International Science and Technology

Policies, Programs and Investments

U.S. Department of Commerce
Technology Administration

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Foreword

Over the past decade, the world has increasingly recognized the vital role of science and technology in driving economic growth, developing new industries, fostering job creation, and improving the quality of life. As a result, many governments have undertaken measures to build and apply national science and technology resources for increased economic productivity and technological innovation. *International Science and Technology: Policies, Programs and Investments* continues the Office of Technology Policy's commitment to enhance the understanding of global technology developments and foreign technology initiatives. Its individual country reports describe what steps other governments are taking to increase national science and technology capabilities, build technology-based infrastructure, amend policies and regulations to facilitate technology-led economic growth, and invest in education and human resource developments. It notes that an increasing number of countries, including several emerging economies, are becoming world-recognized centers of technological excellence and innovation and offers insights for possible business opportunities. Finally, the report underscores the importance of the United States continuing to augment its scientific research base and technology infrastructure in order to remain competitive in today's global economy.

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International Science and Technology: Policies, Programs and Investments

Overview 2000: International Science and Technology Trends

Nations around the world are asking, "what policies and resources are needed to survive and prosper in a global knowledge-based economy?" Many major research-performing countries as well as developing and newly industrialized nations are looking for the answer in the strength of the U.S. economy and in the competitive position of small countries like Finland and Singapore that have used science and technology successfully to sustain and increase their national economic growth.

Innovation and Technology

In the interconnected, yet decentralized global economy, the long-term cost associated with not investing sufficiently in technology, innovation and people is high. While it might have been possible in the past to treat technology as a factor of production to be bought and sold, the technology-based, innovation infrastructure that will be required for economic success in the 21st century is harder to orchestrate or incubate.

This review of national plans, policies and investments in science and technology in 2000 reveals regions, countries and companies are busy reassessing and restructuring their S&T policies and institutions to prepare for the 21st century. Most are coping with similar challenges, and in many cases, drawing similar conclusions. Certain policies and actions -- high levels of R&D investment, strong, innovative small and medium-sized companies (SMEs), highly skilled and educated workforces, domestic and international R&D collaboration, internationally accepted standards, access to information technology and the Internet, and private-sector-led innovation -- have found widespread acceptance as critical elements for survival and prosperity in the global, knowledge-based economy. Most nations also have found their national and regional institutions and their resource base are distinctive enough to warrant the development of their own individual innovation paradigms.

A Truly Global World for R&D

The amount and quality of R&D conducted in a country remain essential components of national innovation strategies. What has changed is that domestic R&D by itself is no longer sufficient because of increased resources and the capabilities of numerous

Country	GDP 1999 (in billion US$)	GDP 1999 Growth Rate	R&D 1998 As % of GDP
USA	9,248.5	3.80	2.679
JAPAN	4,367.7	0.62	2.913
GERMANY	2,091.2	1.30	2.313
FRANCE	1,421.6	2.70	2.236
UK	1,417.4	1.90	1.822
ITALY	1,154.0	1.30	1.094
CHINA	991.2	7.10	0.693
CANADA	639.0	3.70	1.574
BRAZIL	606.2	0.80	0.784
SPAIN	596.2	3.70	0.835
MEXICO	483.5	3.08	0.309
INDIA	440.5	5.76	0.666
KOREA	406.9	6.68	2.681
AUSTRALIA	388.0	4.30	1.672
NETHERLANDS	383.2	3.40	2.089
TAIWAN	288.6	5.67	1.981
ARGENTINA	285.9	(4.10)	0.453
SWITZERLAND	256.5	1.70	2.681
SWEDEN	235.7	3.90	3.853
RUSSIA	181.8	3.20	0.947
HONG KONG	158.6	2.90	0.253
NORWAY	152.5	0.60	1.677
INDONESIA	151.9	0.00	0.092
POLAND	145.4	5.70	0.438
FINLAND	126.1	3.70	2.910
THAILAND	125.3	4.12	0.175
ISRAEL	98.8	2.36	2.651
COLOMBIA	92.6	(3.59)	0.195
IRELAND	91.1	8.60	1.523
SINGAPORE	84.9	5.35	1.799
EGYPT*	80.0	5.00	0.600
MALAYSIA	78.9	5.42	0.199
PHILIPPINES	76.5	2.40	0.078
CHILE	65.3	(1.50)	0.670
NEW ZEALAND	53.3	2.70	0.981
CZECH REPUBLIC	53.1	0.80	1.271
HUNGARY	49.5	4.02	0.723
JORDAN*	8.0	2.20	0.350

Source: IMD, *The World Competitiveness Yearbook*, June 2000
*OTP estimates based on official national statistics

regions and nations to contribute to the global knowledge base. In 1950, the United States contributed nearly forty percent of the developed world's GDP and carried out twice as much R&D as the rest of the world. A half century later, wealth and knowledge are created and distributed more widely around the globe. The United States contributes just over thirty percent of world GDP and carries out only forty percent of global R&D. While eighty percent of R&D is concentrated in just five countries (United States, Japan, Germany, France, United Kingdom), smaller countries like Israel and Sweden have academic and industrial centers of excellence that are having a high impact in specific technology areas.

Because of the increasingly distributed nature of where and how high quality R&D is conducted, many larger corporations have concentrated R&D activities at fewer locations domestically in favor of offshore locations that possess the right resource or innovation mix for a particular technology. This practice is particularly prevalent in areas that require significant investment and a close connection to basic science, e.g., pharmaceuticals and advanced materials.

At the same time, information technology, especially the Internet, allows companies to conduct R&D at numerous locations with a higher degree of strategic and task integration. For R&D in non-capital intensive technologies such as software, it enables more decentralization. As a result, rather than competing for foreign direct investment in manufacturing facilities, many countries like Singapore are competing for foreign direct investment in R&D.

Much More Than R&D

The catchphrase of S&T policies in the Year 2000 is innovation. Innovation is viewed as much more than R&D investment or the ability to apply technology to make new and better products. It is seen as a process driven by:

- Intellectual creativity derived from basic research and human resource development;
- Collaboration in technology clusters and internationally using new technologies and human networks; and
- Entrepreneurship and risk-taking by the private sector.

Basic Research. Japan, Korea and other nations believe innovation requires them to create knowledge through their own basic science research rather than applying technology created elsewhere. For smaller countries like Thailand and New Zealand (and even for some larger ones like the United Kingdom), it means joint public/private sector foresight exercises to prioritize the basic research areas in which their capabilities and resources can be expended most productively.

Human Resource Development. All countries reviewed in this report see human resources as one of, if not the, most critical innovation factors in the knowledge-based economy. Therefore, they are investing in stronger systems of education at all levels. The resulting policies are diverse. Finland and Mexico stress graduate education. Switzerland and Canada have programs to stem "brain drain" by making it more attractive for their researchers to work at home. Nearly all nations have enacted measures to increase the interest of their youth in S&T, and to recruit and train more skilled IT workers.

Speed. The ability to bring high-tech products to market quickly is a critical factor that many countries' S&T policies and programs address in a wide variety of ways. Most national, regional and local S&T policies have strong elements of cluster building or cluster facilitation with the hope that physical proximity among academics, public researchers and companies eases the transfer of technology and knowledge, and makes public research more commercially relevant. Japan and India are modifying laws and regulations to facilitate technology transfer from government laboratories and public universities to the private sector. The Czech Republic and Hungary provide special incentives for the development of science and technology parks.

International Collaboration. Public authorities in Taiwan, Spain and elsewhere have increased their commitment to international and regional collaboration to tap overseas expertise and to obtain the additional associated benefits that derive from a greater diversity of approaches and ideas. Thus, policies and programs are expanding beyond support for national innovation systems to include: 1) help for researchers and companies to take full advantage of the global innovation system, and 2) measures to attract innovation in the form of direct investment and/or researchers to their shores.

Internet and Information Technology. Many countries have determined that upgrading (and at

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times privatizing or deregulating) their telecommunications infrastructure, and making computers and the Internet widely available and affordable are essential in the knowledge-based economy. Access supports their companies' and researchers' ability to utilize global knowledge, and collaborate domestically and internationally. Canada has built the world's fastest, all-optical research network, and connected all its schools and libraries to the Internet.

Strong Private Sector. Innovation relies on a partnership between the public and private sectors in which the government invests in long-range S&T and in mechanisms to promote private sector investment and risk-taking. Because it is closer to the market and "speed" counts, the private sector, working in partnership with the government and university community, is generally perceived as the most appropriate lead partner in determining future technology directions. Therefore, countries like China and Italy with relatively weak private sector R&D capabilities, or that lack sufficient numbers of high-tech companies, are nurturing the creation of technology-based SMEs through venture capital funds, fiscal incentives to undertake R&D and hire researchers, and other measures.

AMERICAS

CANADA

Moving Towards an Innovative Knowledge-Based Economy

Canada is moving quickly to become a knowledge-based society, investing heavily in university research, domestic partnerships, high-tech small and medium-sized companies and the information highway. Canada, which imports a major percentage of its new technologies, is firmly committed to creating an effective environment that will enhance Canada's participation in international S&T, helping ensure its access to global knowledge.

Total Canadian expenditures on R&D reached $9,363 million in 1998, ranking it 7th in the world. This is a decline of about 3 percent ($9,606 million) from 1996. Business expenditure on R&D remained steady, increasing slightly from $5,970 million in 1986 to $5,985 million in 1998.

In 1999, the government funded about 11 percent of R&D performed in Canada. Business funded about 63 percent with universities accounting for 24 percent. Compared to most other OECD countries, universities fund a relatively higher amount of total R&D in Canada.

According to Dr. Gilbert Normand, Canada's Secretary of State for Science, Research and Development, Canadian S&T policy is based on the equation: knowledge plus innovation equals increased productivity.[1] Since Prime Minister Chretien assumed office in 1993, the Canadian government developed and is implementing a wide variety of programs directed at enhancing the elements of this equation. The core framework for the government's S&T policy involves:

- Funding and performing scientific research to support the mandates of departments and agencies;
- Supporting research in universities, hospitals, and other non-government research facilities and Networks of Centres of Excellence; and
- Supporting private sector R&D.

Another core element of Canada's strategy is priority setting. In this regard, Canada established in 1996 the Advisory Council on Science and Technology (ACST). ACST provides expert advice on science and technology policies, goals and emerging issues to the Prime Minister and the Canadian Cabinet Committee for the Economic Union. It has a specific mandate to look at Canada's transition to a knowledge-based economy, including how to increase the number of Canadians with the necessary skills and how government and industry can work in partnership to incorporate new technology into products, processes and services. It has convened three expert panels that have reported on 1) skills development, 2) international science and technology, and 3) commercialization of university research.

S&T Programs and Initiatives

At the forefront of Canada's innovation strategy is the "Connecting Canadians" infrastructure initiative. This initiative seeks to provide all Canadians with access to Canada's Information Highway Infrastructure. By 1999, Canada had connected all its public schools and libraries to the Internet, and invested $55 million Canadian ($35 million)[2] to build the world's fastest, first, all-optical research network (CA*net-3). Under this initiative, Canada announced the selection in June 2000 of 12 "Smart Community" demonstration projects in each of its provinces, in the north and in its aboriginal community. "Smart communities" are ones that use information technology in new and innovative ways to empower their residents, institutions and regions, e.g., for better healthcare, better education and training, and business.

"Technology Partnerships Canada (TPC)," begun in 1996 and administered by Industry Canada, is a technology investment fund that constitutes another major component of Canada's S&T strategy. It supports research, development and innovation in environmental technologies, enabling technologies (advanced manufacturing and processing, advanced

[1] Speech "Creating Canada's Culture of Innovation", May 11, 2000

[2] November 2000 Exchange Rate, 1 US Dollar = 1.549 Canadian Dollars

materials, biotechnology, information technology), and aerospace and defense technologies. As of November 2000, TPC had invested $1.2 billion Canadian ($770 million) in 113 projects that leveraged an additional $5 billion Canadian ($3.23 billion) in private funds.

Another key federal innovation initiative is the "Canadian Opportunities Strategy" begun in 1998. It targets the acquisition of knowledge and skills by providing financial assistance to students, encouraging families to save for education by creating education savings plans, and helping adults upgrade their current skills.

The National Research Council (NRC) is the federal government's major tool for supporting scientific research, development and innovation. As such, it is responsible for several of Canada's S&T programs and initiatives. The "Industrial Research Assistance Program (IRAP)," established over 50 years ago, provides technical advice to over 12,000 small and medium-sized companies per year, and where necessary, financial support for R&D activities. The program is delivered coast-to-coast through a network of more than 260 Industrial Technology Advisors and involves more than 130 members representing provincial research organizations, research centers, universities and colleges, and industrial associations. Newer NRC initiatives include:

- "Atlantic Canada," a $700 million Canadian ($451.9 million) five-year initiative announced in June 2000, is a mix of strategic investments and initiatives designed to build new partnerships on Canadian's eastern coast. It includes support for an expansion of NRC facilities, an investment fund, and training.
- NRC E-Commerce Institute, which will be located at the University of New Brunswick, will open in 2001. It is envisioned to provide the core of a technology cluster in electronic commerce and related information technologies. It will do research and form partnerships with companies, universities and others. It will have a research budget of $37 million Canadian ($23.9 million) over five years and an operating budget of $7.8 million Canadian ($5 million).

One of the biggest challenges for the long-term success of Canada's move toward an innovative, knowledge-based economy is the retention of their best and brightest researchers in Canada. Since 1970, 601,000 Canadians have immigrated to the United States, with higher-income individuals with university degree the most likely to move. The Conference Board of Canada found 3 percent of Canada's natural scientists immigrated to the United States in 1986; by 1996, 11 percent were leaving. In response, Canada is undertaking measures to stem the tide such as instituting more favorable tax policies especially in areas seen as important for attracting high-tech workers (e.g., stock options), and building more world-class research facilities at universities.

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MEXICO and CHILE

Promoting Economic Development Through Networks and Partnerships

The Mexican and Chilean governments are seeking stronger relationships and better coordination among their S&T-related agencies, and greater support from industry in new technology development and innovative business practices. Both are building their information infrastructure; Chile already has linked its research and education network (REUNA) in September 2000 to STAR TAP (Science, Technology, and Research Transit Access Point), allowing its researchers access to Internet2.

MEXICO

The Mexican government recognizes the important role of science and technology in economic and social development. Investment in R&D has remained steady over the years. The government has worked to create an environment favorable to technology innovation. Milestones include implementation of the North American Free Trade Agreement in 1993 and participation in major international agreements regulating the protection of intellectual property rights (IPR). It also has implemented regulations that provide for nondiscriminatory national treatment in IPR matters and established certain protection for trade secrets and proprietary information.

Several elements of the social and political environment in Mexico have a major impact on science and technology strategies. First, many scientific and technological facilities in the public and private sectors are concentrated geographically around Mexico City. Second, there is a strong contrast in awareness about the importance of science and technology between the small number of policymakers and middle class professionals and the large rural population. Third, domestic industry is dominated by small business, most of which is not S&T-based. Fourth, Mexico's demographic distribution has a large proportion of very young people demanding education and new jobs.

CONACYT, Mexico's National Council for Science and Technology, is in charge of promoting, implementing, and coordinating the S&T policies for the government. CONACYT has been promoting its S&T policy through various venues and working with industry to promote Mexico's technological resources.

National Development Plan

Mexico's National Development Plan (1995-2000) incorporated science and technology into the country's economic development strategy. The Mexican government recognizes that it still faces challenges in how it can introduce its public to the significance of S&T and, more specifically, how it can play a more important role in S&T in the 21st century. The plan, therefore, includes steps to enhance support for advanced research and to attract young people to scientific careers.

Developing and creating links and opportunities for partnership between the academic community and industry is another priority of the plan. The plan aims to catalyze these collaborations by creating new multinational programs for research. One positive goal will be the promotion of international meetings that focus on encouraging university-industry links. The government will increasingly be asking for financial and political support from industry in order to promote and implement its S&T policies. Contributions will be requested in the form of the creation of R&D laboratories and quality application programs for emerging technologies.

In his final State of the Nation address on September 1, 2000, then Mexican President Ernesto Zedillo reiterated the importance of science and technology. He stated that, although Mexico had increased R&D expenditures by 45 percent in real terms over the previous six years, the level is still far from sufficient.

Increasing Funding and Human Resources

The Mexican government spends approximately 0.34 percent of GDP on science and technology, up from

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0.22 percent in 1993.[1] Overall S&T expenditures rose from $1,473 million in 1993 to $1,938.5 million in 1998. R&D expenditures grew from $886 million in 1993 to $1,382 million in 1997.

In 1999, Mexican President Zedillo sought and obtained legislation that overhauled R&D funding. The new law is intended to promote and rationalize support for S&T research by establishing a unified, government-wide mechanism for planning and budgeting for R&D.

The law creates a permanent forum of scientists, academics and industrialists to advise the executive and legislative branches of government. The forum is to help ensure a high-level voice in policy discussions of important S&T issues and funding decisions. The new law also changes the way public research centers are administered. It grants more autonomy to ministries to allocate research funds, removing budget caps to permit centers to raise funds from private industry, and allowing ministries and centers to invite and fund proposals from anywhere, including universities.

Major S&T activities include:

- Mexico's largest science project (US$50 million), the large millimeter telescope project. Scheduled to be fully operational in 2002, the telescope project is the product of a binational U.S. and Mexican consortium of public and private entities.

- Established in late1992 as a non-governmental institution, the U.S.-Mexican Science Foundation is a bilateral think tank offers activities in health, water, clean technologies, environmental degradation, and biodiversity.

Mexico also has made a commitment to doubling the R&D work force by the year 2000. In 1998, total headcount of S&T personnel (researchers and technicians) was 449,000 – up from 334,000 in 1993. Full-time equivalent (FTE) S&T personnel rose from 269,000 to 333,000 in the same period. The country is committed especially to expanding the number of personnel with master's degrees and PhDs in science and technology. For example, a scholarship fund was created to support students studying science in Mexico and abroad. About 24,000 students receive these graduate scholarships.

