination of the different sectors of the industry, from research and development to manufacturing and marketing. Member institutions include five universities and four research institutes, all seeking positive ways to turn their research into useful commercial production.[63]

The establishment of groups such as the CCDC and the GCG manifest the government's apparent commitment to combat some of the problems inherent in the computer industry's organizational and management structure. Other efforts to allow and encourage actual systemic change and to invigorate the industry are evident in the government's acknowledgement and acceptance of the new civilian companies that have formed around the major technology centers. The most important civilian companies for the computer industry have been the 40 microcomputer sales and service companies in the Haidian District of Beijing. In 1985, the larger sixteen of these companies had an output value of more than 123 million yuan.[64]

Shanghai's Computer Industry: A Case Study. In the early 1980s, Shanghai's domestic computer industry was crushed by the flood of imports of microcomputers from

62. AFP Sciences in French, Dec. 18, 1986, p. 20; from JPRS-CST-87-011, March 18, 1987.
63. China Daily; from JPRS-CST-87-012, March 23, 1987.
64. Science of Science and Management of Science and Technology (in Chinese), No. 2, February 1987.

abroad. Many of these computers were imported in kit form for assembly and thus were recorded in China's statistics as part of the national "production" total, but they actually contributed little to China's computer knowledge or development experience.[65] This problem is not limited to the computer industry, but actually has been an even greater concern for the IC industry, as discussed under the section on microelectronics. The Chinese integrated circuit is not commonly used in domestic production of computers such as the Great Wall 0520 because of its reputation for poor quality. Government leaders have attempted to combat the problem by imposing controls on the imports of some types of foreign ICs. They have also put stress on the importance of acquiring the technology knowledge of the process of IC development so that eventually the chips can be produced at a higher level in domestic production. As in most large, high-cost, high-tech ventures, the improved chip production will be focused in the four main electronic bases of Beijing, Shanghai, Guangdong, and Jiangsu.[66]

Shanghai has been an early target for computer automation of industry because of its lucrative textile industry. During the sixth Five Year Plan, the textile industry was one of the country's leading sources of foreign exchange, earning U.S. $1.72 billion during that period. Shanghai's own plans include wholesale automation and renovation of electronic plants, the machinery industry, and the textile factories by the 1990s. The hope was that by 1985, 30 to 40 percent of its production could be comparable to world advanced levels of the late 70s, and by 1990 most of the commonly used production techniques of the early 80s would be implemented.

The microelectronics industry in Shanghai was given the highest priority for technological transformation as early as 1983. It was expected that the advances made in this industry could then be diffused across a number of other industries. Shanghai's leaders have made plans for the advancement of computer industries through preliminary arrangements with IC and other coordinated industries, for example the "pivotal development plan for ICs and microelectronic computers in the Yangtze River Delta."[67] Problems have arisen,

65. Simon, Denis, "China's Future Technology Search, Intertrade, Feb. 1987.
66. Ibid.
67. China Business Review, March-April, 1985.

however, from the fact that most of the IC factories in the area are under the jurisdiction of the Ministry of Electronics rather than under municipal control. These industries thus function as rivals to Shanghai's computer industry development. This rivalry has impeded the coordination of component development necessary for the computer industry to advance.

The Shanghai Science and Technology Commission attempted to solve the problem by placing production of ICs at the top of its list of major projects for 1986. Without the cooperation of regional factories, however, it will probably be impossible to reach the targets outlined in the development plans. The competition between bureaus has thus affected every aspect of the project. Despite the individual strength or desire of each unit to work in harmony, it is often impossible because of the nature of government funding. Funding from one source often cannot be used in a joint project across bureau lines. As the Vice-Mayor of Shanghai noted:

> Twenty-seven units in Shanghai are directly engaged in the scientific research, production, application, and service of computers. They come under the vertical jurisdiction of the ministries of Education, Electronics, and Machinery, and relate horizontally to the bureaus of Meters, Higher Education, and Light Industry.[68]

In a supreme effort to pull the various actors together, two municipal corporations were formed in 1984. These were the Shanghai Computer Corporation and the Shanghai Software Technology Development Center. The establishment of coordinating groups such as these has been crucial for many cities that find themselves in similar binds of competing bureaus and groups. Currently the SCC has been able to form a modest corporation involving research and development labs, manufacturing and service centers, maintenance, and training.

In January of 1985, Wang Laboratories signed a joint venture contract with SCC for the transfer of microcomputer technology to one of its main factories. The factory will start with Wang computer kits, but within five years is expected to handle both production and the development of applicable software. Eventually, the corporation plans to produce software at a scale and quality where it is easily exportable on the international market.

The rise of coordinating corporations such as SCC and SSTDC are crucial for the growth of the computer industry in Shanghai, and in the nation. These small, high-tech computer companies have emerged in the large industrial cities where the technological

68. Reported in the China Business Review, March-April, 1985.

infrastructure is already strong. They have arisen as a response to the confusing and often debilitating bureaucratic structure of the computer industry, but more significantly, they have emerged with the full support and promotion of the government. Although decentralization has led to problems in some areas, including the duplication of consumer production lines, and various problems in telecommunications, it has allowed the proliferation of small, flexible, fast-paced computer companies that have been essential to the industry. It has also allowed provinces, and cities such as Shanghai, the autonomy and authority to form coordinating groups such as SCC, that can work through the various entanglements created by a large and intransigent bureaucracy.

The Telecommunications Subsector

During the 1950s and early 1960s China lagged behind the West in military communications by only a few years, but civil communications were largely obsolete by U.S. standards. (See Table 21). Most of the telecommunications equipment of this time period was copied from Soviet equipment. Simple telephone and radio equipment was assembled from imported and domestic components.

The period from 1966 to 1971 showed a decline in both domestic development and importation from non-communist countries. (See Figure 3) However, following the announcement of the fourth Five Year Plan in 1971, in which the importance of building a modern telecommunications network was emphasized, the industrial growth rate, as well as the importation rate, soared. Beginning in 1972, China has purchased four earth satellite stations. These stations have links with Intelsat Pacific and Indian Ocean satellites. Between 1970 and 1986, eighteen satellites connected with engineering, surveying, remote sensing, and political projects were launched. (See Table 22).

