National Science and Technology Strategies in a Global Context: Report of an International Symposium

Government-University-Industry Research Roundtable, National Academy of Sciences, National Academy of Engineering, Institute of Medicine

ISBN: 0-309-59198-8, 54 pages, 8.5 x 11, (1998)

National Science and Technology Strategies in a Global Context

Report of an International Symposium

GOVERNMENT-UNIVERSITY-INDUSTRY RESEARCH ROUNDTABLE

The purpose of this report is to contribute to the discussions of how various countries and regions are developing science and technology strategies in a changing global context. The views expressed are those of the symposium participants and do not represent official policy statements of the Government University-Industry Research Roundtable and its sponsoring organizations, the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

NATIONAL ACADEMY PRESS
Washington, D.C. 1998

Government-University-Industry Research Roundtable

The Research Roundtable, sponsored by the National Academies of Sciences and of Engineering and the Institute of Medicine, was created to foster strong American science through effective working relationships among government, universities, and industry. The Research Roundtable provides a unique forum for dialogue among top government, university, and industry leaders of the nation's science and technology enterprise. The Research Roundtable does not develop advice or recommendations on specific policies or programs within the range of responsibility of participating government officials.

This symposium was made possible with funding support from the National Science Foundation.

Library of Congress Catalog Number: 98-85555
International Standard Book Number: 0-309-06132-6

Printed in the United States of America

Acknowledgments

The Research Roundtable thanks Richard Celeste, William Spencer, Mauricio Fortes-Besprosvani, KunMo Chung, Daniel Vapnek, Michel Cuénod, Ewa Gajewska-Blaisdell, Terrence Heng, Graham Mitchell, Björn Wahlström, Chen Zhang-Liang, Mark Kryder, and Kenneth Flamm for their contributions to this symposium. The symposium was undertaken with the cooperation and help of the National Research Council's Office of International Affairs and Board on Science, Technology, and Economic Policy.

Special thanks to the National Science Foundation for its financial support of the symposium, this report, and related activities.

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Executive Summary

This report covers discussions at a symposium on the International Context for National Science and Technology Strategies. The meeting was held May 7, 1997 at the National Academy of Sciences in Washington, D.C., and was organized by the Government-University-Industry Research Roundtable (GUIRR). The symposium featured presentations by experts representing academic, industry, and government viewpoints, from countries including China, Finland, France, Korea, Mexico, Poland, and the United States. The purpose of the activity was to explore how various countries and regions are developing science and technology strategies in the unfolding context of global economic integration and privatization, as well as mobility of people and information. The implications for future international cooperation were considered in this modern framework. This executive summary covers the key issues explored in the presentations and discussions.

A number of countries and regions represented at the symposium reported that their science and technology strategies are moving in similar directions. Prominent themes raised by several participants included:

- a heightened focus on harnessing science and technology for improved economic performance;
- recognition that the private sector plays the leading role in supporting and performing research and development, but that an effective national strategy requires cooperation and synergy among industry, government, and academy;
- a growing imperative to seek national benefits from global market trends, particularly the activities of multinational corporations;
- an increasing need on the part of research organizations and national science and technology establishments to evaluate research investments in concrete terms, and to improve communications about these evaluations with "customers," including political leaders and the broader public.

A number of participants representing research organizations and policy making bodies reported that they are developing new approaches to boost performance, such as:

- the systematic use of evaluation as a tool in the strategic planning of research;
- new incentives to improve the flow of information and human resources among the government, industry, and university sectors;
- revamping organizations and funding mechanisms to encourage high-quality research.

Several of the presentations and much of the open discussion focused on the new challenges facing nations and research organizations in this changing environment. These challenges were mentioned by several participants:

- reconciling the imperative for increased collaboration with the differing time horizons and goals of partner organizations;
- defining a government role that advances the interests of domestic constituencies while recognizing the global nature of markets and technology development.

Several presentations highlighted the trend of growing international collaboration in science and technology at the private sector level. Other participants asserted that additional work will be needed to learn from positive examples and fulfill the potential for global cooperation in advancing fundamental knowledge. Individual participants suggested a range of possible next steps, including:

- developing a common view of fundamental research as a global good, and organizing mechanisms to ensure adequate support;
- building institutions at the national and international levels that can effectively develop and implement new collaborative initiatives;
- establishing mechanisms for sharing experience and perspective internationally on issues of common concern, such as appropriate evaluation techniques and ways to improve communication between scientists, engineers, and political leaders.

Introduction and Context

Nations and regions are expending ever greater efforts to harness science and technology in pursuit of national goals. At the same time, cross-border linkages between multinational corporations, universities, and other private sector organizations are expanding rapidly, in pursuit of goals that may diverge from those of national governments. Expanding international flows of information and people suggest an emerging global science and technology enterprise. Yet science and technology cooperation at the level of joint programs or agreements between governments has often been difficult to forge.

This global context will increasingly affect U.S. domestic science and technology, requiring new approaches to international cooperation. Currently, U.S. science and technology policy debate is focused on building a post-Cold War rationale for continued strong federal support of research and development (R&D). The traditional foundation of U.S. science and technology strategy, which focused on national security and other clearly defined public missions, is being reexamined and debated. All sectors of the U.S. research enterprise—government, universities, and industry—are being challenged to ensure that research investments are linked to concrete national benefits.

Other nations are facing similar questions in different contexts. Japan, Korea, and other Asian nations have set policies calling for increases in research funding, based on the rationale that a strong research base will be necessary to successfully compete in high-technology industries of the future. At the same time, these policies may face similar challenges from domestic multinational corporations whose transnational research and development goals sometimes diverge from their traditional correspondence with national goals.

Major European countries appear to be retrenching in terms of public R&D funding, while funding prospects have recently improved in the United States due to a brighter budget outlook. Meanwhile, the science and technology programs of the European Union represent a bold attempt at explicitly planned and organized multinational collaboration.

Developing countries are well aware of the role science and technology play in sustaining economic development, but struggle to develop necessary domestic capabilities (human resources and infrastructure) in niches where they can be competitive. More countries are turning away from strategies aimed at achieving economic and technological self-sufficiency, and instead are seeking to strengthen domestic capabilities through links with international partners, most notably multinational corporations.

Given these trends, what can the United States and other nations learn from each other as they seek to improve their capabilities in research and innovation?

How can U.S. institutions tap into growing experiences and capabilities around the world? Could new approaches to international collaboration, both at the governmental and private sector levels, contribute to better leveraging the efforts of individual nations to address global problems? What are the ramifications for national science and technology strategies of an increasingly global research and development enterprise?

The Government-University-Industry Research Roundtable (GUIRR) organized an international symposium on National Science and Technology Strategies in a Global Context to explore these issues. The symposium, which was held May 7, 1997 in Washington, D.C., brought together a wide range of U.S. and international expertise (see Appendix A for agenda and roster). GUIRR Chair Richard Celeste presided at the session, just prior to his appointment as U.S. Ambassador to India.

This report was prepared as a record of the discussions and background materials. The chapters on National Science and Technology Strategies (Overview), Examples of "Effective Practice" in Research Support and Performance, Implementing and Evaluating Science and Technology Strategies, and Issues and New Approaches to International Cooperation reflect the structure of the symposium. The draft was reviewed by workshop participants and their comments were incorporated. In addition to the symposium, several preparatory issues discussions were held with U.S. government officials, industry, and private sector experts, and officials from a number of foreign embassies. An address by Japan's former Minister of State for Science and Technology, Hidenao Nakagawa, was held August 8, 1996 under the auspices of this activity (see Appendix B for a timeline of related activities). The symposium and related events reflect GUIRR's continued interest in international issues affecting the future of the U.S. research and innovation enterprise.[1]

[1] GUIRR, *Future National Research Policies Within the Industrialized Nations* (Washington, D.C.: National Academy Press, 1992); and GUIRR, *Formulating U.S. Research Policies Within an International Context: A Discussion Paper,* January 1994.

Overview

SUMMARY POINTS

• From the presentations made at the symposium, it appears that a number of countries and regions are moving in similar directions with regard to national science and technology strategies. Harnessing science and technology for economic growth is often a key priority. At the same time, maintaining a long-term view for government investment priorities can be difficult, due to fiscal constraints. Players in the science and technology (S&T) system are challenged to do more with less, and to demonstrate the concrete benefits of investment in research and development (R&D). Developing effective mechanisms for cross-sectoral cooperation in R&D, and for linking the S&T community with aspirations of the public and the political leadership, are pressing tasks in many countries.

• Nations and regions are converging from different directions in terms of defining public and private roles, and in setting appropriate time horizons. In Korea, for example, the government has played an important supportive role in providing technical infrastructure for industry. As Korean industry has become more globally competitive, the government role is shifting toward ensuring sufficient funding of applied R&D with longer time horizons, particularly in partnership with industry. In Mexico, national leaders recognize the need for expanded government-industry-university cooperation in order to strengthen the national S&T infrastructure needed for Mexican industry to compete in global markets.

• Participants in the workshop recognized that international cooperation is a significant element in their various national strategies, but its importance and role differ according to the country. In countries that have pursued a focused and coherent national S&T strategy, such as Finland and Korea, developing the international component of that strategy appears to be straightforward. For some other countries struggling with fundamental domestic issues and debates, such as the United States and Mexico, there appears to be less policy focus on international cooperation, even as individual companies and other institutions increase their international linkages.

CONTEXT

For the purpose of this activity, a "national science and technology strategy" may be defined as the goals, time horizons, performers, funders, and funding criteria that characterize a nation's science and technology investment portfolio. The roles of government, industry, and universities, and their relationships, are a particular focus.

An examination of international trends in science and technology policies and performance reveals several important developments.[2] One long-term trend is a decline in the U.S. share of world R&D spending to an estimated 32.3 percent in 1994, down from about half the world total in the early 1970s. This decline in U.S. dominance corresponds with the growth of science and technology capability outside of the United States. A second long-term global trend that has important implications for science and technology is the movement toward more open, market-oriented economic policies.

One hypothesis that was tested and discussed at the conference is the significant movement toward convergence in national science and technology strategies. The elements of this emerging modal strategy might include reliance on the private sector for 60–75 percent of total R&D spending, a public spending focus on science and technology infrastructure needed for improved productivity and economic growth, and emphasis on building more effective collaboration between the government, university, and industry sectors.

Countries are approaching this model from different directions.[3] For countries such as the United States and France, where the national government has traditionally provided about half or more of R&D funding, this has involved constraints on overall government spending and a relative decline in national security-related spending. For Korea and a number of the emerging Asian economics, where R&D has been highly private-sector driven, this has involved increased public sector funding and focus on improving key elements of the infrastructure, such as graduate science and engineering education. Improved inter-sectoral linkages and learning from foreign approaches are being pursued by many countries. A final global trend is the growing international flow of R&D resources. Education and training of foreign science and engineering students in the United States is a long-standing trend. In addition, multinational corporations are playing an expanding role in the globalization of science and technology through overseas R&D labs and related activities.

