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ABSTRACT

This monograph explores the aims, priorities, and international dimensions of the world's research and development (R&D) enterprise. Global R&D priorities in order of importance include military technology, basic research, space, energy, health, information processing, transportation, pollution control, and agriculture. The majority of R&D efforts are made by industrialized nations and are geared to meeting the political and economic goals of industrialized nations. In leading the global R&D race the United States has recently encountered competition from Japan and Western Europe due to their recovery from economic and manpower losses incurred during World War II. One lasting effect of World War II has been the merging of science and government. Control of funds gives governments great influence over national R&D priorities. Formerly producing the atomic bomb, mass production of penicillin, and radar, government-funded scientific R&D now emphasizes nuclear research. Funds for basic research generally are awarded to universities. Corporate R&D receives funds from industry as well as government. In the United States, most of the industrial R&D occurs in aerospace, electronics, and motor vehicles. Because developing nations are so technologically dependent upon industrialized nations, efforts have been made recently to form international R&D coalitions to study Third World problems. (AV)

Knowledge and Power: The Global Research and Development Budget

Colin Norman

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July 1979

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Table of Contents

The Global Research and Development Budget

The accumulation of knowledge and the development of new ways to do things have provided much of the driving force behind social evolution for thousands of generations. During the past generation, however, these activities have been elevated to a central position in national and international affairs. Research and development is now a $150 billion global enterprise employing some three million scientists and engineers.[1] This expansion has been so swift that about 90 percent of all the scientists who have ever lived are alive today.

These massive investments are made by governments and corporations with the express purpose of influencing future events. Research and development (R&D) is seen as the key to solving many of the problems facing the world, and as an essential ingredient in securing the long-term prosperity of nations and businesses. Just as past investments in R&D have helped shape today's world, current outlays will influence the physical, economic, and political structure of the world inherited by future generations.

Yet there is little public knowledge of or understanding about the nature of the world's R&D enterprise—its aims, its priorities, and its international dimensions. Few governments publish accurate, up-to-date figures on research and development conducted within their borders—particularly that carried out by private corporations—and much of the world's scientific work is deliberately cloaked in secrecy, either for military or commercial reasons. Nevertheless, the chief priorities in the global research and development budget are clear. (See Table 1.)

The largest single item by far is the advancement of military technology. More than $35 billion a year, roughly one-fourth of the world's investment in research and development, is swallowed up by military programs, and over a half million scientists are believed to be working on the development of new weapons.[2]

I am indebted to my colleague Christopher Flavin for his help with the research for this paper.

Table 1: The Global Research and Development Budget

Program	Share
	(percent)
Military	24
Basic Research	15
Space	8
Energy	8
Health	7
Information Processing	5
Transportation	5
Pollution Control	5
Agriculture	3
Others	20
Total	100

Source: Author's estimates based on data from national sources and international agencies. Figures are approximate and should be regarded as no more than a rough guide to relative expanditures.

The second largest area of expenditure is basic research—a search for new knowledge that is not necessarily expected to yield information of immediate practical value. About 15 percent of the world's R&D funds are spent on such attempts to push back the frontiers of knowledge.

The next most important item is space R&D, which accounts for approximately 8 percent of the total outlays. Although the proportion devoted to space research has declined in recent years, following the demise of the American Apollo Program, more than $10 billion is spent worldwide on nonmilitary space activities each year.[3]

Military programs, space exploration, and basic research are largely supported by government funds. In the Western world, industry performs most of the military and space R&D under government contracts, while the universities are largely responsible for carrying out basic research. Together, these three items account for almost half the global investment in R&D.

"The global research and development enterprise is overwhelmingly geared to meeting the political and economic goals of industrial nations."

A cluster of items dominates the other half of the global budget. These include research and development related to energy, health, transportation, pollution control, and nonmilitary communications and information processing. Industry finances most of this research, although there is substantial government investment in energy and health. Each of these five areas accounts for between 5 and 10 percent of the R&D budget. Finally, about one-fourth of the world's research and development funds are spread across a wide range of activities that includes the production of new agricultural technologies and the development of various industrial products and processes.[4]

Although this breakdown is at best approximate, it is evident that military programs alone account for more financial and intellectual resources than are devoted to R&D on health, food production, energy, and environmental protection combined. Moreover, some of the world's most pressing problems, particularly those facing the bulk of humanity in the developing countries of Africa, Asia, and Latin America, are receiving relatively little attention. The global research and development enterprise is overwhelmingly geared to meeting the political and economic goals of industrial nations.

Research and development initiatives alone cannot solve the world's problems. Indeed, some of the most important tasks require the application of existing technologies, together with social and political reforms that spread the fruits of technological change more equitably. Increasing food production and overcoming malnutrition in the developing world are not just technical problems, for example. Their solution calls for a wide range of reforms such as changing landownership patterns, overhauling credit facilities, and providing opportunities for the poor to earn sufficient incomes to buy adequate food supplies. New technologies may play a role in solving such problems, but they are only one part of the solution.

Nevertheless, investments in the development of new technologies in areas such as energy production and agriculture are likely to have a major influence on future policies by opening up some choices and foreclosing others. The heavy investments in the research and development of nuclear power during the fifties and sixties, for example, coupled with the relative neglect of other potential sources of energy, largely shaped the energy policies of the industrial world in the seventies.

8 Nearly four centuries ago, English philosopher Francis Bacon wrote that "knowledge is power." That observation is becoming increasingly relevant as governments and corporations sink vast amounts of money into research and development in order to maintain an economic or political edge over their rivals. National investments now being made in the production and application of knowledge will influence economic and political relationships among the industrial countries and between the industrial and the developing worlds decades hence.

The Geography of Research and Development

Much attention has been paid in recent years to national investments in research and development. As the global economy has become flaccid, and as governments around the world have been trying in vain to combat both inflation and unemployment, advances in technology have been widely touted as the key to long-term national economic and social progress.