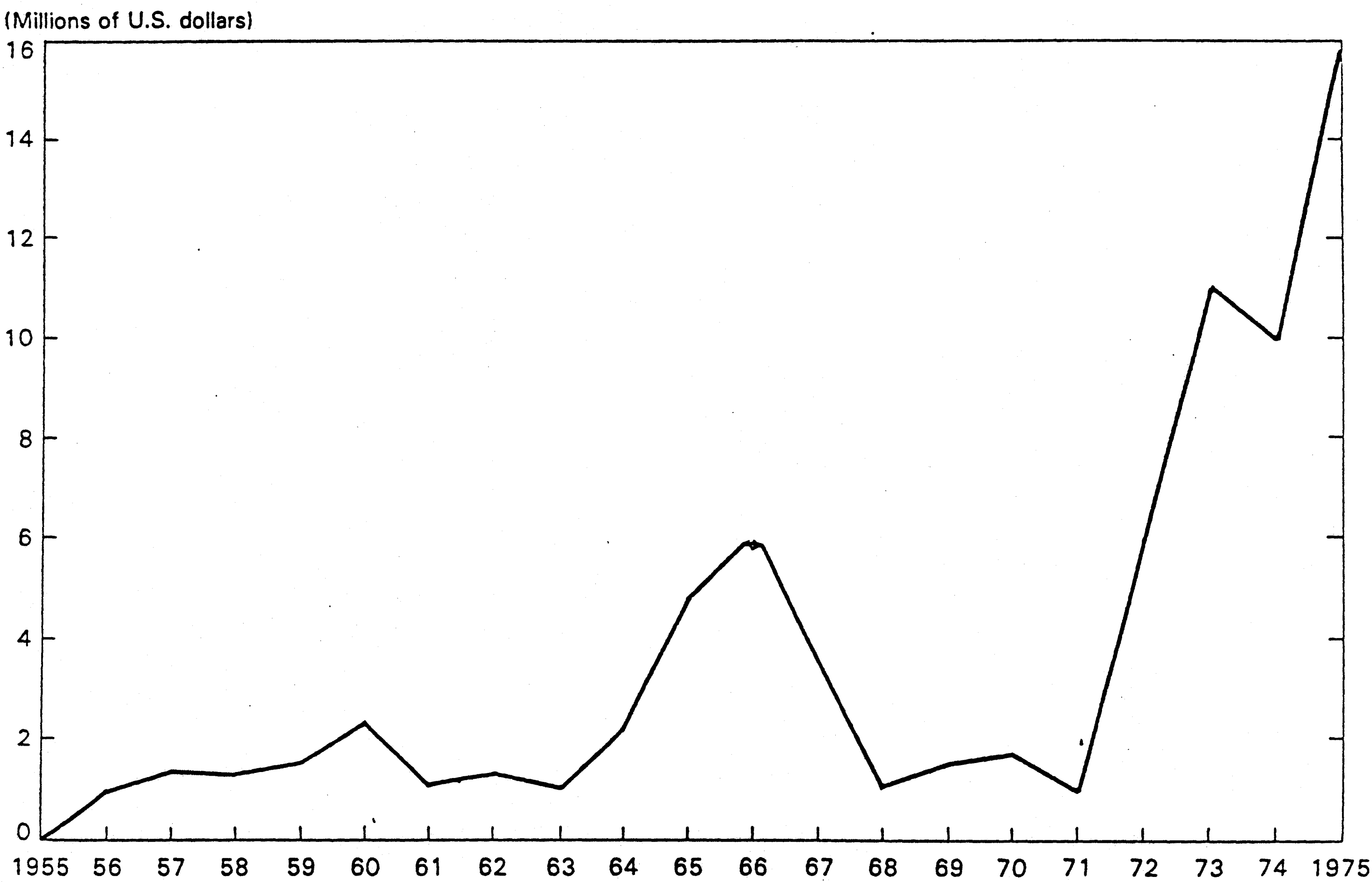
Industrial Diffusion. Despite some great advances in the quality and progress of satellite development and telecommunications technology related to the military, the advantages to industry have remained quite small. In industry, the ability to network from one industry or research center to another is still quite poor. The problems of a weak telecommunication system have exacerbated the traditionally weak links between sectors and led to the duplication of research, duplication of technology imports (including entire

Table 21
Comparison of Chinese and U.S. Military Transceivers

	Chinese 2-watt set	United States, AN/PRC-25	United States AN/PRC-74B
Frequency coverage	1.7 to 6 mc	30 to 75.9 mc	2-17.999 mc.
Channels	430 voice plus 430 continuous wave (CW) (estimated)	920	5,334.
Tuning	Continuous	Detent	Digital/1 kc. per step.
Modulation	AM voice or CW	FM	AM-USB or CW.
Battery life	100 hr. (estimated)	24 hr. to 70 hr.	11 hr. to 40 hr.
Range	10 to 16 kilometers (km) (estimated)	8 km (nominal)	24 km. (nominal)
Weight	15 lbs	22 lbs	29.5 lbs.

Source: Reicher, p.104.

Figure 3
Imports of Telecommunications Equipment From Non-Communist Countries, 1955-75



Source: Telecommunications Equipment, p.8.

Table 22
Satellites Launched, 1970-86

Order	Name of satellite	Launched date	Use
1	Dongfanghong I	Apr. 24, 1970	It carried out experiments on scientific research. The satellite was 173 kg in weight. Our country became the 5th country that launched a satellile independently.
2	Experiment I	Mar. 3, 1971	It carried out space physical survey. The satellite was 221 kg in weight.
3	Satellite I for scientific survey and technologiical testing	July. 26, 1975	It carried out engineering and technological tests.
4	Satellite II for scientific survey and technological testing	Nov. 26, 1975	After orbiting for three days, it was retrieved. China became the 3rd country which has mastered retrieval technique.
5	Satellite III for scientific survey and technological testing	Dec. 16, 1975	It carried out tests in remote-sensing technology.
6	Satellite IV for scientific survey and technological testing	Aug. 20, 1976	It carried out tests in remote-sensing technology.
7	Satellite V for scientific survey and technological testing	Dec. 7, 1976	It carried out tests in remote-sensing technology. After orbiting for three days, it was retrieved.
8	Satellite VI for scientific survey and technological testing	Jan. 26, 1978	It carried out tests in remote-sensing technology. After orbiting for three days, it was retrieved.
9 10 11	Practice II Practice II A Practice II B	Sept. 20, 1981 Sept. 20, 1981 Sept. 20, 1981	Carried out space physical surveys-three satellites were launched by the same rocket.
12	Satellite VII for scientific survey and technological testing	Sept. 9, 1982	It carried out tests in new technology. After orbiting for five days, it was retrieved.
13	Satellite VIII for scientific survey and technological testing	Aug. 19, 1983	It carried out tests in new technology. After orbiting for five days, it was retrieved.
14	Dongfanghong II-1	Jan. 29, 1984	It carried out tests in communication technology.
15	Dongfanghong II-2	Apr. 8, 1984	It carried out tests in communication technology, stationary orbit.
16	Satellite IX for scientific survey and technological testing	Sept. 12, 1984	It carried out tests in remote-sensing technology. After orbiting for five days, it was retrieved.
17.	Satellite for scientific survey	Oct. 21, 1985	It carried out tests in remote-sensing technology. After orbiting for five days, it was retrieved.
18	Dongfanghong II-3	Feb. 1, 1986	It carried out tests in remote-sensing technology. After orbiting for five days, it was retrieved.

Source: <u>White Paper</u>, p.208.

production lines), and the inability to read user needs accurately. In addition, the small industries in outlying areas are not able to produce enough of a surplus to market their products internationally, and their domestic marketing ability is largely confined to regions that can be reached without extensive transportation or telecommunication networks.

Government Policy. In response to these problems, China's leaders have made extensive efforts to improve communication in industry by expanding the telecommunications system and by establishing coordinating agencies that can bring together groups from different regions and different sectors of the industry. The expansion of telecommunications facilities since the Open Door Policy differs from the past in the amount of research and development devoted to the civilian sector. The use of telecommunications technology in national construction has been a major theme since 1977, particularly in the launching of satellites for a variety of economic uses. The director of the Beijing Institute of Satellite Information Engineering, a comprehensive research organization founded in 1987, explained the philosophy of his institute. He said,

> In the past, under the influence of extreme leftist ideological trends, to some degree we saw space satellite technology research as simply the 'placing of political satellites'. But today, the cause of the four modernizations has made new demands on China's research into and development of satellite information application technology, namely, for such high-technology means as satellite sensitivity, satellite communications, satellite navigation and positioning as well as computer measurement control and data management, all of which have brought enormous economic and social results to departments and industries.[69]

China was the 25th country to modernize its domestic communications by leasing satellite space from Intelsat, the international consortium that handles most of the world's transcontinental telecommunications.[70] In 1981, Beijing leased one-fourth transponders on an Intelsat satellite for about $1 million a year. These responders were dedicated to nationwide broadcasts to TV stations and for intercity telephone transmission.[71] In 1985, Intelsat allocated to China one-half transponder on a five-year lease for $400,000. The uses of the transponder were jointly shared by the Ministry of Posts and Telecommunications, the Ministry of Petroleum, the Ministry of Coal, and the Ministry of Water Resources and

69. Reported in the Keji Ribao, Feb. 26, 1987; from JPRS-CST-87-034, Aug. 28, 1987.
70. China Business Review, Jan-Feb., 1984.
71. China Business Review, Nov-Dec. 1981.