[1]Statistics are from RICYT, Inter-American Network of S&T Indicators.

CHILE

The vagaries of Chile's economic growth have had little impact on relatively high levels of public and private investment. R&D expenditures have remained steady at a little over 0.7 percent of GDP since 1991 and reached a high of 0.83 percent in 1995. Total R&D spending, however, declined slightly in 1997 to $497 million (0.65 percent of GDP) and again in 1998 to $489 million (0.67). Expenditures on S&T (including R&D) reached $678 million in 1998, and an estimated $850.93 million (0.98 percent of GDP) in 1999. S&T expenditures are forecast to rise to $1,005 million (1.09 percent of GDP) in 2000.

The Chilean private sector funds about 15 to 18 percent of R&D, but performs only a small percentage, approximately 3 percent, of that portion. However, R&D performed by foreign subsidiaries, particularly in pharmaceuticals is growing. Almost all research is done within Chile's universities where almost 70 percent of researchers work. Most researchers deal with basic sciences and mathematics rather than the engineering sciences. Engineers represent 30 percent of graduates with most going to private industry. Of the funding for universities, most is direct allowances to Chile's 25 traditional universities (31 percent) and technical institutes (17 percent). The government awarded 26 percent of university research funds competitively.

Spending on technology development in the 1990s constituted a steadily increasing proportion of the government S&T budget relative to basic and applied sciences. Modernization, innovation, and flexible systems and structures, accompanied by pervasive dissemination and absorption of new technologies, continue to be perceived as important factors in meeting the country's economic targets. The country has many R&D institutions and specific funding schemes, but it is still looking at how to develop clearer institutional mechanisms for S&T policy formation.

The most intensive S&T activity occurs in eight target areas: farming and animal husbandry, forestry, information technology, manufacturing, mining, fishing and aquaculture, water and energy, and health. The fastest growing areas of research are biotechnology and computer science. Chile's rapid expansion of the information highway is particularly notable. Chile transacts almost twice as many Internet communications with the United States and Europe as do all other Latin American countries combined and has the largest number of Internet hosts per person in

Latin America. It is using this experience to expand commercial ventures into electronic commerce and become a leader in this area as well.

CONICYT, the National Council for Scientific and Technology Research, plays a key role in S&T policymaking, research funding, international cooperation, human resources development and promotion of public awareness of S&T. It administers the National Fund for Scientific and Technological Development (FONDECYT), which funds research projects in basic and applied sciences in all fields of knowledge. The research projects may be up to three years in duration.

The Ministry of Economy conducts the Technology Innovation Program. One part of that program is the National Fund for Fostering Scientific and Technological Research (FONDEF), which seeks to strengthen the research capabilities of national R&D institutions and promote linkages between nonprofit R&D institutions and industry. The creation of the Red Universitaria Nacional (REUNA) is one of the most outstanding successes of FONDEF, decisively stimulating the development of Chile's Internet access. Other parts include the National Fund for Productive Technological Development (FONTEC) and some smaller, sector-specific programs.

In 1998, CONICYT embarked on a review of policies and programs related to science, technology and innovation. Policy issues identified as requiring attention that emerged from that review include: institutional governance; the need for prioritization; technology for SMEs; promoting an innovation culture in Chile; support for the social sciences; and support for health research. In addition, the need for engaging the private sector in joint commitments with respect to long-term S&T investment and for initiatives to support new company start-ups was cited.

ARGENTINA, BRAZIL and COLOMBIA

Latin American Nations Seeking Technology-Led Economic Growth

Argentina, Brazil and Colombia continue striving to increase innovation and scientific research in their private sectors. Building an environment conducive to a vibrant digital economy is a priority in all three countries.

ARGENTINA

Argentina possesses rich natural resources, a highly literate population and a diversified industrial base. Real GDP growth was strong after the peso crisis of 1994-1995, increasing to 8 percent in 1997. The growth brought about an increase in R&D spending that previously had been declining in the early 1990s. Total R&D spending increased, reaching $1.47 billion or 0.45 percent of GDP in 1998.

The upward trend reversed with the international financial turmoil brought on by the Asian financial crisis. Argentina's growth rate dropped to -3.5 percent in 1999 with unemployment estimated at 14 percent in December 1999. While statistics are not yet available for 1999 and early 2000, news reports indicate that the Argentinean government and companies had a difficult time maintaining R&D expenditures at 1998 levels.

Argentina significantly reorganized its S&T structure in 1996. This structure, outlined in *The Bases for the Discussion of a Politics of Science and Technology*, clarified the roles of Argentina's policy, funding and research organizations. Under the plan, Argentina's top policy organization is the S&T International Council (GACTEC), which determines national S&T policy and budget allocations. GACTEC's members include all ministers with some responsibility for S&T. Ministers with large S&T portfolios include Culture and Education, Economy, Defense, Health, and Public Works and Services. The independent secretaries of Natural Resources and Sustainable Development, Strategic Planning and S&T also participate.

The Secretariat of S&T (SECyT) prepares national S&T strategies and evaluates programs for GACTEC. The Secretary of SECyT also chairs the Federal Council of S&T (COFECyT), a policy group made up of regional representatives from the 23 provinces and the City of Buenos Aires.

The National Agency of S&T Promotion provides most of the public funding for research. Its two major funding programs are the Fund for Science and Technology (FONCyT) and the Fund for Technology (FONTAR). FONCyT funds basic and applied research. FONTAR funds innovation and technology modernization within the private sector. The National Council on S&T Research (CONICET) oversees the majority of Argentina's research centers and institutes. INTA (the National Institute of Agriculture Technology) and INTI (the National Institute of Industrial Technology) also carry out R&D.

In recent years, the large amount of government R&D funding that formerly went to the nuclear industry continued its decline as more Argentinean public organizations were privatized. Business R&D expenditures rose sharply in 1998 to $443 million from just $158 million in 1996 reflecting privatization. Business employed about 20 percent of the country's R&D personnel (9,000 out of 43,200) up from only about 8 percent in 1996.

Argentina is placing a strong emphasis on strengthening the technical levels of its small and medium-sized enterprises and upgrading its information infrastructure. Argentina boasts the most computer power per capita (7,880 MIPS per 1,000 people) and the greatest number of connections to the Internet (3.08 hosts per 1000 people) in Latin America but still trails far behind with over 30 other countries ranking higher in these categories.

BRAZIL

Brazil is the largest economy in Latin America and the eighth largest in the world. Brazil also has the largest and most developed industrial base in Latin America, and spends the most on R&D. It has 21,500 R&D personnel (6,800 in business enterprises)

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employed in more than 500 research institutes and 100 federal, state and private organizations involved in S&T activities.

S&T spending by the federal government remained steady through the early 1990s. Total national expenditures on R&D rose sharply in 1996 and then held steady in 1997 at $4.07 billion (0.57 percent of GDP). Expenditures rose again in 1998 to $5.876 billion (0.784 percent of GDP). Most R&D funding goes to universities and government research centers, but the government is attempting to redirect many R&D efforts to the private sector. The government hopes that early in the 21st century total R&D expenditures in Brazil will grow to more than $10 billion, with more than 40 percent coming from private industry. It is pushing hard to have overall S&T resources grow to 1.5 percent of GDP.

Because of the privatization of state-owned corporations, business expenditures on R&D accounted for almost one-third of total expenditures ($2.350 billion) in 1998, up from nearly zero a decade earlier. Brazil has received almost $1 billion in loans from the Inter-American Development Bank and the World Bank since 1997 to improve the overall performance of R&D, including that in the private sector. Brazil's privatization in 1998 of its telecommunications system (Telebras) constitutes a continuing major R&D challenge as it endeavors to maintain the strong long-term R&D establishment formerly centered in Telebras's Research and Development Center (CPqD).

Brazil's Ministry of Science and Technology, established in 1985, implements the nation's S&T policy and coordinates priority areas and R&D activities involving the development, production and application of new and advanced technologies. While Brazil has had some notable successes in the aviation, chemical and transportation industries, the Ministry of Science and Technology has identified computer technology, material sciences and biotechnology as areas of weakness that should be strengthened.

Specific Policy Initiatives

Brazilian President Fernando Henrique Cardoso stated in September 2000 that the major concern of the government in regard to science and technology is the deployment of Internet2. In this regard, he affirmed that the government would continue to apply the necessary resources through FUST (Universal Telecommunications Fund) and other mechanisms. Brazil continues to establish the scientific and technical competence to become autonomous in space technology, including working with Brazilian industry to become competitive in the international space goods and services marketplace.

Brazil has tax write-offs to encourage industry and private-sector enterprises, especially those in the computer and telecommunications sectors, to invest in joint R&D projects with Brazilian research institutions. Most direct R&D funding programs for industry consist of low-interest, medium-term loans and priority is given to multi-entity cooperative projects.

CNPq, the National Research Council for S&T development, coordinates basic programs devoted to strategically important fields and maintains special programs, including Support to Technological Development, the Environmental Technology Development Program, and the Software Technology Development Program.

Brazilian industry has been active in establishing R&D centers, as well as in upgrading quality standards to internationally based ISO 9000 standards. The Brazilian government supports such activities under the Brazilian Quality and Productivity Program (PBQP). It also regulates technology transfer through such mechanisms as the National Institute of Industrial Property (INPI).

The Brazilian government also supports ParqTec, a business incubator primarily for start-up companies. It provides access to facilities and services such as laboratories, Internet service, marketing and legal assistance and training programs.

COLOMBIA

Colombia with a population of only 37 million, spent $158 million (0.195 percent of GDP) on R&D in 1998, ranking it in a similar position as countries like Malaysia and Thailand.

Business R&D expenditures accounted for an extremely large share of total R&D, $132 million or nearly 84 percent, reflecting a long tradition of privately sponsored research. Colombia ranks relatively high in terms of R&D personnel in business with 0.23 per 1,000 people and in the availability of qualified engineers, higher than in most Southeast

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Asian and Latin American countries. Major areas of research are correlated with Colombia's major industries. These areas include agricultural technology, biotechnology, energy and power technologies, and mining technology.

In 1990, Colombia passed a law that established a new National Council of Science and Technology (SNCT). SNCT seeks to modernize the economy, increase private sector investment in S&T and facilitate interaction among Colombia's research institutes, universities and companies. SNCT is composed of twelve programs or areas of work. Each program for its sector coordinates S&T planning, formulates policy, promotes funding and integrates the views of various advisory committees. Programs include areas such as agriculture, electronics, telecommunications and computer science, energy and mining, aquaculture, biotechnology and social sciences.

In addition to SNCT, other major S&T coordinating organizations include: the National Program Council, Science and Technology Regional Commissions and the Committee for Science and Technology Human Resource Development.

Like Brazil and Argentina, Colombia is working toward an information technology infrastructure that will allow it and its companies to play a bigger role in the global knowledge economy.

ASIA

JAPAN

Sustaining a Commitment to Science and Technology

Japan, the world's second largest producer of science and technology, is clear in its vision to remain one of the world's most competitive nations. Even in the wake of its financial downturn, the Japanese government is strongly committed to science and technology. Indeed, Japan views the allocation of resources directed to the development of science and technology as a key mechanism for "growing itself out of" the economic recession in the short term, and at the same time, creating a strong foundation for economic growth in the long term.

S&T Policy

Japan is radically restructuring its science and technology policy and institutions. Many of the institutional changes are scheduled to go into effect January 1, 2001. The changes could portend a greater openness toward foreign participation in Japanese science and technology. The changes are the final step in a process begun in the mid-1990s when Japanese policymakers sought ways to break their economy out of recession and regain their competitive momentum. As Japan's unemployment reached 5 percent in the late 1990s, a record postwar level, the movement took on added urgency.

The Japanese government's first significant step in this process was the passage of the new Science and Technology Basic Law in 1995 that set the stage for doubling government S&T expenditures by 2000, and for reinventing research institutions, and science and technology policy. Then, in June 1999, the Economic Recovery/Industrial Competitiveness Study Team of Japan's ruling Liberal Democratic Party (LDP) called for a new National Industrial Technology Strategy that the LDP subsequently adopted and many of whose suggestions the Diet enacted to nurture leading industries and strengthen science and technology. It included tax preferences and direct funding of R&D projects for high-tech and emerging industries such as biotechnology, software, and telecommunications. These industries are seen as fundamental to sustained economic growth in the 21st century. The Japanese government prepared legislation to make it easier to license government-owned patents to private companies by lowering fees and eliminating paperwork. The government has more than 15,000 patents, most of which have never been commercially developed.

These proposals, as well as statements by Ministry of International Trade and Industry officials and others, all stress the need for the government and large companies to nurture venture businesses, especially those involved in high-technology industries. In a related move, some national universities in late 1998 began to establish "incubation centers" to assist the transfer of university-developed technology to industry. These policies indicate a shift in Japan away from a technology policy centered primarily on large companies.

Changes in 2001 and Beyond

Major changes anticipated in 2001 include the establishment of the National Council for Science and Technology (NCST) within the Prime Minister's Office with authority to make policy recommendations, advise on the strategic allocation of R&D resources, and evaluate national R&D efforts. It is seen as combining the roles played in the United States by PCAST (President's Council of Advisors for Science and Technology) and the coordination functions of the White House Office of Science and Technology Policy.

The Science and Technology Agency will merge with the Ministry of Education, Science, Sports and Culture to become the Ministry of Education, Science and Technology. This new ministry will control almost 70 percent of national R&D, and add substantially to its innovation portfolio by incorporating most of Science and Technology Agency's programs and mandates. Most of the changes slated for the national universities will occur in 2003.

The Ministry of International Trade and Industry (to be renamed the Ministry of Economy, Trade and Industry in 2001) will control approximately 16 percent of R&D funds. The 15 national research institutes controlled by MITI will be reorganized into an independent administrative agency called the Industrial Science and Technology Institute (ISTI). ISTI will have 10-20 small, permanent institutes and 20-30 temporary research centers. Most importantly, ISTI will receive a program budget from MITI but will have the freedom to transfer funds from one project to another and from one year to the next independently.

The actual effect of the restructured science and technology policy and institutions on Japan's industrial structure and innovation system will not be clear for several years. They are intended to increase flexibility and increase merit-based competition for research funds but will take away certain civil service protections from some of the employees of the new independent administrative agencies.

S&T Expenditures

Japan's Basic Plan, enacted by the National Diet in 1995, to implement the new Science and Technology Basic Law was to double the amount of government investment in S&T by Japan FY 2000 from the Japan FY 1992 level. Japan has reached this goal, and is seeking further increases. Despite stagnant growth in overall GDP, the ratio of R&D expenditures to GDP in Japan FY 1998 was the highest ever, reaching 3.26 percent of GDP and marking the fourth consecutive year of increases. This percentage places Japan second in the world behind Sweden. Total R&D expenditures in calendar year 1998 reached $122.3 billion, accounting for close to 20 percent of the world's R&D, about 54 percent of that spent by the United States, but 2.5 times larger than that of third place Germany.

For its part, the Japanese business sector spent $88,093 million on R&D in 1998, about 72 percent of Japan's total R&D expenditures. Japanese industry has become well known for creating new markets by providing products and services that incorporate leading-edge technology, and this practice continues despite the economic downturn. Japanese companies, though making cutbacks in R&D and restructuring elements of their operations, are nevertheless striving to maintain their competitive edge in areas such as electronics and manufacturing and are driving new lines of business in the hottest sectors of the economy, principally information technologies.

According to figures released in late November 2000 by Japan's Management and Coordination Agency, in Japan FY 1999, aggregate R&D spending by corporations, private universities, independent research laboratories stood at 16.01 trillion yen ($145 billion), a decrease of 0.8 percent from the previous year and the first decline in five years.[1] The corporate sector accounted for nearly all of the decline, falling 1.6 percent. University spending fell 0.4 percent while independent laboratories increased spending by 2.6 percent.

The largest multinationals continue to invest in R&D and do not rely on government expenditures. Even during the troubled mid-1990s, surveys of top Japanese companies indicated that, while many had to lower R&D expenditures, they increased R&D expenditures as a percentage of total sales. Growing worries over competitiveness were cited as a primary reason to increase the percentage devoted to R&D and to deregulate the economy in order to encourage additional private investment. In terms of business expenditure on R&D per capita, Japan at $698.76 already outspends every nation except Switzerland and Sweden.

Coming Challenges

The next challenge facing Japan's S&T policymakers is ensuring that the structural changes they have enacted do increase Japan's ability to innovate and compete globally in R&D intensive industries. Part of this challenge will be the ability of innovative small and medium-sized companies to survive and grow. After a hiatus in technology-based start-ups since the end of Japan's high growth period of the late 1950s and early 1960s, there are a growing number of high-tech start-ups especially in information technology, software and biotechnology. The restructuring effort also seeks to encourage sufficient university-industry cooperation and thus more technology transfer by making it easier for national university professors to do consulting and found new high-tech start-up companies.

A second challenge is the growing shakeout of Japanese companies shown by the decline in the number of manufacturers for the eighth year in a row in 1999. The shakeout also is resulting in mergers and alliances that are changing the ways and the areas in which companies perform R&D. It is encouraging additional international cooperative R&D alliances as well as domestic ones.

Surviving companies also are responding by investing heavily in new information technology both to

[1] The aggregate figures includes funding for salaries (7.37 trillion yen) and other related items.

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rationalize manufacturing processes and to boost sales. Information technology expenditures accounted for more than 20 percent of total capital spending by Japanese companies in Japan FY 2000 (April 1, 1999-March 31, 2000). Biotechnology is the second area seeing large increases in R&D as many traditional food and beverage companies trying to diversify join Japan's large pharmaceutical companies in investing in biotechnology research.

