International Competition in Advanced Technology: Decisions for America

A Consensus Statement Prepared by the Panel on Advanced Technology Competition and the Industrialized Allies, National Research Council

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Panel on Advanced Technology Competition and the Industrialized Allies

HOWARD W. JOHNSON, Chairman of the Corporation, Massachusetts Institute of Technology, Chairman

HARVEY BROOKS, Benjamin Peirce Professor of Technology and Public Policy, Harvard University

ROBERT A. CHARPIE, President, Cabot Corporation

RICHARD N. COOPER, Maurits C. Boas Professor of International Economics, Harvard University

ROBERT A. FULLER, Corporate Vice President, Johnson & Johnson

RALPH E. GOMORY, Vice President and Director of Research, IBM Corporation

NORMAN HACKERMAN, President, Rice University

N. BRUCE HANNAY, Vice President, Research, Bell Laboratories (retired)

THEODORE M. HESBURGH, President, University of Notre Dame

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WILLIAM N. HUBBARD, JR., President, The Upjohn Company

SHIRLEY M. HUFSTEDLER, Partner, Hufstedler Miller Carlson & Beardsley

ROBERT S. INGERSOLL, Former U.S. Ambassador to Japan

CARL KAYSEN, David W. Skinner Professor of Political Economy and Director, Program in Science, Technology & Society, Massachusetts Institute of Technology

ALLEN E. PUCKETT, Chairman and Chief Executive Officer, Hughes Aircraft Company

DAVID V. RAGONE, President, Case Western Reserve University

JOHN S. REED, Vice Chairman, Citibank

WALTER A. ROSENBLITH, Institute Professor, Massachusetts Institute of Technology

ROBERT M. SOLOW, Institute Professor, Department of Economics, Massachusetts Institute of Technology

JOHN E. STEINER, Vice President, Corporate Product Development, The Boeing Company
WILLIAM J. WEISZ, Vice Chairman of the Board, Motorola, Inc.
LEONARD WOODCOCK, Former U.S. Ambassador to China

Staff

ANNE G. KEATLEY, Project Director
NORMAN METZGER, Editor
NANCY L. GARDNER, Staff Associate
PAUL KRUGMAN, Consultant

Preface

A central new policy concern—international trade and competitiveness in advanced technology—is asserting itself in the United States and in each of its closest allies and trading partners. This concern is likely to remain in the forefront of American debates for many years because of its ongoing importance in questions of national security and national economic prosperity. In the United States, this concern is accentuated by forces that are affecting the competitiveness of American advanced technology, both within our own vast economy and in world trade. Some shortcomings of our own and concerted actions on the part of other nations are both involved. Leaders in all of the world's most technologically advanced democratic nations are beginning to focus urgent attention on their nations' abilities to marshal their innovative capacities. All appreciate the need for prompt responses to the problems besetting the extensions of advanced technology. They also know that those responses must reflect the increasingly close interrelationships among nations that are, simultaneously, allies, partners, and competitors. Hence, any responses must take into account extremely complex interrelated factors—social and economic and political as well as technical. Given the urgency and complexity of the issues, it was essential for the organization representing the American scientific and technical community, with the special charge of aiding national policy deliberations, to organize intensive studies of the situation in international technological competition as a contribution to the wider multinational debate that has been building up for several years.

Accordingly, advanced technology competition among the industrialized allies was one of a number of national

issues on which the National Academy of Sciences and National Academy of Engineering initiated policy studies during the past 2 years.

The Academies assembled in late 1981 a study panel of experts on technology, industry, labor, education, economics, and foreign affairs to consider the set of problems associated with advanced technology. The panel was composed of 22 members including former senior federal officials, senior members of the academic community, and leaders of advanced technology industries and of the scientific and legal communities.

The Academies asked the panel to describe, in broad terms, the nature of technology in the context of international competition and to recommend fundamental guidelines for national actions that would aid policymakers today and in the years to come. The panel's work was to focus on relations among the major industrialized nations—Canada, the Federal Republic of Germany, France, Japan, the United Kingdom, and the United States. Questions of trade and technology relations with the developing nations, the Soviet Union, and Eastern bloc nations were excluded. Issues and problems of mature industries were to be considered only as they were affected by new technologies.

The panel was asked to consider how frontier technological development comes about and how it affects nations economically and socially; how governments view new technologies and attempt to draw on technological development to serve national needs; and how technological development—and government's responses to it—may affect relations among nations. Finally, the panel was asked to propose a course of action for America's policymakers.

In work that involved monthly working sessions extending over a period of 14 months, the panel heard many public and private sector expert witnesses and reviewed policy papers and analyses developed in the United States and abroad. In addition, the panel commissioned special studies by experts in a wide range of fields and discussed with the authors their findings and conclusions. The process of deliberation took place during a period in which issues of international technological competition increasingly became front-page news.

In setting forth conclusions and recommendations, panel members have attempted to contribute in a timely way to current discussions while at the same time convey

ing judgments that will be a useful basis for policymaking in years to come.

The panel believes the descriptions of the nature of technological development, of the manner in which advanced technology industries carry out their work, and of how government actions may affect innovation globally will be of special relevance. The panel's report should be viewed as a white paper—a consensus statement by a group of experienced individuals who approached the problem from diverse points of view.

Their concern reflects the importance to the nation, not only of this issue, but also of the urgent need for wise and farsighted policy actions as we compete internationally for advanced technology markets.

The panel wishes to express its gratitude to each of those who prepared special studies for its inquiry and who appeared before it to inform the members on issues that were always complicated and often subtle. We wish to express special thanks to Frank Press, President of the National Academy of Sciences; Courtland D. Perkins, President of the National Academy of Engineering; and Philip M. Smith, Executive Officer of the National Academy of Sciences, for their help and support. I wish especially to extend my thanks to Anne Keatley, Project Director; Nancy Gardner, Staff Associate; and Norman Metzger of the Office of Information for their competent support. I thank Paul R. Krugman of the Massachusetts Institute of Technology, now on the staff of the President's Council of Economic Advisors, for his help during the panel's early deliberations, and Victor K. McElheny of MIT for his counsel.

I wish particularly to thank each member of the panel, not only for dedicated service, but also for exceptional efforts in marshaling objectivity and a sense of national interest on subjects where views frequently diverge. Because of their work, the public purpose in this complex and difficult subject may be advanced.

HOWARD W. JOHNSON

CHAIRMAN

PANEL ON ADVANCED TECHNOLOGY COMPETITION AND THE INDUSTRIALIZED ALLIES

Contents

Executive Summary 1
Historical Evolution 2
Technology and the Nation's Economic Well-Being and Military Security 3
National Capacity for Innovation 3
Maintaining Technological Strength 4
Government's Role 4
Management's Responsibilities 6
Advanced Technology Trade Practices 7
U.S. Objectives 8
Negotiations Required 8
Conclusions 10
Recommendations 11

Introduction 14

1 Advanced Technology: Its Nature and Importance to the United States 20
What is Advanced Technology? 20
The Innovation Process 21
Why is Advanced Technology Important to the United States? 22
Advanced Technology and National Security 22
Advanced Technology and Trade 23
Advanced Technologies—Core Technologies in the Economy 24
Need for National Attention 25
Advanced Technology and the Nation's Future 26

2 National Policies Affecting Advanced Technology Capacity and Competition 28
Basic Research 28
Applied Research and Development 29
Production 31

Distribution 31
The Emerging Market 32
Nontariff Barriers and Procurement Policies 32
National Practices—Positive and Negative Consequences 33
U.S. International Negotiating Strategies 37

3 Policies and Practices Affecting U.S. Competitiveness in Advanced Technology 39
Government Policies 40
Macroeconomic Environment 40
Antitrust Policy 41
Capital Supply 42
Export Policies 43
Tax Policy 43
Regulatory Policy 44
Private Sector Policies 44
Management 44
University-Industry Relations 45
Government and Private Policies 46
Human Resources 46
Precollege Education 47
University Education and Research 47
Engineering Education 48
Monitoring International Technology 48
Support of Basic Research and Development 49
What Policies Are Appropriate? 49

4 Conclusions and Recommendations 52

Selected Bibliography 57

Biographies of the Panel Members 61

Commissioned Papers of the Panel 67

Presenters 69

Executive Summary

The health of U.S. advanced technology industries and their international competitive vigor are central issues in current economic and trade policy debates. The United States, like its major industrialized allies, views the ability to generate and use advanced technologies as essential, both to national economic well-being and to military strength. Many governments—most notably Japan and France—have designed comprehensive national policies to help promote successful technology and trade development in major sectors—telecommunications, biotechnology, computers, microelectronics, and aerospace, for example. The United States has no such defined industrial policy.

U.S. policymakers today must respond not only to a growing anxiety that U.S. leadership in advanced technology and trade is in jeopardy, but also to fears of mounting protectionism. Spurred by global economic ills, domestic unemployment, and loss of traditional markets to newly industrialized countries, governments are attracted to economic nationalism and protectionism—policies that can seriously endanger the international trading system, political alliances, and global technological progress. It is these concerns and the issues surrounding them that are addressed in this consensus statement by the Panel on Advanced Technology Competition and the Industrialized Allies.

The panel discusses the nature of advanced technology and its extensive contributions to U.S. economic welfare and military security; the importance of maintaining a strong national capacity for technological innovation, including a vigorous international trade position; and the domestic and international measures required to sustain this effort.

The panel describes U.S. government and private sector advanced technology policies and practices, as well as those of its major trading partners. Finally, the panel discusses how various national practices may be evaluated and negotiated among nations in support of a healthy mutual international trading system—and what steps the United States must take to protect its interests should international negotiations fail.

While the panel recognizes that contending policy objectives may at times take precedence over the requirements for national strength in technological innovation and trade competitiveness, it concludes that the U.S. advanced technology enterprise has been undervalued in the past in the national scheme of priorities and must be held as one of the country's most valued objectives.

HISTORICAL EVOLUTION

The United States' economic and social well-being over the last 100 years has derived substantially from the processes of discovery, invention, and entrepreneurship, which Americans have come to value so highly. The nation's capacity for technological innovation became especially apparent in the 20 years following the Second World War, when the United States was acknowledged worldwide as possessing across-the-board technological superiority. Throughout the postwar decades, however, the major industrialized allies combined their recovery from wartime destruction with a rapid rate of technological progress. The result was a progressive narrowing of American technological leadership. While the United States continued to maintain a higher overall productivity level, Europe and Japan enjoyed far higher rates of productivity growth. Today, the allies vie for positions at economic and technological frontiers that at one time seemed reserved for the United States. In many sectors, other industrialized nations are now the first to expand these frontiers.

The United States could not have expected to preserve its vast technological leadership. What it must preserve, however, is a strong capacity for technological innovation that is vital to the future growth of the entire American economy. Domestic weaknesses and damaging practices of other nations can endanger this innovative capacity, the basis for advanced technology development and international trade competitiveness. The United States must

now adopt measures designed to preserve this vital capacity.

TECHNOLOGY AND THE NATION'S ECONOMIC WELL-BEING AND MILITARY SECURITY

The national capacity to generate and use advanced technology is fundamental to the economic well-being and military security of the United States. Advanced technologies serve to increase productivity in services, manufacturing, and agriculture. The United States has the potential for a new economic surge fueled by advanced technology—a dramatic increase in the productivity of workers utilizing new information-processing technologies, new materials, and new manufacturing technologies. In addition, the U.S. positive trade balance in technology-intensive products and services contributes to domestic employment and economic health.

The nation's innovative capacity is vital to military as well as economic security. A major fraction of defense hardware is procured from technology-intensive companies. Advanced weapons employ frontier electronics gear, and verification methods fundamental to arms control agreements rely on advanced technologies. The interrelationships between the U.S. commercial and military advanced technology systems are complex, but it is clear that military systems rely on a strong civilian industrial base and that many commercial efforts benefit from defense and space research and development expenditures and procurement.

NATIONAL CAPACITY FOR INNOVATION

Our capacity for technological innovation is commonly perceived in terms of industrial sectors—microelectronics, computers, new materials, robots, telecommunications, aerospace, and, most recently, biotechnology. This list is, in fact, a transitory one—changing over time. A new list may supersede this one in a decade or two. The nation's innovative capacity should not be thought of only in terms of specific products; it should be understood as the continuous capability, widely diffused throughout the economy, to produce and put to use pioneering technological resources.

This national innovative capacity is manifested primarily in a system of interrelated activities leading to commercial sales of products, most frequently referred to as the innovation process. This dynamic system not only involves basic research and product development, but also encompasses manufacture, marketing, and distribution. Each part of the process must function effectively to ensure success.

MAINTAINING TECHNOLOGICAL STRENGTH

The United States' capacity for technological innovation and competitiveness in world markets is an essential national resource, requiring a sophisticated and thorough understanding of the innovation process—what it is, how it works, what influences it, and what is necessary for its strength. Maintaining a world-class research structure is essential in the effort to expand technological frontiers. Research is a vital first requisite, but it is only one part of a complex, interwoven process. Product planning requires knowledge of new technologies in the research phases; development of commercially successful products requires links with marketing assessments; and successful commercialization pays for the next round of technological advance.

The innovation process, then, is an interlocking system that must be strong throughout. Its requirements include technologically sophisticated managers, quality research personnel, and a technically competent labor force. The process of innovation also requires a healthy supply of capital—both venture capital for starting up new enterprises and growth capital for established firms. Large-scale economies utilizing world markets are necessary to support succeeding rounds of technological advance.

A more elusive but major influence on the innovation process may be the government's role in establishing a climate that fosters entrepreneurial risk-taking. Stable, informed government policies can lessen uncertainty for innovative entrepreneurs.