Electric power. These Ministries are all concerned mainly with economic development. The Intelsat Network can be seen in Figure 4.

China's successful space program has been important for providing economic and social necessities such as the broadcast stations for TV reception and intercity telephone transmission. It has been equally important, however, for providing political legitimacy. The successful launching of numerous satellites, including contracting its launching services out to other countries, has given the country international prestige, and lent the reformers in government a measure of security with regard to their modernization efforts in this field.

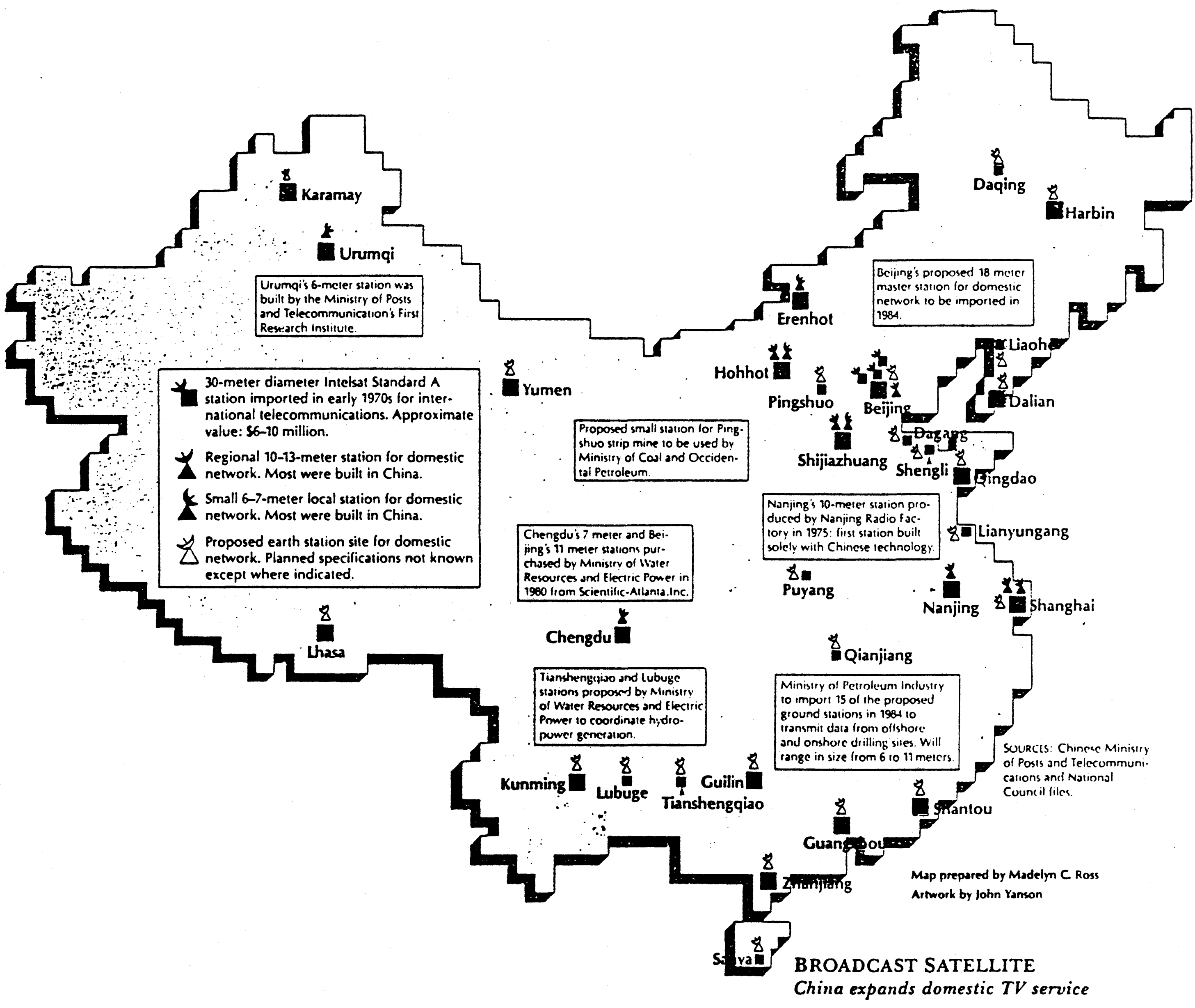
Telephone Communications. In the past, the modern, high-capacity international telecommunications equipment that was developed was often not even hooked up to the much less developed domestic communication network.[72] As late as 1977, only eight cities in China had adopted an automatic dialling system, and that system was only effective for some long-distance calls.[73] By the mid 1980s, despite some increased attention to providing domestic communications, the level of intercity communication in China was still quite poor. It has been noted by many businessmen working in China that it is far easier to make a call from a hotel phone in Shanghai or Beijing to the US, than it is to make a connection between two Chinese cities.

From the beginning, Chinese planners have not been concerned about the provision of telephone communication as a consumer service. Instead, they see the importance of telecommunications as a crucial element in the renovation and improvement of China's industrial and administrative infrastructure. The emphasis in telecommunications has always been on either the improvement of military capability, or on economic and social reconstruction and diffusion of the benefits of technological advancement into industry. Domestic communications has been a secondary priority.

It is apparent, however, that Chinese leaders have considered international communications to be a high priority. Since 1977, the Posts and Telecommunications Bureau has been allocating more funds for the upgrading and increasing of telecommunications facilities--from 75% in 1977 to 82% in 1980. From 1978 to 1982, international

72. Telecommunications Equipment, A Market Assessment for the People's Republic of China, U.S. Department of Commerce, 1977, p. 20.
73. Sigurdson, Technology and Science, p. 132.

Figure 4
China's Intelsat Network



Source: <u>China Business Review</u>.

telecommunications developed at a rate of 30 percent per year, mainly in satellite communications.[74] The number of telephones per 100 persons has increased every year since 1980, as have the number of long-distance domestic calls. (See Table 23). The projections for the seventh Five Year Plan include an increase in the number of inner-city phones by 3 million, and the number of long-distance lines by 60,000.[75] The plans also include the use of new technology in optic fiber communication, although the stress will be to continue to develop applied technology and renovate existing systems.[76]

Decentralization. To allow the post and telephone enterprises greater freedom to pursue modernization goals, there has been some decentralization of the industry since the Open Door Policy. The Post and Telecommunications Enterprises have done quite well as business ventures, showing large gains in income from the years 1984 to 1985. (See Table 24). Newly increased fixed assets have also shown tremendous rates of growth from 1981 through 1985. (See Table 25).

Regional Disparity Exacerbated by Growth of Telecommunications. The problems that have arisen as a result of locally perceived needs for domestic improvement of telecommunications, and the diminishing central control of communications, have become serious in the recent past. Starting in the early 1980s, many provinces began to make deals with foreign companies on their own. This situation led to the uneven acquisition and application of technology and equipment, and great regional disparity and imbalance. (See Table 26). Owing to the connections with Hong Kong, Guangdong Province, in particular, has raced ahead in the effort to improve and extend its communications facilities. Advanced telecommunications circuits, based on digital technology and fiber optics media are penetrating China from Hong Kong, largely through the joint ventures of firms such as Cable and Wireless of Britain. The other major urban centers have hurried to keep up, and the result has been a widening gap between the major metropolitan areas and the rest of the country. The feared marginalization of the rural areas resulting from the development of the

74. China Business Review, July-Aug., 1982.
75. Zhongguo Xinwen She (in Chinese), FBIS-CHI 185, K-16, Sept. 24, 1985.
76. White Paper, p. 198.