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Mexico can be characterized as an industrializing country whose companies are not generally technology-based. We have experienced adjustment pains in moving toward a more open market system. Recent milestones include implementation

[2] See Department of Commerce, Office of Technology Policy, *International Plans, Policies & Investments in Science and Technology,* April 1997; Glenn J. McLoughlin, *International Science and Technology: Issues for U.S. Policymakers,* Congressional Research Service, September 1994; National Science Foundation, *Asia's New High-Tech Competitors* (Arlington, Va.: National Science Foundation, 1995); and United Nations Educational, Scientific, and Cultural Organization, *World Science Report 1996* (Paris: UNESCO, 1996).

[3] For a "classic" typology of various national approaches to technology policy, see Henry Ergas, "Does Technology Policy Matter?" in Bruce R. Guile and Harvey Brooks, eds., *Technology and Global Industry: Companies and Nations in the World Economy* (Washington, D.C.: National Academy Press, 1987).

of the North American Free Trade Agreement (NAFTA) in 1993, and entering the Organization for Economic Cooperation and Development (OECD) in 1994.

Several elements of the social and policy environment in Mexico have a major impact on science and technology strategies. First, scientific and technological capabilities in the public and private sectors are heavily centralized geographically around Mexico City. Second, there is a strong contrast between the awareness of a small number of policy makers and middle class professionals concerning the importance of science and technology, and that of the large rural population living under marginal conditions. Third, domestic industry is dominated by small business, most of which is not S&T-based. Finally, Mexico's demographic distribution has a large fraction of very young people demanding education and new jobs. Table 2-1 shows a comparison of Mexico and the United States along some important dimensions of S&T policy.

The Players: Institutions and Capabilities

Scientific research in Mexico is a very young endeavor. The first research centers were created during the 1930s in most disciplines. Institutionalized scientific activity following international standards was only consolidated in the 1950s when the National University (UNAM) moved to its new campus south of Mexico City. The Metropolitan University and the Research Center for Advanced Studies were established during the 1960s. Along with the National University, they account for over half of the basic research performed in Mexico today. Large universities account for about 19 percent of government investment in R&D.

TABLE 2-1 Unequal Partners

Countries Indicators	USA	Mexico	Ratio
Population	260,000,000	90,000,000	2.9
R&D personnel	5,650,000	26,932	210
B.A., B.Sc. degrees	1,165,178	183,662	6.3
Master's degrees	369,585	7,181	51.5
Ph.D. degrees	42,132	488	86.3
Professional degrees	75,387	5,963	12.6
Mean professor salary (US$)	71,290	34,734	2
S&T investment as % of GDP	2.69	0.38	7.1
S&T investment per capita (US$)	624	3	208
Research personnel per 100 jobs	5.6	0.2	28
Private industry investment in R&D as % of GDP	1.81	0.7	2.6
Patents in Mexico (1981–1990)	957	132	7.25

Sources: Almanac of The Chronicle of Higher Education, 1995; Conacyt Indicators, 1995; Science and Technology Data Book 1992, NSF; Basic Indicators in HIgher Education, SEP, ANUIES, 1993; Susa U. Raymond, New York Academy of Sciences, 1996; Reviews of National S&T Policy, OECD, 1994; National Financiera, 1992.

Government

In 1971, the National Council for Science and Technology (CONACYT) was created as a federal agency under the Ministry of Education charged with the establishment of national science S&T policies. Over the years, CONACYT has provided more than 90,000 scholarships for graduate studies in Mexico and abroad, and also runs a grant program for basic science projects.

A great deal of Mexico's R&D is performed at government facilities administered by CONACYT and other ministries. The CONACYT structure consists of 27 research centers in the natural sciences, social sciences and humanities, and technology development and services. Altogether, they absorb 28 percent of the federal investment in S&T. They are tasked with allocating resources based on objective criteria, increasing the quality of basic research, and encouraging innovation by promoting links with industry.

Federal investment in R&D activities is currently 0.38 percent of the GDP and the present administration has committed itself to reach 0.7 percent by the year 2000.

Industry

Historically, industry has enjoyed a privileged position as industrial development was defined by an import-substitution model. Mexican industry was a closed system, protected by strict import laws and trade barriers. A number of the largest enterprises have been nationally owned. Although this system encouraged the growth of domestic-owned industry, incentives to increase efficiency or innovate were not strong. With little need to exploit proprietary technologies, Mexican industry was slow to develop R&D organizations. Any new technological process required by local industry was acquired from foreign companies, often embedded in imported machinery and equipment. Multinational subsidiaries consulted their home offices for technological assistance.

The current industrial structure of Mexico is well described by a recent report of the OECD.[4] On the one hand, there are a limited number of big companies operating in the mining, steel, cement, glass, petrochemicals, and metallurgical industry sectors; some are subsidiaries of big foreign corporations. On the other hand, there are many small companies with local markets. In between, there are some medium-sized enterprises and the so-called *maquiladoras,* wholly owned manufacturing subsidiaries of U.S. and other international companies, which are mainly located in the border regions.

Mexico began opening its markets to global competition during the 1980s, a process accelerated by NAFTA and entry into OECD. Domestic industry is now exposed to competition both at home and abroad. However, only a dozen or so large companies have their own R&D organizations. Mexican industry now faces

[4] Organization for Economic Cooperation and Development, *Reviews of National Science and Technology Policy* (Paris: OECD, 1994), p. 165.

the urgent challenge of developing innovative capabilities, producing highly trained personnel, increasing investment and developing synergistic linkages with the academic centers.

Up to now, the Ministry of Trade and Industry has not been a major player in funding S&T activities. There is little coordination between CONACYT programs and this Ministry. The creation of a strong independent technology agency, such as the Science and Technology Agency in Japan, might work to fill this gap and build effective links between academic science and industry. This seems to be a fertile time to undertake new initiatives due to the recent privatization of state monopolies and the inflow of foreign investment. A new law on intellectual property was established in 1991, and the creation of the Mexican Institute of Industrial Property has favored imports, including technology. As a result, more intense technology-based competition is already evident in industries like telecommunications.

Other Players in S&T Policy

In 1989, the Presidential Science Advisory Council was created. Its members are the recipients of the National Science and Humanities Award. The Council is charged with producing policy recommendations to the President. Although the number of permanent members (more than 60) appears too large for effective action and coordination, in 1996 the Council signed an agreement with the Mexican Academy of Sciences and CONACYT to undertake several projects, including production of an inventory of advanced, applied science laboratories and personnel.

The Mexican Academy of Sciences has had a long tradition in conducting self-defined, independent studies in S&T policy. The Academy has collaborated closely with the National Academy of Sciences of the United States in recent years on complex, regional and global problems that require a multi-disciplinary approach. In 1995, the Academy published reports on the water supply from the Mexico City Metropolitan Area aquifers, the industrial requirements for technological modernization, and challenges and opportunities of science in Mexico.

Recent Trends in Mexico's National S&T Strategy

During the last 15 years, several initiatives have been pursued to promote Mexican S&T. However, the country still faces challenges in educating the public on the importance of S&T and, more broadly, of knowledge itself as the most important source of wealth in the coming years.

National Plan for Development for Science and Technology (1995–2000)

In developing this plan, the government recognized that it faces important problems. These include the small scale of graduate programs, the relatively low proportion of graduate students (1.9 percent) enrolled in natural sciences programs, the relatively low proportion of faculty with graduate degrees, the concentration of basic and applied research in Mexico City (more than 55 percent of scientists and engineers work in the metropolitan area) and the lack of strong linkages between universities and industry. In addition, government agencies in charge of R&D activities are not well coordinated.

The five-year plan has set some general policies to alleviate these problems. In addition to steps aimed at enhancing support for advanced research and attracting young people to scientific careers, this plan devotes considerable attention to international collaboration. Since a large number of Mexican scientists were trained abroad, there are strong personal links with foreign researchers and institutions. Indeed, access to large facilities in the United States and Europe has helped the Mexican S&T community to stay in close contact with current international problems and quality standards. The plan, therefore, aims at catalyzing these collaborations by creating new multinational programs for research. One positive goal is to promote international meetings that would focus on how to articulate university-industry links.

Setting Priorities

One of the main instruments that CONACYT and other federal funding agencies have put into effect is the financing of research projects through grants approved by peer review committees. Since 1989, CONACYT established that there should be no priorities in scientific or technological areas regarding research grant allotment. The main criterion for approval should be the quality of the proposal as judged by the committees, the rationale being that since the R&D community is still very small, Mexico needs top grade scientific and technological research work in all fields of knowledge. This decision was aimed at consolidating the strong, productive research groups in the country. Furthermore, the *Support Program for Science in Mexico* was also established with a loan from the World Bank of U.S. $500 million in 1993. Its main objectives are the replacement of obsolete equipment in recognized research laboratories and the enlisting of former Soviet Union scientists and engineers in research centers in Mexico.

These initiatives have had a positive impact, but also contribute to a lack of focus on several problems that require urgent attention, such as the need to place a higher priority on areas of knowledge that are weakly developed in the country such as computer science, communication technologies, and agriculture. Also, there are no explicit programs to advance entrepreneurial initiatives within the public higher education system. In fact, academic policies and SNI (see below) regulations act to discourage scientists and engineers from working with industry.

Human Resources

On the other hand, CONACYT and the public higher education system are doing a great deal in the area of S&T capacity building, particularly in human resources. Mexico is committed to doubling the R&D work force by the year 2000 (from the base level in 1993). There are more than 24,000 students receiving graduate scholarships both in Mexico and abroad. Important steps are being made to assess the quality of graduate departments. At UNAM, graduate teaching and research in science and engineering was reviewed by mixed panels of experts from the Mexican Academy of Sciences and the U.S. National Academy of Sciences.

The National System of Researchers (SNI) is an imaginative program created in 1984. It was originally aimed at awarding fellowships to productive, full-time members of the S&T community, including social sciences and humanities. However, the economic crisis of the 1980s had a negative impact on faculty income and SNI became, in fact, a significant portion of the scientist's salary. Researchers qualify for the fellowships on the basis of scientific productivity and their training of students. The amount they receive is nontaxable, indexed to multiples of official minimum salaries, and graded according to level. To stimulate the decentralization of research activities, compensation at each level is higher for active scholars working outside Mexico City. SNI applications are evaluated by peer review committees whose members are distinguished Mexican scientists.

A useful byproduct of SNI is that it provides extremely valuable information on the state of science in Mexico. The information provided by individuals has produced a database that helps in monitoring the situation of Mexican research. There are currently 5,969 researchers in SNI and it is estimated that the country has around 22,625 scientists and researchers hired by universities, research institutions and industry.

In another example, over 20 years ago UNAM initiated a long-term project aimed at opening new research laboratories in different states. The most important projects were the acquisition of two research oceanographic vessels, one each for the Atlantic and Pacific, and the construction of the two-meter telescope in San Pedro Mártir, Baja California. This policy has been quite successful due not only to the benefits of bringing superior scientists and facilities to an otherwise average provincial campus, but because of closer contacts forged with local industry. For example, the technicians and engineers involved in the construction of the telescope's automatic control created a sophisticated instrumentation group that has grown and matured. Many technicians, seeking better salaries, have joined industrial firms throughout Mexico in what seems to be a crucial—though indirect—link between universities and private industry. An important future task will be to build on the insights of this model.