Japan, like most of the rest of the world's nations, also is facing a shortage of skilled high technology workers. In 1998, it had 894,000 R&D personnel just behind the United States' 962,700. However, fewer students are selecting science and technology careers and Japan ranks only 34th in the world in terms of having sufficient numbers of qualified information technology workers. These trends are especially acute in Japan, which faces one of the most rapidly aging populations in the world. It has undertaken major campaigns to increase public interest in science and technology, and encourage students to major in science, technology and engineering. Measures include science camps for high school students, subsidies to local governments to build S&T museums and centers, science competitions and exhibits, and dispatching researchers to speak to students.

PEOPLE'S REPUBLIC OF CHINA and HONG KONG

Encouraging Science and Technology for Economic Development

China's leaders strongly believe future economic development must rely on science and technology, and science and technology must be geared to economic development. Hong Kong is working to become a major technology service supplier to the Chinese Mainland and globally.

CHINA

The People's Republic of China is moving to become a global technological and scientific powerhouse. It wants to rank among the world's top 10 R&D powerhouses by 2010 but still has many challenges ahead if it is to meet that goal. *The World Competitiveness Yearbook 2000* ranked China as 28th in S&T competitiveness, down from 13th in 1998 and Hong Kong, as 27th, down from 25th. While China scores high for its basic research capacity and the involvement of youth in S&T, it lacks sufficient 1) engineers, 2) qualified information technology workers, 3) domestic and international patenting of its advances, and 4) R&D personnel in its companies. In addition, scientific research results still contribute only minimally to economic development, and the importation of advanced technology is not well enough integrated with domestic research.

China spent approximately 1,128.5 hundred million remnibi (RMB) in 1998 on science and technology of which 555.1 hundred million RMB or $6.7 billion was for R&D. This ranks China thirteenth in the world. It also represents an increase of 63 percent over R&D expenditures in 1995 (348.7 hundred million RMB). The private sector accounts for 45 percent of R&D expenditures, an amount that is gradually increasing.[1]

China's goal for science and technology spending, stated by Premier Li Peng in 1995, was to be 1.5 percent of GDP by the year 2000. By 1998, total expenditures for R&D had reached 0.693 percent of GDP and total expenditures for S&T were roughly 1.3 percent of GDP. Reaching this goal was bound to be difficult for China, even though both S&T and R&D expenditures have increased substantially in recent years, because of the rapid overall growth of the economy and the need for more private sector R&D.

[1] It is unclear to what extent this figure might include R&D expenditures by prefectural and local government entities.

The Ninth National People's Congress

The Ninth National People's Congress, held in March 1999, evoked a number of changes in the structure and composition of the national government. Premier Zhu Rongji, appointed at the annual meeting, outlined the goals of Chinese economic policy, including a growth rate of 7 percent, inflation less than 3 percent, and currency stabilization. The government also aims to stabilize most large and medium-sized state-owned enterprises within three years, with no slowdown expected, despite some of the lingering effects of the Asian financial crisis. In addition, the very structure of the bureaucracy will be reformed, with changes in the circulation system for grain, the investment and financing systems, the housing system, the medical care system, and the fiscal and taxation system.

Through the reforms, Premier Zhu aims to rectify the inefficiencies of the Chinese bureaucracy so as to pursue the paramount objective of "revitalizing China through science and education." The government apparatus is expected to be streamlined and simplified, with a 50 percent reduction in staff size and strict elimination of duplicate procedures. In pursuit of enhancing science and education, the entire ministerial structure has been reformed, and a focus group for science, technology, and education was to be established and headed by the new premier.

As one early step in the process of marrying S&T more closely with economic development, China transformed its State Science and Technology Commission into the Ministry of Science and Technology (MOST) in 1998. The current MOST leadership actively advocates and emphasizes that China's priorities should be science and technology development in large and medium-sized enterprises, with a focus on increasing their international

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competitiveness. Part of MOST's mandate includes coordinating science and technology advances with the development of industry, creating a reserve of scientific knowledge and findings, and encouraging innovation through intellectual property rights and youth education. MOST also is focusing on directing research at the macro-level rather that regulating specific programs. It is still unclear, however, what influence the newly reconfigured ministry will have on China's science and technology structure over the long term.

China will continue to target emerging technologies where it has strong basic science capabilities, where benefits cut across industrial sectors, and/or where the application supports China's economic development goals. To fuel innovation in the 21st century, it is investing heavily in advanced materials, clean and renewable energy technology, microelectronics, biotechnology, information technologies, and industrial automation. It also is working hard to increase its companies' abilities to commercialize technology by looking at how to promote venture capital and how to encourage technology transfer. One mechanism used is tax breaks for revenue gained connected with technology transfer, development or services.

Despite the ambitious reforms and China's strong national commitment to technology-driven growth, its biggest challenge is maintaining sufficient economic growth to allow the reforms to its economy overall and to its S&T infrastructure to take effect. Growth in 1999 was 7.1 percent, high compared to most other nations, but less than that many analysts believe China needs to restructure.

China is hoping to achieve the same level of rapid growth in its technical and scientific capabilities that it achieved during the 1990s to support development in the 21st century. It is working to establish centers of innovation in its universities, to increase its ability to commercialize technology, and to have world-class S&T researchers and workers.

Major Research Programs

Research programs have been developed that coordinate research topics with economic objectives and ensure that research institutes compete for an opportunity to work on a particular technical problem or objective. The following are China's major science and technology programs:

- Advanced Technology Development Program (863 Program): supports fundamental research in emerging advanced technologies including advanced materials, microelectronics, biotechnology, information technology, industrial automation and energy.

- Torch Program: supports applied research and commercialization of 863 Program results. Fifty-two technology industrial parks have been established.

- Productivity Promotion Centers: provides technical support for commercialization of technology by small and medium-sized enterprises. Services include business management training, technical assessment, commercial feasibility assessment, prototype development, technical training, and other forms of assistance.

- Spark Program: diffuses advanced agricultural techniques.

- Key Technologies Program: supports research in areas of key importance to national economic development.

While China has the fourth largest R&D workforce of any country (830,000 full-time work equivalents), it has weak skills in some areas, such as engineering and information technology, that are essential for its future economic growth. At the end of 1997, 2.62 million individuals were employed in scientific and technological activities, including 1.68 million scientists and engineers, many of whom undertake activities that are not classified as research. As in most developing countries, China's research personnel are concentrated in engineering fields, which account for approximately 58 percent of all research activity. Chinese researchers also are shifting from government research facilities and academia to state-owned enterprises and technical service organizations.

China is moving to globalize its research and development. It maintains scientific and technological cooperation agreements with 96 countries, including participating in the EU's Fifth Framework Program. Foreign companies are establishing institutions, centers, and labs devoted to R&D with Chinese partners in China. In addition, MOST estimates that more than 2,500 PhDs, 210,000 individuals with master's degrees, and 3,000 other students have returned to China and have been employed in China's high-tech science parks, many of which will play a key role in China's globalization efforts. It still ranks low, however, compared to many developing countries in terms of internationalization, particularly in areas such as cross-border ventures and cooperation between domestic and foreign companies.

HONG KONG

Hong Kong spent $354 million on R&D in 1998, ranking it 37th globally with all but 9 percent coming from the Hong Special Administrative Region government. In order to remain competitive with countries such as Singapore and serve as an intermediary in technology transfers between China and the rest of the world, Hong Kong recognizes that it needs to substantially increase its R&D funding and upgrade the skill base of its traditional industries.

Hong Kong is focusing on encouraging innovation through industrial support funds, development of local talent, and the easing of various government regulations. It hopes to strongly promote information technology, especially in Internet, electronic commerce and software engineering; multi-media-based information and entertainment services; biotechnology with a focus on health foods and Chinese traditional medicine; and supply of technology services to China and globally.

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REPUBLIC OF KOREA

Taking Steps to Stay on Track in the Pursuit of Science and Technology

Korea strives to maintain strong, world-class science and technology capabilities, in part by leveraging Korean and foreign resources through international collaboration. Korea also plans to augment technology commercialization by promoting educational and technical training, supporting venture capital efforts, and fostering local innovation.

The 1997 financial crisis hit Korea extremely hard, with the Korean currency (won) plummeting to half its value. Since then, the Korean government and its businesses have worked hard to restructure their economy. An important part of this effort is building the stronger capability in science and technology that Korea's leadership sees as essential to future economic prosperity in a globalized, knowledge-based economy. Their hard work received a boost from Korea's economic resurgence in 1999 and 2000 that included the largest amount of foreign direct investment in Korea's history.

Even with the economic resurgence, the Science and Technology Policy Institute of Korea (STEPI) estimated that Korea's total R&D spending (public and private) in FY 1999 would be 9.8 trillion won ($8.1 billion), 19.7 percent below the pre-economic crisis amount in 1997. The private sector was responsible for almost all the decline, falling from $8.65 billion in 1996 to $5.86 billion in 1998. Korean businesses also cut back on technology imports and R&D infrastructure development.

Through the five-year period ending in FY 1999, government R&D as a percentage of the total budget has remained relatively steady, with a low of 2.34 percent in FY 1995, a high of 2.81 percent in FY 1997 and a FY 1999 level of 2.60 percent. The government R&D budget resumed positive growth in FY 1999, reaching 3.069 trillion won, after declining in FY 1998 for the first time since 1967. It continued to grow in FY 2000 to 3.53 trillion won. Most of the government's civilian agencies experienced declines or only modest increases in their R&D budgets; overall these reductions were offset by a large budget increase for the Ministry of Defense. The largest decrease from FY 1998 to FY 1999 was in the budget for the Ministry of Science and Technology (MOST), Korea's leading government S&T institution. MOST, founded in 1967, has the primary responsibility for formulation and implementation of S&T policy and for coordination of national scientific matters.

S&T Policy

In its policy statements, the Korean government is placing special emphasis on leveraging Korea's own and foreign resources through selective R&D collaboration, especially international efforts. Among these are projects entitled the "Foundation Established for International Cooperation" and "International Joint Research." The FY 1999 budget, however, allocated less for international cooperative programs.

Other priorities set forth in a 25-year "industry-centered" S&T development plan in late 1999 include the commercialization of technologies by providing support for high-tech venture businesses, improving the educational system to encourage and train Korea's future venture capital business leaders, and promoting innovation at the local level. It moves away from government-defined national development goals toward devising policies that enable universities and government research institutes to support industry initiatives.

Korea has not completely abandoned its policy of funding large-scale government R&D efforts. The Highly Advanced National (HAN) projects are continuing. The HAN budget was reduced in FY 1998 from the FY 1997 level, but it regained ground in FY 1999 with an increase of 23 percent. HAN's recent R&D projects have included next-generation flat panel displays, micro-electromechanical devices and miniature precision machine tool technology, and advanced materials for information, electronics, and energy.

Structural Changes and Priorities

In a move that demonstrated Korea's commitment to S&T, President Kim Dae-Jung in February 1999 raised MOST to a senior cabinet ministry for the first time and restated his commitment to raise R&D spending to 5 percent of the national budget by 2002. Cognizant of

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the fact that it now has fewer financial resources to funnel into R&D projects, the Korean government has formulated policies that will not require huge sums of money to implement, but will support the overall S&T infrastructure.

Based on its assessment that the biggest infrastructure problem in the government's S&T establishment is the lack of coordination and strategic vision on S&T policies and investments, the government set as the number one item on its policy agenda the establishment of a National Science and Technology Committee (NSTC) chaired by the president. The NSTC held its first meeting on April 1, 1999. One of its first items of business was the Grand Plan for the Promotion of Regional Science and Technology, announced in 1998 to promote S&T and innovation at the local level.

As part of its restructuring effort in 1999, the government established the Korea Institute for Science and Technology Evaluation and Planning (KISTEP) to support the review, analysis, and assessment of national R&D projects. The government hopes that KISTEP's open evaluation system will help improve the management of S&T projects and thus their outcomes.

Other goals, akin to those being pursued by Japan and other Asian countries, are the promotion of basic research and the nurturing of creative young minds. Another top policy priority is to encourage the commercialization of technologies through high-tech venture capital businesses, a goal that includes improving the educational system and developing a venture capital market to give rise to the venture business leaders of tomorrow.

Like the government, the private sector continues to restructure through mergers and increased openness to foreign investment as a way to achieve sustainable technology-led economic growth based primarily on private sector R&D rather than a centrally controlled R&D model. In terms of R&D spending, business continues to account for the bulk of Korea's R&D investment, nearly 80 percent in 1998, making successful business restructuring critical to future development.

The number of R&D personnel fell by 8.5 percent in 1998 as some researchers moved overseas. By 1999, however, companies, including the large conglomerates or chaebols (with the notable exception of Daewoo), appeared to be stepping up their R&D spending. Based on a poll of 775 firms with R&D centers, the Korea Industrial Technology Association said that 80.8 percent of the firms planned to increase R&D spending. R&D spending in electronics and telecommunications continues to absorb the largest share of corporate investment.

Already, some younger Koreans are abandoning the chaebols to start small high-tech companies to develop new telecommunications and Internet technologies and products. Their funds come from institutions such as the Korea Technology Investment Corporation and from private domestic and foreign investors. Korea is emerging as one of the leading wired economies, becoming by early 2000 the world's third largest Internet user after the United States and the United Kingdom.

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AUSTRALIA and NEW ZEALAND

Governments Maintaining Long-Term Commitment to S&T Development

Australia is taking full advantage of its position in the Asia-Pacific region and its world-class R&D infrastructure to improve its international competitiveness. New Zealand has declared technology innovation a key factor in sustained growth and that economic success and international competitiveness will depend on the ability of firms to undertake technology development.

AUSTRALIA

Australia held an innovation summit in early 2000 that brought industry and government together to discuss how Australia could become more innovative and world competitive in the new world economy. It found that all business will be exposed to the global winds of change because of the ability of customers to go on-line and purchase from anywhere in the world. Therefore, companies and countries must have aggressive competitive strategies and view innovation both as a core competence and as a core strategy.

The Australian government as its part in facilitating innovation believes it must invest in national technological competitiveness and continue to create incentives for private industry to invest as well. It is investing heavily in its S&T base, emphasizing the aerospace and environmental technology sectors while making impressive additions to its traditionally superior mining and agricultural fields.

Australia's S&T policy has pursued three main objectives over the past decade: maintaining a high-quality public sector research infrastructure, maximizing the practical application of the science base to industry, and encouraging greater innovation by business.

Expenditures

Total R&D expenditures in 1998 stood at $6.8 billion, a relatively low 1.67 percent of GDP compared to other industrialized countries. Business accounted for $3.2 billion, approximately 47 percent of the total.

In FY2000-01, Australia's federal budget for science and technology is AU$4,538 million (US$2,362 million), up 1.1 percent from the previous year. This funding includes:

- Higher Education R&D (AU$1,787.6 million or US$930.4 million);
- Cooperative Research Centers (AU$134.4 million or US$70 million);
- R&D Start Program (AU$154.5 million or US$80.4 million);
- IR&D tax concession (AU$600 million or US$312.3 million);
- Rural R&D (AU$170.3 million or US$88.6 million);
- Energy R&D (AU$131.8 million or US$68.6 million);
- National Health and Medical Council (AU$320.7 million or US$166.9 million);
- CSIRO: Commonwealth Scientific and Industrial Organization (AU$615.8 million or US$320.5 million); and
- DSTO: Defense Science and Technology Organization (AU$263.5 million or US$137.2 million).

Two areas in the budget showed substantial increases, medical research, up 11 percent, and energy R&D, up 18 percent. These increases reflect Australia's growing investment in life sciences and its continued strength in the energy sector where it is upgrading its already world-class capabilities. Other areas, including CSIRO, the R&D Start Program and the defense sector, faced stagnant or slightly decreasing budget allocations.

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Major Institutions

One of the Australian S&T institutions central to implementing the government's strategic objectives is CSIRO. CSIRO, a system of semi-autonomous public research institutions, is the largest Australian organization performing R&D. CSIRO's central focus is on encouraging better links between public-sector research and industry. Its specific functions include performing R&D, advocating and facilitating the application of R&D results, and acting as a liaison between Australia and other countries in R&D matters.

In December 1997, the Science, Engineering, and Innovation Council replaced the Australian Science and Technology Council. The new council is the government's principal source of advice on issues in science, engineering and technology, and relevant aspects of education and training. The prime minister chairs the new council.

Specific Policy Initiatives

The Cooperative Research Centers (CRC) Program is a key mechanism to encourage tripartite R&D linkages among government research agencies, universities, and industry. As of 1998, 67 centers were in operation, working in six areas: manufacturing technology, information and communications technology, mining and energy, agriculture and rural-based manufacturing, the environment, and medical science and technology.

The strategic R&D assistance program, START, began in August 1996. It is available to all non-tax-exempt companies in Australia. START's objectives are to:

- Stimulate business innovation and R&D;
- Provide direct support via competitive grants for outstanding business R&D projects; and
- Complement the broad-based, indirect support provided by the R&D tax concession program.

The government also announced in December 1997 that $108 million would be provided over the next four years for technology diffusion initiatives. These funds are delivered through the Technology Diffusion Program (TDP), which commenced on July 1, 1998. The International Science and Technology Program and the Technology Support Centers Program initiatives and funding were combined into the TDP.

NEW ZEALAND

New Zealand's S&T system, particularly the way in which resources are allocated, underwent extensive reforms in the early 1990s. The government at the same time made a commitment to increase public investment in S&T to 0.8 percent of GDP by 2010.

Funding for research and development is dominated by the government, which provided about 73 percent of total R&D funding ($584 million) in 1998. Business spent $158 million. Total public and private expenditure on R&D in 1998 stood at 0.98 percent of GDP.

In August 1996, the government spelled out its broad strategy for research, science, and technology in *RS&T: 2010, The Government's Strategy for Research, Science and Technology*, which continues to guide New Zealand's S&T investments. The purpose of *RS&T: 2010* was to "provide a strategic context for investment in science by the government, and … to encourage the skills and motivation which will make science and technology work for our national benefit". *RS&T: 2010* set out three major goals for science and technology:

- Fostering societal values and attitudes that recognize science and technology as critical to future prosperity;
- Ensuring an adequate level of investment in science as a component in national life that has cultural value in its own right; and
- Maximizing the direct contribution of science and technology to diverse social, economic, and environmental goals.