GOVERNMENT'S ROLE

In the U.S. economy, institutional arrangements to foster advanced technology operate primarily in the private

sector—in small innovative firms, national and multinational companies, banking and financial communities, and the research universities. The United States has had no national plan nor even a loose coordinating mechanism linking the efforts of these private actors to federal government actions.

The government's primary role in fostering the nation's innovative capacity has been in education and support of basic research. There is, however, a range of government instruments to address broad national objectives that affect various stages of the innovation process, including market development. These instruments—which are compatible with our culture and style (as total government-industry coordination in the manner often attributed to Japan is not)—include tax policies fostering research, development and investment in production facilities, patent laws, regulation and deregulation, antitrust measures, export/import bank loans, and government procurement, among others. Beyond these measures, uncoordinated actions taken by various governmental agencies, designed to serve other purposes, affect the innovation process—unintentionally helping it in some instances, but hindering it in others. The nation's capacity to perform well in advanced technology and trade is, in fact, affected by decisions that are made independently, inter alia, by the Food and Drug Administration, the Environmental Protection Agency, the antitrust division of the Department of Justice, the Departments of Commerce, State, Agriculture, and Defense, the National Security Assistant, the Special Trade Representative, the President's Science Advisor, the National Aeronautics and Space Administration, the National Science Foundation, and the National Institutes of Health. Yet the heads of these executive branch entities rarely if ever have joined together to consider the totality of their separate actions on the nation's advanced technology capabilities and international competitiveness—either what it is or what it should be.

If the United States is to maintain its innovative vitality over time, it is essential that executive and congressional policymakers periodically evaluate both the U.S. comparative international trade position and the health of the nation's innovative capacity. They should do so by means of a broad analysis, conducted at cabinet-level, of all the variables impinging on our capacity to innovate—both domestic and foreign. These periodic assessments would require support by a continuing source

of expertise drawn both from within the government and from outside.

Reviews should be comprehensive. They should assess:

- the impact of U.S. government policies on the nation's innovative capacity and international trade competitiveness;
- the nation's standing with regard to research and development, manufacturing, and marketing;
- the effectiveness (in comparison with other countries) of U.S. elementary and secondary educational systems, postsecondary institutions, and continuing education programs, especially in maintaining and renewing our technological and scientific manpower and knowledge;
- the trends in our comparative international trade standing; and
- the policies of major trading partners and their effects on the United States and the international trading system.

The process of periodic evaluation could result in recommendations, at the national level, to coordinate actions across agencies, to rationalize government policies, or to ensure consistency over time in government practices, as well as recommendations at the transnational level to initiate coordinated negotiations or actions with industrialized trading partners and allies. In addition, the assessment process should stimulate congressional hearings to seek the views of leaders from industry, labor, and other sectors. An opportunity for comprehensive and coherent review of U.S. innovative capacity and international trade competitiveness by representatives of all sectors contributing to it should help to elevate technological innovation goals in the scheme of national priorities.

MANAGEMENT'S RESPONSIBILITIES

A coordinated decisionmaking process is essential, but the nation's performance in advanced technology development and trade will be determined in large part by the efforts of individual firms. Successful firms are those whose managers have long-range vision of how technology affects the growth of their business. They understand the state of technology in their industry worldwide; they

respond to the international climate when planning for research, development, manufacturing, and marketing; and they are open to developing new institutional arrangements to foster technological growth—such as industry-university research relationships, cooperative research ventures among groups of firms, or consortia to seek information and ideas systematically from abroad.

ADVANCED TECHNOLOGY TRADE PRACTICES

U.S. firms face a mixed international trading system in which they are operating independently as private entities, yet are frequently competing with foreign firms, singly or in consortia, that either are government entities or have strong government backing. This mixed international trading environment often effectively places an American company in competition against a country. By "targeting" certain advanced technology sectors, a country may provide its firms with a range of support—from direct and indirect subsidies for research and manufacturing through help in penetrating foreign markets. Such practices are not within the U.S. arsenal of policies. Traditionally, U.S. philosophy has stressed private sector initiatives within a competitive framework.

U.S. firms are understandably concerned about the tactics other countries use to develop markets—both at home and abroad. American firms have difficulty penetrating European and Japanese markets when they are faced with intentional collective actions excluding them. At the same time, too, U.S. businesses must compete with European and Japanese firms for new and potentially lucrative emerging nation markets. Often foreign firms have strong support from their home governments, an advantage U.S. firms do not enjoy to a comparable extent. To lose out in this competition could be extremely damaging, not only for American advanced technology industries, but eventually, because of intersectoral linkages, for other areas of the economy as well.

There is considerable dispute among the industrialized allies regarding which trade practices are acceptable and which are not. Actions that are consistent with one nation's traditions and attitudes may be inimical to another. Friction is exacerbated worldwide by current conditions of slow growth, excess capacity, obsolete plants, and lingering inflation. These conditions make politically more difficult and financially more costly

structural adjustments that would shift financial, manpower, and other resources from less to more competitive industries. Many nations are suffering from record unemployment levels that cause significant domestic political problems.

U.S. OBJECTIVES

U.S. objectives in advanced technology trade must take into account both the needs of our own industries and those of our principal allies. Innovation proceeds most rapidly and efficiently when new products have access to the widest possible markets, thus spreading the costs and risks of innovation over more units and generating the cash flow for follow-on improvements and fresh innovation.

The United States should negotiate in international forums to secure the openness of world markets to innovative entrepreneurs wherever they may be based and to discourage large-scale distortions of free markets. Such a policy is required, both to preserve the U.S. position as a major source of innovation and to ease growing tensions among the industrialized allies, tensions that threaten not only international economic and political management, but also mutually beneficial cooperation in science and technology.

Nowhere is our national welfare more interwoven with that of our allies than in the fields of science cooperation and high-technology trade. The costs and risks of protectionist policies and market fragmentation are probably greater than in almost any other economic field except energy. Paradoxically, the international coordination of trade practices is more backward in advanced technology than in many other fields at a time when both nations and regions within nations are looking more and more to advanced technology as a primary source of economic salvation.

NEGOTIATIONS REQUIRED

Protectionist pressures are strong in today's very difficult economic times. Furthermore, international negotiations on trading practices are complicated by differing viewpoints among allies on what national practices are acceptable. Attempts to sort practices into acceptable and unacceptable categories have been

only moderately successful, but such attempts should continue. Progress may be slow and agreements difficult, but the health of the international trading system is at stake. Negotiations should consider the consequences of actions and place value on maintaining open markets, for they reward innovators by offering innovative products globally.

To foster healthy, mutual competition in advanced technology is a primary objective. Negotiations, though protracted, will serve the interests of the United States and her allies better than precipitous actions. Proposals for legislative action to protect advanced technology industries, currently before the Congress, require careful analysis and consideration in light of the findings of this report.

Cooperation among industry, government, labor, universities, financial, and other sectors is essential in dealing with these exceedingly complex problems in technology and trade. Most difficult will be those circumstances in which U.S. capacities are well nurtured and strong, yet key industries essential to the national welfare are nonetheless endangered. Vulnerability could develop because of successful aggressive policies of our allies, which individually may or may not be considered as unfair, but which together endanger U.S. major technology industries and fundamental advanced technology capacity deemed essential to economic well-being and military security. Where such broad national resources are in jeopardy, the United States must take action.

A first step is to seek to renegotiate multilaterally agreed rules in forums such as the GATT in order to establish clearer guidelines for government actions in high-technology sectors. A basic requirement of such negotiations would be that countries, including the United States, be prepared to consider altering traditional practices.

When there is a specific threat to U.S. interests from a particular country's government policies, the U.S. government should initiate bilateral consultations within the framework of GATT and other appropriate multilateral institutions. The goal of such negotiations would be to reach agreements on a time scale that would prevent or reverse damage to U.S. capacity for technological innovation. If these bilateral consultations are unsuccessful in resolving issues, the U.S. government should utilize formal multilateral dispute settlement procedures to seek a resolution. If those procedures in turn fail or if the

threat of damage is imminent, the United States would be required to take unilateral action to protect the national interest as a step of last resort.

CONCLUSIONS

- The United States must act now to preserve its basic capacity to develop and use economically advanced technology. This innovative capacity is essential for the self-renewal and well-being of the economy and the nation's military security. Trade in advanced technology products and services will contribute enormously to our economic health. Advanced technology products and processes not only permeate the economy, increasing productivity, but also form the basis of modern defense hardware.
- The nation's capacity for technological innovation is vulnerable both from domestic weaknesses and from damaging practices of other nations. Measures designed to maintain this vital aspect of the American economy within a healthy international trading system will include both domestic actions and international negotiations.
- Effective actions require a sound understanding of the nature of innovative capacity and of the innovation process through which it is primarily manifest. Innovative capacity is the capability, widely diffused throughout the economy, to produce continuously forefront technological resources, and to use those resources for the national benefit. The innovation process includes not only basic research and development but also production, marketing, and distribution in domestic and foreign markets. Each part of the process must be sound for success.
- Some of the elements that support our nation's innovative capabilities include a strong national research base, technically educated manpower and a technically literate population, capable and farsighted industrial managers, a financial base that provides capital to both new and established firms, and sizable markets. Essential, too, are a national understanding of and attention to advanced technology as a vital contributor to the national welfare.
- The U.S. government has in effect a range of

policies and practices including tax policies, patent laws, regulation and deregulation, antitrust measures, export/import bank loans, government procurement, and others that, although designed to serve other national objectives, also affect the U.S. technological enterprise and international trade position. These policies and practices and the other domestic and international elements affecting U.S. technology and trade must be well understood by senior policymakers. If viewed in ensemble, existing government instruments may become powerful means to support U.S. technology and trade interests.

- Responsibility for improving U.S. performance in advanced technology and trade rests to a large degree with the individual firm and its management. Successful managers increasingly will have to be cognizant of frontier technologies as they build businesses and compete in an international world.
- Our major industrialized allies—most notably Japan and France—have designed comprehensive national policies to help ensure successful technology and trade development in major sectors. Thus, individual U.S. firms often find themselves competing internationally, not with firms acting alone, but with countries or with consortia of firms with country backing.
- There is considerable dispute among industrialized allies regarding which practices are acceptable and which are not. Efforts to evaluate practices are protracted and difficult, but essential.

RECOMMENDATIONS

Accordingly, the panel recommends the following:

- Advanced technology development and trade must be considered as among the highest priorities of the nation. These vital interests must be well understood domestically and conveyed to our trading partners. The United States must initiate a two-part strategy: to maintain the nation's capacity for technological innovation and to foster an open healthy international trading system.
- The federal government should initiate a biennial, cabinet-level review that comprehensively assesses U.S. trade competitiveness and the health of the nation's innovative capacity in both relative and absolute terms. This review should consider the nation's overall perfor

mance: the private sector activities and the totality of government actions on technology and trade, as well as the effects of other governments' practices. These assessments would consider the strength of key technological sectors across all stages of the innovation process —research, development, manufacture, and distribution. In addition, assessments would evaluate broad elements as they affect innovation, such as the macroeconomic environment, regulatory policy, patent policy, and antitrust policy. Careful attention would be given to maintaining the health and effectiveness of both university- and industry-based research, education, and training. The cabinet-level review should be supported by a continuing mechanism that would draw on expertise both from within the government and from outside.

- Managers of private firms must be cognizant of technological trends as they make renewed efforts to build businesses and compete in an international context. Managers should consider new institutional arrangements—the growing, mutually supportive, industry-university research relationships, cooperative research ventures among groups of firms, or consortia to seek information and ideas systematically from abroad.
- Internationally, the United States should negotiate in existing forums to encourage a healthy mutual trading system. This should include continued efforts to evaluate national trade practices and to agree on criteria for acceptability. An objective must be to encourage open markets and healthy competition.
- Countries, including the United States, throughout negotiations should be prepared to alter fundamental policies so that each country may maintain advanced technology capacities fundamental to its individual welfare.
- The United States should review the content and application of its trade laws to ensure that U.S. industries can obtain timely and meaningful trade and/or other relief in the U.S. market when imports from particular countries, based on unreasonable or excessive foreign industrial policies, threaten them.
- If key technology industries essential to national economic welfare and military security are considered endangered by the actions of another country, even with all necessary domestic efforts to strengthen these sectors, then the United States should negotiate with the other country requesting immediate relief. Negotiations should take place first in existing forums, explaining

our country's vital interest in preserving advanced technology capacity. If such mechanisms prove ineffective or too slow to prevent damage to essential U.S. capabilities, then the United States should negotiate directly with the country in question. If those bilateral negotiations fail or if the threat of damage is imminent, the United States should take immediate unilateral actions as a step of last resort.

Introduction

This consensus statement has two themes:

- The requirement that the United States maintain strong domestic capacity for technological innovation—to benefit its domestic economy, its national security, and its competition for global markets in technological products and services.
- The need to reduce trade frictions that trouble economic and political relations among the major industrialized allies—principally, Canada, the Federal Republic of Germany, France, Japan, the United Kingdom, and the United States.

The leading industrial nations believe that their future economic growth depends on their abilities to create advanced technologies and to sell the resultant products and processes in a global market. Consequently, international trade in advanced technology is a high priority.

International competition has led to concern within the United States about our capacity to create advanced technologies and to develop them into commercially successful products in international and U.S. markets. Competition also has led to frictions among countries because of their differing national practices in supporting development and international trade.