Lessons and Future Tasks

In conclusion, it is fair to say that in Mexico, the three legs of the government-university-industry triangle are evolving in positive directions and with more solid foundations than in the past. The main task for the future will be to make these legs more mutually reinforcing. Government needs to establish better coordination among its agencies and increase its investment in S&T, academic science needs to become more entrepreneurial and responsive to market demands, and industry has to face in a realistic way the need to acquire new knowledge to promote technological innovation. In addition, there is one obstacle that has to be overcome as a condition *sine qua non.* A healthy policy cannot be formulated without greater recognition of the long-term view.

Mexican S&T policies have traditionally taken the form of short-term projects during successive federal administrations. Decision makers in federal agencies want to obtain tangible results from their planning efforts before the expiration of their terms. Long-term projects are viewed as risky since there is no pledge that the next administration will support such programs and society in Mexico does not share a culture that would allow heavy public investment with acceptance that returns will only be seen over a 20- or 30-year period. Public universities are an exception: their autonomy to administer themselves allows them to plan for longer periods. This fortunate situation, combined with a closer collaboration or partnership with industry, represents Mexico's best hope for sustainable economic progress in the future.

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Environment for Korea's S&T Strategy

As in other countries, Korean S&T policy has been influenced by economic, social, and political factors. A strong national consensus that economic development and industrialization would be the primary national goal has been the major reason for this coherence, although it has also meant that S&T policy is subordinate to economic policy. Korean S&T policy has gone through several phases over the past 35 years in response to changes in national development objectives. Per capita income has increased from $87 in 1962 to $10,076 in 1995, while real gross national product (GNP) has increased at an annual rate of about 9 percent per year over that time period. Korea is now the eleventh largest economy in the world, and is among the top five countries in the global production of electronics, semiconductors, ships, petrochemicals, and textiles. Continuous changes in industrial structure have made this impressive performance possible, and science and technology have made important contributions.

As rapid economic growth was achieved in the 1960s, policy makers recognized S&T as an essential element and took steps to build infrastructure. Through the 1960s and 1970s, the main focus was on building the technological capability needed to succeed in export oriented industries such as chemicals, heavy machinery, and shipbuilding. Since most of this technology was available from abroad, policies were aimed at providing the foundations for adopting and utilizing foreign technology. In the 1980s, the need to encourage domestic R&D activities was recognized, and several new national programs were established.

Korea's spending on R&D as a percentage of GNP increased from 0.81 percent in 1981 to 2.71 percent in 1995, the latter being a level comparable to other OECD members. This increase is particularly remarkable in light of the rapid growth in GNP occurring at the same time. Industry is mainly responsible for the increase. Korean industry supports 81 percent of the overall R&D effort. The number of researchers has also expanded dramatically over the past decade and a half. Korea has established several new institutions for advanced science and engineering education, but about two-fifths of Korean science and engineering doc torates are still earned abroad, primarily in the United States. Despite the rapid increase in R&D activity, the large deficit in technology trade (payments for licenses and royalties) shows that Korea still depends a great deal of foreign technology. The scope of basic research is still modest.

Institutions and Players

The Ministry of Science and Technology (MOST) was established in 1967 and has responsibility for formulating S&T policies and basic plans as part of a five-year economic and social development planning cycle. MOST is also responsible for coordinating the activities of the other R&D supporting and performing agencies. MOST does technology forecasting, supports research at government research institutes, universities and industry, and is responsible for "big science" and nuclear technology.

The Presidential Council on Science and Technology (PCST) and the National Science and Technology Council (NSTC) are two mechanisms utilized in the coordination process. PCST was created in 1991 to advise the president on developing blueprints for basic S&T policy, on creating networks and institutions to promote S&T, and on formulating national policies to utilize S&T to promote competitiveness. NSTC was created in 1973 as a cabinet-level body that monitors agency S&T plans and coordinates their implementation. NSTC currently has 18 members, including the prime minister, the minister of the Ministry of Finance and Economy (MOFE), officials from S&T agencies, and four private sector experts. MOFE plays a key role in the S&T budgeting process.

S&T policy in Korea operates under several laws dealing with promotion of various aspects of R&D. One notable recent law is the Special Law for Science and Technology, enacted in March 1997, which calls for the Korean government to push for a total R&D funding level of 5 percent of GNP by the early twenty-first century.

The Korean Advanced Institute of Science and Technology (KAIST) is the only university not controlled by the Ministry of Education. Established in 1971 as the Korean Advanced Institute of Science, the institute was established to fill the increased demand for scientists and engineers with advanced training. As of 1994, almost 2,500 students were enrolled in the bachelor's program, over 1,200 in the master's program, and almost 2,000 in the Ph.D. program. In general, Korean universities face challenges in maintaining top-flight research due to tight funding. The Engineering Research Center/Scientific Research Center (ERC/SRC) program was established to promote research in universities. There are now 21 ERCs and 17 SRCs.

The Korean Institute of Science and Technology (KIST) is a government institute set up in 1966 to meet industrial needs across the broad spectrum of applied technologies. KIST conducts feasibility studies, provides technical services for small-and medium-sized firms, and performs pilot-plant scale engineering studies. Now that Korean industry has become much stronger technologically, the role of government institutes is being reappraised. Rather than basing funding on lump sum budgets, institutes are moving to a project-based system. Eventually, it is expected that funding will move to a competitive grant system.

National Programs and Public-Private Cooperation

If Korea's S&T strategies of the 1960s and 1970s were mainly expressed in the formation of new institutions such as MOST, KIST and KAIST, strategies of the 1980s and 1990s are mainly expressed through a series of national programs. National R&D programs are public-private partnerships aimed at catalyzing industrial restructuring and movement into higher value-added industries through domestic innovation.

The National R&D program was established by MOST in 1982. The Highly Advanced National (HAN) Project was implemented in 1992 as an inter-ministerial program and a significant scaling up of national R&D efforts. The goal is to strengthen capabilities in strategic industrial technologies, both specific product technologies in areas where Korea can potentially capture competitive advantage in global markets, and fundamental core technologies necessary for the broader economy and improving the quality of life.

The government also has a number of tax and other incentives for private R&D investment. As illustrated by the shift in the share of Korean R&D financed by the private sector, from 30 percent in the early 1980s to about 80 percent today, industry plays the leading role in transforming science and technology into economic growth. Industrial R&D is highly concentrated, with the top five companies accounting for about 35 percent of the total.

In industries such as nuclear power generation and microelectronics, Korean industry has been very successful in pursuing a "middle technology" strategy. In these industries, a product niche was identified in which the technical requirements were appropriate for Korea (sophisticated but proven technologies where the fundamentals could be acquired from abroad and quickly mastered) and where Korean firms could quickly develop products that delivered value to a significant range of global customers. The leading position of Korean firms in the semiconductor memory business established in the late 1980s has led to additional opportunities in flat panel displays, which have a similar technological foundation. In nuclear power generation, Korea's focus on lower-cost reactors has opened market opportunities in a wide range of developing countries.

Future Tasks

The focus of Korea's national S&T strategy in recent years has been to build on its recent successes and to lay the foundations for the capability needed to compete in the growth industries of the next century. Rapid growth in R&D spending, new programs, and institutions for advanced research and education, and efforts to forge new international linkages have been prominent.

It will be some time before most of these aggressive, long-term oriented initiatives can be accurately appraised. In the meantime, Korea's efforts to play a greater role in international S&T are worth noting. One example is Korea's active participation and leadership in the S&T activities organized under APEC. As in Korea's overall S&T strategy, the private sector is playing a leading role in the globalization process. Leading Korean companies now have extensive manufacturing infrastructures, particularly in Southeast Asia and North America, but increasingly in China as well.

GRAHAM MITCHELL, DEPARTMENT OF COMMERCE, UNITED STATES

The Global Environment for S&T Strategies

To begin with the big picture, it is clear that the policy environment for formulating national strategies and programs in science and technology was dominated by considerations related to the Cold War through the 1980s and even into the 1990s. Since that time, there has been a remarkable concentration of focus on economic growth as a policy priority, both in the United States and in a number of other countries around the world. Economic growth is a focus not only because increasing the standard of living is good in itself, but also because a strong economy gives countries the maximum flexibility to pursue an array of both foreign and domestic policy options.

A second important trend is that the global economic and competitive environment has changed enormously over the post-World War II period. During the 1950s and 1960s, U.S. companies were dominant and therefore often had an advantage in benefiting from new technology. During the 1970s and 1980s observers came to describe the competitive situation as a horse race among companies based in the developed "triad" of the United States, Europe, and Japan. Particularly at the end of the 1980s, Japan appeared to be in the lead in this race, with Europe second and the United States starting to trail badly. Today, this horse race looks more like a steeplechase with big jumps in it. In the 1990s the order of the horses has changed somewhat with the United States doing better in a whole series of industries. In addition, other "horses" have joined the race, such as Korea and Southeast Asia.

From the point of view of the U.S. government, we have traditionally focused research and development funding on defense and space, energy, and health, which are basic missions of the government. While funding basic research in these areas leads eventually to commercialization of new technology, it is a relatively slow, often haphazard process. What happened in the 1970s and 1980s is that other countries began to develop the infrastructure to absorb and utilize our basic research as well. Increasingly, it was no longer sufficient to do basic research in the United States in order to get a unique national advantage.

Also during this period other nations developed the capacity to rapidly commercialize technology and survive in a climate characterized by shorter life cycles for technology. This led to a policy climate in the United States favorable to efforts aimed at facilitating rapid commercialization of new technology. The differences in the specific rationales for programs like the Advanced Technology Program or the Technology Reinvestment Project are not as important as the common motive of bringing people together to speed up the commercialization of research.

Trends in National Strategies

The statement of U.S. technology policy entitled *Technology in the National Interest,* which my office has worked on with other parts of the government, sets this context very well. Countries around the world are focused on economic growth, advances in technology are the single most important factor in creating growth, and capital will seek the best returns globally. The United States wants to attract the engines of economic growth to locate here and also promote growth in domestic industries by investing in assets that will stay here. These assets include trained and educated people, infrastructure, and a positive business climate that encourages people to develop businesses and to innovate in the United States.

We are all pleased about this policy statement, but when we look around we see that this is the same policy almost every other country in the world has. There has been an almost complete convergence. To illustrate, look at the number of countries that are in the World Trade Organization (WTO) and more importantly, look at the list of countries who are applying for membership. It includes all the former Communist bloc countries of Eastern Europe and others in the developing world. This is a real victory for the Western capitalist system.

The difficulty is that the position of the United States has changed. In the early 1950s we produced 40 percent of the world's gross domestic product (GDP). By 1970 the U.S. share had declined to less than one quarter of the world's GDP, about where it is today. The shift is even more dramatic with regard to R&D. In the 1950s and 1960s, the United States performed two to three times as much R&D as the rest of the world put together. Today, the rest of the world is doing about twice as much R&D as we are. This makes a dramatic difference when we contemplate policies that pretend to serve the U.S. interests by restricting the flow of ideas. This may work when we have all the ideas, but definitely will not when the rest of the world has good ideas too.