Table 23
Development of Posts and Telecommunications

Item	Unit	1965	1981	1982	1983	1984	1985
National development							
Letters mailed annually per capita		3.1	3.4	3.3	3.4	3.8	4.5
Annual subscription of newspapers and magazines per 100 persons		7.7	18.2	19.3	22.4	27.2	28.9
Proportion of provinces with People's Daily available the same day (of printing)	%		66.0	72.4	72.4	72.4	72.4
Telephones per 100 persons		0.29	0.45	0.46	0.50	0.53	0.60
Average long-distance telephone lines from Beijnig to provincial capitals			31.3	32.8	34.5	37.1	43.7
Proportion of counties and above with auto-switchboards	%		38.4	40.1	37.4	38.3	40.3

Table 24
Principal Financial Indicators for Posts and Telecommunications Enterprises (in Rmb 10 thousand)

Indicators	1985	1984	Increase in 1985 over 1984	
			Value	%
Total Posts and telecommunications enterprises				
Business income	382,128.6	299,352.5	82,776.1	27.7
Business expenditure	385,436.9	229,837.3	55,599.6	24.2
Non-business net loss	8,037.9	-392.6	8,430.5	2,147.4
Taxes	12,101.8	8,937.7	3,164.1	35.4
Balance of income and outlay	92,627.8	60,184.9	32,442.9	53.9
Original value of year-end fixed assets	1,261,796.0	1,110,828.8	150,967.2	13.6
(1) Central posts and telecommunications enterprises				
Business income	334,730.3	259,387.7	75,342.6	29.0
Business expenditure	245,446.4	194,394.6	51,051.8	26.3
Non-business net loss	9,505.6	924.8	8,580.8	927.9
Taxes	10,645.9	7,743.4	2,902.5	37.5
Balance of income and outlay	88,143.6	58,174.5	29,969.1	51.5
Original value of year-end fixed assets	1,100,801.3	959,565.5	141,235.8	14.7
(2) Local telephone enterprises				
Business income	47,398.3	39,964.8	7,433.5	18.6
Business expenditure	39,990.5	35,442.7	4,547.8	12.8
Non-business net profit	-1,467.7	-1,317.4	150.3	-11.4
Taxes	1,455.9	1,194.3	261.6	21.9
Balance of income and outlay	4,484.2	2,010.4	2,473.8	123.1
Original value of year-end fixed assets	160,994.7	151,263.3	9,731.4	6.4

Source: China Statistical Yearbook, 1986.

Table 25
Newly Increased Fixed Assets Through Capital Construction, by Sector
(in Rmb 100 million)

Year	Transports, posts and telecommunications	Commerce, catering and service trades and material supply and marketing	Scientific research, culture, education, public health and social welfare	Civil public utilities	Others
1953–1957	75.60	19.82	40.17	12.94	79.45
1958–1962	119.66	19.63	37.65	22.82	38.78
1963–1965	47.24	8.85	21.94	11.02	22.57
1966–1970	91.36	13.72	18.11	11.59	57.46
1971–1975	199.45	33.83	37.65	23.06	72.20
1976–1980	258.16	66.10	94.40	68.50	132.40
Of which: 1978	70.29	11.79	15.84	10.54	23.87
1979	48.29	15.96	25.08	21.92	34.45
1980	61.72	22.29	34.19	26.48	37.15
1981–1985	358.21	149.90	271.52	204.03	252.20
1981	32.77	22.79	35.95	31.85	34.28
1982	54.28	28.53	40.67	32.37	46.63
1983	59.02	25.13	46.61	31.50	51.84
1984	83.85	28.88	62.13	44.54	46.66
1985	128.29	44.57	86.16	63.77	72.79

Source: China Statistical Yearbook, 1986.

Table 26
Postal and Telecommunications Services, by Province, 1985

Province	Service revenue of posts and telecommunications (Rmb 10 thousand)	Letters (10 thousand)	Parcels (10 thousand)	Newspapers and magazines circulation (10 thousand copies)	Telegrams (10 thousand copies)	Photo-telegrams (copy)	Long-distance calls (10 thousans copies)	Urban telephones (subscriber)	Rural telephones (subscriber)
National total	**296,001.6**	**467,824.7**	**2,007.6**	**30,171.7**	**21,898.2**	**139,242**	**382,541**	**7,189,554**	**930,744**
Beijing	22,413.3	27,589.0	304.3	947.7	650	124,943	1,424.4	138,130	1,578
Tianjin	5,296.2	6,722.9	27.7	590.5	232.5	343	558.0	55,313	1,735
Hebei	12,618.6	21,693.1	102.3	1,353	859.8	126	2,042.2	99,340	23,682
Shanxi	6,746.4	12,226.4	52.0	870.1	557.3	260	890.9	56,648	15,377
Inner Mongolia	6,353.4	9,415.7	47.3	635.0	540.6	365	791.7	71,101	15,129
Liaoning	17,302.7	21,001.9	118.6	1,790.8	874.3	846	2,666.2	165,512	58,623
Jilin	8,886.2	12,113.7	43.0	952.4	662.3		1,528.0	81,087	26,020
Heilongjiang	11,193.2	16,048.7	60.3	1,365.1	910.1	756	1,688.0	108,578	25,347
Shanghai	15,949.7	21,910.8	89.8	1,306.9	740.9	6,009	1,784.0	151,949	33,828
Jiangsu	20,337.1	30,365.8	71.6	2,223.1	1,505.2	640	3,368.2	128,406	49,084
Zhejiang	19,544.8	33,742.3	88.5	1,190.8	1,281.3	194	2,651.0	104,430	58,012
Anhui	8,322.4	14,205.3	36.0	1,117.1	677.3	156	1,051.8	64,571	22,686
Fujian	8,935.5	15,239.7	45.4	886.7	763.3	184	1,240.5	54,676	46,669
Jiangxi	7,116.8	15,472.7	38.7	806.5	590.8	9	838.2	52,019	22,798
Shandong	16,186.3	21,930.4	119.5	2,017.0	1,131.9	79	2,325.1	120,851	52,279
Henan	11,056.7	20,304.3	77.7	1,611.9	1,191.1	528	1,291.1	74,999	81,684
Hubei	12,008.6	19,172.1	65.9	1,357.2	1,051.4	204	1,382.0	82,435	48,104
Hunan	10,411.8	19,265.9	58.3	1,465.4	846.5	83	1,270.4	68,052	28,847
Guangdong	21,917.8	37,579.5	87.9	1,408.6	1,872.0	1,498	3,461.7	134,318	107,936
Guangxi	6,991.6	12,822.7	46.5	751.9	682.3	110	755.4	43,410	49,151
Sichuan	15,097.6	29,428.3	132.9	2,125.5	1,373.2	940	1,802.7	102,195	49,890
Guizhou	3,981.0	6,129.2	58.4	461.3	334.5	44	419.4	34,275	15,804
Yunnan	6,674.7	9,496.5	59.8	639.3	577.5	129	730.9	38,524	52,261
Tibet	478.5	656.5	16.4	29.7	101.9	124	11.2	5,981	280
Shaanxi	7,870.9	13,275.3	47.2	869.4	634.1	469	1,013.4	53,828	15,978
Gansu	4,793.6	8,863.3	41.7	540.9	430.9	57	523.5	35,685	9,471
Qinghai	1,720.4	2,328.0	17.0	153.9	161.3	42	168.3	15,012	7,233
Ningxia	1,086.9	1,792.1	12.0	125.1	100.3	8	150.8	10,784	1,467
Xinjiang	4,708.9	7,032.6	40.9	578.9	563.6	96	425.1	37,385	9,791

Source: China Statistical Yearbook, 1986.

electronics infrastructure, has thus not only not been mitigated by the installation of better communications facilities, but seems actually to have been exacerbated by it.