In a recent study of European investments in R&D, for example, André Danzin, Chairman of the European Committee for Research and Development, warned that the United States is outspending Europe on science and technology; he argued that Europe's future depends critically on its ability to remain at the cutting edge of technological development. Marinus Peijnenburg, Minister of Science and Technology in the Netherlands, put it more explicitly: "Lagging technological development will lead to a delay in economic development."[5]

Ironically, it is in the United States that fears of falling behind have been voiced with the most force in recent years, as American industry has encountered stiff competition from Japan and Western Europe in world markets for high-technology goods. In an article examining the alleged decline of American technological leadership, for example, *Newsweek* maintained that "as other industrialized nations such as West Germany and Japan pump more and more money into their own R&D, America's command of the world technology market grows more precarious."[6] That is a far cry from the mid-sixties. American corporations then so dominated world markets for high-technology goods, and the United States so clearly outspent other nations on research and development, that Europe and Japan were expected to remain in America's technological shadow for decades.

Meanwhile, leaders in many Third World countries have expressed alarm at the widening gulf between rich and poor countries in R&D investments. The global research and development budget is, in fact, not global at all. It is concentrated in a handful of industrial countries. "We are witnessing a shift towards the use of access to modern technology as the main vehicle for exerting control over the productive activities of Third World countries," argues Francisco Sagasti, a Peruvian economist who recently completed a five-year study of science policy in developing countries. "A few hundred people in the highly industrialized nations now make decisions on who is going to get which part of new technologies at the world level, and under what conditions."[7]

The geography of research and development has thus become a focus of concern and controversy. Analysts have been looking intently at national R&D spending, on the assumption that national technological strength is likely to provide a good indicator of future economic strength. It is, however, difficult to develop an accurate geographical profile of the world's research and development capacity. Not only are national statistics often sketchy and out-of-date, but international comparisons are also clouded by rapidly fluctuating exchange rates, inconsistent definitions of research and development, and differences in the makeup of national R&D efforts.

One feature of the geographical distribution of research and development spending is especially prominent, however. The worldwide distribution of R&D capacity closely matches the global distribution of economic power. A study by Jan Annerstedt of Roskilde University in Denmark indicates that in the early seventies, six countries—the United States, the Soviet Union, West Germany, Japan, France, and Britain—accounted for about 85 percent of the world's R&D expenditure, and employed about 70 percent of its scientists and engineers.[8]

The developing countries of Africa, Asia, and Latin America between them spent less than 3 percent of the global R&D budget, and employed just 13 percent of the world's scientists and engineers. (See
10 Table 2.)

Table 2: Global Distribution of R&D Capacity, 1973

Region	Funds	Share of World Total	Scientists, Engineers in R&D	Share of World Total
	(billion dollars)	(percent)	(thousand)	(percent)
Developing Countries	**2.77**	**2.9**	**288**	**12.6**
Africa (with South Africa)	0.30	0.3	28	1.2
Asia (without Japan)	1.57	1.6	214	9.4
Latin America	0.90	0.9	46	2.0
Developed Countries	**93.65**	**97.1**	**1,990**	**87.4**
Eastern Europe (with USSR)	29.51	30.6	730	32.0
Western Europe (with Israel and Turkey)	21.42	22.2	387	17.0
North America	33.72	35.0	548	24.1
Other (with Japan and Australia)	9.01	9.3	325	14.3
World Total	**96.42**	**100.0**	**2,279**	**100.0**

Source: Jan Annerstedt.

The striking disparities between rich and poor countries in levels of expenditure on research and development are even more marked when outlays are expressed in per capita terms. In 1979, the United States will spend about $200 for every person in the country, and several European nations will spend close to that level. In contrast, most Latin American nations will spend less than $5 per person, and the

"The center of gravity of the world's R&D is not quite so firmly anchored on the North American continent as it was during the early sixties."

poorer countries of Africa and Asia will be able to afford less than $1 per person.[9]

The developing countries' share of the world's pool of researchers has been growing in recent years, thanks to an expansion of university education in some countries. But the Third World has only a tiny fraction of its labor force engaged in research and development compared with the portion in the industrial world. Jan Annerstedt calculates that there were about 300 scientists and engineers working on R&D for every one million workers in developing countries during the early seventies, while the industrial world had almost 4,000 researchers per million workers.[10]

While these disparities simply mirror many others between rich and poor countries, they nevertheless have important implications. As long as the world's R&D capacity remains highly concentrated in the industrial world, the focus will continue to be largely on the problems of the rich countries, and the developing world will remain dependent on imported—and often inappropriate—technology for its economic development.

Differences among the industrial nations in the amount of money spent on R&D in relation to the size of their national economies and work forces are not as marked as those between rich and poor countries. But they are nevertheless significant, and they are the focus of much controversy. The latest set of figures published by the Organisation for Economic Cooperation and Development (OECD) shows that, in the mid-seventies, the United States accounted for about half the total R&D spending by the non-Communist industrial countries. (See Table 3.) A decade earlier, the American share was about 70 percent. Thus, while the United States still outspends every other country by a substantial margin, the center of gravity of the world's R&D is not quite so firmly anchored on the North American continent as it was during the early sixties.

The dollar figures given in the OECD league table should be treated with caution, for they were calculated at 1975 exchange rates, just as international financial markets were beginning to undergo unprecedented gyrations. At best, they provide a rough indication of the rela-

Table 3: R&D Programs in Major OECD Countries, 1975*

Country	R&D Expenditure	Expenditure Per Person
	(billion dollars)	(dollars)
Canada	1.8	75
France	6.0	114
Germany	8.8	143
Italy	1.7	30
Japan	8.8	79
Netherlands	1.6	117
Sweden	1.2	148
Switzerland	1.2	187
United Kingdom	4.6	83
United States	36.7	165

*Dollar figures calculated at 1975 exchange rates. All figures are approximate.