Most importantly, what we believe is happening, in a fairly crude simplification, is that as GDP per capita rises, countries have to spend a larger share of GDP on R&D to create value added jobs. For example, if average income is only $5,000 per year, creating new jobs does not require much new technology. If, however, you want to create jobs paying $30,000 or $25,000 a year then you have to invent something significant. What we are probably seeing is a progression of countries with growing per capita GDP that are expanding R&D. The technology policies and the programs countries adopt reflect to a large extent where they are in this process.

There are some anomalies. For example, the Republic of Korea is clearly spending what would appear to be a significantly larger portion of GDP on R&D than other countries with similar GDP per capita. Although some of that is military, I believe that it represents a deliberate attempt to move Korea dramatically and dynamically up the ladder. This may represent a change in the rules. One possible worry for the United States is that we are not spending a high proportion of GDP on R&D compared with other countries with similar GDP per capita, and we look even worse when we take out military R&D.

So what does this mean for countries? To a first approximation, it appears that as countries move up this ladder they move through a first phase in which they develop the infrastructure that allows multinationals to operate. In the next phase, domestic policies shift toward helping domestic industries acquire technology. We have seen this in Korea for some time; we see it now in China and many other countries moving up the ladder.

But what happens, we think, is that by the time a country reaches a very high GDP per capita, say $15,000–20,000 dollars per year, it cannot compete as a low-cost manufacturing source with lower income countries. It really needs to invent something different. This is the point where you see a full fledged set of research and development initiatives and infrastructure, such as advanced research universities. And from my recent visit it appears that Korea is making a transition to this third phase well ahead of where it might have been expected to from its $10,000–11,000 GDP per capita. This includes efforts to bring Korean scientists and engineers trained in America back to Korea.

Partnerships and the Government Role

What we have seen in the United States from about 1980 is the emergence of a whole series of partnerships, including legislation to allow research and technology results developed in the federal government to flow to universities and ultimately to industry. The government began to realize it could take steps to make it easier for ideas to flow, in areas like antitrust exemption, funding collaborative research, and so forth.

As a result, we are seeing a paradigm shift. It used to be that government was primarily a customer for research, and effectiveness was evaluated by whether the agency funding the work achieved its mission. Industry's role was to act as a contractor to that end. We are increasingly observing a new paradigm emerge in which more attention is being paid to whether we create jobs in the civilian sector, whether anybody made any money, and whether we actually moved America forward along our mission for economic growth. Just as the role of the Department of Agriculture is not to make the agency rich but to help farmers, a similar attitude is spreading into the Department of Commerce. By interviewing the customers for these programs we learn that they work better precisely to the extent that the government listens to what industry says. The major message is that the government role should be to facilitate information transfer and links between universities, the entrepreneurial sector and larger enterprises.

The historical trends in public and private R&D spending are not as widely appreciated as they should be. U.S. government spending on R&D peaked at about 2.2 percent of GDP in 1966, due mostly to defense and the space race. Since that time it has declined almost continuously, with a small uptick during the build up in defense spending by the Reagan Administration. But over the last decade government R&D as percentage of GDP has fallen uniformly. Intriguingly, the private sector share has grown more or less continuously, so that now it stands at about 1.5 percent of the GDP compared with the government's 1 percent. So industry has become the dominant source.

Also, R&D as a percentage of sales by U.S. companies started shooting up in the 1980s from its historic level of just under two percent. This is very significant. What has happened is the increase is concentrated in two areas: information/communications/electronics, and pharmaceuticals/biotechnology. What we have is a transformation in the industrial research base of the United States that seems to have gone relatively unnoticed. Our models of the industrial research process which are based on the chemical and manufacturing industries represent an increasingly small part of what is going on. This shift has enormous implications. For example, we have continuing shortages of skilled people in information technology related areas. Companies are going to India and elsewhere to fill these jobs. Going forward, the players in the U.S. R&D enterprise, including universities, will need to be more agile in this dynamic environment.

Examples of "Effective Practice" in Research Support and Performance

SUMMARY POINTS

• The presentations illustrate that defining effective research performance differs at the national, corporate, and university levels. For companies, such as Amgen, Inc., research must ultimately contribute to sales and profits. For universities, building the base of fundamental knowledge and training the next generation of researchers are the key tasks. Knowledge building and training are important at the national level as well, but unless these assets are seen as contributing to broad national goals the public view of performance may be skeptical.

• Research organizations in several countries report increased pressure to evaluate results and develop appropriate evaluation metrics and mechanisms. Companies, universities, and international research funding programs have developed a number of approaches to this task.

• Several presentations highlighted that effective recruitment, training, and management of outstanding scientists and engineers are essential to superior research, whether in the industry, university, or government sectors.

• Research organizations in several countries report an increasing need to maintain a global view in order to improve performance by tapping ideas and talent from around the world. Companies are already developing effective techniques for building and managing a global R&D effort.

DANIEL VAPNEK, AMGEN, INC., UNITED STATES

General Elements

Several elements of "best practice" or "effective practice" in research support and performance appear to hold true in all situations and countries. First, it is important that the goals of research and the goals of the organization be clearly articulated, and that the goals of research are set so that meeting them clearly advances larger organizational goals. This is true in companies and universities, as well as at the national level. For example, the other presentations have highlighted how countries such as Korea and Finland have succeeded by building technological capability in focused areas where they could be competitive in global markets. A second common element is to support superior science. This calls for employing excellent, well-trained researchers. Third, it is necessary to provide adequate support to research efforts. Finally, it is necessary for research organizations to maintain a global perspective without national boundaries, in order to scan the globe for superior ideas and people. This is becoming more important as more countries develop the critical mass of science and technology capability necessary to do outstanding research.

Factors Specific to Organizations

In addition to these general features of "effective practice," other elements of superior performance depend on the type of organization. Figure 3-1 shows the roles and interaction of universities and companies, a critical interface.

In universities, the key task is to push back the frontiers of fundamental knowledge and train the next generation of scientific and engineering talent. Publication is a critical factor in communicating and evaluating university research, particularly

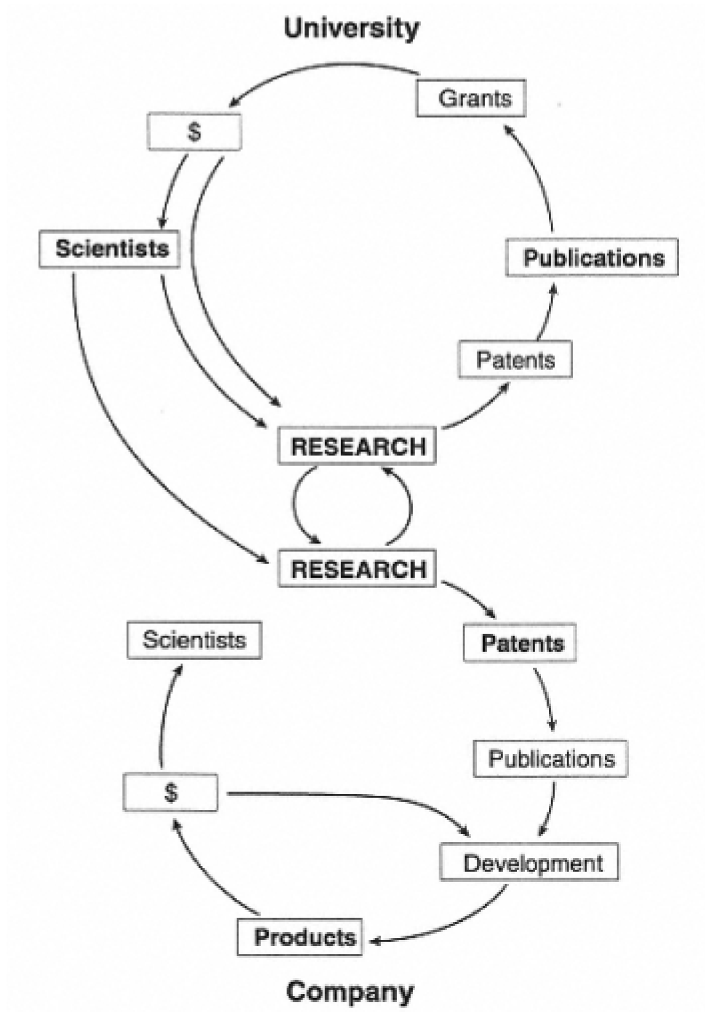

Figure 3-1
The critical interface of universities and industry.

the quality of publications as opposed to the quantity. Adequate support for researchers through a competitive, peer review process has been critical to the outstanding quality of health care and life sciences research at universities here in the United States.

At companies, in addition to general factors such as adequate support and clearly articulated goals, it is important to maintain a balance between focus on internal developments and opportunities to access knowledge from outside. Avoiding a "not invented here" mentality becomes more challenging as the organization grows larger. A global perspective is also important. In the biotechnology industry, we have seen a number of examples where fundamental discoveries were made in one country but were picked up and commercialized by companies in other countries.

Communication is also important in the corporate context. It is critical that top management understand the technical issues, understand the unpredictability of research, and be flexible to change as science changes. This environment and top management focus is easier to maintain in a smaller company.

We are just beginning to explore larger national and international-scale efforts in the life sciences. One example is the Human Genome Project, an effort to sequence the human genome supported by the National Institutes of Health and the Department of Energy in the United States. This program has benefited a great deal from international exchange and communication. The Wellcome Foundation and other private foundations around the world play an important role in this global effort. This has been an excellent example of international collaboration. A second example is the Human Frontier Science Program, covered next by Dr. Cuenod.

MICHEL CUÉNOD, HUMAN FRONTIER SCIENCE PROGRAM (HFSP), FRANCE

HFSP is focused on promoting inter-continental cooperation in basic research in biology and neuroscience. By focusing on support for younger scientists through research grants, fellowships, and workshops, it furthers the internationalization of interdisciplinary research of very high quality. The concept was first proposed at the 1987 G-7 summit by Prime Minister Nakasone of Japan, and the program was launched in 1989 with a secretariat established in Strasbourg. In order to ensure a timely start, Japan agreed to provide the bulk of the support for the program in the initial years, with the remaining support provided by the other management supporting partners (Canada, France, Germany, Italy, Switzerland, United Kingdom, United States, and the European Union).

Basic support is provided in two fields, brain function and biological function at the molecular level. These are fields that require strong support for basic research. The problems are of high complexity. International cooperation appears to make tactical sense. Even the largest countries should profit.

A recent review by an independent panel found that the quality of HFSP awardees and proposed research were of uniformly high quality, and addressed important questions. The quality is ensured by a peer review process modeled on the study section system of NIH, with the review panels made up of two member scientists from each participating country. From the point of view of the scientific community, the absence of political bias and the focus on high quality rather than targeted subjects are particularly attractive features of the program.