Frictions among the industrialized allies may be inevitable now that many nations can adopt or innovate frontier technologies and can manufacture and market advanced technology products. Realistically, the United States cannot expect to maintain the overwhelming market share in advanced technologies that it had during much of the postwar period. The United States, however, must

preserve a strong capacity for technological innovation that is vital to the entire American economy and to its growth. The United States must adopt measures designed to preserve this vital aspect of the American economy within a healthy international trading system.

Trade frictions among the allies have developed in part because of the measures that different countries use to promote their advanced technologies. There are charges that some countries use "nontariff" barriers and other market distorting practices to exclude the products of other countries from their home markets, charges of "dumping" (selling below cost) advanced technology products in order to gain rapidly a substantial share of a foreign market, charges that foreign companies are capable of underbidding American manufacturers through major subsidization by their governments, and charges that governments use so-called side inducements to capture sales in third-country markets. These perceptions, whatever their validity, weaken the bonds among the industrialized allies and may threaten the economic and military strength of all countries of the alliance.

Government and industry are partners in many countries, each with a role in developing globally competitive advanced technologies. In the United States, the private sector traditionally has carried the responsibility for trade development. One result is that many American companies perceive an international system in which they are competing not against individual foreign companies acting alone, but rather against foreign companies and company groups operating in concert with their governments.

While differences in governmental and industrial relations among various countries are to be expected, there is a marked difference between the American style and that of other countries. That difference leads to the prevalent American perception that the forms of guidance and direct support that other governments offer specific industries is "unfair," in the sense of distorting the free market and making it difficult for American companies to compete on equal terms. Ill feelings are exacerbated by the depressed economic environment. The U.S. economic picture currently includes unemployment that exceeds 10 percent, a recorded rate of utilization of our industrial capacity of only 70 percent, depressed corporate profits, and widespread business bankruptcies. Comparable conditions prevail in other industrialized countries. Industrial production in France, Germany, and

the United Kingdom declined in 1982. The unemployment rates in Canada and the United Kingdom are over 12 percent and are projected to exceed 13 percent in 1983. In Japan, export market demand declined substantially in 1982, and only a modest growth in export volumes is predicted for 1983.[1] As a result of these unfavorable economic conditions, orders for new production are depressed, and competition—including competition from imports—is exceptionally stiff. The U.S. trade position has been made more vulnerable by the very strong dollar relative to other currencies, as well as by the 1982 high U.S. interest rates.

In our approach to advanced technology competition in international trade, we have tried to see beyond this current economic trauma. Certainly much of the distress that American firms now feel arises from these general economic conditions. But we believe that some of the problems the country faces in advanced technology go deeper than these adverse economic conditions and need to be addressed directly.

As stated above, each country creates different policies and stratagems to enhance the global competitiveness of its advanced technology industries. Advanced technology sectors are important to the United States and other industrialized countries because their future economic growth depends in large part on the dissemination of advanced technology throughout their economies. In addition, advanced technology industries contribute significantly to productivity growth and product innovation. In the United States, ten industries[2] that in 1980 accounted for only 5 percent of U.S. employment and 13 percent of the value of manufacturing product shipments were responsible for more than 60 percent of total private industrial R&D spending. These industries employed more than 25 percent of the nation's scientists and engineers. In addition, these ten industries had a $31 billion favorable balance of trade. During the 1970s, labor productivity in these industries grew more than six times as fast as in the business sector as a whole. Growth in advanced technology industries benefits the entire economy because it results in rapid employment growth in other industries.[3]

Measures of shares of world exports for products and services embodying advanced technology indicate a deterioration in the U.S. competitive position. Between 1962 and 1980, the U.S. share of the industrialized countries' exports of advanced technology products declined from 30

to 24 percent. During the same period, Japan tripled its industrial country export market share, while West Germany's and France's shares increased slightly."[4] Underlying these trends in the aggregate are significant changes in individual technologies. In electronics, particularly semiconductors, Japan has made dramatic inroads into the U.S. market;[5] in aircraft, the European consortium, Airbus Industries, has captured a substantial share of the commercial jetliner market in which U.S. firms held a 97 percent share in 1976.[6]

These changes stem from many elements that have affected international trade at different periods—for example, the postwar renaissance of European science, technology, and industry; long-term structural changes; and the well-planned effort by the Japanese to raise the technological intensity of their economy. Other factors contributing to a diminishing of U.S. global market shares include the extraordinarily high value of the dollar relative to other countries in 1980 and other years. There is some evidence, for example, that the pattern of trade tensions between Japan and the United States has tracked exchange rate developments.[7] In 1970–71, 1976–77, and again in 1981, a strong dollar against the yen produced large favorable trade surpluses for Japan. In the first two instances, subsequent appreciation of the yen against the dollar reduced the imbalance after a couple of years. In recent months, there has been some strengthening of the yen, but it is too soon to know if it has gone far enough, or how much of the current Japanese surplus will be eliminated, or how any improvement will be distributed across industries.

This setting of intensifying competition, rising frictions among allies, and, for the moment, a bleak economic outlook frames this consensus statement by the Panel on Advanced Technology Competition and the Industrialized Allies.

The panel discusses the extensive contributions of advanced technology to U.S. economic welfare and military security; the importance of maintaining a strong national capacity for technological innovation, including a vigorous international trade position; and the domestic and international measures required for this effort. It describes the many variables affecting the nation's advanced technology enterprise, including U.S. government and private sector policies and practices, as well as the actions of major trading partners. Finally, the panel discusses how various national practices may be evaluated

and negotiated among nations in support of a healthy mutual international trading system and what steps the United States must take to protect its interests should international negotiations fail.

The panel recognizes that the United States has many domestic and foreign policy objectives in addition to the requirements for national strength in technological innovation and trade competitiveness and that these, at times, may take precedence with regard to allocation of resources and policymaking. It concludes, however, that the U.S. advanced technology enterprise has been undervalued in the past in the national scheme of priorities and must be held as one of the country's most valued objectives.

NOTES

1. Organisation for Economic Co-operation and Development, OECD Economic Outlook, No. 32 (Paris: OECD, 1982), pp. 12, 15, 35.

2. Electrical equipment and components; aircraft and parts; computers and office equipment; optical and medical instruments; drugs and medicines; industrial chemicals; agricultural chemicals; professional and scientific instruments; engines and turbines; and plastic and synthetic materials. "An Assessment of U.S. Competitiveness in High-Technology Industries," a study prepared for the Cabinet Council on Commerce and Trade, revised draft, October 1982, p. 4. Statistical evidence on U.S. competitiveness in advanced technology relies on the isolation of technology-intensive industries, defined as industries that have either high R&D-to-sales ratios or industries with a high proportion of scientists and engineers in their work force. Such evidence is useful, but it must be used with caution for several reasons:

- The match between technologies and industries is not perfect. Large parts of an apparently advanced technology industry may involve routine production of traditional products; on the other hand, seemingly "low-technology" industries have components that are at the forefront of technical advance.
- The classification of technologies as advanced ought to be, in principle, a dynamic one since it largely depends on how new the technology is. Today's advanced technology becomes tomorrow's traditional method; on the other hand, an industry that is low-tech now may become a technological leader in the future. Statistical compari

son based on a fixed list of technology-intensive industries are, therefore, potentially misleading.

- All available statistical evidence focuses exclusively on manufacturing. Yet, service exports should in many cases be regarded as technology-intensive. This applies both to financial services and to the overseas earnings of multinational firms, much of which can be viewed as a return to technology.

3. Ibid., pp. 4-5, 29.

4. Ibid., p. 10.

5. For a discussion of the nature of Japan's competitive challenge in semiconductors, see Semiconductor Industry Association, The International Microelectronics Challenge: The American Response by the Industry, the Universities, and the Government (Cupertino, Calif.: SIA, 1981), pp. 33-35.

6. Airbus Industries orders represented 3 percent of the total market for commercial aircraft in 1976 and 32 percent in 1980. Aerospace Industries Association of America, Inc., The Challenge of Foreign Competition to the U.S. Jet Transport Manufacturing Industry, an ad hoc study project of the Civil Aviation Advisory Group, Aerospace Technical Council (Washington, D.C.: Aerospace Research Center, 1982), p. 41.

7. C. Fred Bergsten, "What to do About the U.S.-Japan Economic Conflict?", Foreign Affairs, Summer 1982, pp. 1065-1067.

1

Advanced Technology: Its Nature and Importance to the United States

The nation's capacity for technological innovation is an essential national resource that permeates and strengthens the entire economy. Advanced technology products and processes are central to a range of domestic economic activities and serve to increase productivity. In addition, advanced technology is vital to the military security of the United States and, thus, to the defense of the Western Alliance.

WHAT IS ADVANCED TECHNOLOGY?

Examples of advanced technology industries are extensive, yet changing. They include microelectronics, computers, new materials, robotics, telecommunications, aerospace, and biotechnology. The list of technologies deemed "advanced" changes over time. A new list may supersede this one in a decade or two.

Integrated circuit chips perhaps best illustrate advanced technology's broad impact. Their role is to process data and signals—and hence information, a capacity that is critical not only to all scientific and technological fields, but increasingly to all economic sectors. Microelectronics has become a primary component of technological advance.

It is misleading, however, to describe advanced technology through its products—the computer or the laser. The essential national resource is the capacity for technological innovation—the ability to continuously discover, refine, and produce frontier technologies and to use those technologies throughout the industrial, agricultural, and military enterprises.

The Innovation Process

The capacity for technological innovation is manifested in the innovation process, an integrated complex system. Competition in advanced technology is not simply a matter of generating the best ideas. New ideas are only one essential part—among several crucial components—of what is necessary for a nation to be technologically competitive. The innovation process includes not only research and development, but also manufacture, marketing, and distribution. It may be described roughly in four parts:

Research—whether in a university setting, in research institutes, government laboratories, or in industry—generates new scientific knowledge and new ideas for application. One innovation leads to another by suggesting new directions for further technological investment. In industry, company interests usually dictate research; in universities and research institutes, individual scientists choose whatever scientific leads they deem both important and capable of attracting financial support.

Development translates a new discovery or idea into a usable product aimed at a defined market demand. It encompasses the steps between research and completion of the design of a product. It includes a validation phase, where elements emerge from a research environment to one having risk low enough to be used in a product, and an application phase which integrates such elements into a product design suitable for production. The former frequently proceeds before the application product is known, and certainly long before it is defined. The latter phase, application, occurs after the product is known. It can include prototype or pilot scale tests on either product or process. Development responds both to research results and to feedback from the marketplace.

Manufacturing or production takes the product or process from a single prototype to quantity production that promises the consumer reliable quality and controlled cost. The line between development and manufacturing is expressed in the comment that it's always possible to make one of anything; regular production demands reliability, competitive costs, serviceability, often retooling of the manufacturing plants, setting and enforcing criteria for suppliers, and more.

Distribution entails marketing, delivery, customer training, and support services. It addresses the requirements of the consumer in using the product.

The innovation process is a dynamic and intricately interrelated system: there are interactions and feedbacks among the four stages. Early efforts in development, for example, may reveal gaps in basic knowledge that require the launching of a new research effort, or user experience with a new product may call for redesign at the development level to better adapt the product to consumer needs. Thus successful innovation is characterized by constant rethinking, adaptation, and organizational learning; only rarely is there an orderly, logical process that can be completely foreseen in advance. Indeed, the difference between success and failure often depends precisely on sufficient flexibility and "fast footwork" in changing course to respond to new information.

WHY IS ADVANCED TECHNOLOGY IMPORTANT TO THE UNITED STATES?

Advanced technology has been called the "fuel" of the economy. New technologies—such as microelectronics, computer-aided design, computer-aided manufacturing, robotics, and advanced computer capabilities—spark a surge of economic growth by increasing worker productivity. Military security relies on pioneering technologies for defense systems and for verification of limitations on weapons systems specified in arms control agreements. Advanced technology is perceived as a strong part of our national self image: the United States is thought to excel through "Yankee ingenuity."

Advanced Technology and National Security

National defense relies on advanced technology products for sophisticated military hardware. Technologies used in defense systems can often be exploited for commercial purposes. Very-high-speed integrated circuits, digital telecommunications, and new high-performance materials all were developed for defense or space purposes yet now have commercial spin-offs.

New processing and fabrication methods may also apply to both military and civilian efforts. A goal of the manufacturing technology program of the Air Force was to demonstrate that computers can reduce cost in all phases of manufacturing aircraft and thereby enhance manufacturing flexibility. The driving force behind this program

was the high cost of relatively small production runs typical of military aircraft, but civilian aircraft manufacture benefited as well.[1] The Defense Department's Very-High-Speed Integrated Circuit Program (VHSIC),[2] designed to produce electronic devices that are faster and more reliable than circuits now in use, is being developed for the military but is expected to have important commercial uses.[3]

Military sources of R&D support, however, do carry some disadvantages for the commercial sector. Classifications, export controls, and rigid criteria for research, as well as the drawing away by the military of scientific and engineering personnel, sometimes inhibit, rather than promote, commercial developments.

Advantages flow from commercial research to the military as well. The military's ability to obtain the technology and hardware it requires often stems from the development and production strength that contractor companies have derived from competition in civilian markets. Healthy competition among companies selling semiconductors, lasers, commercial aircraft, computers, and other advanced technology products to a mass market, for example, sped the development of useful military applications of these products. The greater the civilian sales, the lower the per-unit R&D cost for both civilian and military requirements.

The nation must retain both excellence and self-sufficiency in military technology. To that end, a strong domestic technological enterprise is essential.