The Microelectronics Subsector

Most of China's early semiconductor manufacturing equipment consisted of homemade prototypes of old U.S. and Japanese models, or obsolete East European equipment. In addition, COCOM controls applying to semiconductor technology were particularly tight, and there seemed to be little prospect of transferring more sophisticated technology from the U.S. or its allies. Worse, China's own industrial base was not ready for the production of semiconductors owing to a shortage of technical experts and the lack of quality control or modern management expertise. Other problems related to infrastructural bottlenecks, raw materials shortages, and the lack of the strong support industries necessary for semiconductor production.[77]

The large gap between research innovation and production in industry has remained a major problem in semiconductor development. Basic research is of a very high level, but the learning curve that is fundamental for a thorough understanding and assimilation of design and production know-how has not had time to develop. Although it seems problematic to spend time and money on the development of chips that have already been far surpassed on the world market, (such as the 16k chip), the knowledge learned through the various stages of development are important for moving to the next level of innovation. Much of the microelectronics knowledge is inter-connected, so that learning about RAM memory may be associated with LSI learning. And although knowledge of the former may not be essential, LSI development is crucial for the computer industry. (See Table 27 for a list of early developments in microelectronics research in China).

By 1982, at universities and institutes, Chinese engineers had designed several sophisticated products, including CAD systems, ion implantation equipment, photorepeaters, and electron beam exposure systems. On the commercial level, however, factories were still using manual processes to print circuits in the 10 to 15 micron range on 1-inch or 1.5-inch wafers.[78] Diffusion of research developments into industry have apparently been retarded by

77. China Business Review, May-June, 1982.
78. Ibid.

Table 27
Early Development of Microelectronics

	U.S.A.	Japan	China
The first junction transistor	1947	1954	1957
The first silicon	1954	--	1962
Production capacity of transistor formed	51-56	1957	1959
The first sample of IC	1959	1965	1965
Prodction capacity of IC formed	1961	1966	1968
Development time of LSIC	1966	1970	1973
Production capacity of LSIC formed	1968	1971	1981
Development time of VLSIC	1977	1977	--
Production capacity of VLSIC formed	1981	1981	--

Source:"Policy on China's Microelectronics Technology" 1986,IEAS R Report the same problems of poor coordination and lack of economic incentives as have plagued the other subsectors of electronics industry discussed above.

As in the other electronics industries, the semiconductor industry has run into difficulties associated with the lack of a central directing authority and the discipline of a free market. The result has been the proliferation of many small, uneconomical local semiconductor shops, but few modern, large-scale factories. Although the Fourth Ministry of Machine Building has national authority over semiconductor production, few factories or smaller ministries want the Fourth MMB to control them or their future supplies. To combat the problem of poor coordination between sectors, joint companies, akin to the leading groups in electronics and the computer industry, have been formed that can hopefully coordinate the efforts of some of the enterprises and ministries involved in semiconductor production.[79]

One of the first attempts at the use of semiconductor technology in industry was in the effort to construct modern plants for semiconductor TV components in Wuxi, Jiangsu, in 1982. For this project, China relied on the transfer of semiconductor manufacturing technology from the U.S., after it had been carefully screened by U.S. export controllers. The massive importation of semiconductor manufacturing equipment was considered to be the first step in acquiring enough technology to become self-sufficient in the industry. As of 1988, however, China has yet to reach this goal.

The microelectronics industry still lags behind the other electronics industries and is a considerable stumbling block in computer production. Most of the integrated-circuit industry continues to rely on foreign imports, and the percentage that is produced domestically is of a low standard. The reliance on kit production and on foreign imports has retarded the domestic learning curve and has had serious repercussions for China's efforts to promote its own industry. Wang Shouwu, a microelectronics expert, said in 1986:

> Right now, China's integrated-circuit industry falls short of the international standard and we must try hard to catch up. Importation of advanced facilities and technology is of course necessary, but we must make the integrated-circuit industry take root and germinate in China. It is not good to rely on the importation of advanced facilities. We must rapidly establish China's own industries with specialized facilities for integrated circuits; this is a task of top priority.[80]

79. China Business Review, March-April, 1985.
80. Shanghai Electronics and Automation (in Chinese) No. 1, Feb. 20, 1986; from JPRS-CST-87-009, March 19, 1987.

Government Policy. Microelectronics has been one of the major emphases of the seventh Five Year Plan. Shanghai targeted it as one of the seven new high-technology industries for priority development, along with bio-engineering, optical fiber communications, marine engineering, laser technology, new materials, and robotics. The plans for development include the improvement of the 13-inch-diameter to the 4-inch diameter, for preparation into production of the 1-micron-line, and for improvement of photo-etching facilities. Government strategies to reach these development goals include the offer of subsidies to specialized facility industries, the protection of national industries by embargo on the importation of low-standard facilities, the strengthening of management, including expertise from abroad, and the use of imitation as a positive factor. According to one editorial, "we should ensure the developing position of specialized facilities by importing advanced sample products and sample machines and disassembling and copying them. In this way we can cut down on the long process of our own search for knowledge."[81] The impact of these policies has had some effect on the industry, as can be seen in the rise of IC output from 1981 to 1985. (See Figure 5).

Another incentive to encourage the diffusion of microelectronics technology into industry has been the offering of financial aid and preferential loans to enterprises that have renovated their equipment with microelectronics. In Beijing, the Mayor offered preferential treatment and awards to those who used microelectronics and warned of punishments for those managers refusing to "popularize the new technology."[82] According to Mayor Chen, the city saved 24 million yuan by using microelectronics in the renovation of old equipment in 1987.

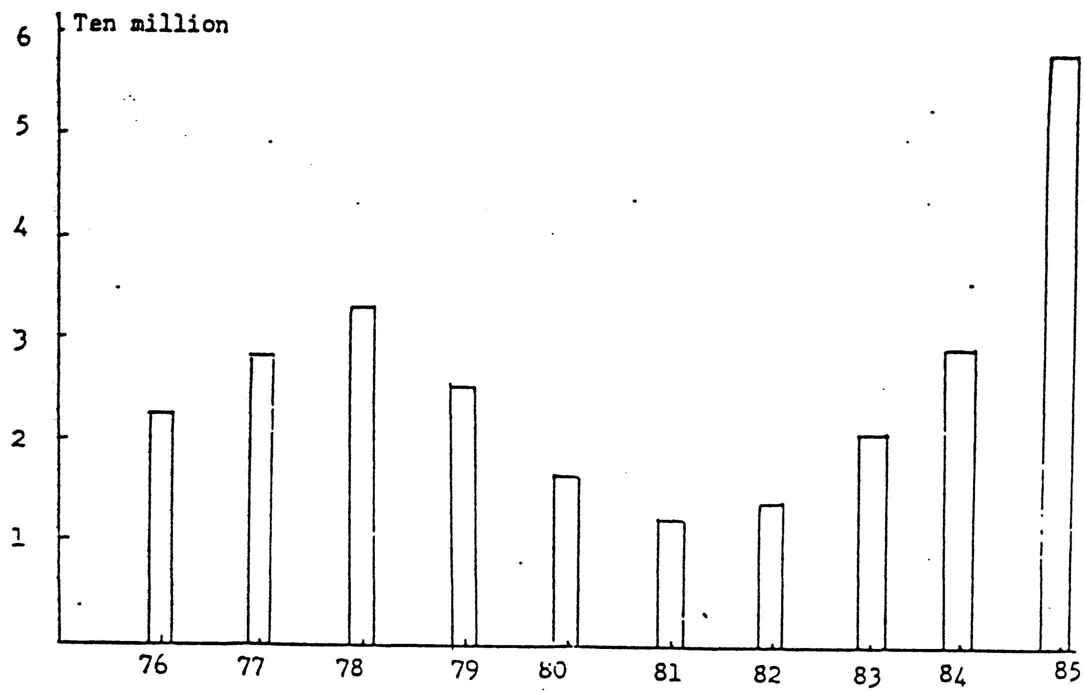
Technology Transfer

Early Military Emphasis

After the Soviet pullout, China turned to non-Communist countries for assistance. Between 1960 and 1970, more than U.S. $200 million of technologically advanced electronics products as well as millions of dollars of production equipment were imported from Japan,

81. Ibid.
82. JPRS-CST-87-035, Sept. 4, 1987.

Figure 5
IC Output, 1976-85



Source: <u>Development of Electronics</u>.