Source: Organisation for Economic Cooperation and Development, *International Statistical Year.*

tive sizes of the R&D efforts of the major Western powers. A better measure of the relative importance each nation attaches to research and development is the proportion of gross national product (GNP) that is spent on science and technology. The OECD figures suggest that the major non-Communist industrial countries are spending at roughly comparable levels, ranging from about 2.3 percent in the United States and Germany to 1.8 percent in France. Two notable exceptions, however, are Italy and Canada, each of which devotes only about 1.0 percent of its GNP to research and development.[11]

In the early sixties, there was wide variation in the levels of gross national product spent on R&D. The United States was spending about 3 percent of its GNP on research and development, Britain about 2.6 percent, and Germany and Japan about 1.5 percent. The ratio declined in the United States throughout the sixties and early seventies; it rose in Japan and Germany until the mid-seventies. (See

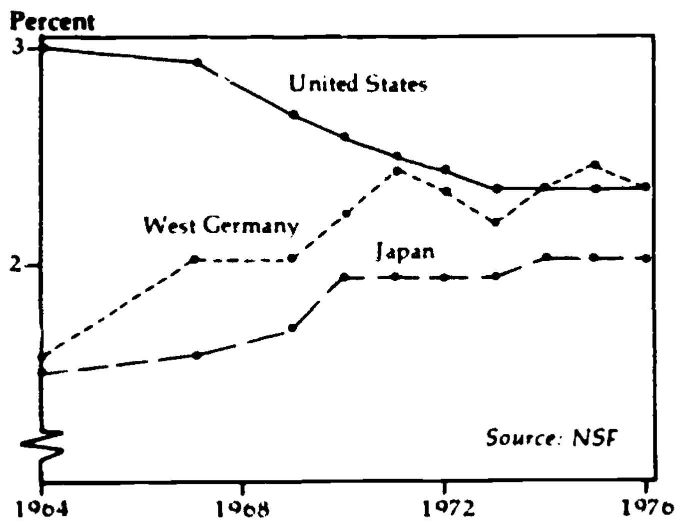

Figure 1: Share of GNP Spent on Research and Development

Figure 1.) In Britain and France, it peaked in the late sixties, and has declined slowly during the seventies.[12]

There have thus been significant changes in the geographical distribution of R&D among the non-Communist industrial countries during the past two decades—changes that provide some support for American fears of a loss of technological leadership. The changes are not surprising, however. American dominance in science and technology during the postwar years was partly a result of the fact that the country emerged from World War II with its industrial and technological capacity essentially intact. Indeed, its technological might had been considerably enhanced by massive government support during the war effort and by the immigration of many leading European scientists during the thirties and forties. The U.S. techrological dominance was thus somewhat artificial, and it was bound to erode following the successful rehabilitation of the war-torn economies of Europe and Japan. As the *New York Times* recently noted in an editorial, "The world challenge to American technology results partly from other nations' recovery from World War II."[13]

The change in the distribution of R&D capacity among the industrial countries was also due to a decline in real expenditure on military R&D in the United States as the Vietnam War drew to a close, coupled with a sharp drop in support for the space program during the late sixties and early seventies. Between 1960 and 1965, the space program expanded from a $400 million enterprise to one that soaked up more than $4 billion a year. Its share of total R&D funds in the United States rose from a mere 3 percent to 21 percent in that short period. By 1975, however, only 7 percent of the nation's R&D funds were being channeled into space research. The rise and relative fall of the space program go a long way toward explaining the apparent decline of the American R&D enterprise in the past few years.[14]

As for the size of the research and development effort in the Soviet Union and Eastern Europe, there are few reliable estimates. The Soviet Government's own reported spending is not directly comparable with that in Western countries because there is considerable doubt about how much military science is included, and it is thought to exclude some expenditures—such as prototype development—that are included in Western figures. Nevertheless, it is clear that there has been considerable growth in expenditures on science and technology in the Soviet Union in the past few decades, as Soviet engineers have developed prowess in many areas of basic research and industrial technology.[15]

The world's R&D budget has now reached about $150 billion a year. About $52 billion is expected to be spent in the United States in 1979, according to estimates by the National Science Foundation, and the combined spending in Western Europe and Japan is thought to be roughly the same as that in the United States. Jan Annerstedt judges that the Soviet Union and Eastern Europe accounted for about 30 percent of the world total in 1973, and their share is believed to have been at least maintained since then. Thus the proportion spent in the developing world is meager—considerably less than 5 percent of the world total.[16]

Science and Government

Few governments paid much attention to the care and nurture of science and technology before World War II. In 1940, for example, U.S. Government support for R&D amounted to a mere $74 million, a sum that paid for a little agricultural research in the land grant colleges, and for a few activities of agencies such as the Coast Guard and the Geodetic Survey. But the war forced science and government into a shotgun marriage that has lasted four stormy decades.[17]

The wartime union of science and government produced a dazzling array of new technologies—the atomic bomb, mass production of penicillin, radar, and long-range missiles, to mention just a few—and the base was established for a long and fruitful partnership. Governments throughout the industrial world have since become deeply involved in supporting a broad spectrum of research and development. In the United States alone, the federal government now channels almost $30 billion of tax revenues a year into such activities.[18]

Control of the purse strings gives governments enormous direct influence over national research and development priorities. In Britain, France, and the United States, more than half the national R&D effort is supported by public funds, and government agencies provide at least 40 percent of the resources in most other industrial countries. Two notable exceptions, however, are Japan and Switzerland, where government funds amount to less than 25 percent of the total.[19]

Government influence also extends beyond those programs directly supported by public funds. Tax policies, regulations, and government purchasing programs all affect priorities for R&D financed by private industry. As John Douglas has pointed out for Japan, "Although government may be the minority partner with industry in funding R&D, the Japanese system of business-bureaucracy cooperation (sometimes called 'Japan Inc.') gives government planners a power of persuasion out of all proportion to the funds they offer."[20]

 Governments generally provide funds for research and development programs that, for one reason or another, are not adequately supported by private industry. Academic research, military science, and space exploration all began to make substantial claims on government budgets in the postwar years, for example. Indeed, just as the war effort brought science and government together in the forties, the arms race and the space race cemented their marriage in the fifties and sixties. More recently, increasing amounts of public funds have been channeled into such areas as health care, energy production, transportation, and industrial innovation, as governments have sought to enlist the scientific community in an attack on social and economic problems.

Like most marriages, the union between science and government has gone through periods of strain. In recent years, for example, as economic growth rates have slumped, government support for R&D has begun to level off in many countries, and expansion has come to an abrupt halt in some. This has caused serious problems in institutions such as university laboratories that rely on the national exchequer for the bulk of their funds. At the same time, efforts to wring as much economic and social benefit as possible from public investments have led to an emphasis on short-term, utilitarian research that is "by no means favorably regarded by the scientific community," notes a recent OECD report.[21]

The slowdown of government investment in research and development occurred first in the United States. After enjoying real growth rates of more than 10 percent a year in the fifties, the federal government's R&D budget began to level off in the mid-sixties. After 1967, annual increases were insufficient even to keep pace with inflation and between 1967 and 1975, the purchasing power of government expenditure dwindled at an average yearly rate of 3 percent. Real growth has been restored in the late seventies, however.[22]

The pattern in other countries has been less pronounced, and the slowdown generally did not occur until the mid-seventies. A survey by the European Economic Commission indicates, for example, that the combined government spending on research and development by the nine member countries of the European Economic Community

"In the United States and Britain, more tax revenues are spent on the development of military technology than on all other government-supported R&D programs combined."