ADVANCED TECHNOLOGY AND TRADE

A U.S. positive trade balance in technology-intensive products and services contributes not only to employment, but also to the general health of the nation's economy. In 1980, advanced technology products showed a positive trade balance of $31 billion, compared to a deficit of more than $50 billion for all other manufactured goods.[4] The U.S. currently holds the highest market share of the industrialized countries' exports of high-technology products. That share declined, however, from 30 percent in 1962 to 22 percent in 1978 and has increased only marginally since.[5] Figure 1 shows that, in absolute terms, the U.S. trade balance in high-technology products increased over eightfold from 1962 to 1980. The statistic is less heartening when compared to the trade balances of

Japan and West Germany during the same period. Their positive balances increased more than two-hundredfold and ninefold, respectively, starting from a much lower 1962 base.

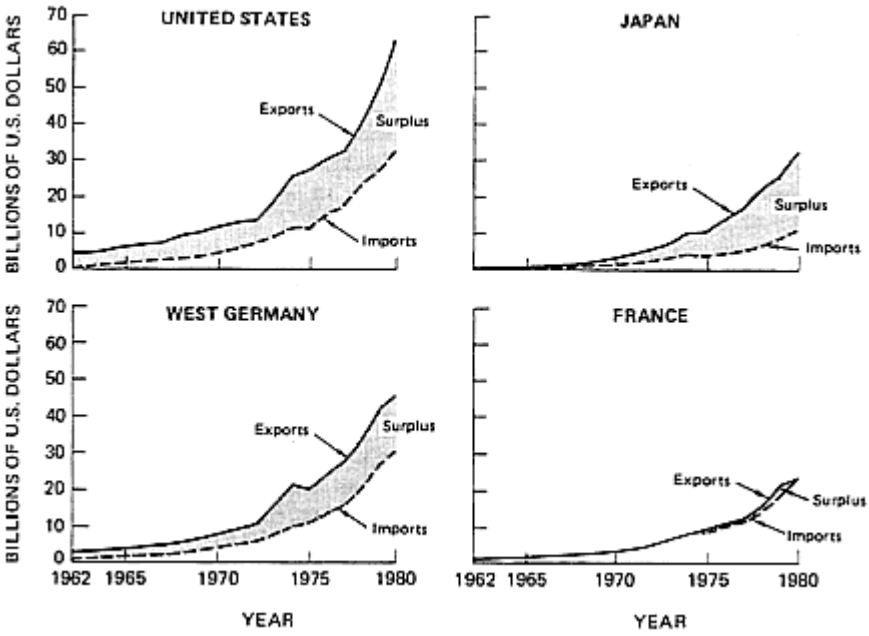

Figure 1
Relative changes in the balance of trade in high-technology products: United States, Japan, West Germany, and France, 1962 to 1980.
Source: U.S. Department of Commerce, International Trade Administration, from U.N. Series D Trade Data, as reported in "An Assessment of U.S. Competitiveness in High-Technology Industries," a study prepared for the Working Group on High-Technology Industries of the Cabinet Council on Commerce and Trade, final draft, May 19, 1982.

Advanced Technologies—Core Technologies in the Economy

The benefits of advanced technologies extend beyond the military and trade spheres to virtually all sectors of the American economy, including the service sector, manu

facturing, and agriculture. Electronics is one core technology arena in the form of integrated circuitry of increasingly higher density, digital devices for communication, an enlarging array of computers, and increasing sophistication in "user-friendly" software. Another emerging core technology, embraced by the umbrella term of biotechnology, includes not only modern-day fermentation techniques using recombinant DNA methodology, but also new biological techniques for the manufacture of hormones and drugs.

Core technologies have far-reaching influence upon the state of the American economy. The rapidly improving performance and falling costs of these advanced technology products are key to rising productivity. In 10 years, productivity in advanced technology industries has risen 5.6 percent, compared to 0.9 percent for business generally—a sixfold difference.[6] In addition, productivity in mature industries may be increased through the application of advanced technology throughout the manufacturing and distribution processes. Also, seemingly low-technology industries such as ceramics or glassware have components that are at the forefront of technical advance.

The diffusion of advanced technologies throughout the economy can be subtle. For example, the service sector in America is growing. Employment in service industries (banking, health care, insurance, transportation, utilities, etc.) between 1940 and 1980 grew from 46 percent of total employment to 68 percent.[7] Pressured by the need to improve productivity and to serve a growing population, service industries draw increasingly on new technologies: electronic tellers, word processors, and small stand-alone computers have become commonplace only a few years after their introduction.

NEED FOR NATIONAL ATTENTION

The advanced technology enterprise has special characteristics that strengthen its claim to national attention. Even small companies can be technologically innovative and economically viable, but a new innovative product is subject to cumulatively increasing returns to scale over time, that is, with research and production experience there is a reduction in average cost. On the other hand, temporary setbacks, if severe, can cripple

future efficiency by starving the scientific and technological roots of the innovation process. It is easier to stay at the frontier than to achieve it.

Were the United States to lose its capacity to innovate core technologies, it might still benefit from foreign innovations, just as other countries have benefited from advanced technologies originating in the United States. It is the innovating country, however, that has the best access to new technologies and, thus, the best opportunities to use them. The rapidity of change in many important technological fields requires knowledge of technological innovation in progress and immediate access to new technologies. Without that knowledge and access, a country's capacity to plan for new products would lag those of the innovating country. The effects of such a lag could be felt throughout the U.S. economy, affecting not only advanced technology industries, but also others that require the products of these industries for advancement, including the now widespread service industries.

ADVANCED TECHNOLOGY AND THE NATION'S FUTURE

The social fabric of a nation is knitted by its citizens' common purposes and widely shared beliefs in the integrity and stature of their country and in the belief in a strong future. Throughout our history, Americans have believed in the capacity of the United States to adapt to new circumstances, to use native skills and resourcefulness—"Yankee ingenuity"—to create practical objects of commercial value. That belief endures as a national assumption that the country will continue to expand technological frontiers and thus ensure the well-being of its people. The capacity of Americans to innovate and to adapt to change is thus important to sustain, as much for the national optimism, as for the technological benefits that flow from technological prowess.

NOTES

1. See National Research Council, Innovation and Transfer of U.S. Air Force Manufacturing Technology: Three Case Studies (Washington, D.C.: National Academy Press, 1981), pp. 6-18.

2. For descriptions of the scope and goals of the VHSIC program, see Jim Martin, "Very-High-Speed Integrated Circuits—Into the Second Generation, Part I: The Birth of a Program," Military Electronics/Countermeasures, December 1981, pp. 52-58, 71-73.

3. National Research Council, An Assessment of the Impact of the Department of Defense Very-High-Speed Integrated Circuit Program (Washington, D.C.: National Academy Press, 1982), p. 13.

4. "An Assessment of U.S. Competitiveness," p. 44.

5. Ibid., p. A-38.

6. Ibid., p. 45.

7. Service sector is defined in the broadest sense to encompass all enterprises not engaged in the production of goods. Unpublished data from the Department of Labor, Bureau of Labor Statistics.

2

National Policies Affecting Advanced Technology Capacity and Competition

The innovation process, as we have seen, embraces research, development, manufacturing, marketing, and distribution. A wide variety of government policies affect this process—those explicitly intended to strengthen it, such as federal support of basic research; those framed for a broader impact, such as the nation's fiscal and monetary policies; and those aimed at other objectives that may unintentionally adversely affect the process, such as export controls. In this chapter we consider how national policies affect a nation's advanced technology capacity and international trade position.

Many governments have designed comprehensive policies to ensure successful technology and trade development. Their efforts span the whole of the innovation process. The U.S. system supports basic research applicable to broad national goals but does not systematically support the other parts of the process leading to commercial sales. Responsibility for product development, production, marketing, and distribution are left to the individual firm. This system of free enterprise has worked remarkably well. However, as other governments coordinate—and provide increasing support to—their advanced technology industries, American firms find themselves competing internationally with government aided firms or groups of firms. U.S. industry feels burdened by an unfair disadvantage.

BASIC RESEARCH

Governmental support of basic research may serve broad national needs—for national defense, for food production, for medical care, and for energy availability, but

current spending on basic research is only tenuously linked to current competition for markets for advanced technologies.

Investment in basic research is a capital investment with a payback period measured in decades rather than years. Because the results of basic research are quickly available globally, governmental support does not spark international conflict. Each country's research benefits others. Indeed, the United States is a major beneficiary not only of its own research but of the research abroad as well.

Strength in a nation's research infrastructure, however, is no guarantee of successful technological competition. A country may lead in basic science, but lag in the process of making innovative ideas commercially profitable. On the other hand, a country may lag in research, but draw on research conducted abroad as a base for creating commercially successful advanced technologies. Japan has followed this strategy with remarkable success. Japanese leaders recognize, however, that an economically and technologically advanced country must develop a strong domestic research base in order to excel at making world-class technological advances.[1] France, too, has chosen to increase support of basic research. The United States has one of the strongest research bases in the world, but this base is not invulnerable. Federal support for basic research rose rapidly in the United States from 1960 to 1968 discounting inflation, but has increased only marginally against inflation since then (Figure 2).

APPLIED RESEARCH AND DEVELOPMENT

National practices diverge more sharply with regard to support for applied research and development than with regard to basic research. The three most prominent positions favoring some support follow.

First, a traditional U.S. position held by many industrial leaders and recent administrations is skeptical of any government effort to select particular sectors of industrial R&D for support. It holds rather that decisions on investing in development and the subsequent stages of industrial innovation are best made by private industry. This view, however, does espouse government support through tax credits for industry determined research.

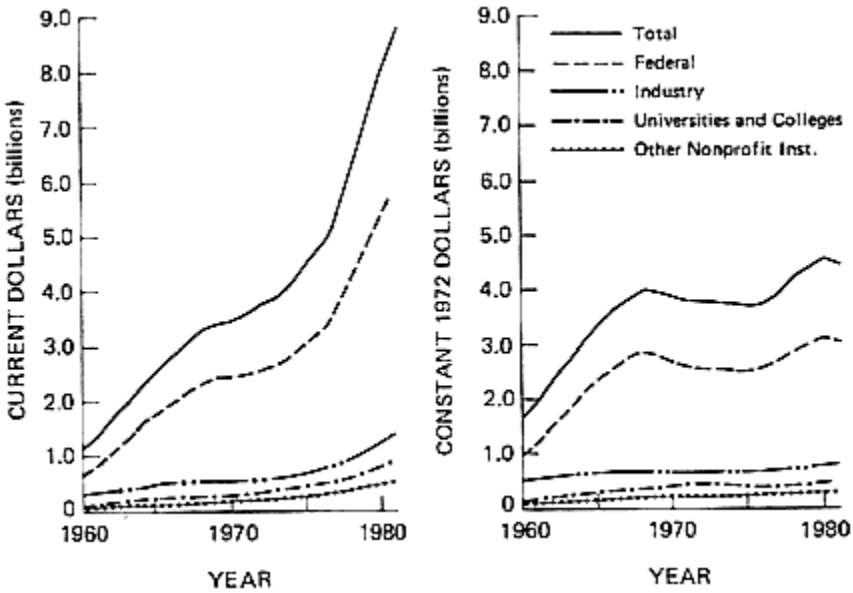

Figure 2
Basic research expenditures by source, 1960 to 1981. Estimates are shown for 1979–
81. GNP implicit price deflators used to convert current dollars to constant 1972 dollars.
Source: National Science Foundation, Science Indicators 1980.

Another view, occasionally argued in the United States but practiced primarily in other countries, suggests that the diffuse benefits, or "spillovers," of technological development warrant federal targeted support to particular technologies. It is argued that such support leads to commercially successful products—indeed, that favorable technological spillovers are likely even if the targeted products or processes are unsuccessful.

A third position, taken by some foreign governments, is that government support is warranted for those technologies for which there is a national need and in which the private market would tend to underinvest, either because of high risks and costs or because the benefits likely to result from research and development are not

easily captured. Certainly, in the United States and elsewhere, defense and those space technologies where the government is the prime customer receive full governmental research and development support.

PRODUCTION

France and Japan, among others, believe that government support for new technologies should in part assure production of the new industrial products. Proponents of this view stress that experience gained in manufacturing is crucial, that there is no clean break between development and production, and that, in any case, intervention by governments in advanced technology is justified by enhancing employment and making broad contributions to the national economy. Support can take a number of forms, including direct subsidies, low-interest loans for production facilities, and governmental absorption of potential losses.

Governmental actions affecting production costs also include regulatory policies—factory environmental standards, worker safety procedures, or production standards.

DISTRIBUTION

Government programs that support new technological developments politically may require support for the succeeding stages of innovation, including marketing and distribution. It is in the distribution stage that government intervention can be most damaging to free trade. Governments may protect domestic markets through procurement policies or nontariff barriers. They also may attempt to ensure third-country markets through below-market export credits* or political inducements. Such practices fragment international markets, denying the economies of scale that drive the continuing evolution of advanced technologies.

* Any form of financial assistance, direct or indirect, intended to provide financing in whole or in part for a transaction.

The Emerging Market

The latest area for intense competition in advanced technology industries is the Third World's emerging market—the some 113 countries that account for about 40 percent of the world's GNP. Sales to the newly industrializing nations —Brazil, Korea, Mexico, Taiwan, etc.—are a powerful determinant of success in international competition in advanced technologies. The nations or firms that make initial sales to an emerging nation tend to continue as preferred sources. There is concern that competing exporting governments may offer special inducements for commercial sales such as weapons, nuclear technology, export credits, or bilateral agreements favorable to the purchasing nation. The perceived use of such inducements has already provoked bitter conflicts.