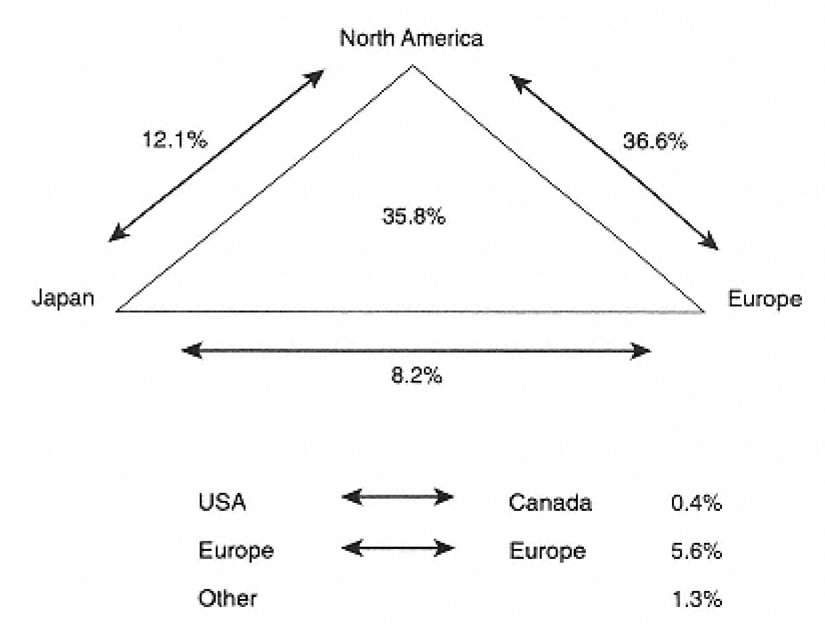

Figure 3-2
Continental distribution of 232 research grant awards and of research teams during 1990–1995.

Research grants are given to groups of four members on average from at least two different countries or if possible, two different continents. The program is very competitive; only about 12 percent of the proposals are funded, while recent review committees believe that about 30 percent are worthy. Grants run for three years, and practically no renewals are given. This is a short time for a project to show results, particularly for an international team, but budget constraints dictate this. The average grant amount was $220,000 in 1997 for a team over three years. The average age of 1997 grantees was 42.6. Figure 3-2 shows the regional distribution of grants, based on results from 1990–1995. The added value includes the exposure of young scientists to different ways of thinking about science culture, and encouragement of national science agencies to think globally. This relatively small, unique program has demonstrated the efficacy and desirability of promoting international collaboration.

In 1997, 160 long-term fellowships were awarded. The success rate is about 20 percent. They run for two years at $40,000 per year. Fellows must either be from, or travel to, a member country. Most of the awardees go to the United States. This leads to most of the funding for HFSP going to the United States. The United States receives about five times more in grants and fellowships than it contributes to the program.

The total budget in 1997 is $47 million, with about 60 percent going to grants, about 30 percent going to fellowships, and a very small amount to workshops. About 7 percent goes to administration, a very low amount for an international program.

Restrictions or delays in publication are not allowed in HFSP research. Intellectual property rights have not been a problem. The center where particular research was performed is responsible for IPR.

Although the participating countries agreed with Japan's goal that other member countries should contribute about half the funding over time, this has not been achieved. Japan still funds about 80 percent of the program. Japanese decision makers are showing impatience with these trends, and achieving more balanced funding is the most challenging long-term issue for HFSP. There are several reasons for the difficulties in this area. There is budget pressure in most of the member countries, which tends to put a higher priority on national programs. HFSP supporters make the argument that promotion of international cooperation is cost effective and delivers significant leverage, but not all accept it. Also, officials in some member governments will argue that Japan's disproportional share of support for HFSP represents a small and long overdue counterbalance to the benefits the country has received over the years from basic research funded elsewhere.

EWA GAJEWSKA-BLAISDELL, BLAISDELL & CO., POLAND

The end of the Cold War and break-up of the Soviet Union are resulting in new opportunities and choices for Poland and other countries that had been under Soviet domination. The science and technology research structure in Poland is mostly leftover from the Communist era. We face many challenges in building up our capabilities. Poland needs to look to other countries, both at the official level and the corporate level, in order to develop a science and technology infrastructure that can fuel economic development. Promoting Poland as a desirable location for high-technology international companies is one aspect of this task. Education of Polish political leaders about the importance of science and technology is another. Poland can benefit a great deal from increased exposure to effective practices in science and technology from around the world.

During the Cold War, research and development was dominated by large state-owned heavy industry enterprises, which have either disappeared or are facing severe pressure. The ministry responsible for R&D activities is responsible for supporting about 200 remaining government units. Recently, the ministry retained a Western consulting company to evaluate these facilities, identify best practices, the best institutes, and the ones that should be closed. Of the 200, eight were found to have promise, but the rest need to rapidly improve in order to stay open. R&D institutes have cut staffing by 30 percent in the last three years, and funding has also been cut. Government funding provides about a third of the funding for public institutes, with the rest coming from private sources for particular projects. Despite the challenges, Poland is one of the best places for developing emerging technologies. As part of activities related to joining the European Union, Poland is setting strategic priorities for research and industrial development. The first priority is to strengthen capabilities in enabling industrial technologies, such as materials. The second is to focus on infrastructure related work. For example, Poland is in an important location in Europe, lying between Western Europe and Russia, so that advanced highway technologies and other transportation related fields would be appropriate. A final focus is on research relevant to state functioning.

TERRENCE HENG, MOTOROLA, INC., UNITED STATES

The Role of R&D in Motorola

Motorola considers R&D to be its lifeblood. Annual sales total about $30 billion, and last year the company invested about $2.4 billion in R&D. This is a considerable investment, and it is expected to deliver significant returns. The R&D organization consists of corporate R&D, about ten percent of the total, and sector or business unit R&D. Corporate R&D focuses on research with a time horizon of more than five years, while business unit research focuses on what will be needed in products in the immediate future.

There are several primary reasons for making such a large R&D investment. One goal is to enhance the company's portfolio of technology platforms. Motorola lives on new product cores and new industries. Motorola created the walkie-talkie industry, the car radio industry, the mobile phone industry, and the paging industry. The company is in the process of creating the satellite telephone industry, with the Iridium joint venture.

Innovation is necessary to maintain a high rate of growth, and to avoid becoming an "also ran" company. Competition from around the world is formidable. A few years ago Fujitsu was the benchmark for a follower strategy, in that when Motorola introduced a new product Fujitsu would have something just as good within nine months. The top Korean firms are now able to do this within six months. In pursuing a business strategy based on innovation, intellectual property protection is critical. Motorola has been able to enter markets and stop entry of other companies thanks to its patent position.

Another task for the R&D organization is to eliminate technology surprises. CDMA, the emerging digital wireless technology, is a good example. Several years ago Motorola was on the leading edge with a few other companies, but now there are about 60 companies around the world working on CDMA. Motorola does constant competitor analysis. It is necessary not only to know what competitors are doing today, but to project what they are likely to be doing in five or ten years. Often new competition emerges unexpectedly from unlikely sources due to paradigm shifts.

Globalization of R&D

A final task for R&D is to play a leading role in the globalization of the company. Currently 62 percent of Motorola's sales are outside the United States. The proportion of U.S. sales is expected to fall to 25 percent by 2000. This trend toward international sales has been apparent for some time, but R&D had not been keeping pace until recently. Five years ago almost 95 percent of Motorola's R&D personnel worked in the United States. Today there are 20 Motorola R&D organizations outside the United States, with about half of corporate R&D being performed abroad.

Our top management has mandated this globalization effort. Motorola has been reorganized into three regions—Pan American, Asia, and Europe/Middle East/Africa. While North America is not growing that quickly, sales in Latin America are growing rapidly. In Asia, growth is especially rapid in China. Five years ago Motorola had virtually no sales and no employees in China, but in 1997 the company expects $4 billion in sales and will employ 10,000 people. In addition to the direct benefits of participating in high growth markets, Motorola's global approach helps it stay attuned to the strategies of potential competitors and prevent them from maintaining domestic profit sanctuaries. This lesson was learned from Japan. By competing head-to-head in Japan, Motorola has been able to prevent Japanese companies from using a protected home base to finance market entry in the United States and elsewhere. Today, Japanese firms are not major global players in the cellular phone business or the paging business.

Governments are also encouraging Motorola and other international companies to do R&D in their countries as part of doing business. This encouragement can be implicit or explicit. Although explicit pressure may go against World Trade Organization rules, it is a fact of life in a number of countries. Governments also provide positive incentives. In Singapore, government programs support a significant fraction of Motorola's R&D costs.

Another reason for globalizing R&D is to gain access to world class talent. Motorola prides itself on hiring best-of-class people. However, competition for top scientists and engineers is tight in the United States. Motorola recruits foreign nationals studying at U.S. universities, and sends them back to their home countries. The R&D centers in India, China and elsewhere also hire the best within the country. In India, Motorola hires one of 27 who are interviewed, in China, one of 40, and in the United States, one of two. Foreign engineers can develop unique solutions to major research issues. Russian engineers, for example, often look at things in ways unique to their backgrounds.

Motorola's foreign R&D centers are organized in a number of different ways. For the most part they are wholly owned by Motorola, in order to ensure protection of R&D. Several initiatives take the form of "virtual organizations," and involve collaboration with universities and institutes. One example is a joint venture with the Chinese Academy of Sciences.

Formulating Strategy and Measuring Success

Part of how Motorola chooses its R&D programs comes from expected return on investment. Each business division has to develop a 10-year technology roadmap. Iridium, for example, was conceived 10 years ago. It is often said that technology moves quickly, but a major new platform requires 8 to 10 years of development.

R&D plans are also generated by business units. In essence, Motorola needs to create a billion dollar business every year in order to continue growing at the rate of 15 percent per year.

Research managers also generate ideas. "Minority reports," which outline ideas outside the official strategy, are an important technique. Iridium and cellular telephones both started as minority reports. Another technique utilized in starting a new business platform is to task a group with finding reasons that the new effort will not work, or factors that would essentially kill the project. If this group cannot come up with a good reason to kill the project, it is an encouraging sign.

Metrics and evaluation are also important. Motorola's most important measures at the company level are related to product sales. For example, the company's target for percentage of sales generated from products introduced in the last six years is 60 percent. This is not the case currently, but progress is being made. Cycle time from concept development to product release is also an important metric. A few years ago the company average was 36 months. Motorola's "10X Program" set the goal of becoming 10 times faster. The average is now seven months, reflecting significant progress. Metrics are also important at the individual and group levels, for example the number of patents per engineer. Motorola's current average is 1.5, with the goal being 2. Percentage of on-time completion of key milestones is another critical metric. If the company commits to sufficiently support a project to reach its key milestones, 80 percent should be reached on time.