Table 28
Imports of Electronic Equipment From Non-Communist Countries
(in $1,000)

Type of equipment	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970 [2]	Total 1960–70
Professional and scientific instruments and apparatus	5,224	1,883	736	2,318	7,802	18,741	24,947	20,308	15,078	11,589	7,926	116,552
Telecommunications apparatus	2,247	978	1,238	933	2,127	4,705	6,035	3,501	967	1,480	1,524	25,735
Electric measuring and controlling instruments			915	2,136	6,614	14,146	14,312	9,073	5,116	4,267	4,340	60,919
Electron tubes, photo cells, and semiconductors		283	156	242	433	440	493	452	507	183	207	3,396
Total	7,471	3,144	3,045	5,629	16,976	38,032	45,787	33,334	21,668	17,519	13,997	206,602

[1] Source: Summary of exports and imports from Communist areas in Eastern Europe and Asia. Prepared by: International Trade Analysis Division, Bureau of International Commerce, and U.S. Department of Commerce.

[2] Data incomplete.

Source: Reicher, p.89.

West Germany, the United Kingdom, France, and Switzerland. (See Table 28). The imports were mainly military and industrial electronics that would have required extensive developmental research for China to be able to produce domestically. This imported equipment allowed China to expand its production base from 60 major electronic plants in 1960, to 200 by 1971.[83]

Despite the many limitations on exports to China, China was able to obtain access to modern solid state technology in the 1960s. These solid state components were usually used in military technology such as the transistors and diodes in missile systems, radars, nuclear instrumentation, military communication equipment, and computers. Most of the integrated circuits were used in military electronic equipment such as missile guidance systems. The transistors, diodes, and other components that were considered to be of a slightly inferior quality were diffused into the civilian sector for use in transistor radios and general testing equipment. Some solid state devices were also reported in industrial use.

In addition to solid state components, China imported approximately U.S. $157 million of instrumentation (about three-fourths of China's total imports of electronic equipment from non-communist countries) between 1960 and 1971. This ability to import advanced Western instrumentation is important considering that modern instruments are crucial in industrial and military programs, particularly China's nuclear and missile systems. At least half of the instruments used in China were used by the military during these years.[84]

Recent Government Policy

China's strategy for electronics technology transfer has changed considerably since the Open Door Policy. In the electronics industry, as in other dynamic, rapidly changing industries (such as materials, and biotechnology), there is a great expense involved in product development and a rapid rate of product obsolescence. The role of the market is crucial, as it must be expanded in order to distribute costs. Competition is also high, and there is a reluctance by many foreign concerns to transfer technology unless guaranteed a long-term

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83. Reichers, "The Electronics Industry of China," p. 88.
84. Ibid. p. 95.

presence and access to the Chinese market.[85] Organizational systems and manpower must be flexible, communication must be good, and high quality management is essential.

The needs of foreign firms wishing to transfer electronics technology thus all depend on a modern and complete infrastructure. The Chinese government has begun to appreciate the necessity of providing a good infrastructure for its own purposes as well. Since 1984, there have been some policy changes designed to facilitate reform and systemic change in the process of technology transfer. These reforms relate to both the needs of foreign firms seeking to transfer technology, as well as to the needs of the State in assimilating and diffusing this new technology into industry. These policy reforms will be examined in the computer industry.

Computer Technology Transfer

China's strategy for technology transfer in the computer industry has changed over the nine years since 1979. At the beginning of the Open Door Policy, government leaders wanted to import more advanced computer equipment than was allowed under COCOM controls at that time. In 1981, IBM's proposed sale of its state of the art 4341 computer was overruled by Reagan in May of that year. Concerned by the delays caused by the COCOM restrictions, China obliged several computer companies to post bonds against performance of their contracts, in the event of a negative response from Pentagon.[86]

With the establishment of new guidelines for export in 1983, approximately 75 percent of high technology purchases desired by Beijing could be automatically approved. Of the more sensitive areas including general-use computers, microcircuits, semi-conductor fabrication equipment and software for computer-aided design and manufacturing, the levels of technology that might be available were raised, and the procedures for licensing were simplified. With the more flexible regulations, negotiations relating to computers grew impressively in 1984 and 1985. (See Table 29).

With the loosening of restrictions, coffers full of foreign exchange, and a positive atmosphere with foreign companies, China was able to conclude scores of transactions

85. OTA, Technology Transfer to China, p. 53.
86. See for example, Honeywell's contract posting a US$24 million bond against performance on a US$75 million contract in 1983; from the Far Eastern Economic Review, April 7, 1983.

Table 29
Negotiations Relating to Computers, from April 1984

Foreign Partner	Chinese Partner	Line of Business, Contract Content
Nippon Electric	China Software Center (JV with the China National Computer Technology Service Corp.)	Software production
	Ministry of Electronics North China Terminal Equipment Co. (Baoding)	Local production of PC-9801F (16-bit microcomputer); annual production 20,000 units, joint development of Chinese system
Suwa Seikosha Epson		Technological assistance for small printers for personal computers
Fujitsu	China National Technical Import Corp.	Wide-application large-sized computers: System 24 FACOM M-360R (3 units) " M-360S (13 units) " M-340S (8 units) (for installation at the Meteorological Data Service Center, Beijing, and research organs in Beijing Normal University and other universities in Shenyang, Chongqing, Shanghai, etc.
	Qinghua University	Joint software development
	Science and Technology Commission, Tianjin Municipality	Joint production of CEF (Chinese-language data filing system)
Tokyo Sanyo Electric (planned)		Joint production of MBC series (16-bit personal computer)
General		Export of LBC-220 (8-bit personal computer): 1,000 units from Feb. 1983 to Oct. 1984, via Hong Kong; 1,000 units in Nov. 1984-Jan. 1985 period (to use Chinese-language software developed by Hong Kong's Renfrew Co.)
Sord Computer Systems Kyokuto Shokai	Beijing Micon Training Center (Society of Industrial Economics; Industrial Economics Institute, Academy of Social Sciences)	Exhibit at Micon fair (Oct. 12, 1984)
B.U.G.	Shenyang Machinery and Electrical College	Personal computer parts export (100 units); Technological assistance for personal computer production (initially semi-knock down; 100% local production in second year)
Futaba Electric	Bank of China, Chengdu Branch Sichuan Computer Technology Diffusion and Service Corp.	Joint venture in the Shekou Industrial District, Shenzhen, with Southwest China Electronics Co., Ltd., Digital World (U.S.) and Design Future Computer Products (Hong Kong); Manufacturing know-how and parts supply for a switching power source for microcomputers; 16-bit microcomputer production (monthly production capacity 500 units)
IBM (U.S.)	Ministry of Machine Building, Beijing	Establishment of IBM China (Nov. 1984) Establishment of computer center and consumer training center; local construction of Chinese language IBM 5550 (16-bit personal computer)
IBM Hong Kong		Development of Chinese-language software
Wang Laboratories (U.S.)	Ministry of Electronics	Establishment of joint firm within 3 years (investment $50 million, wide application small computer production) Production of OA equipment (50,000 units, including software development) over 5 years in Shanghai region; Production of Wang personal computers in Xiamen SEZ.

Table 29 (cont.)