The government established a new Science and Innovation Advisory Council in 2000 to assist it in facilitating a future for New Zealand as a knowledge society. Its duties are to: 1) increase the public status and recognition for scientists and science; 2) promote a long-term strategic direction for research, science and technology; 3) build private sector commitment to new science and technology policy directions; and 4) enable co-ordination of government policies and community activities at the highest level.

The Ministry of Research, Science, and Technology, the Foundation for Research, Science and Technology, the Royal Society of New Zealand, and the Association of Crown Research Institutes are New Zealand's principal

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science and technology agencies. The Foundation, established in 1990, along with the Royal Society of New Zealand and the Health Research Council constitute the government's "purchase agents" for science and technology.

The largest single source of government funding had been the Foundation for Research, Science and Technology's Public Good Science Fund. It provided approximately NZ$327 million (US$133.4 million) in research funds in FY 1999-2000. In 2000, it was split into five more-focused funds: Research for Industry, Maori Knowledge and Development Research, Health Research, Social Research, and Environmental Research.

The 2000-2001 budget illustrates the government's ongoing commitment to invest in science and technology, building on the policy commitments announced in RS&T: 2010. The budget calls for a NZ$474 million (US$193.4 million) "Science Envelope" - the portion of the budget within which support for science and technology is included. Budget priorities included increasing high-quality science and technology investment, including health research; raising investment in new research to support the operations of government departments; and enhancing values and attitudes supportive of S&T.

In 1997 the government also introduced a scheme, known as Technology New Zealand to increase the ability of companies to adopt new technology and to apply technological innovation for business growth. It is funded at NZ$24.7 million (US$10.1 million) in the 2000-2001 budget. It includes TechLink, which coordinates the provision of national and international information and technology services, including the establishment of Internet-based technology services and expansion of existing programs. Other programs include: Grants for Private Sector R&D (NZ$11.8 million or US$4.8 million), Research for Industry (NZ$171.1 million or US$69.8 million) and New Economy Research Fund (NZ$50.7 million or US$20.7 million). Graduates in Industry Fellowships support S&T projects conducted by an individual for a company or group of companies.

TAIWAN, SINGAPORE and MALAYSIA

Banking on Technology-Led Growth

Taiwan and Singapore are among the Asian countries least affected by the recent Asian financial crisis. Malaysia had greater economic problems in 1997 and 1998, but also is on the way to economic recovery. All three now count themselves among the fastest growing economies in the world. All remain strongly committed to technology-led growth, with particular emphasis on the information technology industry.

TAIWAN

Taiwan recognizes that it needs to stimulate stronger economic growth and build the international competitiveness of its industries through continued scientific and technological development. In fact, the government is seeking to transform Taiwan into a high-tech island. It is already a world leader in the manufacture and research of many microelectronic components such as motherboards, displays, scanners and notebook PCs.

Taiwan's 1999 GDP grew at 5.67 percent, down somewhat from 6.8 percent in 1997 but still in the world's top ten. Total expenditure on R&D grew from 1.86 percent of GDP in 1996 and reached nearly 2 percent (1.98 percent) of GDP in 1998. It is seeking to raise R&D to 3.0 percent of GDP by 2010. Taiwan currently ranks 15th in the world in terms of expenditures. Taiwan also ranks eighth in terms of total R&D personnel in business per capita with three full-time employees per 1,000 people, roughly equivalent to the United States.

Business funds about 65 percent of R&D, a percentage that is steadily increasing. R&D expenditures as a percent of sales for all industry increased from 1 percent in 1992 to 1.37 percent in 1998. The integrated circuit industry is the highest spender, illustrating the fact that Taiwan is the third largest producer of information technology products behind only the United States and Japan.

Government policy has moved toward a more concentrated focus on increasing the budget and manpower devoted to research and development of new technologies. Taiwan sees human resource development as critical and is raising the number of international scientific educational exchanges, increasing the number of graduates in sciences at the master's and PhD levels, creating new R&D institutions, and emphasizing science in the schools.

Taiwan's Science and Technology Advisory Group in 1997 sponsored a Strategy Review Meeting that included industry representatives from Taiwan and information technology experts from several other countries. The group assessed the status of the electronics, information technology and telecommunications industries in Taiwan and elicited strategic recommendations for their future development. This strategy strongly reinforced the National Information Infrastructure Plan's objectives for development of networked multimedia software by the year 2000. The Plan successfully helped:

- Advance electronic government and electronic commerce;
- Develop digitized multimedia technology;
- Expand Taiwan's export position within the Asia-Pacific software market; and
- Taiwan become a leading supplier of bundled software.

In August 2000, the Taiwanese Cabinet adopted a plan that identifies six major issues associated with the global knowledge-based economy for which it is developing new strategies and programs. These issues are: 1) an innovation mechanism to support venture capital enterprises; 2) an Internet application infrastructure; 3) application of information and communication technology into daily life; 4) training and supply of manpower; 5) a customer and service-oriented government; and 6) social and economic costs. It also stresses the important of international cooperation.

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The National Science Council remains responsible for overall national S&T development along with institutions such as Industrial Technology Research Institute (ITRI). Taiwan, however, is adjusting its legal structure to support innovation. It promulgated a new Basic Science and Technology Law in 1999 that establishes a stronger legal foundation for S&T development. It modified procedures for the ownership, management and utilization of publicly funded intellectual property to facilitate technology transfer to industry and for how the National Science and Technology Development Fund can be used. It also stipulates that the government must submit a report on S&T prospects and strategies every two years and formulate a national S&T development plan every four years taking into account the views of all relevant parties including academia, industry and the public. As of December 2000, the National Science Council had yet to promulgate regulations to implement the new law.

SINGAPORE

Singapore continues to invest heavily in science and technology and to attract high tech foreign direct investment. It is well on its way to serving as the knowledge hub of Southeast Asia. It achieved a GDP growth rate of 7.76 percent in 1997. The rate dropped to 1.5 percent in 1998 as a result of the Asian financial crisis before rising again to 5.35 in 1999.

Singapore's total expenditure on R&D held relatively steady through the 1990s, reaching 1.8 percent of GDP in 1998. Private industry has been particularly active in propelling R&D growth, increasing investment by 14 percent to $981 million in 1998 over 1996. The bulk of Singapore's investment is channeled into electronics research, engineering, and information technology where it is already a world player. The country is committed to maintaining one of the world's best national information technology infrastructures and to applying information technology to all sectors of the economy to boost productivity and increase efficiency.

The government has been extremely active in supporting the development and application of technology. The National Science and Technology Board (NSTB) operates a number of programs in order to finance R&D projects and facilitate the commercialization of scientific results. The Technopreneur Assistance Center provides partial financing for high-tech start-ups. The Technology Fund contributes initial funding to companies. The Research Incentive Scheme for Companies was established as a grant system to encourage companies based in Singapore to develop on-site R&D centers, with the goal of enhancing industrial competitiveness.

In October 2000, Singapore released a new $7 billion (US$4 billion) five-year science and technology plan to identify and build world-class capabilities in selected leading-edge nitch technologies in order to, partially, diversify its information technology heavy portfolio. More than one-third of these funds are slated for promoting private sector R&D in basic science. Another 20 percent of the funds will go to human resource development through fellowships and other direct assistance to expand the number of scientists and engineers beyond the current level of 70 per 10,000 workers. Singapore perceives that, in order to maintain a knowledge-based economy, it must keep up with demand for local talent as well as attracting more global talent. There also is movement towards making information technology and/or biotechnology compulsory subjects for undergraduates.

Singapore also is targeting life sciences and biotechnology. It has created a number of mechanisms (e.g., Pharmbio Growth Fund, Singapore Bio-Innovations and Life Sciences Investments) to provide funds to the private sector to upgrade technologies and form joint ventures with leading international biotechnology and pharmaceutical companies.

MALAYSIA

Malaysia's GDP grew at a moderate rate of 7.8 percent in 1997 but turned negative (-7.0 percent) in 1998. In reaction to the Asian financial crisis in 1997, Malaysia imposed regulations on its banking and financial sectors in order to curb any further shock and uncertainty in its market. With these regulations, Malaysia's financial markets began to regain lost ground in 1998 and 1999. The GDP growth rate in 1999 regained its momentum reaching 5.42 percent.

Malaysia's total expenditure on research and development was $265 million in 1998, 0.199 percent of GDP. Business accounted for nearly 75 percent ($195 million) of R&D expenditures.

Malaysia's long-term economic strategy continues to strongly emphasize shifting from labor-intensive industries to high-technology, capital-intensive industries. Focusing on its goal to become the "corridor of high technology within Asia," Malaysia created the Multimedia Super Corridor (MSC) to shift

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Malaysia from manufacturing into a high-technology hub of the region as part of its seventh economic plan (1995-2000). Progress has been slower than expected because of the 1997-98 economic crisis and smaller than hoped for foreign direct investment. Approximately 360 companies, about 60 percent of which are Malaysian, have signed on to the MSC but not all have begun operations. Companies must promise to perform R&D activities within the corridor in return for a ten-year exemption from income tax and other benefits. Hurdles have included getting sufficient venture capital funding for technology start-ups, and perceptions that MSC investment is not generating economic growth in general. Malaysia's 2001 budget includes new plans to push IT development.

Vision 2020, Malaysia's program to recognize the importance of science and technology to the country's industrialization efforts and its global competitiveness, supports the creation of the MSC. One MSC project is Kuala Lumpur International Airport. Others are the first "smart cities"--Putrajaya, the new seat of government and administrative capital of Malaysia, where the concept of electronic government will be introduced, and Cyberjaya, an intelligent city with multimedia industries, R&D centers, a multimedia university and operational headquarters for multinational corporations.

With its driving force and ambition and more than $2 billion invested thus far to become a fully developed economy by the early 2000s, Malaysia sees itself suited for high-tech-driven industries and is taking gigantic steps to establish its position. It knows that it must move in this direction because it is losing its competitive advantage in labor-intensive manufacturing to countries such as China, Vietnam and India.

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PHILIPPINES, INDONESIA and THAILAND

Emerging Asian Economies' Policies Underscoring the Importance of S&T

Before the Asian financial crisis, the emerging Asian economies had put in place policies and activities to build their indigenous capacities through foreign investment, extensive workforce and industrial training programs, and funding for selected areas of R&D. Although activities and investment have had to be scaled back, the recognition of the links among science, technology and economic growth remains.

PHILIPPINES

The Philippines traditionally have relied on agriculture and light industry to support economic growth. The Philippine government increasingly has recognized the importance of a sound science and technology base. Efforts at achieving high levels of technology-propelled growth, however, are still undercut by politics, poor coordination, a shortage of highly trained engineers and scientists, and in late 2000, political scandal.

The Department of Science and Technology (DOST) leads the government's efforts. Under the direction of the Secretary of DOST, a number of activities have been initiated to support S&T. Activities are guided by the Science and Technology Agenda for National Development (STAND Philippines). STAND Philippines 2000 aimed to carry out its objectives through:

- Use of emerging technologies;
- Increasing private-sector participation;
- Networking;
- Manpower development;
- Review of policies affecting science and technology; and
- Technological dynamism and monitoring.

DOST's specific activities in this regard are based on:

- Improved access to technological initiatives and a system of continuous assessment;
- Implementation of an R&D agenda to facilitate the shift from a factor-based advantage to an innovation-centered advantage;
- Cooperation and integration of professionals in the public and private S&T sectors;
- Intensification of industry-oriented skills development;
- Establishment of sophisticated R&D centers and laboratories; and
- Development of both cultural and physical infrastructures that foster technological development.

R&D investment fluctuated during the 1990s, reaching 0.218 percent of GDP in 1996 before falling dramatically to 0.078 in 1998. Total expenditures fell in the same period from $115 million to $51 million. Massive declines in the value of Philippine peso, which by late 2000 was trading near an all-time low, and government spending declines were behind the fall. Business R&D expenditures actually increased from $3 million in 1996 to $21 million in 1998. The bulk of national expenditures on R&D are in the areas of biotechnology, information technology and agriculture.

With almost half of the country's labor force centered in agriculture, the Philippine government is making concerted efforts to enhance the technological base and competitiveness of farming. These efforts include a large number of R&D programs to support increased fruit production. Biotechnology is also strongly supported as is a significant amount of research on health and nutrition.

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Most research in information technology is conducted by two organizations. The Advanced Science and Technology Institute's research is centered on creating a rural telecommunications network. The Department of Science and Technology has emphasized the electronic networking of universities and research institutions. The Philippine IT project, initiated in 1994 with the first Internet connection, boasted 130 Internet service providers by the end of 1997. While still small, information technology research is projected to grow over the next several years. The Philippines have a large number of information technology workers which should help it move into higher technology markets in the 21st century.

INDONESIA

Indonesia showed signs of increased economic and political stability in late 1999 and 2000 but had not recovered economically. After the country's GDP posted a dismal 13.7 percent decline in 1998, GDP stopped falling but was still unable to grow in 1999. The October 1999 election of Indonesia's new president, Abdurrahman Wahid, and the announcement of a "national unity cabinet" have increased political confidence. Major hurdles remain, however, with the ongoing political transition and financial sector reform.

Since mid-1997 Indonesia has suffered more than its Asian neighbors from political and financial turmoil. The World Bank's financial rescue package forced Indonesia to start extensive internal and administrative reforms, especially in the areas of monetary policy, bank restructuring, the budget, subsidies, structural reforms, and debt. Indonesia's ability to invest in science and technology policy also has been affected. Before the financial crisis, the country made significant progress in the development and application of advanced technologies, including commercial aircraft, shipbuilding and telecommunications equipment.

Even before the financial crisis, Indonesia's total expenditure on research and development, which had grown in the early 1990s, had started to decline. It fell to $187 million (0.092 percent of GDP) in 1996 from $282 million in 1995. By 1998, it stayed at the $187 million level. The Indonesian government S&T spending decreased approximately 10 percent in FY 1999-2000 from the previous year under Indonesia's "survival" zero-growth budget, that relied heavily on foreign loans.

While it is unclear what will happen in the future, the Indonesian government's past development strategy has embraced technological experience as a key component to industrializing the economy, with technological proficiency ranging from low/rural technology to medium technology to medium and high technology.

Indonesia also has made numerous changes in its regulatory framework to improve the business climate and encourage increased foreign investment, especially in technology transfer. The passage of stronger intellectual property protection laws and a movement to privatize previously restricted sectors such as roads, electric power and telecommunications improved Indonesia's investment climate.

THAILAND

Thailand faces the question, made more difficult by the Asian financial crisis, of how best to transition from a labor-intensive to a capital and technology production-oriented economy. It recognizes it will have to invest more in high-value-added, technology-intensive industries such as automobiles, electronics and consumer goods. As part of the rescue package it received from the World Bank in 1997, Thailand obtained a $1.5 billion loan aimed at restructuring the industrial sector and boosting exports with new technology.

Thailand, which was the first country hit by the Asian crisis, experienced negative GDP growth rates of -1.3 percent in 1997 and -7.0 percent in 1998. It announced a 130 billion baht (US$3.5 billion) economic stimulus package in March 1999 to strengthen domestic demand and create jobs, and its economy regained momentum with about 4 percent growth rate in 1999.

Thailand's total expenditure for research and development was $197 million (0.175 percent of GDP) in 1998, up from $154 million in 1995 and down slightly from $208 million in 1996. Business expended $42 million in 1998, 21 percent of the total.

The Ministry of Science, Technology, and Environment (MOSTE) began its eighth five-year plan in 1997. Its main tenets are:

- Promote the use of technology as a tool to boost the competitiveness of the manufacturing sector by emphasizing the development of

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appropriate technologies that are consistent with workers' capacity to learn, while bearing in mind the economic returns from the adoption of new technology.

- Promote private-sector participation in the development of science and technology and technology transfer by granting tax privileges and promoting investment in research and development, so that research is consistent with the demands of business establishments.

- Continuously expedite the production and development of personnel in science and technology, and also encourage the private sector to play a greater role in this connection.

- Expedite the development of measurement sciences to promote exports to enhance private-sector competitiveness in international markets.

Thailand is still developing its infrastructure and will continue to rely on foreign direct investment, R&D and technology attracted by the country's low labor costs and open markets. The plan remains in effect, although progress has been slower than expected.

Thailand's National Science and Technology Development Agency (NSTDA), affiliated with MOSTE, was established in 1991 to spur science and technology development through policy formulation, funding of research, and other S&T activities. It will be reorganized in 2001, making many of its departments independent public organizations. Some of its activities are: 1) a 10-year Reverse Brain Drain project to bring Thai professionals back home; 2) grants, low-interest loans, and technical assistance to private and university R&D efforts; 3) support for the Science and Technology, Research and Development Park; 4) research laboratories in electronics, materials, and biotechnology; 5) the APEC Center for Technology Foresight; and 6) GINET, the national information infrastructure project.

Thailand recognizes that it must adapt to the global knowledge-based economy. It is in the process of drafting a National Science and Technology Act and has created a National S&T Policy Council chaired by the Prime Minister. It hopes both of these actions will reinforce the country's commitment to S&T.

INDIA

Unleashing the Creative Potential of Scientists and Innovators

India is seeking to strengthen the foundations necessary for science and technology in order to realize the full potential of knowledge-based industries and improve the performance of all its sectors. Although India's decision to test nuclear weapons has complicated its international S&T relationships, the country is pursuing an aggressive strategy to become the world's leader in information technology.

Information Technology-Led

Prime Minister Vajpayee has called for India to become an information technology superpower within the next 10 years and one of the largest generators of software in the world. Recognizing the impressive growth India has achieved since the mid-1980s in information technology, he announced a plan to make IT the primary catalyst to modernize India. The plan's objectives include the following:

- Information Infrastructure Drive, to accelerate the establishment of a world-class infrastructure through the spread of fiber optics, satellite communications, and wireless networks;
- Target ITEX 50, to create more than $50 billion annually in exports of IT software and services;
- IT for All, to accelerate the rate of ownership of personal computers to one per 50 people by 2008, up from one per 5,000 (among the lowest in the world), along with universal access to the Internet.