(EEC) rose steeply until 1973, and then leveled off in real terms until 1977, the latest year for which figures are available. That trend was most conspicuous in West Germany, according to the EEC data. In Japan, too, real growth in R&D funding began to slow considerably in 1973, after a decade of rapidly expanding budgets. As for the Soviet Union, although comparable figures are not readily available, expenditures on science and technology reported by the Soviet Government show substantial increases, running at more than 10 percent a year, throughout the sixties and early seventies. In the mid-seventies, however, the growth rate dipped to around 5 percent.[23]

While substantial amounts of public funds are channeled into research and development in every industrial country, each country has its own set of scientific priorities. Perhaps the most significant difference between countries is the share of the government R&D budget devoted to military science. In three countries—Britain, France, and the United States—military programs take the largest single slice of public research funds. They undoubtedly take up a predominant share of the Soviet Union's R&D budget as well. In the United States and Britain, more tax revenues are spent on the development of military technology than on all other government-supported R&D programs combined. In France, about 30 percent of the government's R&D budget goes to the military. In contrast, Germany devotes about 11 percent of its public research funds to military science, and Japan spends only 2 percent.[24]

The United States, Britain, and France each invested heavily in military R&D in the postwar years, as the United States entered into an arms race with the Soviet Union, and as Britain and France developed their own independent nuclear capabilities. Those investments led to the establishment of major government R&D institutions devoted to military programs, and the fostering of close links between defense agencies and private industry—a partnership that President Eisenhower named the military-industrial complex. Private industry not only builds new weapons under government contracts, but it also carries out a large amount of military research that is paid for with government funds. Such arrangements have played a key role in science policymaking, for they provide a built-in constituency in favor of expanding military research budgets.

While military R&D continues to dominate the science budgets of some countries, its share of total public research funds has declined in the Western world during the past two decades. (See Table 4.) 18 Britain seems to be the only major country in which military R&D has claimed a growing share of the public science budget during the seventies. The *Economist* recently asked, "Is it sensible for a small country like Britain to devote £800 million a year to inventing tomorrow's defence technology when its armed forces are still usually equipped with yesterday's arms, and never seem able to have enough money to buy today's?" The *Economist* might also have questioned whether such a high level of military spending is warranted in view of Britain's other pressing social and economic problems.[25]

Table 4: Share of Government R&D Budgets Devoted to Military Programs

Country	1961	1970	1974	1976
		(percent)		
United States	71	52	52	50
United Kingdom	65	41	47	48
France	44	32	34	30
West Germany	22	18	12	11
Japan	4	2	2	2

Source: National Science Foundation, *National Patterns and Science Indicators*; European Economic Commission, *Government Financing*.

Military research and development expenditures in the Soviet Union are cloaked in even more mystery than are other Soviet science expenditures, and they are a subject of bitter dispute among arms analysts in the United States. Whatever the actual amount spent, it is clear that the Soviet Union is putting enormous financial and intellectual resources into weapons development and into blunting the technological edge that most observers believe the United States now enjoys. Such competition is the primary fuel for the arms race.

The other chief research area that has benefited from competition between the superpowers is space exploration. The launching in 1957 of the Soviet *Sputnik* satellite sent shock waves through the U.S. Government. Research and development in the United States was given an immediate financial shot in the arm, and the race to the moon was on. It has already been noted that the Apollo Program absorbed a vast amount of government funds in the sixties, and that spending on space exploration has declined in real terms during the seventies—a rise and fall that greatly affects any international comparison of research and development spending. Nevertheless, the space program is still the third largest item in the U.S. budget, and it dwarfs the total research and development programs of such countries as the Netherlands, Sweden, and Switzerland.[26] 19

The Soviet Union is believed to be putting more resources into its space program than is the United States. From 1975-79, there were more than 400 launches of Soviet space vehicles, compared with just over 100 American launches, and the Soviet space effort is believed to be largely geared toward defense purposes.[27] No other country is channeling a substantial share of its public R&D resources into space research at present.

Although there has been substantial shrinkage in the space program in the United States, defense and space together still account for more than 60 percent of the federal government's R&D budget. (See Figure 2.) In recent years, however, outlays on energy and health R&D have been growing rapidly. Between 1972 and 1979, government spending on energy R&D rose from $500 million to $3.5 billion—an increase of more than 300 percent even after inflation is taken into account. Outlays on health R&D rose by 40 percent in real terms during that period. These two items each account for roughly 13 percent of the government's R&D budget.[28]

Because different governments classify their research and development programs in different ways, it is impossible to compare the priorities reflected in the U.S. budget with those of other countries. The EEC has, however, attempted to compare the budgets of European countries. Its findings indicate wide variation within Europe in research priorities, although every country puts a large fraction of

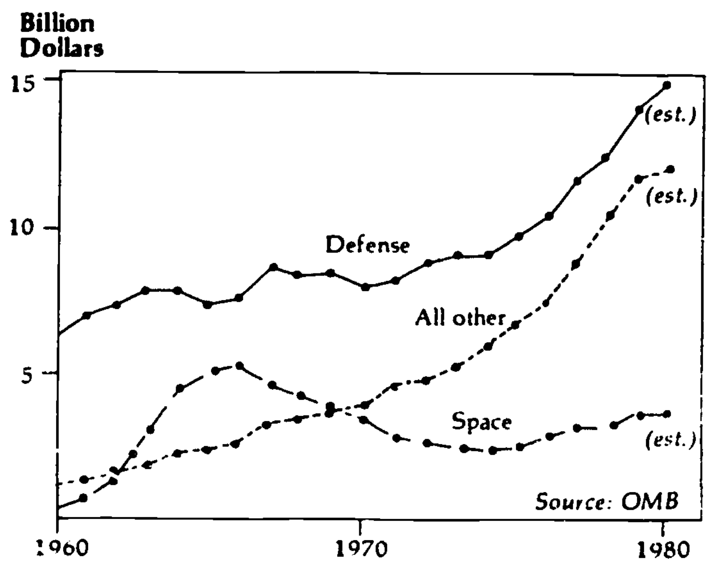

Figure 2: U.S. Government Expenditures on R&D, 1960-80

its R&D resources into the advancement of knowledge—mostly basic research carried out in universities and similar institutions. (See Table 5.)