Implementing and Evaluating Science and Technology Strategies

SUMMARY POINTS

- Participants from several countries pointed out that taxpayers and the market are increasing the pressure on R&D organizations and national governments to not only do good research, but to produce results as quickly and cost effectively as possible. The need to set priorities and achieve specific goals is providing impetus for the development of new approaches to managing programs, as well as evaluating and communicating results.
- For several of the research institutions and programs discussed at the symposium, defining a clear contribution and role within the overall organizational or national effort is an important fundamental step in effective implementation and helps lay the groundwork for constructive evaluation methods.
- Finland's Technical Research Center (VTT) is a national facility that is partly funded through budget allocations and partly supported through contracts with government and industry customers. It is one of the longest existing national programs aimed at civil industrial technology in the world. A recent evaluation of VTT has prompted significant changes in organization.
- China has been pursuing a broad strategy to increase its science and technology capability to serve national goals such as improved agricultural productivity, better health, and economic growth. A key thrust has been to encourage scientists and engineers at universities and institutes to launch new technology-based enterprises.
- The Data Storage Systems Center at Carnegie Mellon University is a successful example of the university-industry partnerships that have spread in the United States over the past 15 years. In these sorts of efforts, the willingness of companies to help fund research, hire students trained through collaborative programs, and otherwise participate can be measured and evaluated.

BJÖRN WAHLSTRÖM, TECHNICAL RESEARCH CENTRE (VTT), FINLAND

National Context

At the start, I want to stress that Finland is a small country with a population of only about 5 million. Nevertheless, several of our companies have enjoyed success in global high technology markets. Perhaps the best known is Nokia, which is a leader in cellular phones, and whose portable communication products are adding functions such as email, fax, and so forth. Although the natural resource based industries such as timber and mining are still prominent, Finland has achieved rapid growth in high-technology production and exports during the 1990s. Systematic investment in technology, including private and government investment, has played a major role.

At a national level we have done several studies over the years to look at Finnish science and technology policies. These studies allow us to develop a vision of the future, which I believe is very useful. The major players in Finnish science and technology policy include VTT, a national laboratory doing applied technical research, and the Technology Development Center (Tekes), which funds research. The Science and Technology Policy Council has also played an important role in recent years. Council members include the Prime Minister, other elected cabinet officials, the directors general of VTT and Tekes, and representatives from industry, universities and other institutions.

We have set a national goal of spending 2.9 percent of GNP on R&D in 1999. We started setting these kind of goals in the mid 1970s, and this has provided an important national focus. In 1996 Finland spent about $2.7 billion on R&D (at 5.54 FIM per dollar), with industry accounting for about 67 percent and government 33 percent. Our goal is to reach a 60-40 ratio between private and public spending. Other major national priorities are to increase international cooperation and to improve the training of research scientists.

The Role of VTT and Tekes

VTT's budget is about $180 million per year, accounting for 6–7 percent of Finnish R&D. In 1993, an international group was charged with evaluating VTT and recommending directions for the future. One outcome of the evaluation was a restructuring into nine research institutes, as shown in Figure 4-1. The basic idea was to form larger institutes with a consistent structure. As the figure shows, we cover all technical fields. VTT operates in several locations within Finland, with most of the 2,700 staff in Espoo. To take my own institute, VTT Automation, as an example, it is quite typical in terms of funding sources. Figure 4-2 gives a breakdown. About one-third of our funding comes from the budget and about two-thirds comes from individual projects. This financing structure has several important benefits. The budgeted money gives us the flexibility to do longer term, speculative sorts of research. At the same time, the need to get project funding forces us to incorporate a customer orientation into what we do.

Included in the project funding is government support through Tekes and other agencies. The role of Tekes is very important. It stresses very much that participation by industry is crucial in all stages. Tekes does have flexibility to fund projects with a longer time horizon with larger numbers of companies as well as projects with a shorter time horizon. It is even able to give development loans. A recent evaluation of Tekes-funded projects found that the volume of net sales and exports achieved with Tekes funding is 10–20 times the initial investment, that four to five new jobs are created per million marks invested, and that without the funding a quarter of the projects would not have been realized and two-thirds would have been limited or slower.

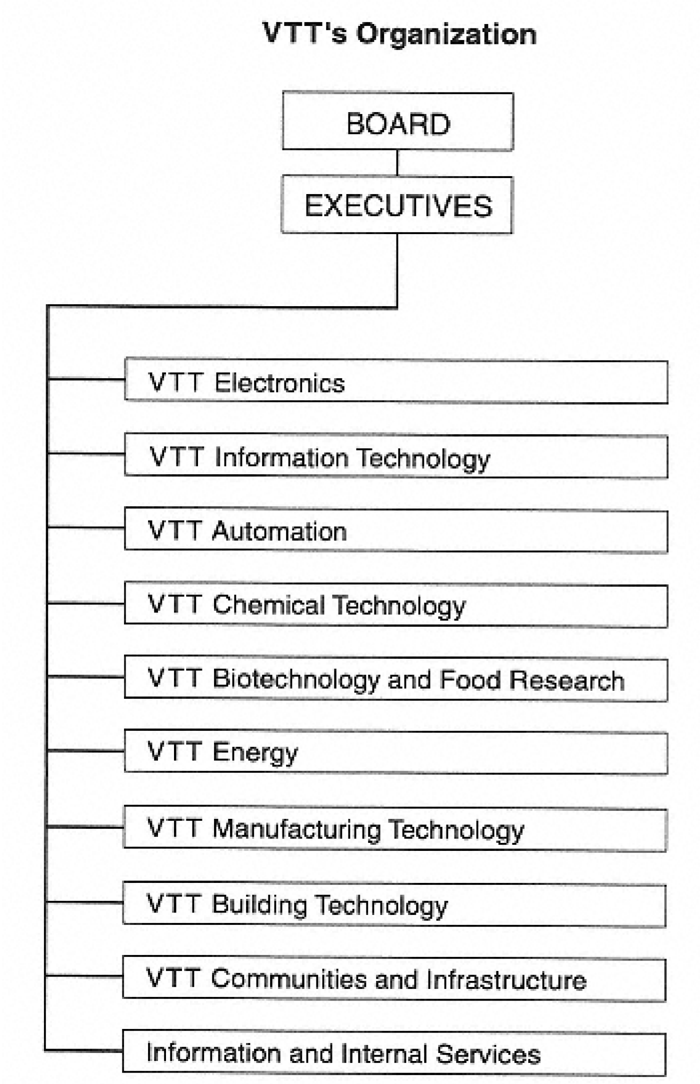

Figure 4-1
The restructuring of VTT resulted in nine research institutes and an Information and Internal Services group.

International Cooperation

As I mentioned, we are very interested in expanding international cooperation. Certainly the European programs are a natural focus for us. Finland is now a member of the European Union, and we are a full member of all the programs. Active participation in the R&D programs such as the Framework Program, Eureka, and so forth, is especially important in order to help define the content and objectives. For example, the EU is formulating the Fifth Framework Program, and Finland is very active in the development.

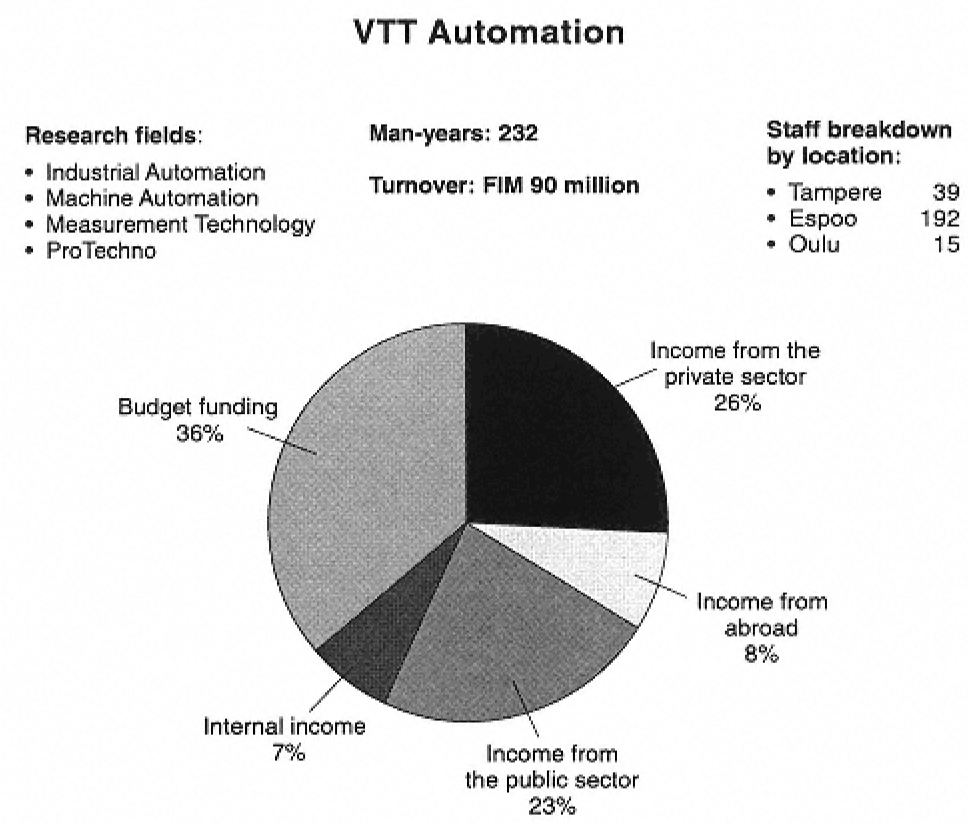

Figure 4-2
Breakdown of funding sources for the VTT Automation research institute.

To summarize, I think that several factors have contributed to Finland's success. We are a small country with a high educational level, and people seem to be very fond of high-technology gadgets. Also, I think that the systematic promotion of cooperation between companies and between different organizations as well as regular evaluation and feedback have been very important. On a more general level, I think the world is changing at a rapid rate, and it is clear that organizations and countries need to adjust. Networking on a global basis is necessary, because only those who are in the forefront in development and investment can really compete.

CHEN ZHANG-LIANG, PEKING UNIVERSITY, CHINA

National Context for Chinese Science and Technology Policies

I would like begin with a brief overview of the national priorities that the Chinese government is working to address, and explain how strategic planning for science and technology policies and changes in the organization of science and technology relate to these national goals. The four national goals. I want to mention are: (1) increasing the productivity of agriculture, (2) improving health and medicine, (3) improving the efficiency of state-owned enterprises, and (4) controlling inflation. The first three have the most relevance to science and technology. The first area is agriculture. China has a population of about 1.2 billion, roughly 23 percent of the world's total, and about 7 percent of the arable land. The stability and productivity of agriculture is an important issue for China and other countries as well. We have heard concerns from other countries about whether China can produce enough food over the long term to feed its own citizens.

There are several long-term pressures on Chinese agriculture. To begin with, the population is continuing to grow, which leads to a rise in demand for food. Also, with rapid economic growth cities are expanding, more factories are being built, and farmers are building larger houses as they get wealthier. This puts pressure on agricultural land. There are also irrigation problems. One example is a city near Hong Kong which has grown very rapidly over the past ten years. Farm land and rice cultivation have declined, while the average income of farmers has risen. There is a great deal of controversy within China and abroad over whether China will need to import a great deal of food and cause problems for the world. We believe that China needs to be self sufficient in food, which is why we are focusing on introducing modern technology into Chinese agriculture, especially agricultural biotechnology. The Chinese government has been putting resources into this, and will continue to do so.