Honeywell (U.S.)	China National Instruments Import-Export Corp. Mingxing Computer Service Center	Establishment of technical center for large-scale computers; technological assistance for large-scale computer maintenance; training of Chinese engineers (disassembly, reassembly)
Gould (U.S.)		Manufacturing and marketing of programmable controllers: contract value over $10 million, contract period 10 years (production site is Tianjin city)
Burroughs (U.S.) (Jan. 1985)	Yunnan Import-Export Corp. Yunnan Electronics Factory	Licensed production, marketing and maintenance of small computers; contract value $20 million
Sinclair Research (U.S.)	Shandong University	Supply of personal computers (600 units)
Phillips (Sweden)	Shanghai Telecommunication Equipment Factory (under Ministry of Posts and Telecommunications)	Joint production of microcomputer-controlled teleprinter; annual production 5,000 units in the first 3 years on compensation trade basis; later an additional 3,000 units
Hewlitt-Packard (U.S.)	China National Electronics Technology Import-Export Corp.	Establishment of joint computer production firm
Computerland (U.S.)	Ministry of Electronics	Establishment of joint venture, Computerland China, to market computer products

Source: China Newsletter.

involving computer technology transfer. U.S. computer sales to China rose to $150 million in 1984, a 500 percent increase over sales in 1982.[87] So many enterprises and provinces were eager to purchase the newly available computer technology that China overbought, with the result of the considerable warehousing of computers, mentioned above. Hardware was also bought without much consideration for the necessity of corresponding software, know-how, or maintenance services.

Beginning in 1985, China began to reduce its import of microcomputers and to pay more attention to the purchase of software and the transfer of know-how and skills, preferably through joint ventures. China's requirements have also become more specific and careful. The new idea is to buy into a technology package rather than just purchase hardware equipment. One of the current leaders in this new style of hi-tech joint venture is Hewlett Packard. China Hewlett-Packard combines technology transfer with training abroad, marketing, manufacturing, and research and development.

The Role of Foreign Companies

One of the earliest U.S. companies to make a major deal with China was Honeywell Information Systems. Honeywell came out the lowest bidder on a major contract connected with the World Bank University Development Project. In this $200 million dollar project, at least one quarter of the funding was scheduled for computer purchases. Other early U.S. firms to agree to major contracts with China were Gould SEL Computer Systems, IMS International, and four main suppliers of microcomputers--Cromemco, Zilog, Motorola, and Tandy Corporation.[88]

The World Bank's loan for university development also favored AI Electronics Corporation of Japan, which sold several 16-bit microcomputers to 23 universities and research institutes. Japan has been a major exporter of low-level technology and consumer goods to china, but has not engaged in much high-technology transfer. After the policy shift toward greater real transfer of technology and knowledge in 1984, many American companies have been favored with contracts. Wang announced the first large-scale manufacturing joint venture in China worth over $150 million over three years. Sperry and Burroughs also signed

87. China Facts and Figures Annual, p. 130.
88. China Business Review, March-April, 1983.

joint venture contracts with China, and Digital Equipment Corp., IBM, Perkin Elmer, and Apple Computer all made inroads. China's policy was quite clear: the importation of products must be coupled with the transfer of technology; China would not buy from a company unless that company was willing to transfer desirable technology.[89]

Hong Kong's role in computer transfer is as both source and transfer point for other countries. It is estimated that between ten and twenty percent of Taiwan's computer output is sold to China through Hong Kong, at a total amount of 20,000 units average per month.[90] Additional computers have entered China illegally through Hong Kong, but users find it difficult to get them serviced.[91]

Despite the promising start of most joint ventures in China, few have been completely successful. The government leaders' dilemma between wanting sophisticated computer technology to aid in the modernization movement, and needing to protect the fledgling domestic industries, has led to some vacillation on import restrictions and prices, tax laws, and contract laws. Many foreign companies have expressed dismay at the seemingly capricious changes that have occurred over the past few years, and threatened to pull out. In addition, access to the domestic market has been curtailed recently, leading some foreign businessmen to believe that there is no future in selling to China.

Conclusions

The guidance and direction of technological development in China since 1949 has clearly been linked to political and social imperatives as well as to economic goals and needs. The development of technology in China, and the utilization of that technology in the military and in industry, has not followed a linear or logical progression because the needs of the State have not followed a linear or logical progression. The changing needs of the State over the past four decades, and the reflection of those needs in government policy, have caused the development of technology to proceed erratically and unevenly. As a result, the current concerted effort to introduce and to produce important new technologies for China's

89. Far Eastern Economic Review, October 31, 1985.
90. JETRO, China Newsletter, No. 56, May-June, 1985.
91. China Facts and Figures Annual, p. 130.

modernization has met with many unsuspected difficulties that are retarding the modernization process.

Some of the stumbling blocks currently affecting China's technology developments are related to socio-historical themes. These include the problems inherent in a cumbersome and overly-centralized bureaucracy, a tendency to prefer self-reliance to outside contacts or aid, and a strong belief in the ability of the younger generation to catch up and surpass any kind of knowledge that has been discovered by foreign nations in the past two decades. In addition, the fundamental confusion as to the exact definitions and manifestations of socialism have led to considerable political battles in the past decade--many related to differing conceptions of management.

Other problems are related to political and economic issues. These include the early reliance on the Soviet Union, which exacerbated the pre-existing tendency toward a large, centralized bureaucracy emphasizing vertical coordination, and, following the U.S.S.R.'s withdrawal, the fundamental conviction of the importance of self-reliance. The early emphasis on heavy industry, most notably steel, is also undoubtedly the result of the Soviet influence. The continuous reliance on military technology probably contained an element of all these themes, exacerbated, of course, by the isolation imposed by the outside powers, as well as by the tenuous position of the new government during the first few years of its establishment.

The government's attempts to solve these ongoing problems have led to other, equally insidious problems. Political debates about economic reforms, about the nature of socialism, and about the Party itself have caused a decided split between two groups, which I have labelled the reformers and the leftists. Although the reformers have been in political ascendancy since the Open Door Policy, the leaders of the opposing faction have considerable power and influence as well. The result of this dichotomy has been a general movement toward economic reform, but a fundamental intransigence of political or infrastructural change. In addition, there has been a series of minor policy shifts and vacillation relating to management and organizational reforms, that have led to confusing situations for individuals, for enterprises, and for industry.

For the development of the electronics industry, the situation is particularly serious. Because of the nature of the new information technology, a complete infrastructure, including management and organizational reform, is essential for its best use. As the development of electronics technology is now considered by China to be an essential ingredient in modernization and in the connection to the world economy, the State policy choices relating to the electronics industry are particularly germane for China's modernization efforts.

The somewhat contradictory organization of the industry itself has produced much competition among the various Ministries, State Commissions and Leading Groups. The foundation of The Leading Group for the Invigoration of the Electronics Industry in 1984, was one attempt to mitigate some of the difficulties associated with these bureaucratic competitions and delays. It has, however, produced conflict of its own, adding to the bureaucratic confusion. Competition among different groups and regions seems to have proliferated rather than dwindled, and all subsectors of the electronics industry have suffered as a result.

The development of electronics policy since the Open Door period began can be divided into two time frames: the initial five years from 1979-1984, and the past four years. Each of these periods has different features which characterize it. The first five years of electronics policy were similar to the general technology policy in the emphasis on technology transfer and the purchase of sophisticated equipment. In the second period there was a decided shift toward more fundamental reforms in organization and management, yet still seemingly without much systemic change of the bureaucracy itself. Rather than the purchase of electronic equipment in large quantities, the emphasis shifted toward more selective purchase with real technology transfer considered as a requisite package. The technology package included software and know-how, as well as equipment. Another important feature of the second period was the importance accorded technical renovation and upgrading of pre-existing factories. Electronics technology was imported and produced that could help in the upgrading and modernization of China's key industries, such as the textile industry in Shanghai. This has been part of a general development strategy based on a theory of competitiveness starting at the bottom of the world markets.