India already ranks first in the *World Competitiveness Yearbook 2000* in terms of the perceived availability of qualified information technology workers and of qualified engineers. India is able to draw from a strong human resources base. It ranks 12th overall in the world in total R&D personnel, with 114,400 full-time equivalent workers. In addition, along with those in Singapore, the compulsory science curriculums in India's schools are among the strongest in the world.

The benefits for the world from India's information technology boom are large. Indians have started more than 770 high-tech firms in Silicon Valley, a number that is growing. It also is creating a large bilateral flow of IT expertise. The compound annual growth rate of the Indian software industry in the 1990s was 42.35 percent, with the software export industry constituting almost 54.3 percent of production. According to CBS Market Watch, e-commerce transactions originating in India reached $9.7 million in 1999 and are forecasted to reach $4.3 billion by the end of 2004, many of which are destined for North America. India is also working to increase exports of Indian technologies and technical services particularly in the IT area to developing countries in Southeast Asia, the Middle East, Africa and Latin America.

R&D Structure

India spent $2.3 billion on R&D (0.67 percent of GDP), ranking it 24th in the world in 1998. Indian research is overwhelmingly funded by the national government. Although industry R&D is increasing, expenditures by business in 1998 still amounted to only $448 million, just 19.4 percent of total R&D expenditures.

India's Department of Science and Technology (DSIR) continues to identify and promote front-line and priority areas of research and development in many disciplines of science and technology. The department promotes S&T by providing financial assistance and establishing research facilities. DSIR activities include:

- Council of Scientific and Industrial Research;
- Departmental Schemes for R&D by Industry (RDI);
- Program Aimed at Technological Self Reliance (PATSER);
- Scheme to Enhance the Efficacy of Transfer of Technology (SEETOT);

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- National Information System for Science and Technology (NISSAT); and

- Two public enterprises, National Research Development Corporation (NRDC) and Central Electronics Limited (CEL).

The Council of Scientific and Industrial Research (CSIR) helps to implement the government's R&D priorities of competitiveness, technology transfer, and innovation. CSIR controls more than 40 national laboratories and 80 field centers. It works on technology for agricultural as well as for industrial uses. It is responsible for facilitating the use of the results of research conducted at other public laboratories for the development of Indian industry.

Additional Innovation Programs

In support of science and technology, India has created 12 Science and Technology Entrepreneurs Parks near engineering and other academic institutions regarded as centers of excellence. The parks seek to provide technical resources, equipment support, and world-class R&D facilities. These parks are forming an integral part of India's technological infrastructure. This strategy has been particularly effective in the software sector. The Government of India's Department of Electronics "Software Technology Parks" (STP) scheme fosters the growth of software exports from special technology parks. The STP scheme comes under the auspices of the Software Technology Parks of India (STEP-I) - a society established by the Department of Electronics.

The Indian government has implemented a variety of other programs to provide incentives for innovation, increase the speed of commercialization of research, and transfer technology. These programs include the following:

- Income tax benefits for private companies to perform R&D and to form relationships with universities and national laboratories. These tax benefits include customs rebates for a variety of R&D-related resources.

- Funds for upgrading indigenous or imported technology. The government will fund research for which the development process is too onerous or risky for a business to undertake. The industry sectors that the government is most concerned with for this type of funding are electronics, microelectronics, pharmaceuticals, and biotechnology.

- Research in High-Priority Areas. This program targets priority areas of science such as nano-materials and carbon chemistry, neuroscience, and climate research.

- The Technology Development Fund. This fund is generated from a specific import tax and used for technological development, with an emphasis on innovation.

EUROPE

EUROPEAN RESEARCH PROGRAMS

Creation of A European Zone for Science and Innovation

The European Union (EU) and its constituent governments are working hard to encourage the emergence of an European Research Area to sustain and expand European competitiveness in the global economy. Their efforts are reinforced by the other major long-standing European cooperative research efforts, the European Space Agency (ESA), EUREKA and COST.

THE EUROPEAN UNION

The European Commission in January 2000 agreed to establish a European Research Area. The European Research Area would consist of a frontier-free area for research wherein special attention is given to better coordination of what is perceived currently as a fragmented European research effort. It will network centers of excellence, develop a European approach to large research infrastructure, and undertake measures to promote spin-offs from research (patents, venture capital) and researcher mobility. This effort seeks to counter the European Union's growing deficit in trade of high-tech products and decline in R&D relative to GDP, and help transition Europe into a knowledge-based society.

The European Union's existing major research effort is the five year (1998-2002) multinational research program, the Fifth Framework Program (FP5). The 15 member nations of the European Union, through a consultative process in collaboration with the European parliament, have instituted the major research programs within the Fifth Framework.

The Fifth Framework Program represents a break from previous Framework programs in many ways. Well aware of what has been called the European innovation "paradox," the EU has shifted its focus to applied research and science in the service of society and the economy. The research programs have been streamlined to make them more responsive and relevant to European industry. The Fifth Framework Program (FP5), now open to all EU associated and candidate countries, also seeks to increase the participation of women in European science. The EU also is attempting to focus its Framework efforts by improving the consistency of the overall approach and paying greater attention to management and the exploitation of results.

FP5 focuses on four "thematic" research programs and three "horizontal" programs. The thematic programs are: 1) improving the quality of life and the management of living resources; 2) creating a user-friendly information society; 3) promoting competitive and sustainable growth; and 4) energy, environment and sustainable development. The horizontal programs are: 1) promoting innovation and participation of small and medium-sized enterprises; 2) international cooperation; and 3) improving human research potential and the socio-economic knowledge base. A major innovation of FP5 is the focus on "key actions" to ensure concrete outcomes directed toward a common European or global challenge.

The total budget for the FP5 for 1999-2002 is 14,960 million Euro ($12,840 million), a tremendous increase from the First Framework Program's budget of $4 billion.[1] This figure includes 1,260 million Euro ($1,081 million) for the 5th Euratom Framework Program, which defines research and training activities in the nuclear sector. Although the FP5 budget represents only 4 percent of overall public research expenditures in the EU member states, the program has a considerable impact on the shape of European research. FP5 is broken down into the following categories:

- Quality of life and the management of living resources ($2.1 billion);
- User-friendly information society ($3.1 billion);
- Competitive and sustainable growth ($2.3 billion);
- Energy, environment, and sustainable development ($1.8 billion);
- International cooperation ($407 million);

[1] Based on the November 2000 Exchange Rate; $1.00 = 1.160 Euros

- Small and medium-sized enterprises ($312 million);
- Human potential ($1.1 billion);
- Joint research center ($634 million).

In addition to its FP5 efforts, the EU intends to promote innovation by improving the investment and regulatory climate for its enterprises through its "Innovation and SME Program." This program supports European SMEs' full participation in FP5 activities and contributes to a more innovation - friendly business climate in Europe (i.e., creation of new companies, expansion of venture capital, diffusion of new technologies, emergence of the new economy, foster an innovation culture, improved technology transfer).

Europe is making strides in the financing of innovation. In 1995, for example, only 24 percent of Europe's total capital investments went to technology and science-based firms; (the corresponding number for the United States was 70 percent). However, Europe's version of NASDAQ, the EASDAQ, is starting to stimulate and direct capital to high-tech enterprises; the number of start-up investments listed more than doubled between 1997 and 1998.

THE EUROPEAN SPACE AGENCY

The European Space Agency (ESA), a 15-member organization, promotes technology development and scientific research in space. ESA has helped Europe develop an independent launch and space technology capability to compete with U.S. firms. Member countries use ESA as a mechanism to develop their national aerospace industries. France has been ESA's largest contributor and beneficiary, although Italy, Germany, and Britain also have each derived substantial benefit. Although ESA collaborates with NASA on scientific missions, the two agencies do not undertake joint technology development.

In May 1999, the European Ministers who oversee ESA extended a freeze on space science spending for another four years. This places the ESA annual science budget for 1999 to 2002 at just 370 million Euro ($317.3 million), approximately the same amount received annually since 1995. The Ministers also approved a one-time payment of 40 million Euro ($34.3 million) to ESA's science directorate. ESA has hard choices facing it. It has expensive projects pending such as the mission to Mars planned for 2003 and two new astronomy satellites, and growing cooperation with the European Union particularly in the fields of navigation, telecommunications, and Earth observation.

EUREKA

EUREKA is a framework through which industry and research institutes from its 30 members, 29 European countries and the European Union, develop and exploit technologies deemed critical to European competitiveness in R&D-related fields and high-technology markets. The most recent members who joined in 2000 are Croatia, Latvia and Israel. Launched in 1985 as a response to the U.S. Strategic Defense Initiative, EUREKA coordinates and sponsors joint research projects in advanced technology proposed by firms within the member countries.

As of June 2000, the total number of EUREKA projects stood at 705 with an average funding of 3.36 million Euro. This number includes 164 new projects (worth 406 million Euro) announced at the 28th Session of the EUREKA Ministerial Conference held in June 2000 in Hanover, Germany. Since its inception, EUREKA has generated over 1,500 projects. Just over two-thirds of project participants are from industry, and just under half are small and medium-sized enterprises. In 1998, Eureka's portfolio included over 667 finished projects, worth an estimated investment of $12.6 billion.

At the Hanover meeting, the Ministers adopted new measures, *Guidelines EUREKA 2000plus*, to enhance project generation. The guidelines focus on the availability of financial and other support for international R&D cooperation. Members reiterated that EUREKA is an industry-driven, non-bureaucratic, and flexible method for cross-border cooperation in market-oriented, high-technology research. They agreed to undertake all possible efforts, both financially and with respect to manpower, to help generate and support EUREKA projects including such things as special funding schemes, opening national R&D projects to cross-border participation, accelerating decisions on funding to take no more than six months after a project is submitted, and encouraging the participation of private sources of funding. They also proposed creating a European Innovation Area to complement the European Union's European Research Area.

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COST

COST is an intergovernmental framework for European cooperation in the field of scientific and technical research. Founded in 1971, it involves over 30,000 scientists from its 32 European member states. In addition, 50 institutions participate from non-COST countries including the United States.

COST undertakes "Actions" that are coordinated national research projects in fields in which there is interest from institutions in at least five different member states. Each "Action" lasts approximately five years and is based on a Memorandum of Understanding signed by the governments of the participating countries. There were nearly 200 Actions in 1999. There is no central funding for Actions. All funds come from nationally funded research. COST funding is used primarily to cover additional expenses associated with international workshops, conferences, travel costs, contributions to publications, and short-term research missions.

FRANCE and GERMANY

Promoting Public-Private Cooperation to Enhance Technology Diffusion and Innovation

Although national S&T priorities differ, many European countries including France and Germany are taking a hard look at their national systems of innovation and making changes to enhance the contribution of the S&T system to economic performance. These changes include programs to promote technology diffusion and to enhance the linkages between the public research sector and industry to speed the development of new technologies. The countries also are examining ways to promote better the creation of innovative, technology-based firms.

FRANCE

The Socialist-led coalition government, elected in June 1997, made major changes in French science and technology policy. In 1997, the Jospin government elevated the role of research by creating a new "super ministry," the Ministry for Education, Research, and Technology (MERT), to oversee France's schools, universities, elite schools, and public research organizations, as well as its space program and space agency. In April 2000, French research was again restructured with MERT being divided into separate research and education ministries. Roger-Gerard Schwartzenberg, the new Minister for Science and Technology in charge of the new research ministry, set forth in May 2000 France's research priorities:

- Rejuvenating research by a steady flow of young people into the field;
- Promoting interdisciplinary research;
- Improving the evaluation of research activities;
- Bringing higher education closer to research;
- Promoting innovation and technology transfer;
- Developing the life sciences;
- Improving public awareness of science;
- Using science to manage and maintain the environment more effectively;
- Bringing science closer to society;
- Creating a dynamic space policy;
- Strengthening the European research framework.

In 1998 Prime Minister Lionel Jospin set up a permanent National Science Council to advise the government on research strategy. The council, which includes 28 French and international scientists, is headed by the Minister of Science and Technology and reports directly to the prime minister. The same year he established the Interministerial Committee for Scientific and Technological Research (CIRST) that approves national S&T policy and defines scientific research priorities. The prime minister chairs CIRST.

France spends approximately 2.24 percent of its GDP in R&D. Government spending and incentives to business accounted for roughly 50 percent of total French R&D expenditures ($31.1 billion) in 1998, a higher figure than in many industrialized nations.

Focus on Innovation

The results of a study on industrial innovation and technological development in France, released in April 1998, confirmed French competitiveness in the aerospace and nuclear sectors and in key environment and transportation-related technologies, but underlined shortcomings as well. The study found that:

- Industrial research funding by the government is much higher than in other industrialized countries, but France's position in key technologies, such as electronics, information technologies, materials, and biotechnology, is deteriorating.

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- Most public industrial research funding goes to a handful of large firms; medium-sized, independent firms and small and medium-sized enterprises received less that $200 million out of a total public allocation of more than $2.5 billion distributed by French ministries.

- Fewer innovating firms are set up in France than in other industrial countries.

The study also noted insufficient links among research labs and between research and industry. It underscored factors such as the lack of an entrepreneurial culture in French academia, the lack of incentives to encourage researchers to develop links with industry, discrepancies between the orientation of the research labs and the priorities of industry, and insufficient venture and seed capital investments. Preceding the official release of this report, the French government announced that it had decided to launch an action plan with four main priorities:

- Promote and better coordinate technological research among public agencies;

- Improve cooperation between the scientific community and industry, primarily through mobility of human resources;

- Facilitate the setting up of innovating firms by encouraging risk-taking; and

- Improve state efficiency in providing research and innovation incentives.

Prior to a May 1998 "national debate on innovation" the French government announced a series of measures to help promote technology transfer and the creation of innovative companies. These included fiscal measures to encourage private investment in new high-risk technology companies, and a governmental "seed money fund" to be used by researchers to develop projects to the point where they can solicit private investment. The 1998 French government funding for the seed money fund was $16.5 million. The government also announced that additional funding would be earmarked over a three-year period for developing national networks in key technologies (information technology, biotechnology, materials, electronics) to bring together public and private laboratories. Priority was to be given to projects involving small and medium-sized enterprises.

To encourage researcher mobility, the French parliament adopted a bill granting public researchers the right to set up private firms and/or hold financial interests in the private companies for which they may be doing research. Under the bill workers are no longer prohibited from participating on the boards of private companies or working as part-time consultants to the private sector.

GERMANY

Total R&D expenditures ($53.6 billion) in Germany comprised an estimated 2.31 percent of GDP in 1998. Of this spending, two-thirds originated among sources in the private sector. Most of the remaining expenditures originated from the federal government and the individual states.

During much of the 1990s, German R&D investment stagnated. However, recent figures indicate that investment in innovation is edging up once again, and that growth and exports have been driven by research-intensive industries. New areas of competence have been established in laser technology, nanotechnology, and robotics. In addition, German companies are at the forefront in creation and production of motor vehicle, pharmaceutical, industrial chemical, aerospace, and telecommunications technologies as well.

Germany's venture capital (VC) sector has been booming, reflecting the worldwide growth of the VC industry in recent years. Germany's Ministry of Education, Science, and Research (BMBF) has been contributing to the success of small, high-tech, start-up firms in Germany through its "Direct Investment Capital for Small Technology-Based Companies" program. The program allocated some 300 million DM ($170 million) to such firms in 1996, and by 1998 the figure had increased by 240 percent. These companies' R&D capacity is beginning to offset to some extent German R&D declines in the defense arena and in the more traditional small and medium-sized manufacturers, many of which greatly reduced or even abandoned R&D in the early 1990s.

Ministerial Apparatus

For the first time in many years, the BMBF in 1999 enjoyed a real increase in its annual budget. The ministry's 1999 budget was up 900 million DM ($500 million) from 1998, to a total of 14.9 billion DM ($8 billion). This positive trend is largely attributed to the 1998 change in government, which brought into office an administration actively seeking to improve

Germany's S&T policies. The highest policy priority identified thus far is the need to increase public funding of state universities and research institutes. Other central tenets in the government's current platform include improving opportunities for women, supporting job-creating technologies, and further improving existing environmental protection technology. At Germany's universities, new buildings, improved financial aid for students, and funds earmarked for "strategic research" are some results of the new government's agenda.

Policies

Germany continues to be active in encouraging industrial research and technology diffusion in its eastern areas. The government invested $5.2 billion in R&D in the eastern states between 1991 and 1994, and announced in 1997 that East Germany would receive an additional 1.5 billion DM ($80 million) between 1998 and 2001 for use in industrial research. The extra funds were to be used to foster the creation of new start-up companies through innovation and to sustain small to medium-sized companies.

Future areas of innovation will certainly include the development of environmentally sound products and production techniques. Late in 1997, the government announced its "Research for the Environment" program, which went into effect in 1998. Approximately 1 billion DM ($560 million) is allocated to this program annually. The program continues in the spirit that solid economic advantages result from efforts at environmental protection. It is hoped that this program will stimulate jobs and eventually reduce environmental costs borne by German consumers. Other targeted areas include information technology (artificial intelligence, photonics, multimedia research, advanced computation) and biotechnology. Biotechnology remains a controversial field of research in Germany today.

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UNITED KINGDOM and REPUBLIC OF IRELAND

Talent As The Key To A Knowledge-Based Economy

The United Kingdom (U.K.) and Ireland are investing in science, engineering and technology to drive wealth creation and to improve the quality of life. Like many countries around the world, both are investing in science education and workforce training to help ensure that their people are ready to participate fully in the global knowledge-based economy.