Nontariff Barriers and Procurement Policies

Explicit barriers to trade currently are not the major tools for protecting markets. Tariffs for advanced technology trade are quite low among the industrialized countries. Formal quantitative restrictions are ruled out by the General Agreement on Tariffs and Trade (GATT). The "voluntary restraints" and "orderly marketing agreements" through which exporting nations agree to curtail sales in another country are familiar in traditional industries, but are absent in the advanced technology area. Instead, protected markets are created through national procurement policies, through suspension of antitrust enforcement, and through nontariff barriers to imports, such as customs delays and regulations. These barriers can be quite effective. For example, national procurement policies limit trade in telecommunication products between the large European countries, even though the advantages of large-scale production and the costs of duplicative research and development may justify specialization and free trade.[2]

Nontariff barriers may be institutional and attitudinal factors, such as national loyalties inclining nations to support domestic industries, which effectively prevent import of foreign goods.

Imports of foreign goods that compete with domestic products may be ensnared in complex bureaucratic customs procedures, or marketing of products may be blocked by the interlocking control of business. For example, mar

keting and distribution firms may be owned by or have a special relationship with domestic manufacturing firms and thus refuse to serve foreign suppliers, or local lending institutions may deny financing for foreign product distribution.

Investment barriers, like trade barriers, may take the form either of overt legal restrictions or more subtle pressures. A country may limit foreign direct investment in certain domestic businesses.

In addition, a government may deny foreign-owned firms "national treatment," i.e., the same privileges as domestically based firms, or foreign subsidiaries may be denied access to low-interest loans, excluded from local procurement, or denied the right to participate in collaborative R&D. In many cases, firms investing in countries seek local participation, perhaps at a majority level, to avoid this "second-class" treatment.

There are several other ways in which governments' restrictions on foreign investments may be to the disadvantage of firms attempting import:

- firms may be unable to invest in necessary complements to advanced technology exports, such as local parts and service facilities;
- "offset" requirements or "local content" laws may force firms to produce products in-country (occasionally at low volume and high unit cost) as a condition for access to the local market;
- firms may suffer unfavorable conditions of technology transfer—e.g., licensing at disadvantageous terms—because the preferred route of direct investment is closed.

NATIONAL PRACTICES—POSITIVE AND NEGATIVE CONSEQUENCES

The extent to which our national welfare is interwoven with that of our allies in the fields of science cooperation and advanced technology trade is not generally appreciated. The costs and risks of protectionist policies and market fragmentation are probably greater than in almost any other economic field except energy. Paradoxically, the international coordination of trade practices is more backward in advanced technology than in many other fields at a time when both nations and regions within nations are looking more and more to advanced technology as a primary source of economic salvation.

Innovation proceeds most rapidly and efficiently when new products have access to the widest possible markets, thus spreading the costs and risks of innovation over more units and generating the cash flow for follow-on improvements and further innovation. Thus, the United States should negotiate in international forums to secure the openness of world markets to innovative entrepreneurs wherever they may be based and to eliminate those national actions practiced by other countries that distort the free market operation in the United States. Such a policy is required, both to preserve the U.S. position as a major source of innovation and to ease growing tensions among the industrialized allies, tensions that threaten not only international economic and political management, but also mutually beneficial cooperation in science and technology.

There are a number of practices that effectively close markets in a given country to the advanced technology products of another country. Government intervention to force purchase of products from domestic suppliers is an example. Such practices reduce the total size of the market open to an innovator, reduce the rewards for the innovating firm, and limit the distribution of innovative products globally. Other practices may result in one country rapidly acquiring a larger share of the market in another country than would occur under conditions of free competition. Export credits on highly concessionary terms is an example. Some practices may not be outlawed by international agreement, but may be injurious to trading partners. An example would be the suspension of antitrust policy for specific advanced technology industries in order to accelerate product innovation and foreign sales.

Commercial and financial practices that are generally agreed to be harmful to the world trading system as a whole, even if at least temporarily advantageous to the perpetrating country, are not necessarily the ones that cause the most damage. While it may be easiest to eliminate by agreement the practices that are acknowledged to be unfair and which add nothing to aggregate world production, it may be more urgent to take aim at some more debatable tactics that cause clear danger. These tactics are difficult to categorize, but they may be the most important and call for the most immediate hard bargaining. They may be protectionist, trade distorting, or harmful to world welfare. Examples of such practices are:

- Predatory pricing sales abroad at prices below the domestic selling price or below cost. (Below cost pricing may be defined as pricing that does not permit recovery of production costs over any plausible projection of the learning curve. This may be very hard to define for advanced technology products because of the steepness of the learning curve and because of the subjectivity of business judgments as to how long a time is reasonable for recovery of "front end" costs.) When systematically applied, predatory pricing can be used to "pick off" one sector after another. Protection against this practice is not readily available from either GATT rules or traditional domestic policies of the U.S. government.[3]
- "Targeting" of specific U.S. advanced technology markets by foreign countries through governmentally orchestrated industrial strategies that suspend normal business or regulatory practices with respect to the targeted product line, such as cartelization. Coordinated "picking off" of particular U.S. markets through a concentrated effort is especially pernicious.
- Nontariff type barriers that effectively exclude U.S. products from fair competition with local products in local markets.
- Government intervention to force purchase of products, especially advanced technology capital goods, from domestic suppliers despite competitive price and/or performance of foreign products. (This would include "Buy American" requirements on U.S. federal or state government contractors.)
- Restrictions on foreign direct investment, particularly those that effectively deny distribution outlets for U.S. advanced technology products in the host country.
- Exclusion of U.S. foreign subsidiaries from "national treatment" equivalent to that afforded national firms.
- Use of political leverage or concessions to influence purchasers in third-country markets to buy a foreign product in competition with a U.S. product. This includes tying sales to trade agreements, military weapons support, nuclear development projects, economic/regional assistance, and similar programs.
- Official or unofficial preferential government procurement favoring domestic producers when contrary to GATT rules.

- Capital or operating subsidies, including concessionary loans that result in extra market penetration of foreign advanced technology products into U.S. markets or world markets. Invocation of the GATT subsidy rule may provide some protection for the injured party. Unfortunately, unless it is vigorously pursued by the firms and country affected within the framework of the GATT rules for subsidies, redress is obtained too late to prevent substantial damage.
- Export credits on highly concessionary terms, based on government subsidies. In the absence of international agreement on what constitutes a reasonable concessionary interest rate, however, it is difficult to fix a criterion unilaterally that would trigger retaliatory action. Such retaliation might be equal or better concessional terms.
- Practices that stimulate innovation by relaxing various domestic rules in the exporting country may nevertheless have some positive spill-over effects. They might be best matched by adopting similar modifications of domestic ground rules for the competing industries in the importing country. If the rule changes were relatively mild—for example, exempting research consortia from antitrust regulations, or permitting patent or other information exchanges among competing domestic firms—the net effect might even be positive.
- R&D subsidies to accelerate the development and commercialization of particular products. Such targeting is considered difficult by many, yet the Japanese record of success seems to be good.
- Exchange of technical information and agreed product specialization (or "market sharing") among competitive firms in a broad technological area. It is frequently pointed out that Japanese law and administrative interpretation permit a degree of both market sharing and technical cooperation in domestic markets that would be illegal under U.S. law and/or regulatory policy. While this may be "unfair practice" from an American point of view, it is within the traditions of the Japanese system.
- Mutual support among independent firms belonging to industrial "groups" whose members enjoy preferential financial and intellectual or other cooperative relationships with each other. Such "group strategy" gives the practitioner a relative competitive advantage in the American market. It represents the kind of rationalization pursued by large U.S. corporations in the early

twentieth century that U.S. antitrust policy was designed to prevent. It may be acceptable, however, when viewed from some standpoints, e.g., buyers in the emerging market rather than from the standpoint of "fair competition" with the United States.

U.S. INTERNATIONAL NEGOTIATING STRATEGIES

In the preceding discussions, we have described governments' practices affecting their respective advanced technology industrial systems and suggested criteria for assessing those actions according to their consequences for the international trading system. These criteria place value on maintaining open markets, thus rewarding innovators, and making innovative products available globally. We believe that the United States must continue to negotiate in international forums to maintain international systems that foster healthy, mutual competition in advanced technology. Such competition will be to the ultimate economic advantage of the world.

The United States must give immediate attention to efforts to strengthen its advanced technology capacity and international trade competitiveness. Such efforts will require both a national focus on the importance of advanced technology to U.S. military and economic interests and the need to compete vigorously in international markets. Recommendations for domestic actions will be discussed in Chapters 3 and 4.

We recognize that there may be circumstances in which, although our domestic advanced technology capacities are well nurtured and strong, still a few key technological sectors essential to our national welfare may be endangered. Successful aggressive policies of our allies could create such vulnerability. If capabilities in a significant advanced technology sector, deemed essential to U.S. economic and military interests, are seriously endangered because of the loss of markets, the United States must take remedial actions. Damage to the nation's total innovative capacity, however, is far more pernicious than adverse impact on a particular product or firm.

A first step is to seek to renegotiate multilaterally agreed rules in forums such as the GATT. Such negotiations should seek to establish clearer guidelines for government actions in high-technology sectors. A basic requirement of such negotiations would be that countries, including the United States, be prepared to consider altering traditional practices.

When there is a specific threat to U.S. interests from a particular country's government policies, the U.S. government should initiate bilateral consultations within the framework of GATT and other appropriate multilateral institutions. The goal of such negotiations would be to reach agreements on a time scale that would prevent or reverse damage to U.S. capacity for technological innovation. If these bilateral consultations are unsuccessful in resolving the issues, the U.S. government should utilize formal multilateral dispute settlement procedures to seek a resolution. If those procedures fail or if the threat of damage is imminent, the United States would be required as a last resort to take unilateral action to protect the national interest.

NOTES

1. Japan Committee for Economic Development, Building an Industrial Structure for the 21st Century (Tokyo: JCED, 1982), pp. 14-15.

2. Organisation for Economic Co-operation and Development, Telecommunications Equipment Industry Study (Paris: OECD, 1981), p. 19.

3. The negotiations in the Tokyo Round of GATT on subsidies developed criteria for "material injury" caused by such subsidies. Such criteria would probably define the limits of acceptable practice even when a theoretical argument might conclude that the causative practice resulted in a total mutual benefit that exceeded the injury to one of the parties. Certainly in the case of subsidies to advanced technology industries, the machinery of GATT should be available, although the standards of proof of injury may be harder to apply in the case of advanced technology than for other goods. Richard Rivers and John Greenwald, "Subsidies and Counterveiling Measures," Law and Policy in International Business, 2 (1979), pp. 1465-1495.

3

Policies and Practices Affecting U.S. Competitiveness in Advanced Technology

Three conclusions emerge in examining the varying practices of nations toward advanced technology development and trade: (1) other nations do indeed have comprehensive national plans supporting technology and trade objectives; (2) the United States does not take a cohesive and coordinated look at its policies and practices and those of our trading partners regarding advanced technology; and (3) the United States has available to it tools for addressing the needs of its advanced technology enterprise, to strengthen both its capacity for technological innovation and its international trade competitiveness.

Such tools include federal programs for support of research and education; governmental policies and practices with regard to taxes, antitrust, patents, regulation, and technology exports; and broad national economic policies.

Clearly many of these policies and practices are designed to support other national objectives. In the processes of policymaking and allocation of resources, however, the nation's technological capacity and international competitive strength must be highly valued among national objectives. Furthermore, the variables affecting the U.S. advanced technology enterprise must be well understood. This may be accomplished by a high-level assessment reviewing domestic governmental and private actions, the industrial and trade policies of other nations, and the broad global environment. The United States has no adequate assessment process now. In consequence, governmental policies evolve without any broad assessment of how they will affect the strength of U.S. advanced technology capacity and trade.

One reason for this oversight is that the United States views technology and trade policies differently from its competitors. The United States formulates its trade policy in terms of a process; it sets rules for competition and lets the private sector operate within that framework. Some other countries tend to choose a desired outcome and then define policy accordingly.

Furthermore, the United States views international competition as having rules defining a "level playing field" for firms from different countries—the game should then be left alone. But some other countries, having decided on desired outcomes of the competition in terms of, say, market share or employment, feel the rules allow them to intervene if their national firms are not doing as well as they would like. This difference in approach makes negotiation difficult.

The often adversarial relationships of U.S. government and business, evolved early in the country's history, also may impair U.S. competitiveness. Industry and government have to be prepared to work more cooperatively in order to achieve national goals.

A further problem is that policymakers are rarely people experienced in the industrial innovation process—those who through active experience know the difficulties of creating, producing, and marketing new products and processes embodying advanced technologies. Maintaining a continuing expertise, through a highly qualified and stable governmental career staff, is a corollary difficulty.

Finally, U.S. companies often see themselves competing against national systems rather than individual foreign companies—U.S. aircraft manufacturers see their competitor as a government-supported consortium; individual semiconductor, robotics, and computer manufacturers here face a cooperative network of Japanese companies working with a governmental agency. So mixed an international trading system complicates international negotiation and agreement.

GOVERNMENT POLICIES

Macroeconomic Environment

While the depressed worldwide macroeconomic environment intensifies the pressures we have been describing for every nation, the effects may be greater in the United

States than elsewhere. Some of the erosion of the U.S. lead in advanced technology may be blamed on macroeconomic factors, particularly the low rate of investment and the consequent slackening of demand for new technologies.

U.S. macroeconomic policies obviously serve a range of national needs beyond those of the advanced technology enterprise, but their impact on U.S. technological development should be well understood. Slack domestic demand reduces the current profits of all firms, their ability to finance investment, and the expected profitability of new investments in capital or technology. The problem is intensified in the advanced technology sector because the payoff to new investments is more uncertain and comes after a longer delay than in traditional industries.