Like the *Sputnik* launch in 1957, the 1973 Arab oil embargo galvanized a few Western governments into pumping large amounts of money into research laboratories. In the four years following the embargo, energy R&D expenditures among the countries that belong to the International Energy Agency (all the major Western nations except France) almost doubled. The United States reported the largest increase—181 percent--while the other governments raised their combined spending by about one-third.

"Sweden stands alone in devoting a large chunk of its national energy research program to the development of conservation technologies."

Table 5: Government R&D Programs in Major European Countries, 1976

Program	Britain	France	Germany	Italy	Netherlands
			(percent)		
Advancement of Knowledge	23.4	25.3	51.5	44.5	54.3
Agriculture	4.3	4.3	2.0	3.1	7.4
Defense	47.7	29.5	11.4	4.5	3.2
Energy	7.7	8.5	11.0	20.7	4.7
Health	2.8	5.4	4.3	3.7	7.0
Indus. Technology	7.0	11.8	6.8	10.3	4.8
Space	2.3	5.5	4.5	8.8	2.7
Other	4.8	9.7	8.5	4.4	15.9

Source: European Economic Commission, *National Patterns*.

By far the major beneficiary of this increased spending in most countries is nuclear energy. Nuclear R&D claimed more than 70 percent of the energy research budgets of Britain, Canada, Germany, and Japan in 1977, and even in those countries where nuclear programs take less than half the total, such as the United States, they still account for the largest single slice of the energy R&D budget. (See Table 6.) In every country, government support for nuclear research completely dwarfs that for solar energy and other renewable resources, and Sweden stands alone in devoting a large chunk of its national energy research program to the development of conservation technologies.

In most respects, the energy research and development programs of the Western world represent an extension of government policies during the fifties and sixties, when nuclear power was widely expected to offer a safe, cheap source of energy. Most governments sank virtually all of their energy R&D funds into nuclear energy in those years, and many—the United States, for example—expected private industry eventually to take over nuclear development. Those investments have shaped the industrial world's energy policies during

Table 6: Government Expenditures on Energy R&D, 1977

Country	Funds	Nuclear	Renewable Resources	Conservation	Real Growth 1974-77
	(million dollars)		(percent)		
Canada	121.0	68.8	5.3	9.1	-4
Germany	601.2	71.3	2.4	3.7	30
Italy	264.2	55.8	2.8	4.1	81
Japan	529.9	79.7	3.3	7.9	48
Netherlands	109.7	56.7	4.8	12.3	86
Sweden	58.6	21.9	11.3	39.4	173
United Kingdom	234.6	75.6	1.9	5.0	-16
United States	2,800.0	34.8	8.1	2.3	181
IEA Total*	4,929.0	48.1	6.2	4.4	89

*Includes smaller countries not listed in table.

Source: International Energy Agency.

the seventies. Government spending on nuclear energy in most countries is now geared toward answering key questions about the safety of nuclear plants and finding acceptable ways of getting rid of radioactive waste materials. Far from being able to turn nuclear development over to private industry, governments around the world are finding themselves faced with escalating nuclear energy research bills.

About one-third of the Western world's investment in nuclear R&D is spent on developing the breeder reactor, a nuclear plant that will generate plutonium. Breeder reactors are not expected to make much of a contribution to energy supplies before the turn of the century, just about the time when solar energy could make up a substantial share of the world's energy budget. Yet spending on breeder reactor development in 1977 was six times higher than that on solar development among the International Energy Agency members. Even in the United States, where the Carter Administration has declared itself to be pro-solar and uncommitted to the breeder reactor, spending on

"The rapid growth rates in government science budgets have come to an end in most countries."

breeder reactor research in 1979 ran at about $750 million, while that on solar energy was just over $500 million. Although nuclear energy still dominates the R&D budget of the U.S. Department of Energy, accounting for $1.2 billion in 1979, the United States has greatly stepped up its spending in other energy research areas in recent years. Research and development on fossil fuels—chiefly coal—has increased sharply, and the nuclear fusion program has also expanded considerably.[29]

The partnership between science and government is four decades old, and the relationship is now relatively mature. The rapid growth rates in government science budgets that occurred during the postwar era have come to an end in most countries, and, with the possible exception of energy programs, no very large prestige projects like the Apollo Program are in sight. Yet governments still have enormous influence over R&D priorities. National research and development programs are likely to become increasingly controversial in the years ahead, as economic and social problems bring those priorities into question.

The Search for Knowledge

Long considered the province of a few lone, even eccentric, scientists, the search for knowledge has become big business in recent decades. Basic scientific research, aimed at developing a better understanding of everything from atoms to galaxies and from cells to humans, is now a major function of the world's universities and a recipient of billions of dollars of public funds each year.

Basic research lies at one end of a broad spectrum of activities that fall under the rubric of research and development. Undertaken with no short-term application in mind, basic research is often described as an effort to extend the boundaries of human understanding: a search for knowledge for its own sake. It is distinguished from applied research, which is designed to unearth information with a definite use in sight, and from experimental development—the incorporation of research results into new products and processes.

The borders between these three activities are blurred. It is often difficult to tell where basic research ends and applied research begins, and where applied research becomes experimental development. But the evolution of modern technology usually involves a progression along this research and development spectrum. The development of atomic weapons, for example, began with the arcane studies of scientists such as Albert Einstein, Niels Bohr, and Ernest Rutherford, who probed the structure of atoms and molecules in the three decades before World War II. Their seemingly esoteric research laid the base for the intensive applied research effort during the war years that culminated in the production and testing of the atomic bomb.