UNITED KINGDOM

The Blair government has made science and technology a cornerstone of its competitiveness agenda, as described in its white paper, "Our Competitive Future–Building the Knowledge-Driven Economy," published in December 1998. It pledged to increase total government spending on science and technology to over 20 billion pounds ($28.4 billion) over the three year period of 1999-2001, an 11 percent increase over the previous three year period, representing a level of investment higher in real terms than at any time in the current decade. Moreover, for the first time, budget allocations for science could now be made for three years rather than one, giving departments and research councils more stability for better long-term planning.

The Blair government released an update to the December 1998 white paper in July 2000. Entitled the "Science and Innovation White Paper: Excellence and Opportunity - a science and innovation policy for the 21st century," it calls for:

- Investing in the U.K.'s world-class science base;
- Stimulating stronger university-based links so that science and engineering excellence is turned into successful and innovative products and services; and
- Fostering a confident relationship with science.

U.K. expenditures on R&D were just under $24 billion (1.8 percent of GDP) in 1998, up six percent from 1996. Government expenditures accounted for approximately 35 percent of the total. Despite the large percentage of total R&D funded by business, there is concern that U.K. companies are investing less intensely than their foreign competitors. A November 1999 study by the Department of Trade and Industry showed that the top 561 U.K. companies had increased the total investment in R&D by 6 percent (3 percent in real terms) compared to 12 percent by the 300 top international companies. The exception was the U.K. pharmaceutical industry which continues to lead the world with an R&D intensity of 15 percent against 13.5 percent for its international competitors. The United Kingdom estimates that its total R&D expenditures in 1999 reached 11.3 billion pounds ($16 billion) with business R&D expenditures estimated at 9.6 billion pounds ($13.6 billion).

The government's spending plans for science, engineering, and technology for 1999-2001 are described in "Forward Look, 1999," which was produced by the Office of Science and Technology in the Department of Trade and Industry. Actual spending plans are reviewed each year by both the individual departments and the Chief Scientific Advisor. The primary focus of the U.K.'s S&T policy continues to be the application of science and technology to enhance economic growth and partnerships between research and industry. The budget for innovation, for example, will grow by 20 percent over the next three years. Highlights include:

- the LINK program, which encourages partnerships between private companies and research institutions to encourage pre-competitive R&D for early-stage technologies; and
- the SPUR (Support for Products Under Research) and SMART (Small Firms Merit Award for Research and Technology) programs to assist small companies in moving products from research to commercialization.

In addition, the United Kingdom announced in July 2000 plans for a new 1 billion pound (US$1.42 billion)

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investment to transform the U.K. science and engineering base, modernize the research performance, and help boost economic growth. This new investment was made possible by a path-breaking public-private partnership with the Wellcome Trust, which will contribute an additional 400 million pounds ($568 million), roughly one-third of the budget. The additional money will be used to build new and refurbish existing university laboratories, support other infrastructural needs, and provide additional money for U.K. research councils to meet capital costs of new projects in priority areas.

At the same time, the United Kingdom announced that it will boost research spending by 250 million pounds ($355 million) in key areas for the 21st century: genomics, e-science, and basic technology such as nanotechnology, quantum computing and bioengineering.

The Foresight Program, launched in 1994, aims to improve the competitiveness of the U.K. economy and enhance the quality of life by bringing together business, the science base, and government to identify and respond to emerging opportunities in markets and technologies. In 1995, the first set of visions and recommendations for action was published, followed by four years of development and implementation. Another round of Foresight Program began in April 1999. The most recent round, launched in November 2000, is funded initially at 15 million pounds ($21.3 million).

As part of its focus on partnerships, the U.K. Government is also forging a public-private partnership for its Defense Evaluation and Research Agency (DERA), the agency responsible for the bulk of the Ministry of Defense's non-nuclear research, technology, and test and evaluation. DERA is one of Europe's largest research organizations, with a budget of about $1.6 billion and a staff of 12,000.

In 2000, the United Kingdom focused increasingly on expanding the number, and the quality and level of competence, of its science, technology and engineering graduates. It announced that it would launch a "Science Year" starting in September 2001. It will include a new Science Ambassadors Program in which top university science students will provide coaching and mentoring to younger students at the schools from which they graduated. It also will include new competitions and awards, and hands-on workshops. In November 2000, the U.K. Science Minister announced an addition of 6 million pounds ($8.5 million) to its Science, Technology, Engineering and Maths Network (SETNET) to promote science in schools. The funds will be used to ensure every pupil will be able to take part in a science activity over the next three years.

REPUBLIC OF IRELAND

Even though it is smaller than the European S&T powerhouses of the United Kingdom, Germany, France, and Italy, Ireland ranks 7th in the world in terms of overall competitiveness, higher than any other European country. It ranks 28th in the world in terms of total R&D expenditures ($894 million in 1998). Business accounted for over 90 percent ($811 million) of total R&D expenditures. Ireland also is beginning to produce high-impact patents in information technology areas.

Irish S&T policy entered a new era with the publication of the "TIERNEY White Paper on Science, Technology and Innovation" published in October 1996. It concluded, "We have assumed that as a small, relatively isolated country, we do not need to develop our own expertise and can rely on purchasing innovation from others." While this model has worked in the past, the TIERNEY Report concluded further that by relying on the purchase of others' innovation, Ireland was losing potential economic growth associated with the loss of talent and human potential. It therefore set out an S&T policy that would work to create an economy characterized by sustainable high employment, high living standards, and competition and innovation in the private sector by:

- Emphasizing the use of skilled and qualified staff and increasing R&D expenditures;
- Trading products and services using processes and technologies which continuously improve to meet the highest international competition;
- Generating and enhancing, as well as absorbing, new technology and new techniques;
- Placing particular emphasis on raising the competence of indigenous companies.

The TIERNEY Report also stressed the importance of a technologically and scientifically capable workforce capable of performing research at an international level combined with improved linkages between companies and universities. The government,

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therefore, has sought to better coordinate existing support for doctoral and post-doctoral research, including doubling stipends, improving S&T curriculum in primary and secondary schools, and promoting life-long learning.

The National Policy and Advisory Board for Enterprise, Trade, Science, Technology and Innovation (Forfas) oversees and promotes industrial promotion and technology development in Ireland. It advises the Minister of the Department of Enterprise and Employment and other government bodies, promotes the development of industry, technology, marketing, and human resources within Ireland, and encourages foreign direct investment. It also is working on programs to promote interfirm collaboration. Other Irish S&T initiatives include the:

- Introduction of a 60 million pound ($602.5 million) seed and venture capital scheme to promote investment in Irish technology-based firms;
- Establishment of the Irish Council for Science, Technology and Innovation (ICSTI) to advise on the strategic direction of S&T and innovation policies;
- Creation of Technology Foresight Ireland in March 2000, with initial funding of 560 million pounds ($64.5 million);
- Promotion of international collaboration, especially within the 5th Framework Program.

FINLAND and SWEDEN

Continuing Leadership in R&D Investments

Finland and Sweden invest impressive levels of their resources in R&D, the highest percentages of GDP in Europe. Both have consistently promoted strong national innovation systems as the basis for the growth of knowledge and skills, and thus, the growth and technological competitiveness of their economies.

FINLAND

For more than 20 years, Finland has touted technology innovation as its primary engine for economic growth, and has sought to improve the quality, efficiency, and scientific and social relevance of its research system. The goals of Finland's technology policies are to strengthen the competitiveness of key industries and to generate new products, jobs, and businesses. The creation of new jobs through technology-led economic growth has been critical for Finland with its continuing concerns about high unemployment although that concern has diminished some as the numbers of unemployed dropped from 18 percent in 1994 to 10.3 percent in 1999.

Despite the relatively small size of its economy (approximately US$120 billion) and population (about 5 million), the Finnish government adopted a program in 1996 to raise the level of research and development funding from 2.35 percent of GDP in 1995 to 2.9 percent by the end of 1999. For public expenditures funding, this meant an increase of around 1500 million Finnish markka ($21.3 million) in annual spending. By 1998, the country had already surpassed its goal, spending an impressive 2.9 percent of its GDP on domestic R&D. Finland also consistently ranks among the top six nations in percentage of output spent on R&D. The private sector's share of R&D expenditures is growing, rising to almost 68 percent in 1998. The share of university research funding grew slightly throughout the 1990s, while the share of public research institutes has declined.

Information Technology and Other Priorities

By any indicators, Finland excels in the IT realm. For example, Finland boasts roughly 678 cellular phone users, making it the world leader, and 118 Internet hosts per 1,000 inhabitants, second only to the United States. In March 1998, the Finnish government launched its Action Program aimed at increasing rapidly the number of qualified teachers and students in the field of information technology; (projections indicated that Finland will need more of both). The Action Program is scheduled for a comprehensive review in 2002.

Other significant programs implemented recently include the Electronics for the Information Society (ETX) and Integrated Technology for Wireless Communication (INWITE) projects.

The ongoing development of new technologies remains the foremost priority of Finnish research policies. The Finnish government has fostered an environment of cooperation among high-tech industries and government research entities known as the "cluster-based" approach. It also stresses university-industry cooperation. According to the *World Competitiveness Yearbook 2000*, Finland ranks first in both technological cooperation among companies, and between universities and industry.

Aside from information technology, significant research areas include environmental protection, energy development, and Arctic research. Developing areas seen as key in the future are nanotechnology, services, biomedicines, and advanced materials.

The development of a skilled workforce is one of Finland's top S&T priorities. It created a graduate school system in 1995 that now has over 100 schools with about 4,000 doctoral students. As a result, Finland is graduating annually almost twice as many PhDs as it did in 1990. Finland also has placed great emphasis on recruiting and training women for careers in research.

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Ministerial Apparatus

The Council of State is the head of the government R&D network, which encompasses divisions of the Science and Technology Council, the Ministry of Education, the Ministry of Trade and Industry, and the Ministry of Agriculture and Forestry. Operating under the jurisdiction of the Ministry of Trade and Industry, the Technology Development Center of Finland (TEKES) is the primary entity charged with the implementation of technology policy. Its functions include launching, funding, and coordinating technology programs in Finland (such as ETX and INWITE), as well as facilitating relationships and international cooperation the Fifth Framework Program and other EU research activities.

SWEDEN

Currently at a level of 3.85 percent of GDP ($8.8 billion), Sweden's spending on R&D as a percentage of GDP has remained the world's highest since 1983. Roughly two-thirds of this total ($6.6 billion) is funded by private industry, a fact attributable to the large number of high-tech multinational firms based in Sweden. Public expenditure on R&D is mainly directed toward universities and to a lesser extent research institutions.

R&D activity in Sweden in recent years has been most concentrated in the fields of transportation technologies, telecommunications, energy and industry technologies, machinery, and pharmaceuticals.

Ministerial Apparatus

Responsibility for S&T initiation and development in Sweden has rested primarily at the agency level with no single, large-scale entity directing S&T policies. In the late 1990s, Sweden perceived a need for greater coordination among its S&T related agencies in order to stay internationally competitive.

As part of the drive to coordinate research activity more fully in pursuit of societal relevance, the government passed the 1997-99 Research Bill which contained, for the first time, objectives and overarching guidelines for Swedish S&T policy. Emphasis was placed on strengthening the link between universities and industry, achieving gender equality in research, increasing the use of information technology, and directing increased S&T to small and medium-sized colleges and businesses. A number of programs have been organized to address these goals, including the ongoing use of "competence centers." Administered by the Swedish National Board for Industrial and Technological Research (NUTEK), the 29 competence centers serve as research loci for universities and industry and encourage greater integration of research goals.

Further movement toward a more coordinated S&T policy occurred in 1999. Sweden announced that it would create by January 2001, a Science and Technology Council chaired by the Prime Minister. It also announced that it would reorganize its research councils down from five to three: the National Science Council, the Research Council for Social Issues and Working Life, and the Research Council for the Environment, Agriculture and Community Planning.

As part of the institutional changes, there will be a new agency for R&D that will have responsibility for commissioned R&D in support of the innovation system, sustainable development and growth issues. It takes over the responsibilities of the Transport and Communications Research Board, the R&D financing portions of NUTEK, and some parts of the Council for Work Life Research. In addition, there will be a Research Forum to increase dialogue and collaboration among researchers, research funders, the general public, the government and the private sector. It also will initiate a public debate on important crosscutting research issues such as the ethical aspects of research, gender issues, and conditions and opportunities for interdisciplinary work.

The existing agency-level actors can be grouped into three categories:

- Research councils under the Ministry of Education. The five research councils under the Ministry of Education independently finance research at Swedish institutions and provide the Swedish contribution to relevant international organizations. Four-fifths of funds allocated from these sources are directed toward domestic research at state universities.

- Sectoral R&D funding agencies. These agencies are dedicated to research in particular economic sectors. Examples are the Swedish National Space Board, the Swedish International Development Agency, and the Swedish National Energy Administration. The government agency sponsoring technological and industrial development, NUTEK, is central to the formulation of Swedish S&T policies.

- Defense sector. Nearly 25 percent of government R&D funding is allocated to research in defense.

Along with the institutional changes, NUTEK issued a new Swedish industrial policy entitled *Growth 2000* in September 1999. It sets out four areas in which investments are needed to ensure Sweden maintains its place internationally, captures a greater percentage of the world market, and secures future prosperity. The four areas are: good entrepreneurship, capable people, dynamic innovation systems, and strong regions. It stresses a holistic approach involving close coordination among policies for the four areas. It also points to the need to take full advantage of Sweden's membership in the European Union and work on effective and creative means of domestic and international collaboration.

Growth 2000 includes an emphasis on information technology, stating that Sweden should exploit and aggressively develop its lead in information technology. Over 13 billion Swedish krona ($1.26 billion) or close to 20 percent of Sweden's R&D expenditures are spent on telecommunications, electronics products and IT-related services. In particular, it calls for a comprehensive IT program focused on small and medium-sized companies to increase their ability to work and develop within networks and partnerships.

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NORWAY and SWITZERLAND

Promoting Public-Private Cooperation to Enhance Technology Diffusion and Innovation

Norway and Switzerland are outside of the European Union (EU) but both have tied their R&D strategies to that of the EU. Switzerland already places over 2.7 percent of its GDP into R&D, ranking it fourth in the world. Norway, for its part, has an aggressive strategy to meet or exceed the OECD average R&D expenditure of just over 2 percent of GDP by 2004.

NORWAY

Norway's government envisions significant challenges for the country in the years ahead. Income from petroleum is likely to decline, the number of elderly to be cared for will increase, and environmental concerns persist. Norway's government believes the ability to develop and apply new knowledge will be critical to meeting these challenges and achieving productivity growth.

As of June 1999, the government had taken several proactive steps to improve national R&D investments, which have held steady at 1.7 percent of GDP or 18 billion Norwegian kroner (NOK) ($2.6 billion) since 1993. Information technology accounted for approximately NOK 3 billion ($434 million), and biotechnology and aquaculture for about NOK 700 million ($101.4 million). National expenditure on R&D is balanced between industry (57 percent) and government (43 percent) with industry's share increasing in the late 1990s. By 2004, the government would like to increase the spending level to meet or exceed the OECD average of over 2 percent. Meeting this goal means an annualized increase of at least six percent.

Norway's comparatively low level of present research activity is a result, in part, of the predominance of small and medium-sized (SME) firms in the Norwegian economy. Over 97 percent of Norwegian companies have less than 20 employees. Therefore, Norway has put special emphasis on SME access to venture capital and on e-commerce initiatives that it sees as essential for SMEs to be innovative and competitive. In June 2000, the government launched its national e-Norway Plan to create a green knowledge economy and an information society. It also is promoting Norway as a testbed for IT technology touting its highly educated and technologically astute population.

Ministerial Apparatus

The responsibility for dispersing public R&D funds rests primarily with the Research Council of Norway. Norwegian policymakers reformed significantly Norwegian research policy in the 1990s. The Research Council of Norway acts as 1) a government advisor, identifying present and future needs for knowledge and research, 2) a funding agency for independent research programs and projects, strategic programs at research institutes, and participation in international research programs, and 3) coordinator and initiator of networks among research institutes, ministries, business, and other R&D-related entities within Norway.

The Research Council streamlined its R&D activity and facilitated greater integration between basic and applied research by incorporating five separate research councils into a unified structure. The Industry and Energy Division conducts research programs in manufacturing industries, information technology, processing, and corporate development. The Science and Technology Division's defined purpose is to facilitate basic and strategic research within the industrial and energy sectors. It is also responsible for facilitating scientific research partnerships and funding 14 technical-industrial contract institutes. Emphasis is placed on promoting research in the key areas of biotechnology, information technology, materials technology, and petroleum-related research.

Research

The Norwegian parliament launched several R&D initiatives in recent years. The Research and Innovation Fund, initiated on July 1, 1999, contributes the proceeds of a partial privatization of certain state industries to government priorities in research policy. This innovation program is based on the example set by the Canadian Foundation for Innovation, and it is expected to generate roughly $385 million for research when all planned public offerings have been completed. Norway also plans to establish a system of Centers of Excellence similar to those in other European countries.

The government is working to improve innovation in two of its key economic sectors: oil production and aquaculture. Norwegian oil producers have responded to global price fluctuations by scaling back as much as 50 percent on R&D. The 1999 national budget set aside $20 million for the development of new technologies to be used on the continental shelf. For fishing and aquaculture industries, Norwegian legislators have been debating the merits of an R&D levy, or tax, on small producers to fund research. Along with marine research, the Norwegian government has set aside special funding for research in information and communication technology, medicine and health care research, and the energy/environment relationship.

As a small country, Norway is active internationally and is taking part in the European Union's Fifth Framework Program. Six Norwegian laboratories receive support from the EU as "European Research Infrastructures."