Further, advanced technology industry is unusually vulnerable to high real interest rates that work differentially against long lags in cash flow. The mix of macroeconomic policy in the United States has caused interest rates to be high and volatile for a long time. Apart from the effect already mentioned, this choice has caused the dollar to appreciate substantially against other currencies. The strength of the dollar relative to the yen, especially, makes U.S. firms less competitive precisely in those markets that are endangered for other reasons. Finally, inflation may have inhibited investment in long-range planning and new technology.

Antitrust Policy

While U.S. antitrust policy has begun taking international competition into account, its implementation still fails to give sufficient weight to international trade considerations. The manner in which antitrust statutes are interpreted and applied is charged with interfering in international competitiveness. For example, firms have difficulty retaining the benefits of research that are the product of multifirm collaboration; prospective "safe-harbor" rulings are not readily available; and there is a general uncertainty regarding what corporate actions may elicit legal actions on the basis of antitrust legislation.

Because of this uncertainty, management cites antitrust policy as creating excessive risk for a range of activities that may benefit innovation and trade, such as pooling research efforts, pooling information on the work of international competitors, or pooling development

programs whose costs are too large for any one firm in an industry to undertake. By contrast, foreign governments—for example, Japan and France—encourage cooperation among firms through mergers or cooperative programs.

U.S. antitrust policy, however, has successfully fostered beneficial domestic competition. Any changes must be carefully considered. But, in the context of the new era marked by increased relative importance of international trade, by offshore production and investment, by the emergence of world-scale markets, and by the differing policies of other nations, antitrust regulation and enforcement should be reexamined in the light of the international context in which U.S. firms must compete.

Capital Supply

Cost and availability of financing are major factors, both in the start-up and growth of new companies and in the modernization of established firms. Over the past decade, capital costs have been 50 to 100 percent higher in the United States than in Japan.[1] The supply of venture capital for new U.S. firms, however, is large and flexible; that contributes significantly to the abundance of small advanced technology firms here.

Technological innovation by large established firms requires both the capital and the incentive to make large-scale investments. Japan appears to have an advantage over the United States in this area because the cost of capital in Japan (in real terms) is lower due to more thrifty savings habits and superior macroeconomic performance. The difference is aggravated by the economic volatility that has characterized the United States during the last decade. Also, financing of large firms in Japan is less dependent on open capital markets than is true for their American counterparts; thus, Japanese firms' abilities to invest are not dependent on promises of short-term results.

To take one example, Japanese semiconductor firms, some of which are part of large industrial groups that include banks, tend to be heavily financed from within the group.[2] U.S. firms are competing with foreign firms that receive their capital at reduced rates from their governments or from banks encouraged by their governments.

Export Policies

Ideally, we would prefer a world without corruption, without trade restrictions against our allies, without government financial support for exports. We would like to expand U.S. trade in a free market environment. At the same time, we would like to limit the military technological development of our potential adversaries. However, our pursuit of these objectives must be tempered by our interest in the health of U.S. industry.

U.S. advanced technology firms operate in an increasingly competitive world market. Americans should be conscious of the impact of U.S. policies on U.S. exports as they help or hinder viability of advanced technology firms. This competitive environment need not deter American pursuit of their major objectives, but such pursuit must acknowledge what is realistically attainable and may entail compromises with this reality.

For example, some of our leading competitors justify using official export credits because they protect jobs and nurture industrial development. Until we can achieve agreement to minimize government sponsorship of export credits, we should be prepared to provide similar support for our own industries as we have done in the past through the Export-Import Bank.

Similarly, the United States imposes on exports to currently out-of-favor nations controls for both foreign policy and national security reasons. In the past, these restrictions have been partly based on the questionable assumption that the United States had an effective monopoly in providing the products in question. The consequence may be a loss of U.S. sales; the foreign policy goals may not be achieved. To be in the best interest of the nation, the economic and political costs and benefits of controls must be carefully assessed, and they must be undertaken multilaterally—consulting and cooperating with other leading industrial or agricultural countries.

Tax Policy

Because technological progress diffuses throughout the economy, there is a strong case for special tax treatment for research and development. Indeed, the Economic Recovery Tax Act of 1981 offered several incentives to business investment, including subsidies for a 5-year period for research and development expenditures and

accelerated write-offs for capital expenditures. The United States is not alone in providing tax incentives for industrial research and development, though many nations prefer to provide direct subsidies. Sometimes new and rapidly growing advanced technology firms are targeted for benefits such as accelerated depreciation and tax benefits during their start-up phases. Policy assessments of the effectiveness of current tax policy in support of research and development (for example, the actual effect of the 5-year limit mentioned above) would be welcome.

Regulatory Policy

Health, safety, environmental, and other regulations have been criticized for raising the costs of product development and manufacture, and thus raising prices of American products. The counterargument is that added costs are warranted because of their benefit.

There is now a general mood in this country for reexamination of regulatory policies. That reexamination should include consideration of the effect of regulatory policies on the capacities of U.S. industries to innovate and to compete in world markets.

PRIVATE SECTOR POLICIES

Nongovernmental variables affecting the advanced technology enterprise may be influenced by government policy. These include the nature of corporate management, university-industry relationships, and financial resources.

Management

American industrial management, long regarded as the standard for excellence, has recently come under criticism. Failure to maintain product quality, searches for short-term market payoffs, and failure to invest in long-term technological innovations are some of the alleged faults. Management has been accused of placing undue emphasis on short-term financial goals, yet our system requires companies to fund their own growth—even and especially in a recessionary period.[3]

Short-term financial concerns have come to dominate many U.S. corporations for various reasons—among them, the increased size and complexity of corporate structure, the harsher macroeconomic climate, the uncertainty in government regulation and policy, and (somewhat ironically) the intensifying international competition. Managers equate this near-term emphasis with the need to survive, yet the result—a reluctance to take long-term risks—sacrifices major technological innovations. A blanket indictment of American management is simplistic and erroneous, of course. Examples abound of technologically astute management willing to take risks and invest in an innovative future.

Effective application of American styles of management coupled to a deeper understanding of the critical role of technological innovation in future economic growth may be more appropriate than studying Japanese or other management models. The rapid evolution of advanced technologies offers remarkable opportunities for corporate exploitation and growth. Despite the recession, U.S. industry has seen those opportunities and responded by increasing its research and development spending by 15 percent in 1981.[4]

University-Industry Relations

Historically, the federal government has provided the majority of funds for academic research. Industry has contributed only modestly—4 percent to 6 percent yearly of total academic research and development expenditures from 1960 to 1981.[5]

University-industry collaborations can be, nevertheless, remarkably effective in improving the transfer of advanced technology research results to commercial applications. An obvious example is the influence of MIT and Stanford University in contributing to the growth and success of advanced technology enterprises populating Boston's Route 128 and Palo Alto's Silicon Valley.

New university-industry relationships are emerging in such fields as biotechnology and electronics. Stanford University's Center for Integrated Systems and Carnegie-Mellon University's Robotics Institute have benefited from corporate support in establishing multimillion dollar research facilities.

We applaud such efforts, and we encourage universities and industry to continue to enter into collaborative

arrangements that may create new knowledge, quicken its commercial translation, and strengthen components of the nation's advanced technology capacity. It is crucial, however, that those involved must ensure that research findings in the university are generally open and available to the entire scientific community. Deviations from this rule should be fully disclosed, should be under constant scrutiny and review by the universities and companies themselves, and should be based only on the most compelling short-term reasons. This need not obviate targeted industrial research grants to universities consistent with rewards to the sponsor. In addition, such openness will maintain the concept of free scientific communication and open university.

GOVERNMENT AND PRIVATE POLICIES

The following are areas for which both government and private sector actions affect national capabilities.

Human Resources

The U.S. educational system, public and private, is complex. It involves local, state, and federal governance, and its funding sources range from state subventions to indirect cost charges against research. A coherent examination of the educational system within a broader review of policies and practices affecting the nation's technological capacities would not be easy, but it is necessary.

A diverse set of human skills is essential to national technological innovative capacity: a technically competent labor force, a first-rate and constantly freshened basic research force, and well-trained baccalaureate and graduate engineers, scientists, and technologically sophisticated managers.

Advanced technologies are powerful tools, but their power is realized only through individual imagination applying them in novel ways. This requires that some technological sophistication be prevalent throughout the population. To illustrate, about half of research and development done in the manufacturing sector flows to the service sector—insurance, banking, utilities, transportation, education, etc.[6] Such flows—and the economic gains they provide—occur because of the technological

understanding and imagination of those working in both sectors.

The United States still has the Western world's largest technologically sophisticated population, both absolutely and in the numbers of scientists and engineers as a proportion of the total work force. Since the early 1970s, however, it has been adding to its pool of scientists and engineers more slowly than Japan and West Germany.[7]

Precollege Education

The American primary and secondary high school system for teaching science and mathematics is in trouble. State-by-state statistics show insufficient numbers of qualified science and mathematics teachers. A 1981 survey revealed a shortage of high school chemistry teachers in 38 states, of mathematics teachers in 43 states, and of physics teachers in 42 states.[8] American high school graduates have quantitative skills and understanding of science and technology that is today inferior to those of their counterparts in Japan, Germany, and the USSR. The higher productivity growth of the Japanese economy has been attributed, in part, to the high quality of Japanese secondary science and mathematics education.[9]

University Education and Research

The close coupling of research and graduate education is the core of the strength of the American research system. The system is now suffering not only a virtual stasis in research funding, but also squeezes on endowments of private universities and diminished governmental support for state universities.

Total national basic research spending averaged 4.4 percent annual growth from 1975 to 1980, with the federal government accounting for 70 percent of that increase.[10] Growth has tapered off since then and would be negative but for increased research spending in defense and space. The effect on universities of diminished growth in resource funding is direct, given that they accounted for half of all basic research expenditures in 1981 and given that basic research was 69 percent of all academic R&D expenditures.[11] A direct result of this funding lag has been a deterioration in the utility and availability of scientific instrumentation in university research

laboratories. It is estimated that modernizing university equipment alone would cost at least $1 billion.[12]

While the federal government historically has distinguished support of research from support of universities per se—in contrast to the dual-support systems of France, West Germany, and the United Kingdom—that distinction is necessarily somewhat arbitrary in the case of the research universities.

Engineering Education

Problems in training future scientists and engineers are apparent in U.S. engineering education. While Japan, with a population less than one-half of the United States, graduates more engineers than does the United States,[13] the deeper issue is the quality of education received by American engineering students, both at the baccalaureate and graduate levels. The large number of unfilled engineering faculty positions—estimated in 1980 to be at least 1,800[14] —spells serious trouble for the quality of engineering education, particularly because undergraduate engineering enrollments are at an all-time high. The unfilled positions are commonly attributed to higher salaries in industry than academe. Industry attracts bachelor-degree engineers in ever greater numbers—a process that has been aptly termed "eating our seed corn." And, as with the sciences, university engineering education is beset by deteriorating and obsolescent instrumentation.

Monitoring International Technology

Many nations have developed mechanisms for monitoring foreign technological developments and reporting them back to their domestic industries.[15] Nothing comparable exists in this country. Several facets of the issue might be examined, including any barriers to industrywide collaboration in acquiring and sharing foreign technological intelligence and mechanisms for public and private cooperation in acquiring and disseminating technical information.

Support of Basic Research and Development

We have emphasized earlier the various approaches that the United States and other nations take to the support of research and of various stages of development. The U.S. federal government has accepted its role as the patron of basic research in the United States, and the issue, therefore, is the level of support and the relative emphasis given to various fields.

Support for development, as well as for applied research, is a more difficult matter, involving not only levels of support but even whether support for these endeavors is a federal responsibility. Development is supported in defense, many areas of space technology and aeronautical research, agriculture, and some areas of energy. Some advocate broadening support to include advanced technologies; others oppose this on the grounds that the federal government does poorly in choosing which technologies to support.

WHAT POLICIES ARE APPROPRIATE?

The traditional U.S. position on the government role in supporting advanced technology development and trade has been that governments should restrict their intervention to basic research and education and leave the other components (development, production, distribution, etc.) to the marketplace. Our competitors, however, do not accept this view; they intervene to support the advanced technology system at all stages—research through marketing. The traditional U.S. instruments used to foster technological industrial performance still may be adequate in the face of the more intrusive policies of other countries; but they can only be truly effective with a coordinated and national focus on strengthening the nation's trade competitiveness and advanced technology capacity.

Certainly, any change in the use of existing instruments, or the addition of others, means a major departure in governmental policies toward the industrial economy. However, given the intervention of other governments in international competition, such a departure should be widely debated. For the reasons cited in the first chapter of this report, the United States must maintain the strength of its national capacity for technological innovation. That capacity can be damaged by weak

domestic policy. It can also be damaged through practices of our industrialized allies. The problem in responding is to define policies that maintain our technological strength and comport with our national character and values.

NOTES

1. "An Assessment of U.S. Competitiveness," p. 79.

2. See M. Therese Flaherty, "Determinants of Market Share in International Semiconductor Markets," a presentation to the Panel on Advanced Technology Competition and the Industrialized Allies, Washington, D.C., February 9, 1982, pp. 1-13.

3. Robert J. Hayes and William J. Abernathy, "Managing Our Way to Economic Decline," Harvard Business Review, July-August 1980, pp. 67-77.

4. National Science Foundation, National Patterns of Science and Technology Resources 1981 (Washington, D.C.: U.S. Government Printing Office, 1981), p. 10.

5. Ibid., p. 21.

6. F. M. Scherer, "Research and Development, Patenting, and the Microstructure of Productivity Growth," a report to the National Science Foundation, June 1981.