The second area is medicine and health. This is also an area with long-term problems. For example, we know that China has the largest incidence of hepatitis B. Almost 10 percent of the population carries the virus, and among them 10 percent develop the disease. For cardiovascular disease, diabetes, and cancer there is quite a large patient population, and it is increasing.

In the medical field, you are familiar with the large per capita expense for medical care of the United States. In China, the per capita annual medical expense is only four or five dollars. In five or ten years suppose we reach the level of the Philippines. That would mean a tremendous increase in the amount of pharmaceuticals needed. Many of the Western pharmaceutical companies are entering the Chinese market, but we need to build and sustain the pharmaceutical market and production within China. This is another area where science and technology can make a contribution.

The third issue is state-owned enterprises. China is a socialist country with a growing market economy. The state-owned enterprises make a great contribution, but face many challenges. For example, the techniques of many state-owned enterprises are more or less out of date, and it is difficult to make improvements. Further, each factory has a very large workforce, some on the order of 100,000. Also, the Chinese government has encouraged investment in the state-owned enterprises, regardless of the investment fundamentals, and is now cutting its subsidies. So it is difficult for these enterprises to invest and manage themselves in a way where they could compete with the very efficient multinationals entering China, such as McDonald's Motorola, and Boeing. Improving the technology of state-owned enterprises is another key task of national policy.

Government Infrastructure

The Chinese National Science Foundation (NSFC) is one of the key agencies in Chinese science and technology policy, and is growing very rapidly. NSFC funds basic science. In 1986 the Chinese government also established a new program to fund research grants in high technology, which is very important. The major priority areas for science and technology funding include biotechnology (for agriculture and health), space, informatics, new materials, and energy.

We think that we have accomplished a great deal over the past ten years. One example is in biotechnology. As a result of the high technology planning and investment program in agricultural biotechnology much is being done in areas such as disease and insect resistant crops, higher quality varieties, and yield improvement. China is one of the leading countries in terms of field release of transgenic plants. Many new biopharmaceuticals are also being introduced and developed in China.

Another focus of Chinese government funding support is special economic zones. This involves support for professors who are encouraged to run an industrial company in one of the zones. Also, tax exemptions are given for three to five years to new companies in these zones. One of the most famous is Shenzhen near Hong Kong. Another is in Beijing, especially in the area near Peking University. The whole area is a high-technology zone, with many computer companies and biotechnology companies being launched.

Most Chinese high-technology companies have been around for less than ten years. The vast majority have as CEOs scientists from universities or the Chinese Academy of Sciences (CAS). We have only recently started management education, so it is necessary for scientists to move directly into management. Legend Computer is one of the famous examples of a Chinese spin-off enterprise.

Spin-Off Enterprises at Peking University

Launching high-technology enterprises from universities and CAS institutes is an important part of the Chinese government's strategy. Peking University, also known as Beijing University, is one of the largest universities in the country. So far we have established about 80 companies that are wholly owned by the university. One of these companies now has over 2,000 employees, with $15 million in gross income, of which $3 million goes to support university research. Our university is perhaps the most advanced in running enterprises, but other universities around the country are moving in this direction. This is having an impact on the university budgets.

Another example is a biotechnology company in which the university controls a 40 percent share and a multinational company's pension fund controls the rest. These changes are causing considerable debate about whether we are on the right track. We are following the imperative that we need to move knowledge and talent into applications, and launching a number of initiatives to see what approaches work best.

Future Issues

We have established an evaluation system for science and technology but it is only at the early stages of implementation. Although we have achieved great progress by switching emphasis from basic science to applied science and building high technology businesses with scientists as managers, we still have quite a few challenges. First, the overall education level is still quite low for our 1.2 billion population, in contrast to developed countries. Second, there are still bureaucratic problems involved with encouraging scientists to launch enterprises. Third, our legal system still needs improvement, especially in the area of intellectual property rights. This has been an international issue, as well as domestically among Chinese scientists. Finally, we lack a system of venture capital which is so significant in the United States for promoting high-technology development.

We do have some emerging strengths that we can build on. For example, if we look at the scientific leadership in China, the most active group in terms of publishing in international journals are those born in the 1930s and 1940s. Although in many countries the most active group was born in the 1950s, in China we lost this generation due to the Cultural Revolution. But starting in the late 1970s the university system started to function again, and we started sending many students to the United States, Japan, and European countries. This younger group is coming along rapidly, and will be taking on more leadership in science and launching high-technology enterprises, especially as more people return from abroad. So over the next 10 or 15 years we can expect to see a great deal of progress in Chinese science.

So far the Chinese government has moved quickly to promote science and technology. I am a member of the National People's Congress and we are making some changes in that body. The Chinese government should continue to invest more in high-technology areas and continue to encourage universities and CAS institutes to get involved in industry and establish companies. We also need to encourage industry to support research in universities. This is difficult because we do not have many large companies that are strong at this point. Which is why we need to continue working with multinational corporations. Many of the top multinationals are in China and are making a contribution. Many have R&D facilities as well as production facilities.

Finally, the journals *Nature* and *Science* published articles on Chinese science at the end of 1995. Overall they are very accurate. *Nature* says that we are in much better shape than we were ten years ago, and *Science* says that we are making aggressive attempts to upgrade basic research. Both go over the challenges. *Science* emphasizes the change in structure that is needed. We are in fact changing our structure for science and technology, which was adapted from the Russian system. For example, CAS runs about 120 research institutes and each institute has over 300 researchers on average. Reforming the structure of science and technology will be the major issue over the next ten years, and I am confident that we will be successful.

MARK H. KRYDER, CARNEGIE MELLON UNIVERSITY, UNITED STATES

Context

I will outline the de facto strategy put in place to help the U.S. data storage industry overcome some of the problems it was facing in the early 1980s and where we are today. To start with the background, in the early 1980s there was a lot of concern about U.S. competitiveness. We were losing the DRAM business to Japan, we had lost the television business to Japan, we had lost the videotape recorder business to Japan, the automobile industry was on the ropes, and so forth. If you look at magnetic recording, not only were all VCRs made in Japan at that point, but also forty percent of the magnetic disk drives for computers. There were a number of highly successful Japanese industry consortia supported by the Ministry of International Trade and Industry (MITI), and the products made by Fujitsu, Hitachi, and NEC were making heavy inroads. U.S. firms such as IBM and Digital Equipment which had large manufacturing and product development operations in Japan did make attempts to get involved with some of these consortia but were denied permission to do so.

Interestingly enough, data storage at that point was comparable to the whole electronic memory business. It is currently about a $100 billion per year industry. Yet, there was a sense that you could count on one hand the number of professors in the United States working on issues in this industry. In contrast, you could go to almost any research university in the United States and find someone working on semiconductors. There are complex reasons for this situation, but the net result was that there was almost no university support for the industry, and virtually no Ph.D. graduates in the United States who understood magnetic recording.

Development of the Data Storage Systems Center

Based on my own experience at IBM and a belief that something needed to be done, I organized a workshop at Carnegie Mellon in 1982 involving about a dozen of the key technical people from industry. These included IBM, Xerox, Ampex, Verbatim, and others in the magnetic recording business in the United States. Over the two days we developed about thirty "Ph.D. topics" which were suitable for Ph.D. research in the university environment. Based on that, I wrote a proposal and gained the support of the companies after about a year of discussion. IBM and 3M were the first two to jump in, agreeing to contribute $750,000 each over three years to get this effort started. By the end of 1983, we had $3 million per year in funding from a large number of companies, and the Magnetics Technology Center (MTC) was formed. This was possible because the total vacuum in university efforts was obvious, and because IBM and several of the other companies involved understood the challenge from Japan, based on experience in other industries.

Over its first five years, funding for MTC grew to $5 million per year. The associate members who were contributing about $250,000 a year to the center guided the research agenda, but there was no overall strategic plan. This meant that the university research effort was being pulled in many different directions. By 1988 I had become a broker for the faculty at CMU in terms of facilitating research projects from industry, which was not as much fun as I had in starting MTC. In that time frame, European countries were allowed to join, but because Japanese consortia excluded U.S. companies, Japanese companies were not allowed to become members of the center. At the same time, other universities jumped into this field, including the University of Alabama, the University of California at Berkeley, the University of Minnesota, Washington University in St. Louis, and Santa Clara University.

In the mid 1980s, the U.S. Congress was also concerned about U.S. competitiveness and provided extra funding to NSF to launch the Engineering Research Centers (ERC) program. Given the disagreement in the community over whether priority should be given to single investigator or center work, it is important to note that the ERC program involved extra money that did not come from funds that could have supported single investigators.

By 1989, it seemed that the way to make MTC effective in the long term would be to develop a coherent centralized focus to the research. We applied to NSF for one of the ERCs in systems-oriented research projects. Magnetic recording is very systems oriented and multi-disciplinary, in that it involves electronics, mechanics, media interface, chemistry, materials, and computer science at the systems level. In 1990 we were awarded an ERC and changed our name to the Data Storage Systems Center. As part of the grant, we had to lay out a rather detailed 11-year strategic plan for three generations of data storage systems, both magnetic and optical. Interestingly, industry was very supportive of the systems approach once we had secured this long-term centralized funding, although before they had always tried to pull the research agenda in a particular direction that most interested them.

Several other interesting developments occurred soon after the launch of DSSC as an ERC. First, the National Storage Industry Consortium (NSIC) was founded in 1991 to coordinate university-industry-government research in the data storage industry. The background to this is that IBM, which had founded much of the research in this area, was making significant cuts. Profit margins at all companies were very low due to the intense competitive environment. The formation of NSIC was helpful in developing additional research programs in the data storage area, which were funded by the Defense Advanced Research Projects Agency (DARPA) and by the National Institutes of Standards and Technology (NIST) through its Advanced Technology Program (ATP).

A second development is that the Agency for International Development and NSF funded DSSC to help form a Magnetics Technology Centre at the National University of Singapore. This project was strongly supported by U.S. industry sponsors of DSSC, many of which had manufacturing facilities in Singapore.

Results and Future Issues

Here are some of the results of these efforts over the years. First, this research has contributed to a number of products with multi-billion dollar markets today, such as lower flying sliders for disk drives, improved magnetic head technologies, lower noise magnetic media, improved disk drive actuator technology, and an electro-optic beam scanner. There has also been about a 20-fold increase in the number of Ph.D.s being graduated in the field.

But perhaps the biggest impact is that the systems-oriented approach of DSSC better prepares students to make an immediate contribution in industry. For example, a typical student who has done work in a narrow discipline like mechanical engineering may join a magnetic recording company where the first problem he is asked to work on is to develop a head for a certain interface. So he sits down and sitting across the table may be an electrical engineer worried about the signals and noise coming out of the head, and sitting next to him a chemical engineer who is worried about the lubes that go on the disk. While the typical engineering Ph.D. needs at least a year or two of on-the-job training to understand enough about the whole system to become effective in the company, the Ph.D. who spends significant time with DSSC can contribute immediately.