SWITZERLAND

Switzerland, with a population of only 7.1 million, is one of the world's most active countries in terms of R&D. Swiss firms are very active in R&D both at home and overseas. In 1998, Switzerland spent 2.7 percent of GDP on R&D, ranking it as the fourth most research-intensive nation in the world. Total R&D expenditures reached $8.1 billion. Business accounted for $5.7 billion or just over 70 percent of total Swiss R&D expenditures. Swiss chemical (including pharmaceutical) and engineering companies are among the most research intensive in the world (e.g., F. Hoffman-La Roche, Novartis, Nestle, ABB). Switzerland had the highest per capita R&D expenditure in the world at $1,143, 13 percent higher than second-ranked Sweden. It also had the second highest number of research personnel per capita (7.1 per 1,000 people) in the world. Research quality is high with Switzerland possessing the highest number of Nobel prizes, patents and scientific citations per capita in the world.

Switzerland is one of the most prosperous countries in the world, known for its exports of financial services, biotechnology, pharmaceuticals, and special purpose machines. It has a literacy rate near 100 percent. It ranks in the top ten in use of new information technology with 408 computers and over 32 Internet hosts per 1,000 people. According to a Science magazine quotation survey, Switzerland ranks first in the world in immunology, molecular biology, pharmacology and physics and second only to the United States in astrophysics, biochemistry, chemistry and microbiology.

A major concern in Switzerland is its relatively low level of domestic venture capital activity that could hinder the future development of high-tech companies, particularly in the information technology sector. Swiss capital is sufficient but has tended to be invested overseas rather than at home. Switzerland invests large amounts in the United States and has been the largest foreign investor over 20 years, accounting for 18 percent of U.S. industrial R&D financed by majority-owned, foreign firms in 1996 – down slightly from 22 percent in 1980. Another issue, like in many other countries, is maintaining sufficient high-tech labor and preventing brain drain. Switzerland, for example, has a program designed to assist Swiss scientists return home after working overseas.

Because of its small size, Switzerland has placed great importance on international R&D collaboration, investing in excess of 350 million Swiss francs in various European research institutions (CERN, COST, EUREKA, ESA) and the Fifth Framework Program.

Policy Institutions

The Swiss Science Agency, headed by the Secretary of State for Science, coordinates science policy. It also overseas two Swiss Federal Institutes of Technology (ETH Zurich and EPF Lausanne) and four national research institutes.

The Ministry of Economy's Commission for Technology and Innovation (CTI) is the primary organization responsible for the Swiss federal government's technology policy. It encourages and funds joint projects among companies, research institutes, and universities. It also supports technology transfer between research laboratories and companies. CTI consists of 25 unpaid members drawn from industry and the scientific community. The chair is the Director of the Federal Office for Professional Education and Technology. It has a strong focus on supporting small and medium-sized companies through access to information about new technologies and emerging markets, facilitating

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collaboration with universities and research institutes, and funding small-scale R&D projects.

The Swiss National Science Foundation supports basic research through its National Research Programs, Swiss Priority Programs, and National Priority Research. It also supports fellowships for students and research professorships. In addition, it runs international exchange programs, and coordinates Swiss participation in European Union and other international research programs.

The Swiss Science and Technology Council (SSTC) provides advice to the Swiss Federal Council on science, education, research and technology issues. It also undertakes technology assessment studies. In 1998, the SSTC's composition changed to include only scientists and not representatives of political and other public organizations as it had previously. It has 10 to 15 members chosen by the Federal Council and works through two centers: the Center for Technology Assessment (CTA) and the Center for Science and Technology Studies (CEST). CTA studies the effects of new technologies on society and the economy, and organizes public debates on these topics. CEST identifies and analyzes information affecting research, higher education and technology primarily for the SSTC but also at the request of Swiss research institutions, and Federal or cantonal agencies.

ITALY, NETHERLANDS and SPAIN

Promoting Technology Innovation in Small and Medium-Sized Firms

Although not expending the level of GDP for research and development as some of their European neighbors, Italy, Netherlands, and Spain all managed to sustain R&D funding and are beginning to expand their investment in science and technology. All play important roles in European research activities.

ITALY

Italy is the sixth largest economy in the world, with a GDP of US$1,154 billion. Despite Italy's effort to reduce a large public debt, spending on R&D has not sustained large cuts, and spending on key areas has remained strong. Total overall R&D expenditures at $13 billion in 1998 rank Italy within the top six nations for science and technology development.

Expenditures on R&D declined slightly from 1.4 percent of GDP in 1992 to 1.09 percent in 1998. In terms of governmental expenditures, the 1998 budget allocated a 23 percent increase to the Technological Innovation Fund, and the Italian Space Agency was allotted $753 million, a 19 percent increase from the previous year. The only priority area in which spending declined was the budget for the National Research Center (CNR), the autonomous institution responsible for coordination and S&T consulting activities. The budget for CNR was $610 million for FY 1998, a 1.5 percent decline. Within the CNR, the funding for its Determinants Projects program has been slashed significantly over a period of years. Even though this program funded research on advanced technologies such as biotechnology and new materials, the program has had difficulty attracting the interest of companies and industrial groups because of the academic nature of the research.

In March 1997, S&T in Italy was highlighted as a restructuring of the administrative system began. The goals of the restructuring were to increase the autonomy of research facilities and universities, internationalize the research base, and facilitate technology transfer, with an emphasis on innovation and small and medium-sized industries. The central government granted the Ministry of Universities, Research, Science, and Technology (MURST) a great deal of autonomy to orchestrate the changes efficiently. MURST, established only in 1989, supports slightly less than half of the budget of the National Research Program (NRP), which promotes industrial innovation and provides funding for research in private agencies. The industrial partners provide the rest of the funding. The goal of the NRP is to turn these co-funded research projects into practical applications.

The government continues to invest in industry primarily through projects submitted by individual firms. The Italian government has made an effort to eliminate inefficiency in the conduct of R&D and makes its funding more strategic. In the Second Triennial Plan for Research and Development, 1996-98, MURST, together with CNR, made recommendations to improve the administration of research activities so as to reduce costs, eliminate duplication, and streamline the bureaucratic process. One result was the creation of the Inter-Ministerial Committee for Economic Planning (CIPE) that adopts the multi-annual National Program for Research and innovation and allocates the resources of the newly created Fund for Interventions of National Relevance. The desired system, while avoiding the placement of all funds under MURST supervision, allows for a better organization and coordination of research objectives.

Science parks continue to play an important part in Italy's S&T policy. In 1996, in conjunction with MURST, the Ministry for the Mezzogiorno selected 13 regional and local science parks for public financing and funded approximately 50 special technological projects that are now completed. There are other national, local, and private initiatives that helped establish science parks in central and northern Italy.

In terms of business expenditures, Italy ranks in the middle with about 54 percent ($6.9 billion) of total R&D coming from the private sector. Large firms such as Fiat and Comau are responsible for most of Italy's private R&D expenditures. Italy, like many countries, is working to promote the development of high-tech

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small and medium-sized companies (SMEs), and encourage existing SMEs, especially those who want to move beyond traditional sectors, to participate in R&D projects or invest more in R&D themselves. Incentives for SME R&D include:

- Allowance of $18,000 for two years for each new employee with a doctoral degree and of $12,000 for each new employee with a Laurea (master's) degree (not to exceed a total of $36,000 per company per year).
- Fiscal incentives for R&D carried out on a company's behalf by a public research laboratory.

NETHERLANDS

Despite a modest investment in terms of R&D as a percentage of GDP, the Netherlands' research system has consistently scored highly internationally. The Netherlands ranks high in the number of scientific publications per researcher, and is second only to Switzerland in the number of patents per researcher.

The Netherlands ranked ninth in the world with total R&D expenditures of 15 billion Netherlands guilders ($8.3 billion or about 2.1 percent of GDP) in 1998. Government research expenditures as a percent of GDP are forecast to decline from approximately 0.83 percent to less than 0.77 percent by 2003.

Business accounts for approximately 50 percent of R&D, a percentage expected to rise in coming years. Business R&D in the past was primarily done in large companies like Phillips, Shell, Unilever, and Akzo Nobel in the electronic, chemical and food industries. In the 1970s, such firms accounted for about 70 percent of private sector R&D. The large corporations increasingly have concentrated and centralized their research activities. Concentration has meant undertaking R&D activities at fewer locations in the Netherlands (e.g., Philips' high-tech campus at Eindhoven) or, in other cases, closing a Dutch research facility and moving the activities offshore (e.g., Shell's Plastics Laboratory at Delft). In the 1990s, small and medium-sized companies and more recently the service sector have increased their relative share of total R&D to over 50 percent due, in part, to the growing amount of R&D done by the large companies offshore.

The coming of the knowledge-based society has raised concerns about future competitiveness. The biggest concern is an increasing shortage of researchers, and inflexibility in both public and private research institutions and universities. The Netherlands is strongly promoting research as a career and the participation of women in S&T, especially at senior levels, as one solution to the shortage. The Netherlands' Advisory Council for S&T Policy also recommended in 1999 that subsidies be directed at more innovative and productive research areas on which the future economy can be based, and recommended greater emphasis on foresight research to prioritize research.

SPAIN

During the 1990s, Spain has struggled to maintain and increase investment in science and technology. In this respect, its spending levels fall considerably below its EU partners. Total R&D expenditures were steady at about 0.83 percent of GDP ($4.94 billion) in the second half of the 1990s with business accounting for about 50 percent ($2.3 billion).

Spain recognized the fundamental importance of science and technology to future economic growth in its National Plan of Scientific Investigation, Development and Technological Innovation (2000-2003) adopted by the Spanish Cabinet in November 1999. It calls for increases in government S&T expenditures and the creation of a more favorable business climate for technological innovation.

The Inter-Ministerial Commission for Science and Technology (CICYT) coordinates Spanish S&T policy. The Ministry of Science and Technology also is responsible for science and technology development, and coordinates Spanish participation in international R&D programs such as the EU's Fifth Framework Program. The Ministry of Education and Culture is responsible for science policy and coordinates closely with the Spanish Scientific Council (CSIC). CSIC, created in 1939, is an autonomous multi-sectorial, multi-disciplinary public research center affiliated with the Ministry of Education and Culture. It creates and executes scientific and technological research projects, assists in the analysis and selection of future Spanish scientific and technological objectives, provides advice to the government, fosters basic research, trains researchers and technicians, and collaborates with universities. With a budget of approximately 56,819 million Spanish pesetas ($288 million), it has 105 centers and institutes.

The Ministry of Industry and Energy also promotes technology development and innovation through its Centre for the Development of Industrial Technology (CDTI). CDTI, like CSIC, is an autonomous public research institution. It provides technical and economic assessments and funding for company R&D projects, promotes international technology transfer, provides support for technological innovation, and manages and supports Spanish company participation in international R&D programs such as the European Space Agency, EUREKA, and the European Laboratory for Particle Physics (CERN). In October 1999, CDTI in cooperation with Spain's Official Credit Institute launched a Bank Credit Line for Technological Innovation to make it easier for companies to obtain financing. In its first four months, CDTI had approved 340 projects representing an investment of more than 300 million euros ($253 million).

CZECH REPUBLIC, HUNGARY and POLAND

Central Europe: Pushing S&T Reform and Innovation

The Czech Republic, Hungary and Poland have recognized that S&T reform and the development of strategies to promote innovation play an important role in economic transition. Each country has developed programs to reform its scientific infrastructures and promote industrial R&D. However, the challenge of economic transition continues to complicate S&T policies and programs. In all three countries, international cooperation, particularly with the European Union (EU), has become an important part of S&T policy.

CZECH REPUBLIC

Progress in economic transformation that began after the 1989 Velvet Revolution has been accompanied by hard spending choices for the Czech government. GDP fell dramatically before stabilizing in 1993. The Czech economy grew again between 1993 and 1996 reaching 95 percent of its pre-revolution size. Growth again turned negative in 1997 and 1998 before beginning a mild recovery in mid-1999. Real GDP in 2000 is expected to grow by about 1.5 percent.

Mirroring the general economic situation, total spending on science and technology as a percentage of GDP declined by more than 75 percent between 1989 and 1993. R&D expenditures slowly rose during the 1990s, reaching 1.271 percent of GDP in 1998. The number of R&D personnel fell from almost 82,000 in 1991 to slightly more than 22,000 in 1998.

Over the past decade, the Czech government has instituted policies and programs to tie the country's S&T capabilities more closely to the country's economic goals. The Czech government, in order to massively restructure the existing research establishment, created the Academy of Sciences of the Czech Republic (ASCR) in 1992 to replace the existing Czech Academy of Sciences. ASCR's mandate is to help strengthen and rationalize Czech S&T. As part of the rationalization process, ASCR in 1992 dissolved 18 research institutes and 4 service facilities, and reduced staff by 50 percent over 1989 levels.

After the creation of the ASCR, the next set of reforms, introduced in 1994, concentrated on reforming the system for basic and applied research funding. These policies focused on the following:

- Transition from institutional funding of science to competitive, merit-based systems for financing research.
- Moving from funding individual R&D projects to larger, multi-project, applied-research programs in support of ministry mission objectives.
- Increased support for international collaboration, especially with EU countries.

Despite these reforms and the modest growth in the Czech economy, total spending on R&D in the Czech Republic continued to fall because the small firms that were leading the Czech economic recovery were unable to afford large R&D investments. In response, the government in 1997 revised its S&T policies to focus more explicitly on applied and industrial R&D. It set its goal at 0.7 percent of GDP, with half of the expenditures directed to basic and university research and half to targeted R&D. For example, 20 percent of state R&D funding was dedicated to supporting industrial and industry-laboratory technology transfer programs. By 1998, R&D expenditures had recovered to $708 million and surpassed the target set in 1997, reaching 1.271 percent of GDP. Both government and business investments grew with business accounting for 65 percent of total R&D expenditures by 1998.

The government also is seeking to spur university-industry partnerships to support technology commercialization, investing in the transportation and communications infrastructure needed for industrial growth, and moving to lower tax rates and regulations on R&D. Moreover, the Czech Republic has institutionalized several programs designed to spur R&D in small and medium-sized businesses. TECHNOS is designed to support innovation and diffusion of

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technologies among small and medium-sized Czech enterprises; PARK supports the establishment of S&T parks; and the Technology Innovation Center is a small business technology incubator.

HUNGARY

Hungary's R&D sector is just beginning to recover from the economic austerity of the early 1990s, when public- and private-sector investment in R&D fell from more than 2 percent of GDP in 1988 to 0.67 percent in 1996, one of the lowest levels in the Central European region. In 1998, it had risen to 0.784 percent of GDP. During the same time, one-third of all Hungarian researchers lost their jobs, their number falling to 20,800 in 1998. Favorable external economic conditions for exports and growing domestic demand resumed in 1999 with GDP growth reaching 4.2 percent in 1999 and 6.2 percent in the first half of 2000.

Recognizing the connection between technological innovation and economic growth, the Orban government, which has placed top scientists in key administrative positions, pledged to increase R&D spending to 1.5 percent in the five year period (1999-2003) and facilitate high-tech investment through tax measures and other policies. In the meantime, Hungary's technical workforce, industrial infrastructure, and favorable investment climate (including modern patent and venture capital laws) have made the country attractive as a technology center in Central Europe. Several large multinational companies, including GE, IBM, and Ericsson, have invested in technology-based projects in Hungary. Commercial projects take advantage of Hungarian expertise in electric lighting, software, telecommunications, and pharmaceutical research. Like many other countries, Hungary is concerned about the outflow of talented Hungarian IT experts abroad and has estimated it is 25-30 percent short of the programmers it needs. Several foreign companies are offering software training courses or opening IT training academies such as Cisco Systems did in April 2000.

To increase the country's technology-based economic competitiveness further, the Hungarian government is investing in a multifaceted program. The National Committee for Technological Development (OMFB), which administers Hungary's publicly financed R&D programs, is pursuing a two-pronged strategy. First, OMFB is seeking to improve the quality of Hungarian R&D by targeting programs in areas where Hungary enjoys a comparative technical advantage and through more active engagement in international R&D activities. Second, OMFB is promoting diffusion of technologies through the Hungarian economy. Specific programs under OMFB include the following:

- Central Technology Development Fund. Under the Fund, which had a $30 million budget in 1997, OMFB sponsors the Applied R&D Competition System, which provides three-year, zero-interest loans to finance up to 50 percent of project costs.

- New Information and Communications Technology Applications. This program offers competitive grants to support the development of the Hungarian information technology industry.

- R&D Infrastructure Improvement Grants. This program supports purchases of up-to-date instruments and equipment by university laboratories.

- KFKI Technology Park provides research institutes and business and research facilities with marketing and administrative support, legal assistance, and good Internet access.

OMFB also oversees small business programs, offers support for conferences, and coordinates Hungary's participation in international organizations and programs, such as the EU's Fifth Framework and NATO Science programs.

POLAND

As in the Czech Republic and Hungary, spending on R&D in Poland fell steeply when the country began its economic transition. In 1996, total spending on R&D in Poland constituted just 0.76 percent of GDP ($880 million). By 1998, it had fallen further to 0.438 percent ($692 million). The number of researchers is relatively large, standing at 83,800 in 1998, of whom about 72 percent worked for government.

The Polish government has responded to the crisis in S&T by reforming existing scientific agencies, developing new institutions, reducing the number of research-related enterprises, and introducing

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competitive grant-making systems. In 1998, President Aleksander Kwasniewski announced he would instantly sign anything that enlarges the Polish science budget to support Poland's place in an integrated Europe.

The creation of the State Committee for Scientific Research (KBN) was the major institutional reform of the Polish R&D system. The KBN replaced the Polish Academy of Sciences as the chief decision-making body in Polish S&T policy. The KBN develops budgets, coordinates policies among S&T-related agencies, and identifies priorities in research and funding.

Industrial research is a high priority for the KBN. The agency has identified chemicals, precision instrumentation, engineering, building materials, and food processing as areas of Polish industrial R&D strength. In its broader R&D funding strategy, KBN established the following four priority areas: health and environmental protection; agriculture and food processing; high-tech industry, including defense; and the development of the infrastructure for science, education, and technology transfer. KBN also provides specific support for research in materials and biotechnology, information technology (infrastructure and software), and biological sciences. It has developed new regulations and funding mechanisms, such as direct funding of institutional research, cost-shared grants for industrial research projects, and investments in R&D infrastructure, to support innovation in these areas. Support for international scientific cooperation is also critical. The Polish government reportedly has earmarked 10 percent of its national research budget for cooperative projects under the EU's Fifth Framework Program.