The transformation of basic research from an activity carried out by a few scattered individuals with diverse sources of support into a highly organized, lavishly funded enterprise has been swift and dramatic. Even during the twenties and thirties, much basic research consisted of relatively small-scale studies, and while some European work was supported by government funds, there was little public financing of basic research in the United States on the eve of World War II. The wartime alliance between scientists and the military amply demonstrated the practical value of basic knowledge, and the transformation of basic research commenced.

The metamorphosis was completed with heavy government investment in the postwar years as public authorities in most countries established arrangements for channeling tax revenues into research laboratories. Universities have been the chief beneficiaries of this government largess in the Western countries and Japan. Governments are the main source of funds for basic research and universities are the chief performers of the work—an arrangement that has altered the character not only of basic research but of universities as well. In the United States, for example, there is no system for channeling federal money into universities for general use, and research grants have become an important avenue of financial support for higher education. As science writer Daniel Greenberg has commented, "Congress . . . permitted 'research' to become the vehicle for pouring federal assistance into the university system. And, not surprisingly, research, with its own mores, values, and rewards, tended to overwhelm the educational function of many universities."[30]

The federal government will provide about 70 percent of the $7.4 billion that is expected to be spent on basic research in the United States in 1980, and universities will conduct about 60 percent of the nation's basic research effort. The federal government and industry will each perform about 16 percent of the total in their own laboratories, and nonprofit institutes are expected to carry out about 8 percent. Broadly similar patterns will prevail in most other Western countries. This is in sharp contrast to the situation in the early fifties, when universities conducted only 32 percent of the basic research in the United States, industry was responsible for 34 percent, and the federal government for 23 percent.[31]

In the Soviet Union and Eastern Europe, arrangements for the support of basic research are very different from those in the Western industrial countries. About 80 percent of Soviet basic research is carried out in specialized laboratories of the Academy of Sciences, a location that separates research from teaching. A network of Academy laboratories stretches across the country, and its scientists are the best qualified and the most highly paid researchers in the Soviet Union.[32]

Basic research accounts for roughly 15 percent of the money spent on R&D around the world, but its share varies from country to country. Exact comparisons between countries are difficult to make without a consistent definition of what constitutes basic research. But even a rough comparison is revealing. In the United States, the Soviet Union, and Japan, between 12 and 15 percent of the total R&D expenditure goes into basic research. In Britain, the share is about 16 percent, in France it is about 20 percent, and in Germany between 20 and 25 percent.[33]

The relatively low levels in the United States, the Soviet Union, and Britain are partly due to the fact that each country puts a large part of its R&D resources into military programs, which tend to encompass mostly applied research and experimental development. The relatively low Japanese level is largely the result of the high share of industrially sponsored research, which tends to be similarly concentrated on the applied end of the R&D spectrum.

The most conspicuous aspect of the postwar change in the character of research has been the growth of what science historian Derek de Solla Price has called "big science."[34] Nature yields its secrets grudgingly. Each new piece of scientific knowledge seems to open up a new and intriguing set of questions that require more research and more powerful instruments to answer. As a result, whole branches of science now rely on complex and expensive hardware, and many teams of scientists are working on different aspects of what once seemed a single problem. The biologist with a $100 optical microscope in the thirties has become, in the seventies, a molecular biologist with a $100,000 electron microscope.

This progression toward more complex machinery is especially evident as scientists have been probing deeper into the heart of the atom. The research that was begun a half-century ago to determine the structure of the basic building blocks of matter is now carried out with atom smashers that cost hundreds of millions of dollars to construct and operate. A scientific paper describing the results of such research often has more than a dozen authors. Similar cost escalations have occurred in astronomy, as the telescopic power required to answer new questions about the stars and planets has grown, and as the instruments have begun to move from the earth into space.

Such research has become so expensive that some countries can no longer afford to support it on their own. Several European countries, for example, have clubbed together to build and operate a giant particle accelerator near Geneva to study atomic physics; a joint European observatory is under construction in the Canary Islands; and Europe and the United States are collaborating on the construction and operation of part of the space shuttle. Such international cooperation is likely to increase as the cost of big science continues to escalate and as national science budgets become more and more constrained.

The postwar growth in support for basic research has produced a vast range of new knowledge and understanding of the physical and biological universe, but in recent years the structure of the basic research enterprise has come under severe strain in many countries. "The unsatisfactory situation of university research is spreading and worsen-

"The biologist with a $100 optical microscope in the thirties has become a molecular biologist with a $100,000 electron microscope."

ing," stated a recent OECD report on science policy in the Western world.[35]

At the root of the trouble is a shortage of funds. The steep growth in financial support for basic research during the fifties and sixties has tailed off in most countries in the past decade. And the difficulties caused by this transition have been compounded by structural changes that have occurred in the universities as members of the postwar "baby boom" have passed through the higher education system.

The decline in funding has been most evident in the United States, where it began in the late sixties. After inflation is taken into account, spending on basic research by the federal government dropped by 16 percent between 1968 and 1975. In Germany, a 1976 report by the German Research Society stated that after years of growth, support for science had come to a standstill; in Britain, there has been virtually no growth in funds for basic research since the early seventies.[36]

These downturns have come on the heels of a period of massive university expansion, designed to accommodate a large influx of students in the sixties and early seventies. As student numbers increased, so did the number of faculty members, and many of them were given tenure. But enrollments in many science courses have declined in recent years and universities have virtually stopped hiring new faculty members. As a result, young scientists with newly minted PhDs are having a tough time finding academic research and teaching jobs, and the average age of university teaching staffs is rising. David Davies, editor of the British science journal *Nature*, vividly describes the situation in Britain in recent years:

> From 1974 on, universities have been under severe pressure to keep staff recruitment under the strictest control. . . . Retirements, the major source of jobs, have been largely confined to the older universities and at present are running at less than 1 percent of all posts occupied; but with poor student enrollments even the posts that do fall vacant have often been 'frozen' or irretrievably lost. . . . Maybe within the next year or two, the bad news will at least ensure that fewer graduates

gaily set out on the path to a PhD in the blithe belief that those letters after their names are the open sesame to a lifetime of research in an academic environment.[37]

A decline in research support coupled with a drop-off in student enrollments has presented financially hard-pressed universities with serious problems, and in the United States it is causing some reassessment of the close integration of research and teaching. A study published in 1977, for example, warned that many universities had been trying to overcome the fiscal drought by delaying the purchase of new laboratory equipment. As a result, instruments were beginning to deteriorate badly. The same report also suggested that some colleges and universities may ultimately be forced to drop research in a few disciplines. That would begin to divorce research from teaching, a move whose implications need careful study.[38]

The Carter Administration has not been deaf to these warnings. Since 1976, support for basic research has enjoyed some real growth in the United States. But Congress has been less than enthusiastic about expanding research budgets, and some basic questions about the financing of basic research remain unanswered.