Themes that have run through both time periods include the fundamental preference for self-reliance, which influenced the early reliance on steel, and retarded the introduction of software and know-how. Also important has been the ongoing conflict between the desire to encourage domestic industry, and the perceived need to transfer sophisticated technology in order to upgrade industry and compete internationally. China's leaders have attempted to combat this problem with a policy of reforming and improving domestic capabilities while at the same time importing large quantities of equipment for the short term. This approach, however, has led to a host of other problems related to the inadequate construction of a strong, permanent infrastructure. A third theme has been the central role of the military. The importance accorded military capability in the early years of China's development often precluded major advances in the civilian sector. The military is still of primary importance in China's development plans, but it now must share its place in the hierarchy with the concerns of national economic development. Recent attempts have been made to diffuse military innovations in electronics technology into civilian industry, and to gear a number of military projects toward a useful end product for the average consumer.

The emphasis on the needs and wishes of the nation's "average" consumer is a new concern that could be important for China's modernization efforts. Since the beginning of the Open Door Policy, China's leaders have made a concerted effort to provide consumer electronics, particularly televisions, on a national scale. The effort has had some negative repercussions in the duplication of production lines across the country, and in the low levels of electronics technology diffusion into industry. The positive aspect, however, is an apparent concern for the provision of some amenities and the gratification of the populace.

The timing of this recent shift toward the provision of consumer electronics is interesting as it coincides with both a considerable loss of ideology resulting from the Cultural Revolution, and also a period of change and conflict at the highest level of the Party hierarchy. The political battles between the reformers and the leftists have undoubtedly caused a period of instability. The reformers, seeking political legitimacy and support for their economic reforms, have encouraged the importation and production of consumer electronics to win the approval of the people. This has been an important step, not only in the short-term effects of the policy itself, but also in the acknowledgement of the need to follow a strategy desired by a majority of the people. Thus, in some measure, the government's policies directing the development of electronics technology in China have been governed by the people themselves.

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CONCLUSION
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In concluding this exploratory study we will emphasize four major propositions that do not appear to be contradicted by our empirical observation. Since the conclusions to each one of the Parts of this Research Report summarize and comment the findings of the case studies with some detail, we will not reiterate here what has already been stated. Instead, we will focus on the elements that have analytical relevance for the understanding and elaboration of technological policies.

First, States are decisive actors in shaping technological development through their policies. While this has always been the case, it is particularly so in the historical period of a major technological revolution whose mastery largely conditions the assertion of political power and the access to economic well-being. In spite of the fact that this is an elementary statement, it has far reaching consequences, often neglected in the analysis of processes of technological development. The main implication is that, because States are institutional outcomes of political processes, technology will be shaped and determined, by and large, by social conflicts and political strategies, referred to the specific orientations of nations, classes, social groups, political forces, and Governments, rather than by business strategies or scientific rationality. Thus, the political economy of high technology commands the analytical field of technology assessment and technological policy.

Second, a direct consequence of the political determination of technological policies is the crucial role played by military programs in the fostering of technological policy and in the guidance of technological development. Regardless of the moral position or political opinion of the researchers concerning the use of scientific discovery at the service of military goals, we must recognize the importance of such goals, at the very core of the dynamics of States, in structuring technological innovation. Furthermore, in some instances, the superior interests of national security, as understood and assumed by a given State in a given moment, shield the pace of technological development from short term strategies or from the narrow concerns of specific interest groups. Thus, without the affirmation of the national security interests in the field of military technology China could have lost all its technological basis during the disruptive period of the Cultural Revolution. It is also doubtful that Brazil could have engaged in the pace of limited endogenous development in informatics without the support given by the military (and particularly by the Navy) to the group of nationalist technocrats that argued for such policy. And even in the United States, the critique of the militarization of high technology often forgets that, in the American context (unlike in Japan), the exclusive emphasis on commercial applications often imposes limits to the long term financing and planning that is required for major technological advancement. In other words, it is unlikely that the logic of the market by itself could yield the results achieved by State-led technological programs. We must differentiate between commercial applications and civilian uses of technology. While the conversion to civilian uses seems to be both technologically fruitful, socially sound, and morally responsible, the predominance of market strategies in the model of technological development underestimates the need for coherent, long term planning and resource mobilization in achieving significant results in basic technologies. If we add the fact that major States (unless some very special circumstances concur, as in the case of Japan until the 1980s) will always give priority to military technology, it would seem that much of the debate between commercial versus military applications is simply irrelevant. Military technology will continue to be a major part of any country's technological policy, and it will receive paramount attention from the State, the key actor in the overall process of technological development. Thus, the real issue is the articulation between State-led programs of technological development (including the military component) and the economic effects and social uses of the new technologies. From this perspective, we can object to the excessively narrow military specifications of technological programs, to the often unnecessary secrecy of the results that slows down diffusion, and to the lack of consideration of national economic development as a national security objective. What our study suggests is that the problem is less the conversion from military technology to commercial technology (a distinction often artificial), than the articulation between the mobilization of technological resources around national objectives, and the diffusion of the results of such major programs throughout the industrial structure and the organizational system.

Third, the world has become not only economically interdependent but technologically interdependent as well. And this interdependence is asymmetrical. Thus, even countries with strong nationalist policies, aiming at self-reliance, as in the case of Brazil and China, have to articulate their efforts of endogenous development with processes of technology transfer from the technology holders, particularly the major multinational corporations. Our study shows that even policies as controversial as the Brazilian Informatics Law do not preclude intimate connection with the multinational corporations. Indeed the overall informatics policy could not have proceeded without the cooperation of some of these corporations. Similarly, China is relying on selective agreements with major corporations as one of the key elements of its new policy of transferring know-how rather than importing equipment. Thus, nationalist policies of technological development are articulated in fact to the strategies of negotiation and cooperation in the technological and economic international arena. Yet, the ability of a given State to obtain better conditions in such international bargaining process largely depends on the success of its policies in fostering some level of self-reliance in some technological fields. On the other hand, multinational companies recognize the fact that an active State, able to develop an endogenous industrial and technological infrastructure, is a better partner for dynamic development than a subservient but much less efficient Government. Thus, nationalist technological policies and processes of technology transfer through multinational corporations are not contradictory but complementary, and the conflicts arising from their implementation are in fact the expression of an endless bargaining process, not unlike the alliances and competitions between the multinational firms themselves.

Fourth, Mission-oriented technological policies, in the terms of the typology proposed in our introduction, seem to provide the framework for other types of policies to operate. This emphasizes the role of governments in shaping technological policy. An alternative logic, not necessarily contradictory with the content of the policies inspired by a national goal, is provided by the strategies of large corporations, pursuing their specific business interests. The world of high technology is increasingly dominated by the dynamics between the States and the multinational systems producers. In between, innovative entrepreneurs are becoming absorbed into the networks of large corporations or into the national programs established by the State. Market dynamics is still the driving force of the economy, but the technological medium is fundamentally shaped by the interests of governments and of large corporations. Any alternative path of technological development, would require a strategic alliance between the industrial innovators and the forces of civil society not represented into the dominant logic of the State. For instance, the reconversion of technological policies toward goals of social development or toward commercial applications organized around different sets of values would require the mobilization of social movements and political interests putting pressure on State policies to reorientate technological development. Thus, in the absence of a new historical alliance between the actors of the process of social change and the actors of technological innovation, technological policies, and thus technological trajectories, will be fundamentally determined by the conflictual and complementary relationship between national Statism and multinational capitalism, establishing their networks and playing their strategies in the world arena.

In the last analysis, the power of technology will be dependent upon the technology of power.

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