One current issue is changing funding patterns. NSIC attempted to get programs in the hard disk area funded on an ongoing basis, but was unsuccessful. What happened is that ATP appeared to shift its focus from pre-competitive research to projects which would have a clear business plan and a clear product orientation. The optical recording industry still has good ATP support, but the hard disc drive industry does not. The research agenda in this field is developed on a strategic planning basis by the universities and industries working together. The NSF/ERC program has been critical to doing this. However, DARPA funds mission oriented research, predominantly related to the defense industry, and ATP is now funding programs expected to lead to new businesses in a 5-year timeframe. This does not fit the needs of a major industry which is in very strong long-term competition. Interestingly enough, the U.S. disk drive industry will not be submitting any ATP proposals because they are more interested in the 5–10 year horizon rather than things that turn into products in 5 years. Ironically, in this instance government has a shorter time horizon than industry.

This contrasts with the situation in Japan. As I mentioned, MITI-funded consortia were highly successful in the early 1980s, and then support in this area declined in the late 1980s and early 1990s. More recently, Japanese industrial firms formed a consortium, with no government sponsorship, with the stated purpose of forming centers like those at CMU, the University of California San Diego, and Stanford. They want to fund university research in Japan much like NSIC is doing in the United States. The Japanese government is now putting more money in storage research as part of a larger program that funds research in semiconductors and displays. So it is possible that Japan is working to revitalize the research base of this industry while we may be moving in the opposite direction.

BOX 4-1 EVALUATION OF UNIVERSITY-INDUSTRY COOPERATIVE RESEARCH PROGRAMS

General Criteria

- New Relevant Fundamental Understanding
- New Measurement and Modeling Capabilities
- New Technologies
- Quality and Quantity of Graduates

Systems Research Criteria

- Is there effective multidisciplinary systems oriented research?
- Is there a testbed for the system?
- Are the systems level goals being met?
- Do the graduates have a good understanding of the systems level goals?
- Are the graduates effective in team research?

Box 4-1 shows some of the criteria that I believe are important in evaluating cooperative university-industry research programs. For example, new measurement and modeling capabilities should be a major output. DSSC has produced a number of these in areas such as finite element modeling and instrumentation, which spin-off companies have commercialized. Of course new technologies, quality and quantity of the graduate students are all important. But it is very important that we make this transition in the United States to a systems-oriented education for our students in order for graduates to be instantly employable and useful.

As for the future, I will give one final comment. Although the ERC program has been highly successful, there are only a limited number of these in the United States. One of our problems as a country is expanding that impact to a larger group of universities. Currently, there are about a dozen U.S. universities with ongoing research in the data storage area and NSIC has put in $1.5 million dollars to form a nationally coordinated program.

Issues and New Approaches to International Cooperation

KENNETH FLAMM, THE BROOKINGS INSTITUTION, UNITED STATES

I would like to set out two fundamental issues that are international in scope but very difficult to answer. The first point is illustrated by the Korean approach discussed by Dr. Chung. As I understand it, the aim is to acquire proven advanced technologies and commercialize them. This is increasingly the focus of U.S. private industry as well. In historical context, the United States was willing support a high percentage of the world's basic research when it was assured of gaining a high percentage of the return. But when we can only be assured of gaining 35–40 percent of the return on basic research investments and other countries are getting a return without making the corresponding investment, then it is less attractive to continue supporting basic research at the same level.

In short, the first issue is that given the globalization of R&D in a competitive world where there is no predominant party capitalizing most on basic research, there will be a temptation to do less and less basic research. So how do we go about equitably making investments in this global good? How do we share the load? Coming up with some kind of global arrangement to share the cost and expense in investing in the basic overhead for the entire science and technology infrastructure is a significant issue that we are just beginning to confront today.

The second issue is somewhat related. Just as countries have different perspectives on the value of research, so do government and private industry. When the U.S. government invests dollars in an enterprise that supposedly contributes to productivity and standard of living in the United States, it is using a national concept of return on investment. But when a private company invests in that same activity, it is thinking about its shareholders.

There are some obvious circumstances under which the return to the nation from a taxpayer investment in R&D might logically diverge from the returns of the company on a private investment in R&D. In one example, we had a cooperative development program with a foreign nation in aircraft, with the foreign nation essentially producing an indigenous, somewhat modified, version of the U.S. aircraft. The United States had invested billions of dollars on the technology of this aircraft. From the point of view of the private aircraft manufacturer whose cooperation was required to transfer the technology, the relevant consideration was whether the transfer would create a potential competitor downstream. And they could assess this risk and figure out that for $800 million or $1 billion dollars it made sense to go ahead with the deal.

Yet this technology was the fruit of U.S. government investment, possessed by several companies. So this single company making a decision on its break-even point was not taking into account lost sales and possible downstream competition for other companies. In this context, does the U.S. government, which used tax-payer money to fund the technology in the first place, have a responsibility to take the big picture into account?

In any event, the issue is that if the investment is a truly private investment, then there is no problem. Companies are free to go ahead and make whatever kind of deal that makes sense taking into account cost, revenues, profits, potential competition, and so forth. But where the government is involved in funding investment, selling or trading technology becomes a much more complicated matter. There do not appear to be neat formulations that might resolve either of these issues.

QUESTIONS FOR FUTURE DISCUSSION RAISED DURING THE SYMPOSIUM

- The symposium participants raised and grappled with a number of critical questions that have come to the fore due to the ongoing globalization of science and technology.[5] If national strategies are increasingly focused on S&T investments that spur economic growth, and the private sector will play a predominant role in overall funding and globalization, how do we ensure adequate long-term investment in S&T that addresses global problems? Is there a role for expanded international cooperation? What lessons have we learned from positive and negative examples of the last decade? What contributions can existing and new institutions, such as ICSU, OECD, EU, APEC, IIASA, UNESCO, and others make?
- Would it be desirable to pursue a more coordinated global approach to funding research that advances fundamental knowledge and aims at broad areas of application? If knowledge is a global public good, how do we ensure adequate investment and address the problem of "free-riding" by those who use that public good but do not contribute to it?
- Even as national science and technology strategies converge, and international S&T cooperation in the private sector expands rapidly, differences in national approaches to political economy (producer-oriented vs. consumer-oriented economies) continue to cause international friction. There continues to be tension between national S&T investments for national benefit, on the one hand, and the global movement of capital, technology, and people facilitated by MNCs. Who benefits and who loses when information flows freely but markets are not fully open?

[5] See two recent reports of the Academy complex: Hamburg Institute for Economic Research, Kiel Institute for World Economics and National Research Council, *Conflict and Cooperation in National Competition for High Technology Industry* (Washington, D.C.: National Academy Press, 1996), and National Academy of Engineering, *Foreign Participation in U.S. Research and Development: Asset or Liability?* (Washington, D.C.: National Academy Press, 1996).

• If nations and individual organizations need to redouble efforts to access knowledge produced abroad, and forge partnerships with foreign-based entities, they need a capability to uncover and pursue international opportunities. At the national level, science and technology personnel in the foreign ministry and foreign service play an important role. In the United States, budget pressures are leading to cuts in this capability. Is there a strong rationale for continued investments in "science and technology diplomacy," including foreign service personnel and resources devoted to monitoring and interfacing with R & D activities abroad?.

• Although the private sector role in overall R & D is growing, and nations apear to be more focused on economic growth as a goal of R & D investments, national governments still want to pursue other public goals (national security, energy efficiency, environmental protection, public health). Are there good examples of national approaches to leveraging private sector R & D to advance non-commercial national goals (e.g. recent shifts in the U.S. defense industrial base)? Can these synergies be pursued systematically?

• Recognizing that forging more effective international cooperation in science and technology is an incremental, long-term task, would an orgoing exchange could take up several of the issues covered in the symposium, including approaches to program evaluation, participation by foreign companies in government-sponsored programs, greater coordination of national investments to address areas of global importance, and other issues.

Appendixes

SYMPOSIUM AGENDA

MAY 7, 1997

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, D.C.

9:30 a.m. **Opening Remarks**

Richard Celeste, Former Governor of Ohio and Partner, Celeste & Sabety, Ltd.

9:45 a.m. **Overview of National Science and Technology Strategies**

William Spencer, President and CEO. SEMATECH, United States (moderator)

Mauricio Fortes-Besprosvani, Chairman, International Committee, Mexican Academy of Sciences

KunMo Chung, Ambassador-at-Large, Atomic Energy Commission, Korea

10:45 a.m. **Open Discussion**

11:00 a.m. **Examples of "Effective Practice" in Research Support and Performance**

Daniel Vapnek, Senior Vice President for Research, Amgen Inc., United States (moderator)

Michel Cuénod, Secretary-General, Human Frontier Science Program, France

Eva Gajewska-Blaisdell, President, Blaisdell & Co., Poland

Terrence Heng, Vice President, Motorola, United States

12:15 p.m. **Open Discussion**

12:30 p.m. **Lunch**

1:45 p.m. **Implementing and Evaluating Science and Technology Strategies**

Graham Mitchell, Assistant Secretary for Technology Policy, U.S. Department of Commerce (moderator)

Björn Wahlström, Research Professor, ITI Automation, Technical Research Center of Finland

Chen Zhang-Liang, Academic Vice President, Peking University, China

Mark Kryder, Data Storage Systems Center, Carnegie Mellon University, United States

3:30 p.m. **Roundtable Discussion of New Approaches to International Cooperation**

Kenneth Flamm, Senior Fellow, Brookings Institution, United States (moderator)

3:50 p.m. **Open Discussion**

5.00 p.m. **Adjourn**

PROJECT TIMELINE

August 8, 1996	**Speech at National Academy of Sciences by Japanese Minister of Science and Technology Hidenao Nakagawa**
September 19, 1996	**Discussions with National Science Foundation**
October 2, 1996	**Discussions with Representatives of European Commission**
October 29, 1996	**Correspondence with European Parliament**
Late 1996	**Refine symposium plan with GUIRR Working Group, sponsors and others**
Early 1997	**Organize symposium, organize lunch seminars with embassy science counselors, U.S. government officials**
May 7, 1997	**Hold international symposium**
Late 1997	**Prepare report**
Spring 1998	**Complete project, issue final report**

ATTENDANCE ROSTER

Claude Barfield
American Enterprise Institute

Laszlo Belady
Mitsubishi Electric ITA, Inc.

Bennett Bertenthal
National Science Foundation

William Blanpied
National Science Foundation

Justin Bloom
Technology International, Inc.

Jacques Bodelle
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José Costa
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Jonathan Davis
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Charles Larson
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Larry McCray
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Steve Merrill
National Research Council

Norman Metzger
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Linda Moodie
National Oceanic and
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Scott Morris
Committee for Economic Development

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Patti O'Neill-Brown
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Norman Paulhus, Jr.
U.S. Department of Transportation

Robert Palmer
House Committee on Science

Young-Il Park
SRI International

Pierre Perrolle
National Science Foundation

David Peyton
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Robert Price
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Tom Ratchford
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Linda Reck
National Institutes of Health

Proctor Reid
National Academy of Engineering

Philippa Rogers
British Embassy

Gregory Schuckman
American Association of Engineering
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John Schumacher
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