The Foundation for Polish Science was organized in 1991 as a non-profit institution to support science, humanities, and technology. It is governed by a council of seven from different disciplines of whom at least four have to be members of the State Committee for Scientific Research. By the end of 2000, it will have provided over 180 million Polish zloty ($39.4 million) in funding to S&T projects.

RUSSIA

Maintaining Large S&T Infrastructure Despite Contraction in Spending

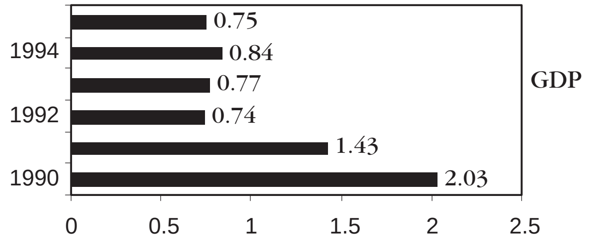
Despite sharp declines in spending on scientific research and industrial R&D since the breakup of the Soviet Union, Russia's S&T infrastructure remains quite large, with more than 6 million full-time personnel engaged in research at more than 4,000 institutions. As the Russian economy converts to a market-based economy, the Russian government is designing programs and policies domestically and in cooperation with international partners to transform its R&D infrastructure. This effort is designed to reduce the size of the R&D infrastructure while preserving excellence in science and stimulating the development of technologies with commercial potential.

Crisis and Contraction

Since the breakup of the Soviet Union at the end of 1991, Russia's S&T establishment has undergone an intense contraction. Total Russian spending on R&D has fallen precipitously, from about 2 percent to about 0.75 percent of GDP in 1995, although it was back up to 0.947 by 1998 ($2.58 billion). In real terms, by 1998 national spending on R&D (mostly from Russian government sources) had fallen to just 25 percent of its 1991 level when viewed in constant prices. Russian R&D expenditures, in current prices, grew from 13 billion rubles in 1990 to 24.4 billion rubles in 1997. The situation was further aggravated by the financial crisis in 1998, with many institutes now receiving only a portion of budgeted funds, the amount of which often remains unknown or undisclosed.

Since 1991 the Russian government has instituted policies to pare down the Soviet-era science infrastructure and has begun to refocus resources on Western-style, merit-reviewed competitions for research grants. As part of this strategy, the government has designated 61 leading institutes as State Research Centers (SRCs), qualifying them for special federal funding as well as tariff, tax, and other privileges. The government also has established the Russian Foundation for Basic Research, which awards grants to scientists based on peer-reviewed competitions. Altogether, by the beginning of 1998, there were 4,137 R&D institutions, down by 11 percent from 1990 due to a reduction in industrial R&D and design and project organizations.[1]

"Total R&D Expenditures as Percentage of GDP"



Although frequent changes in the Russian Cabinet have made consistent priority-setting a challenging exercise, the government has identified the following eight priority areas for state funding in applied research:

- Interdepartmental fundamental research;
- Information technologies and electronics;
- Production/industrial technologies;
- New materials and chemical products;
- Technologies of living systems;
- Transport;
- Fuel and power engineering; and
- Ecology and efficient use of natural resources.

Employment in R&D fell by 52 percent from 1990 to 1997. Many researchers went to business as managers in banks, joint ventures, and other entities – with most citing opportunities for larger salaries.

[1] Center for Science Research and Statistics (1999) *Russian Science and Technology at a Glance*.

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Technology Commercialization

As part of its restructuring policies, the Russian government has become increasingly interested in promoting commercial applications for existing technologies and increased investment in commercially oriented applied research. The Ministry of Science and Technologies has marketed technologies from the SRCs through exhibitions, conferences, and technology catalogues/databases. The Russian Foundation for Technological Development and the Russian House for International Scientific Cooperation, both under ministry purview, promote commercialization of technologies from industry.

In 1994, the Ministry established the Foundation for Assistance to Small Innovative Enterprises, which supports small, technology-based businesses through grants and the provision of financial training and analysis. In 1996 the Ministry helped establish the Russian Non-Profit Partnership Innovation Agency, which offers to search Russian institutes for technologies of interest to Western firms and arrange for their development, production and sale. The Ministry of Science and Technologies also sponsors, along with other organizations, the St. Petersburg Regional Foundation for Scientific and Technological Development, established in 1995, which supports small, innovative enterprises on a refundable basis.

Despite these efforts, the environment for technology commercialization in Russia remains difficult. The tradition of concentrating on military technologies and state orders, rather than civilian technologies and engagement with markets, has inhibited the creation of private companies that would develop technologies for the civilian domestic or foreign market. The focus on basic, rather than applied, technologies also makes it difficult to develop and produce products based on Russian scientific expertise. In addition, legal and regulatory impediments inhibit foreign investment.

Resources have also been an acute problem. State funding for science has been cut severely, and institutes receive only a portion of their reduced but officially budgeted funds. The government's share of R&D expenditures remained steady at about 25 percent but increasingly has gone to basic research performed by the Russian Academy of Sciences. While the Academy's share of government R&D funding increased from 8 percent in 1990 to 12 percent in 1997, industrial R&D institutes and universities did not fare as well.

International Cooperative Activities

Since 1991, the Russian government has worked with the United States to sponsor a number of programs designed to bolster Russia's S&T capabilities, pursue nonproliferation goals, and promote the development of a commercial technology sector. These programs have helped support Russian science during a time of economic crisis, provided opportunities for scientists with arms-related expertise to pursue useful civilian research in cooperation with U.S. scientists, and trained Russian scientists in technology commercialization business principles.

Bilateral programs include:

- U.S. Civilian Research and Development Foundation (multi-agency and private support);
- Initiatives for Proliferation Prevention and the Nuclear Cities Initiative (Department of Energy); and
- International Business Technology Incubator (USAID).

On a multilateral basis, the United States participates in the International Science and Technology Center, which also provides opportunities for scientists who formerly worked on Soviet weapons of mass destruction programs to work on civilian research activities, at times in partnership with U.S. companies. Other international programs to support Russian scientists and engineers include the European Union's INTAS program and a variety of government bilateral and non-government programs.

Ministerial Reorganization

In a May 2000 reconfiguration of Russian government ministries, a new Ministry of Industry, Science and Technologies was created. The new Ministry assumed many of the duties and responsibilities formerly held by the Russian Ministry of Science and Technologies. According to the decree establishing it, the new Ministry is responsible for implementing the state industrial, science and technology and innovation policy, developing appropriate regulations and procedures, and coordinating the work of other federal executive agencies involved in science and technology. It is expected that the new ministry will continue to give priority to issues related to the commercial application of Russian science and technology.

MIDDLE EAST

ISRAEL

Leading in the Global High-Tech Community

Israel is actively reorienting its economy away from traditional industries and into one providing high-tech products and services for the global market. It stands poised to become a globally recognized technology powerhouse drawing from its tremendous pool of high-tech workers, available venture capital and technology innovative-friendly national policies.

Israel's economy, with a GDP exceeding $99 billion in 1998, is among the largest in the Middle East. Combining a ready supply of venture capital, innovation-oriented policies, and the world's highest per capita concentration of scientific and technical workers, Israel remains a leader in the global high-technology community.

R&D expenditures held steady at around 2.1-2.3 percent of GDP during 1994-97. Israel's long-term goal is to see this figure increase to a sustainable 3 percent by the year 2005. Israel moved closer to this goal in 1998 reaching R&D expenditures of 2.65 percent of GDP due primarily to an increase in R&D spending by the high-tech private sector. National R&D expenditures totaled approximately $2.6 billion in 1998 of which business spending accounted for $1.5 billion or about 58 percent of the total. About 30 percent of business expenditures were in the software sector.

Economic growth slowed somewhat in 1998, as a result of the financial crisis in Asia, but continued growth in key high-tech sectors, coupled with tight monetary and fiscal policies, has kept future trends looking positive. By late 1999 and early 2000, Israel appeared to be pulling out of its downturn, recording 5.5 percent GDP growth in the first quarter of 2000. Traditionally strong industries include the telecommunications, medical electronics and software sectors. Between 1996 and 1997, Israel's software industry boasted an increase in exports of 275 percent. The high-technology sector now constitutes approximately two-thirds of Israel's industrial output and roughly 80 percent of its total industrial exports. Areas identified for increased development in the future include biotechnology, space-related technologies and "multidisciplinary" subjects, which combine biology, computers and electronics.

High-Tech Investment

Venture capital has contributed greatly to the success of Israel's high-tech companies. Israel consistently ranks among the top countries attracting money from U.S. capital markets. During 1999, $1.012 billion was raised both in Israel and overseas. Among U.S. states, only California, Massachusetts and Texas draw higher amounts of direct investment than Israel. Israel's government retains its own capital for financing high-technology projects, which it allocates competitively, most often to small businesses planning ventures with high levels of risk.

Ministerial Apparatus

The Office of the Chief Scientist (OCS) at the Ministry of Industry and Trade is responsible for implementing government policy to support and encourage industrial research and development. The OCS employs an "incentives approach" to promote innovation. The OCS offers various grant programs that provide between 30 and 66 percent (depending on the circumstances) of estimated R&D expenditures. For example, in 1992 OCS launched the Generic Pre-Competitive Technological R&D Program (MAGNET), which provides support for industry and academic teams to collaborate on the development of basic technologies. MAGNET funds 66 percent of the approved estimated R&D expenditures. As of early 1998, MAGNET included 18 consortia of industry and academic institutes and three user associations. Other services provided through the Office of the Chief Scientist, for example, are through a network of incubators established in response to the influx of scientists and engineers from the former Soviet Union in the early 1990s.

Also central to Israel's R&D infrastructure are the programs administered by the Ministry of Science,

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particularly those that support strategic research. Since 1994 the "strategic research agenda" has focused on research projects for economic growth and building a bridge between basic and applied research. The Executive National Committee for the Development of Scientific and Technological Strategic Research (commonly referred to as the Committee of Thirteen and established in January 1994), advises the Ministry on strategic directions and reviews specific proposals. Areas designated as high priority by the Committee of Thirteen often receive increased funding. Targeted areas include: electro-optics, biotechnology, advanced materials, information technology and micro-electronics. Recent additions to the committee's priority sectors include: environmental research, water resource development and applied mathematics. The Ministry of Science oversees the government's initiative to develop the Next Generation Internet, involving the investment of almost $40 million over a period of about four years that began in 1998.

In recent years, the OCS also has played a central role in the negotiation and implementation of bilateral R&D partnerships with such counterparts as the United States, Singapore and the European Union. Israel is party to science and technology agreements with 26 countries and regions worldwide. These agreements include the U.S.-Israel Science and Technology Commission (USISTC), the U.S.-Israel Binational Industrial Research and Development Foundation (BIRD), and the U.S.-Israel Binational Science Foundation (BSF). These programs unite U.S. and Israeli researchers, developers and entrepreneurs to pursue priority research and develop new technologies.

Most recently, in June 2000, Israel and Germany signed an agreement covering industrial cooperation and research and development. Each side will support companies from its own country. Israel also became the first non-European member of EUREKA, a research framework through which industry and research institutes from its 30 members develop and exploit technologies deemed critical to European competitiveness in R&D-related fields and high-tech markets.

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EGYPT and JORDAN

Looking For Growth Through Workforce Training and Information Technology

The Arab Republic of Egypt and Jordan regard science and technology as essential for achieving economic growth and improving the quality of life for its citizens during the 21st century.

EGYPT

The Government of Egypt seeks to industrialize its mainly agrarian economy by the year 2017 through science and technology applications. A key component of Egyptian S&T policy is to create a more globally and regionally competitive workforce that uses innovative scientific and technological methods. Fostering S&T business-to-business partnerships and industrial alliances between Egyptian and international firms is another priority. Egypt is also developing a new regulatory environment that is conducive to international investment in the Egyptian S&T private sector.

With the exception of the petroleum, software, and IT sectors, the government owns all Egyptian S&T institutions and organizations. The main S&T organizations in Egypt are the Academy of Scientific Research and Technology (ASRT) and the Ministry of State for Scientific Research and Technology (MOSR). Other major government research organizations include: the National Research Center with nine research institutes and about 6,000 employees; the Agricultural Research Center with more than twelve research institutes and 30 field stations; the Water Research Center with 11 research institutes; and the Ministry of Health with 15 affiliated research facilities.

ASRT is responsible for coordinating and supporting scientific research in the Egyptian national interest. The organization is divided into 14 research councils comprised of approximately 40 appointed members total. The councils review and oversee projects that are intended to:

- Augment the S&T infrastructure;
- Support basic and applied scientific research;
- Enhance end-user oriented research;
- Promote technology development;
- Contribute to local and regional development;
- Improve local science and technology services;
- Popularize S&T; and
- Foster international cooperation in S&T.

Universities conduct basic and applied research. Despite the fact that more than 80 percent is applied research, only a small percentage results in commercial development. Lack of marketing experience, absence of private sector links and outdated regulations are serious obstacles.

The Mubarak City for Scientific Research and Technological Applications (MCSRTA), a technology park located near Alexandria, Egypt, was created by presidential decree in March 1993. MCSTRA hosts the Genetic Engineering and Biotechnology Research Institute (GEBRI) and the Informatics Research Institute (IRI). A third institute for research in new materials is scheduled to open in 2002. The MCSRTA is located near the Borg Al Arab industrial zone which is a private-sector-led manufacturing area containing engineering, food processing, textile, chemical, pharmaceutical and other industries. Its objectives are:

- Promotion of the development of new technologies and the application of scientific methodologies in different areas of production and services;
- Advising the government in the establishment of Egyptian science and technology policy;
- Providing consultation, training and technology transfer services to industry and service organizations in Egypt and the region; and

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- Developing applied R&D projects to improve the performance of different organizations working in MCSRTA fields of specialization.

Although Egypt has significant capabilities in scientific research, the linkages between public and private sector facilities are limited. In order to enhance technology commercialization, the Minister of State for Scientific Research, who is also Minister of Higher Education, established a Permanent Technology Committee in March 1999 via a decree from the Prime Minister who nominally serves as chair. It is tasked with: 1) preparing a national plan for technology development; 2) establishing integrated technology centers; and 3) managing cooperation between national and international agencies

Egyptian government spending on S&T in the present five-year plan (1997-2002), increased to 0.6 percent of the GDP from 0.3 percent in the previous five-year plan (1992-1997). The government allocated approximately $335 million for the current five-year plan. This is about seven times greater than the previous five-year plan S&T budget. International financial support was about 11 percent of the spending.

The largest share of research funding is allocated to the Ministry of Agriculture, about $84 million in FY 96-97. MOSR receives the second largest share which equaled about $60 million in FY 96-97. The Ministries of Electricity, Health and Petroleum each spent about $30 million during the same two-year period, as did the Ministry of Public Works and Water Resources. In January 1999, the MCSRTA was allocated about $15 million. In addition, about $30 million was allocated for the development of the National Institute of Standards.

Focus on Information Technology

In July 1999 President Mubarak identified development of the IT private sector, including e-commerce, as the single, most important technology growth priority in Egypt. Currently, Egypt Telecom monopolizes telecommunications, although 20 percent of the monopoly is scheduled to be sold by late 2000. There were 60 Internet service providers and approximately 200,000 Internet users in mid-2000, making Egypt the second largest population of Internet users in Africa after the Republic of South Africa.

In late 1999, a new Ministry of Communications and Information Technology (MCIT) was formed with the primary purpose of building the IT private sector and expanding the Egyptian IT infrastructure. The National Plan for Telecommunication and Information, created by MCIT and approved by the Egyptian Parliament, seeks to expand the role of IT throughout Egypt and create a globally competitive IT workforce. MCIT is undertaking a number of wide-ranging IT initiatives that are designed to increase the number of innovative Egyptian companies, build a cadre of expert human resources, increase public sector demand for products and services and promote international partnerships.

JORDAN

The Jordanian national S&T policy is focused on developing information management resources, creating technologically proficient and globally competitive human resources, building R&D capabilities and enhancing the transfer and adaptation of modern technologies.

The Jordanian workforce is among the most skilled in the region. Jordan boasts an 87.5 percent literacy rate with more than 17 percent of the population pursuing higher education. Applied research and development activity in Jordan is still modest, both quantitatively and qualitatively. Much of the R&D effort is focused on basic or academic research. National expenditure on R&D is still at a relatively low level, at best not exceeding 0.35 percent of the gross national income.

In the early 1970s, the Royal Scientific Society (RSS) was established as the first national scientific research center with a mandate to intensify national efforts in building R&D capacities, expand industrialization and facilitate public and private sector access to S&T. Domestic and international circumstances and limited resources have prevented Jordan from generating much of its own technology to serve national goals. Instead, Jordan has placed emphasis on transferring, adopting and harnessing technology developed elsewhere.

In mid-2000, the Government of Jordan announced that strengthening the information technology sector was a national priority. A national strategy for IT development, known as the REACH Initiative, was developed by Jordanian public and private sector entities. The overall goals of the initiative include developing an internationally competitive IT industry that will attract international and local investment, generate high-value jobs and produce substantial levels

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of exports in the near to medium term. Jordanian authorities recognize that implementing the strategy will require modernization of both the public and private sectors. These goals, to be achieved by 2004, seek to create 30,000 IT-related jobs, generate $550 million in exports and attract $150 million in cumulative foreign direct investment.

By late 2000, Jordan made significant progress toward achieving the goals of the national IT development initiative. The local telecommunications monopoly was privatized and Jordan developed a positive reputation for stringently enforcing intellectual property rights. The Ministry of Post and Telecommunications is striving to make major changes to government legislation that will be conducive to e-commerce, e-banking, cyber security and privacy.

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