Although basic research may well be intellectually exciting, governments and corporations are not primarily interested in funding it as a cultural activity. As John Holmfeld, a science adviser to the U.S. Congress, has pointed out: "Although no one can define what the 'right' level of support for science as a cultural activity should be, it is surely exceeded by the present level. In fact, the current level can only be justified in terms of an eventual technological benefit to society." President Carter summed up the justification for supporting basic research even more explicitly in his first State of the Union address: "The creation of new knowledge is important to our economic wellbeing, to our national security, to our ability to help solve pressing national problems in such areas as energy, environment, health, natural resources."[39]

The expectation that the results of basic research would eventually find their way into new technologies was, in fact, the chief justification for major increases in government support for research during the fifties and sixties. In a period of rapid economic growth, governments in most countries cheerfully funded basic research without too much close questioning of that expectation. But as economic growth has slowed, and as government expenditures are coming under attack from taxpayers in many countries, the nature of the link between basic research and technological development is being called into question.

The problem this poses for the basic research community is very difficult to overcome. The links between basic research and technological innovation are so complex and uncertain that while the inputs to research are easily measured, the outputs simply cannot be quantified. It is easy to point to some success stories—the transistor, the eradication of many infectious diseases, and so on. But in the current economic climate, there is little chance of a return to the golden days of the postwar era, when basic research enjoyed popular support and exponential growth.

The Selling of Knowledge

Research and development has long been an important component of industrial production. Vast industrial empires have been built on the engineering breakthroughs of inventors such as Thomas Edison and Alexander Graham Bell, and their intellectual predecessors like James Watt and Richard Arkwright. Indeed, corporate laboratories established in the late nineteenth and early twentieth centuries became the world's earliest large-scale organized R&D centers. At the turn of the century, they employed thousands of scientists and engineers.[40]

This early industrial involvement with science and technology has blossomed into a close, even symbiotic, relationship in recent decades, with the rise of new industries based on the exploitation of scientific knowledge. Basic understanding of the behavior of molecules and atoms lies at the core of such industries as electronics, communications, petrochemicals, and atomic energy. These science-based industries have been at the leading edge of industrial growth in the past few decades.

Government leaders around the world have thus been paying considerable lip service to the need to stimulate industrial research and development and technological innovation. In his State of the Union message in January 1978, for example, President Carter announced that he would recommend "a program of real growth of scientific research and other steps that will strengthen the nation's research centers and encourage a new surge of technological innovation by American industry." At about the same time, Leonid Brezhnev told the 24th Party Congress, in rather more colorful terms, that "we have to create conditions that would compel enterprises . . . literally to chase after scientific and technical novelties, and not to shy away from [them], as the devil shies away from incense."[41]

While governments provide the bulk of the funds for research and development in some countries, private industry performs most of the work. It carries out about two-thirds of all the R&D in the Western industrial countries and Japan. Funds for corporate R&D thus come from two chief sources: industry and government. Industry finances its own R&D in much the same way as it funds other business ventures—through reinvested profits, bank loans, and so on—while governments channel substantial sums of money into industrial laboratories through contracts. Close to one-third of the industrial R&D carried out in Britain, France, and the United States is paid for by tax revenues, funneled mostly through defense agencies. In sharp contrast, in Japan and Switzerland, which have relatively small defense programs, less than 2 percent of corporate R&D is paid for with public funds. (See Table 7.)

Industrial R&D in the Soviet Union tends to be more highly compartmentalized than in the non-Communist world, and Soviet production enterprises—the rough equivalent of Western corporations—perform comparatively little R&D. In general, institutions connected with the Soviet Academy of Sciences concentrate mostly on basic research, industrial ministries conduct applied research, and the enterprises carry out the development of new products and processes. Although there are complex links between these three components in the R&D system, this division of responsibilities among different agencies has been criticized for inhibiting the process of technological innovation.[42]

Table 7: R&D Performed by Industry in Major OECD Countries, 1975*

Country	Share of Nation's R&D	Industrial R&D Funds	Source of Funds**		
			Gov't.	Industry	Foreign
	(percent)	(billion dollars)		(percent)	
France	60.9	3.c1	28.0	63.8	7.8
Germany	66.5	5.88	17.9	78.8	3.2
Italy	60.2	0.99	6.5	90.6	2.5
Japan	64.3	5.63	1.7	98.0	0.1
Netherlands	58.6	0.94	3.6	90.0	6.4
Sweden	68.6	0.83	15.9	81.9	2.1
Switzerland	70.6	0.92	1.5	98.5	0
United Kingdom	62.7	2.91	30.9	62.8	6.3
United States	66.6	24.16	35.6	64.4	0

*Dollar figures calculated at 1975 exchange rates.
**Percentages may not add to 100 because minor sources of funds have been omitted.

Source: Organisation for Economic Cooperation and Development, *International Statistical Year*

Private corporations in the Western world carry out a wide range of research and development activities under contract to government agencies. Willis Shapley, a veteran observer of R&D policy in the United States, describes these activities concisely:

> [Companies] are developing weapons systems, space hardware, energy technologies, and new medicines; they are doing applied research and development on new technologies, new equipment, and new instruments; and they are building experimental and demonstration plants and federal R&D facilities. They are doing an enormous volume of paper studies of new concepts and design options, sometimes backing them up with experimental

> tests of crucial features. They are providing the government with a wide range of support services for federal research, development, test, and evaluation activities, ranging from full responsibility for the operation of laboratories and test centers to the provision of more specialized analysis, computational and other technical services.[43]

For some corporations, federal R&D contracts dwarf all other business, and a large amount of corporate energy is devoted to securing a steady flow of future contracts. Activities such as writing proposals, bidding on contracts, and lobbying for Congressional support for specific programs take the place of promotion and advertising in the selling of the major product of these companies—scientific expertise.