7. National Science Board, Science Indicators 1980, p. 4.

8. Paul Hurd, "The State of Precollege Education in Mathematics and Science," presentation to a Convocation on Science and Mathematics in the Schools, National Academy of Sciences, Washington, D.C., 1982.

9. New York Stock Exchange, Office of Economic Research, People and Productivity: A Challenge to Corporate America (New York: New York Stock Exchange, Inc., 1982), pp. 10-13.

10. Calculated from data on basic research expenditures by source, National Science Board, Science Indicators 1980, p. 255.

11. National Science Foundation, National Patterns of Science and Technology Resources, p. 12.

12. National Research Council, Revitalizing Laboratory Instrumentation, the report of a workshop of the Ad Hoc Working Group on Scientific Instrumentation (Washington, D.C.: National Academy Press, 1982), p. 1.

13. Business-Higher Education Forum, Engineering Manpower and Education: Foundation for Future Competitiveness (Washington, D.C.: Business-Higher Education Forum, 1982), p. 13.

14. John D. Kemper, "Graduate Enrollments in Engineering: Meeting National Needs for Productivity and Innovation" (University of California, Davis, July 1980), p. 7.

15. For a discussion of some of the mechanisms used by Japan and Western Europe in the field of computer science, see National Research Council, International Developments in Computer Science (Washington, D.C.: National Academy Press, 1982).

4

Conclusions and Recommendations

In this consensus statement, the Panel on Advanced Technology Competition and the Industrialized Allies has described why the United States must elevate, in the scheme of national priorities, efforts to strengthen the nation's capacity for technological innovation, including a vigorous international trade position. The panel believes that the U.S. advanced technology enterprise has been undervalued in the past and now must be placed as one of the nation's most valued objectives. The panel has described also how the United States may negotiate internationally to strengthen the international trading system in harmony with healthy, mutually beneficial trading relations, and how the United States may respond should these international efforts fail.

The following is a summary of the panel's conclusions and recommendations.

CONCLUSIONS

- The United States must act now to preserve its basic capacity to develop and use economically advanced technology. This innovative capacity is essential for the self-renewal and well-being of the economy and the nation's military security. Trade in advanced technology products and services will contribute enormously to our economic health. Advanced technology products and processes not only permeate the economy, increasing productivity, but also form the basis of modern defense hardware.
- The nation's capacity for technological innovation is vulnerable both from domestic weaknesses and from damaging practices of other nations. Measures designed to

maintain this vital aspect of the American economy within a healthy international trading system will include both domestic actions and international negotiations.

- Effective actions require a sound understanding of the nature of innovative capacity and of the innovation process through which it is primarily manifest. Innovative capacity is the capability, widely diffused throughout the economy, to produce continuously forefront technological resources, and to use those resources for the national benefit. The innovation process includes not only basic research and development, but also production, marketing, and distribution in domestic and foreign markets. Each part of the process must be sound for success.
- Some of the elements that support our nation's innovative capabilities include a strong national research base, technically educated manpower and a technically literate population, capable and farsighted industrial managers, a financial base that provides capital to both new and established firms, and sizable markets. Essential, too, are a national understanding of and attention to advanced technology as a vital contributor to the national welfare.
- The U.S. government has in effect a range of policies and practices including tax policies, patent laws, regulation and deregulation, antitrust measures, export/import bank loans, government procurement, and others that, although designed to serve other national objectives, also affect the U.S. technological enterprise and international trade position. These policies and practices and the other domestic and international elements affecting U.S. technology and trade must be well understood by senior policymakers. If viewed in ensemble, existing government instruments may become powerful means to support U.S. technology and trade interests.
- Responsibility for improving U.S. performance in advanced technology and trade rests to a large degree with the individual firm and its management. Successful managers increasingly will have to be cognizant of frontier technologies as they build businesses and compete in an international world.
- Our major industrialized allies—most notably Japan and France—have designed comprehensive national policies to help ensure successful technology and trade development in major sectors. Thus, individual U.S. firms often find themselves competing internationally,

not with firms acting alone, but with countries or with consortia of firms with country backing.

- There is considerable dispute among industrialized allies regarding which practices are acceptable and which are not. Efforts to evaluate practices are protracted and difficult, but essential.

RECOMMENDATIONS

Accordingly, the Panel Recommends the Following

- Advanced technology development and trade must be considered as among the highest priorities of the nation. These vital interests must be well understood domestically and conveyed to our trading partners. The United States must initiate a two-part strategy: to maintain the nation's capacity for technological innovation and to foster an open healthy international trading system.
- The federal government should initiate a biennial, cabinet-level review that comprehensively assesses U.S. trade competitiveness and the health of the nation's innovative capacity in both relative and absolute terms. This review should consider the nation's overall performance: the private sector activities and the totality of government actions on technology and trade, as well as the effects of other governments' practices. These assessments would consider the strength of key technological sectors across all stages of the innovation process—research, development, manufacture, and distribution. In addition, assessments would evaluate broad elements as they affect innovation, such as the macroeconomic environment, regulatory policy, patent policy, and antitrust policy. Careful attention would be given to maintaining the health and effectiveness of both university- and industry-based research, education, and training. The cabinet-level review should be supported by a continuing mechanism that would draw on expertise both from within the government and from outside.
- Managers of private firms must be cognizant of technological trends as they make renewed efforts to build businesses and compete in an international context. Managers should consider new institutional arrangements—the growing, mutually supportive, industry-university research relationships, cooperative research ventures among groups of firms, or consortia to seek information and ideas systematically from abroad.

- Internationally, the United States should negotiate in existing forums to encourage a healthy mutual trading system. This should include continued efforts to evaluate national trade practices and to agree on criteria for acceptability. An objective must be to encourage open markets and healthy competition.
- Countries, including the United States, throughout negotiations should be prepared to alter fundamental policies so that each country may maintain advanced technology capacities fundamental to its individual welfare.
- The United States should review the content and application of its trade laws to ensure that U.S. industries can obtain timely and meaningful trade and/or other relief in the U.S. market when imports from particular countries, based on unreasonable or excessive foreign industrial policies, threaten them.
- If key technology industries essential to national economic welfare and military security are considered endangered by the actions of another country, even with all necessary domestic efforts to strengthen these sectors, then the United States should negotiate with the other country requesting immediate relief. Negotiations should take place first in existing forums, explaining our country's vital interest in preserving advanced technology capacity. If such mechanisms prove ineffective or too slow to prevent damage to essential U.S. capabilities, then the United States should negotiate directly with the country in question. If those bilateral negotiations fail or if the threat of damage is imminent, the United States should take immediate unilateral actions as a step of last resort.

The panel concludes that the advanced technology enterprise has the potential to contribute significantly to economic and social welfare, both in the United States and throughout the world. It is essential that the industrialized allies work individually and cooperatively toward advanced technology development and a healthy free trade system for their mutual benefit.

Selected Bibliography

Aerospace Industries Association of America, Inc. The Challenge of Foreign Competition to the U.S. Jet Transport Manufacturing Industry. An ad hoc study project of the Civil Aviation Advisory Group, Aerospace Technical Council. Washington, D.C.: Aerospace Research Center, 1981.

Baranson, Jack, and Harald B. Malmgren. Technology and Trade Policy: Issues and an Agenda for Action. Washington, D.C.: Developing World Industry and Technology, Inc., 1981.

Bergsten, C. Fred. "What to Do About the U.S.-Japan Economic Conflict," Foreign Affairs, Summer 1982, pp. 1059-1075.

Caves, Richard E., and Masu Uekusa. Industrial Organization in Japan. Washington, D.C.: The Brookings Institution, 1976.

Center for Science and Technology Policy. Current Issues in Export Controls of Technology: Background Information and Summary of Discussion. New York: New York University, 1981.

Commission of the European Communities. The Competitiveness of European Community Industry. Brussels: Commission of the European Communities, 1982.

Commission of the European Communities. Report of the Study Group on Industrial Policies in the Community: State Intervention and Structural Adjustment. Brussels: Commission of the European Communities, 1981.

Council of Economic Advisers. Economic Indicators, December 1982. Prepared for the Joint Economic Committee. Washington, D.C.: U.S. Government Printing Office, 1982.

Defense Science Board. An Analysis of Export Control of U.S. Technology—A DoD Perspective. Washington, D.C.: U.S. Government Printing Office, 1976.

de Saint Phalle, Thibaut. U.S. Productivity and Competitiveness in International Trade. Significant Issues Series, 2. Washington, D.C.: Center for Strategic and International Studies, 1980.

Diebold, William. Industrial Policy as an International Issue. 1980s project/Council on Foreign Relations, Inc. New York: McGraw-Hill Book Co., 1980.

Elston, C.D. "The Financing of Japanese Industry." Bank of England Quarterly Bulletin, December 1981, pp. 510-518.

Forester, Tom, ed. The Microelectronics Revolution: The Complete Guide to the New Technology and Its Impact on Society. Cambridge, Mass.: The MIT Press, 1981.

Gray, Paul E. "Technology Transfer at Issue: The Academic Viewpoint." IEEE Spectrum, May 1982, pp. 64-68.

Japan-United States Economic Relations Group. Report of the Japan-United States Economic Relations Group. Washington, D.C.: U.S. Government Printing Office, 1981.

Japan-United States Economic Relations Group. Supplemental Report of the Japan-United States Economic Relations Group. Washington, D.C.: U.S. Government Printing Office, 1981.

Kaiser, Karl, Winston Lord, Thierry de Montbrial, and David Watt. Western Security: What Has Changed? What Should be Done? New York: Council on Foreign Relations, Inc., 1981.

Lesson, Kenneth. Trade Issues in Telecommunications and Information: United States Trade in the Merchandise of Information Industries, 1. Washington, D.C.: U.S. Department of Commerce, 1981.

Maddox, John. "Science in West Germany." Nature, 297, May 1982, pp. 261-297.

Malmgren, Harald B. Changing Forms of World Competition and World Trade Rules. Significant Issues Series, 3. Washington, D.C.: Center for Strategic and International Affairs, 1981.

Martin, Jim. "Very-High-Speed Integrated Circuits—Into the Second Generation, Part 1: The Birth of a Program." Military Electronics/Countermeasures, December 1981, pp. 52-58, 71-73.

Martin, Jim. "Very-High-Speed Integrated Circuits—Into the Second Generation, Part 2: Entering Phase 1." Military Electronics/Countermeasures, January 1982, pp. 60-66.

Ministry of International Trade and Industry. The Vision of MITI Policies in 1980s. Tokyo: Ministry of International Trade and Industry, 1980.

National Academy of Engineering. Antitrust, Uncertainty, and Technological Innovation. Washington, D.C.: National Academy of Sciences, 1980.

National Academy of Engineering. The Process of Technological Innovation. A symposium sponsored by the National Academy of Sciences, April 24, 1968. Washington, D.C.: National Academy of Sciences, 1969.

National Academy of Sciences. Scientific Communication and National Security. Washington, D.C.: National Academy Press, 1982.

National Science Board. Science Indicators 1980. Washington, D.C.: U.S. Government Printing Office, 1981.

Organisation for Economic Co-operation and Development. Impacts of Microelectronics on Productivity and Employment. Proceedings of a special session of the Working Party on Information, Computer and Communications Policy, November 27-29, 1979. Paris: OECD, 1981.

Organisation for Economic Co-operation and Development. Industrial Policies for Promising Activities: A Review of Issues, Policies, and Experiences. Paris: OECD, 1981.

Organisation for Economic Co-operation and Development. Innovation Policy: Trends and Perspectives. Paris: OECD, 1982.

Organisation for Economic Co-operation and Development. International Implications of Government Support Policies for Promising Industrial Activities: Main Issues and Questions for Discussion. Paris: OECD, 1981.

Organisation for Economic Co-operation and Development. OECD Economic Outlook, December 1982. Paris: OECD, 1982.

Organisation for Economic Co-operation and Development. Science and Technology Policy for the 1980s. Paris: OECD, 1981.

Organisation for Economic Co-operation and Development. Technical Change and Economic Policy. Paris: OECD, 1980.

Organisation for Economic Co-operation and Development. Telecommunications Equipment Industry Study. Paris: OECD, 1981.

Reich, Robert B. "Making Industrial Policy." Foreign Affairs, Spring 1982, pp. 852-881.

Semiconductor Industry Association. The High Technology Trade Act of 1982. Cupertino, Calif.: SIA, 1982.

Semiconductor Industry Association. The International Microelectronics Challenge: The American Response by the Industry, the Universities and the Government. Cupertino, Calif.: SIA, 1981.

U.S. Congress, Senate. Reciprocal Trade and Investment Act of 1982 (S 2094). 97th Cong., 2nd sess., 10 April 1982.

U.S. Congress, Senate. Reciprocal Trade, Services and Investment Act of 1982 (S 2071). 97th Cong., 2nd sess., 4 February 1982.

U.S. Congress, Senate, Committee on Finance. Trade Agreements Act of 1979 (Report 96-249). 96th Cong., 1st sess., 17 July 1979.

U.S. Department of Commerce. Advisory Committee on Industrial Innovation, Final Report. Washington, D.C.: U.S. Department of Commerce, 1981.

U.S. Department of Commerce. Export Control of Technical Data. Washington, D.C.: U.S. Government Printing Office, 1982.

U.S. Department of Commerce. 1982 U.S. Industrial Outlook for 200 Industries with Projections for 1986. Washington, D.C.: U.S. Government Printing Office, 1982.

Vanderheim, Robert M. "VHSIC: Midterm Report on a Dynamic Circuit Program." Defense Electronics, February 1982, pp. 54-62.

Wolf, Nancy L., and David B. Hobbs. Trade Issues in Telecommunications and Information: The Role of the United States Government in the Financing of Export of Major Telecommunication and Information Products, 4. Washington, D.C.: U.S. Department of Commerce, 1981.

Wolgate, Robert. "Science in France." Nature, 296, March 1982, pp. 285-304.

Biographies of the Panel Members

HOWARD W. JOHNSON, Chairman, is Chairman of the Corporation of the Massachusetts Institute of Technology. An economist and an authority in management science, Mr. Johnson joined the faculty of MIT in 1955 and was appointed Dean of the Sloan School of Management in 1959. He became President of MIT in 1966 and served in that capacity until 1971, when he was appointed to his current position. Mr. Johnson serves as Director of several major companies and as Director or Trustee of several not-for-profit organizations.

HARVEY BROOKS is Benjamin Peirce Professor of Technology and Public Policy at Harvard University. Dr. Brooks, an educator and physicist, was formerly Dean of Engineering and Applied Physics at Harvard. From 1959 to 1964, he was a member of the President's Science Advisory Committee. Dr. Brooks is a member of the National Academy of Sciences and National Academy of Engineering and a senior member of the Institute of Medicine.

ROBERT A. CHARPIE is President of the Cabot Corporation. Before joining Cabot in 1969, Dr. Charpie was President of the Bell & Howell Company, Chicago. From 1961 to 1968, he served in numerous management positions with the Union Carbide Corporation. Dr. Charpie is a physicist and a member of the National Academy of Engineering.

RICHARD N. COOPER is Maurits C. Boas Professor of International Economics at Harvard University. From 1961 to 1963, Dr. Cooper was a Senior Staff Economist with the Council on Economic Advisers. He served as

Deputy Assistant Secretary of State for International Monetary Affairs from 1965 to 1966 and was Under Secretary of State for Economic Affairs from 1977 to 1981. Dr. Cooper is a member of the Council on Foreign Relations, and is the author of numerous articles on economic policy.

ROBERT A. FULLER is Corporate Vice President of Johnson & Johnson. Dr. Fuller, a biochemist, joined Johnson & Johnson (Canada) Ltd. in 1955 as a research chemist. He was named Director of Pharmaceutical Research in 1958 and Director of Research and Development in 1961. In 1966, Dr. Fuller was appointed Director of Research and Development for Johnson & Johnson Domestic Operating Company and became Vice Chairman of Johnson & Johnson International in 1975. He was appointed to his current position in 1981. Dr. Fuller is a Fellow of the American Institute of Chemists and a member of the Board of Directors of the Oak Ridge Associated Universities.

RALPH E. GOMORY is Vice President and Director of Research for the IBM Corporation. He is responsible for IBM's research laboratories in Yorktown Heights, N.Y.; San Jose Calif.; and Zurich, Switzerland. Dr. Gomory joined IBM in 1959 as a research mathematician at Yorktown Heights. In 1964 he was made an IBM Fellow, a rank conferred on a small number of scientists and engineers by IBM. In 1970 he was named Director of Research and was elected a Vice President in 1973. Dr. Gomory is a member of the National Academy of Sciences and National Academy of Engineering. He is a Chairman of the Advisory Council of the Department of Mathematics, Princeton University, and a member of the Advisory Council, School of Engineering, Stanford University.

NORMAN HACKERMAN is President of Rice University. Dr. Hackerman joined the faculty of the University of Texas, Austin, in 1944 and served as Chairman of the Chemistry Department from 1952 to 1961 and President from 1967 to 1970. Dr. Hackerman was Chairman of the National Science Board from 1974 to 1980. He is a member of the National Academy of Sciences and Defense Science Board.

N. BRUCE HANNAY is the retired Vice President for Research and Patents for Bell Laboratories. Trained

as a chemist, Dr. Hannay's career with Bell Labs spanned almost four decades. Dr. Hannay has served extensively in an advisory role to academia and the government. He currently is active in board and consulting activities with a number of corporations. Dr. Hannay is a member of the National Academy of Sciences and serves as Foreign Secretary of the National Academy of Engineering.

THEODORE M. HESBURGH has been President of the University of Notre Dame since 1952. Father Hesburgh has served on numerous commissions, including the Civil Rights Commission (1957-1972); the Carnegie Commission on the Future of Higher Education; and the Commission on an All-Volunteer Armed Force (1970). He is a Trustee of the Rockefeller Foundation, the Carnegie Foundation for the Advancement of Teaching, and the Woodrow Wilson National Fellowship Foundation and is Chairman with rank of Ambassador to the U.S. delegation, U.N. Conference on Science and Technology for Development. In 1964, he was awarded the Presidential Medal of Freedom.

WILLIAM R. HEWLETT is Chairman of the Executive Committee and co-founder of the Hewlett-Packard Company. From 1969-1977, he was President, Chief Executive Officer, and Director of Hewlett-Packard. Mr. Hewlett was a member of the President's Science Advisory Committee from 1966 to 1969 and is currently a Trustee and Chairman of the Carnegie Institution of Washington. He is a member of the National Academy of Sciences and National Academy of Engineering and holds patents on several electronic devices.

WILLIAM N. HUBBARD, JR., is President of The Upjohn Company. Dr. Hubbard received his M.D. degree in 1944 and served as Dean of the University of Michigan Medical School (1959-1970) and Professor of Internal Medicine (1964-1970) before joining The Upjohn Company in 1970. He was elected President of Upjohn in 1974. Dr. Hubbard is a member of numerous medical honorary societies and currently serves as a consultant to the National Science Board.

SHIRLEY M. HUFSTEDLER is a Partner with the law firm of Hufstedler Miller Carlson & Beardsley. Judge Hufstedler was admitted to the California bar in 1950

and served as Judge, Superior Court, Los Angeles from 1961-1966. In 1968, she was appointed Circuit Judge, U.S. Court of Appeals. In 1979, President Carter appointed her as Secretary of the Department of Education. Judge Hufstedler is a Trustee of the California Institute of Technology and the Aspen Institute for Humanistic Studies.

ROBERT S. INGERSOLL served as Deputy Chairman of the Board of Trustees for the University of Chicago from 1976 to 1981, following 4 years of service with the Department of State, first as U.S. Ambassador to Japan (1972 to 1973), then as Assistant Secretary for East Asian and Pacific Affairs (1974), and finally Deputy Secretary of State (1974 to 1976). Before his service in Japan, Mr. Ingersoll spent 33 years with the Borg-Warner Corporation. He was Chairman of the Board and Chief Executive Officer of Borg-Warner at the time of his appointment to Japan. In June of 1979, President Carter apointed Mr. Ingersoll Co-Chairman (for the United States) of the Japan-United States Economic Relations Group. Mr. Ingersoll is a member of the Council on Foreign Relations and is Chairman, Japan Society, Inc. (NYC).

CARL KAYSEN is the David W. Skinner Professor of Political Economy and Director of the Program in Science, Technology, & Society at the massachusetts Institute of Technology. Dr. Kaysen received his Ph.D. in economics in 1954 and was a Senior Fulbright research scholar at the London School of Economics from 1955 to 1956. He served as Deputy Assistant to President Kennedy for National Security from 1961 to 1963. Before joining the faculty at MIT, Dr. Kaysen was Director of the Institute for Advanced Study (1966-1976). Dr. Kaysen was also the Vice Chairman and Director of Research for the Sloan Commission on Government and Higher Education from 1977 to 1979.

ALLEN E. PUCKETT is Chairman of the Board and Chief Executive Officer of the Hughes Aircraft Company and has been in key management positions with the company for nearly three decades. Prior to joining Hughes, Dr. Puckett was a research associate in aerodynamics at the California Institute of Technology, Technical Consultant at the U.S. Army Ordnance Aberdeen Proving Ground, and Chief of the Wind Tunnel Section for the California Institute of Technology's Jet Propulsion

Laboratory. He has served on numerous industry and government committees, including the Defense Science Board and the Aerospace Industries Association. Dr. Puckett is a member of the National Academy of Sciences and National Academy of Engineering and is the author of several technical papers on high-speed aerodynamics.

DAVID V. RAGONE is President of the Case Western Reserve University. Dr. Ragone was a member of the faculty of the Department of Chemical and Metallurgical Engineering at the University of Michigan, Ann Arbor, from 1953 to 1962. He joined the General Atomic Division of General Dynamics as Chairman of the Metallurgy Department in 1962 and was appointed Assistant Director of the John J. Hopkins Laboratory for Pure and Applied Science in 1965. In 1972, Dr. Ragone returned to the University of Michigan to assume the position of Dean of the College of Engineering. Dr. Ragone is a member of numerous professional engineering societies.

JOHN S. REED is a Vice Chairman of Citibank. Mr. Reed joined Citibank in 1965 and was named Head of the Consumer Services Group in 1974. In 1980, he was appointed Senior Executive Vice President of Citicorp/Citibank and was in charge of the corporation's worldwide banking business with individuals. He was appointed to his present position in 1981. Mr. Reed is a member of the Corporation of the Massachusetts Institute of Technology.

WALTER A. ROSENBLITH is Institute Professor at the Massachusetts Institute of Technology. Professor Rosenblith joined the faculty of MIT in 1951 as an Associate Professor of Communications Biophysics and was appointed Professor in 1957 and Institute Professor in 1975. From 1971 to 1980, he served as Provost of MIT. Professor Rosenblith was a member of the President's Science Advisory Committee from 1961 to 1966. He is a member of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine and currently serves as the Foreign Secretary of the National Academy of Sciences.

ROBERT M. SOLOW is Institute Professor at the Massachusetts Institute of Technology. He joined the faculty of MIT in 1949 and was appointed Professor of

Economics in 1958 and Institute Professor in 1973. Dr. Solow was Senior Economist for the Council on Economic Advisers from 1961 to 1962 and a consultant from 1962 to 1968. He has been a member of several presidential commissions and is a member of the National Academy of Sciences.

JOHN E. STEINER is Vice President for Corporate Product Development for The Boeing Company. Since 1941, he has been active in the technology, development, design, testing, certification, product evaluation, and program management of virtually all Boeing airplanes. During his career with Boeing, Mr. Steiner has served in numerous management positions, including Design and Program Head of the initial 727 airplane program (1960-1964). He has represented the air transport industry through his many appointments and congressional testimonies in the areas of R&D, industrial productivity, safety, regulations, airline economics, and military procurement. Mr. Steiner is a member of the National Academy of Engineering and the Royal Aeronautical Society of Great Britain.

WILLIAM J. WEISZ is Vice Chairman of the Board and Chief Operating Officer for Motorola, Inc. Mr. Weisz joined Motorola in 1948 following receipt of a degree in electrical engineering. He was elected a Vice President in 1961, President in 1970, and in 1972 became Chief Operating Officer. In 1980, he was elected Vice Chairman of the Board, continuing as Chief Operating Officer. In 1981, Mr. Weisz was presented with the Electronics Industries Association's highest personal recognition, the Medal of Honor, for his outstanding contributions to the advancement of the electronics industry.

LEONARD WOODCOCK served as Ambassador to China from 1978 to 1981 and Chief of Mission with rank of Ambassador for the U.S. Liaison Office in Peking from 1977 to 1978. Mr. Woodcock was International Vice President of the United Auto Workers from 1955 to 1970. He was elected President of the UAW in 1970 and President Emeritus in 1977.

Commissioned Papers of the Panel

"Determinants of Market Share in International Semiconductor Markets," by M. Therese Flaherty, Assistant Professor, Graduate School of Business Administration, Harvard University

"Industrial Policies and International Competition in High Technology Industries," by Richard R. Nelson, Director, Institution for Social and Policy Studies, Yale University

"International Competition in High Tech Industries: A Framework for Discussion," by Carl Kaysen, David W. Skinner Professor of Political Economy and Director, Program in Science, Technology & Society, Massachusetts Institute of Technology

"Making U.S. Trade Policy: Government Organization, Politics, and Interest Groups—A Survey," by Harold P. Luks, International Trade Consultant

"Picking Winners: Who Wins?", by William Nordhaus, Professor of Economics, Yale University

"A Presentation to the Panel on Advanced Technology Competition," by Robert A. Swanson, President, Genentech, Inc.

"Technological Innovation and Industrial Competition," by William Perry, Partner, Hambrecht & Quist (Former Under Secretary for Research and Engineering, Department of Defense)

"U.S. Technological Leadership and Foreign Competition: De Te Fabula Narratur?", by Nathan Rosenberg, Professor of Economics, Stanford University

"U.S. Trade Policy and Industrial Policies: Separate Issues but Related Problems Regarding U.S. International Competitiveness," by Harold P. Luks, International Trade Consultant

(Photocopies of the commissioned papers of the Panel on Advanced Technology and the Industrialized Allies are available from the Office of International Affairs, National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, DC 20418.)

Presenters

NAOHIRO AMAYA, Special Adviser to the Japanese Minister of International Trade and Industry

JOHN COPELAND, Director, International Projects, Motorola, Inc.

CLAUD GINGRICH, Trade Counsel, Subcommittee on International Trade, Senate Finance Committee

MARVIN GOLDBERGER, President, California Institute of Technology

ROBERT D. HORMATS, Vice President for International Corporate Finance, Goldman, Sachs & Co. (Former Assistant Secretary of State for Economic and Business Affairs)

DAVID R. MACDONALD, Partner, Baker & McKenzie (Former Deputy U.S. Trade Representative)

HARALD B. MALMGREN, President, Malmgren, Inc.

ALAN Wm. WOLFF, Partner, Verner, Liipfert, Bernhard, and McPherson