Government support for industrial R&D is heavily concentrated in a few industries, chiefly those of interest to defense and space agencies. In the United States, tax revenues pay for almost 80 percent of the research and development performed by the aerospace industry, and 45 percent of that carried out by the electrical equipment and telecommunications industries. In France, aerospace companies draw 64 percent, and electronics companies 30 percent, of their research and development funds from the national exchequer.[44]

In contrast, corporations making pharmaceuticals, motor vehicles, and iron and steel perform very little government-sponsored research and development. For such companies, R&D is just like any other business activity—it must be justified in terms of its potential contribution to profits. It must also compete with advertising, the purchase of capital equipment, and similar items for its share of corporate funds.

The amount of R&D financed by private industry in Western Europe, North America, and Japan has risen steadily in the past few decades, and the R&D programs of some corporations now dwarf those of entire countries. (See Table 8.)

Between 1967 and 1975, corporations increased their R&D expenditures by about 30 percent in real terms, according to an OECD survey. In contrast, government support for industrial R&D dropped by

"**The R&D programs of some corporations now dwarf those of entire countries.**"

Table 8: R&D Expenditures by Selected Countries and Corporations, 1975*

Country or Corporation	Expenditure
	(million dollars)
Germany	8,847
Italy	1,656
Sweden	1,216
General Motors	1,114
International Business Machines	946
Belgium	764
Ford Motor Company	748
American Telephone and Telegraph	619
India	420
Spain	262
International Telephone and Telegraph	219
South Korea	127

*Corporate figures do not include research performed under government contracts. Expenditure calculated at 1975 exchange rates

Source: OECD, *Business Week*, and UNESCO.

about 22 percent over that period, with much of the decline occurring in the United States as a result of shrinkage in the space program. Government funding picked up a little in the late seventies, however, with large budget increases for energy R&D leading the way.[45] These conflicting trends grossly distort international comparisons of expenditures on industrial R&D. Countries such as Japan, in which virtually all industrial R&D is financed by company funds, have seen a steady rise in their total industrial R&D spending. On the other hand, countries such as the United States and France have seen rising corporate funding offset by dwindling government support.

What is all this money spent on? There is no easy answer, for few governments keep accurate information on the R&D activities of private corporations, and even in those countries that do compile a wealth of data—such as the United States—it is not easy to group corporations into well-defined industries. Nevertheless, a rough estimate published by OECD indicates that in 1975, almost two-thirds of the total industrial R&D in Western Europe, North America, and Japan was performed by three industrial groups: electronics and electrical goods, with 28 percent of the total; chemicals, including the drugs industry, with 19 percent; and aerospace, with 17 percent. As already noted, the aerospace and electronics industries receive considerable amounts of defense money in the United States, Britain, and France, and thus military needs play a substantial role in the leading industrial R&D sectors.[46]

In the United States, six industries—aerospace, electronics, chemicals and drugs, motor vehicles, machinery, and instruments—performed more than four-fifths of the nations' industrial R&D in 1977. (See Table 9.) According to a survey by *Business Week*, three companies—General Motors, Ford, and International Business Machines—each

Table 9: Leading Performers of Industrial R&D in the United States, 1977

Industry	Expenditure	Source of Funds: Gov't	Source of Funds: Industry
	(billion dollars)	(percent)	
Aerospace	7.1	77.7	22.3
Electronics and Communications	5.9	45.4	54.6
Machinery, including Computers	4.0	14.5	85.5
Motor Vehicles	3.3	12.5	87.5
Chemicals and Pharmaceuticals	3.3	9.0	91.0
Professional and Scientific Instruments	1.4	10.8	89.2

Source: National Science Foundation, "Industrial R&D Rises."

spent more than $1 billion of their own funds on research and development in 1977, and ten corporations accounted for more than one-third of all industry-funded R&D in that year. On the average, investments in R&D by American corporations amount to 1.9 percent of sales, with a high of 16 percent in the electronics industry and a low of 0.3 percent in the service industries. The oil industry spent a tiny 0.4 percent of its sales on R&D in 1977.[47]

While universities in the Western world are the chief locus for basic research, corporations concentrate their research and development activities on turning knowledge into goods and services. They perform mostly applied research and experimental development. In 1978, according to the National Science Foundation, experimental development made up almost 80 percent of the total industrial R&D in the United States, while basic research accounted for a meager 2.7 percent. In fact, after inflation is taken into account, corporations in the United States conducted 25 percent less basic research in 1978 than they did a decade earlier.[48]

This concentration on experimental development is not surprising, since designing and testing new products and adapting old ones is an expensive business. In the development of a new drug, for example, the basic biological research is likely to be only a small fraction of the cost of developing, testing, and evaluating the drug itself. As Willis Shapley has pointed out:

> Most industry-funded R&D is concerned with the actual design and development of the products to be sold. . . . This is where the payoff comes, so this is where most of its R&D money goes. The engineering design and styling of each year's crop of new automobile models, for example, accounts for a major part of the $3 billion estimated annual R&D expenditures by the automobile industry; incremental improvements or changes for change's sake likewise characterize some of the R&D on many other consumer goods—the name of the game is to put something on the market that will sell.

red Secrest, executive vice-president of Ford Motor Company, lamented recently that federal regulations had forced his company to put 43 percent of its R&D funds into fuel economy and emissions control. He did not say where the other 57 percent was going.[49]

36 It is impossible to estimate precisely how much industrial R&D is directed toward relatively trivial changes to existing products, changes that serve simply to maintain a market edge. But the share is undoubtedly substantial and some observers suggest that it may be growing. "There has been recent evidence of a shrinking of time horizons and a growing conservatism regarding industrial R&D," suggests Richard Nelson of Yale University. The reason is that high levels of inflation and economic uncertainty are steering corporations away from exploratory R&D that is likely to have its payoff only in the long term, and toward activities designed to maximize short-term profits. Government regulations are also forcing corporations to put more resources into pollution control, energy conservation, and occupational safety and health—tasks that require urgent attention.[50]

The decline in the share of industrial R&D that is devoted to basic research is one indication of this shift away from more exploratory ventures. Another is the drop in the share of major innovations that are regarded as radical breakthroughs compared with those classed merely as technological improvements. According to a study by the National Science Foundation, the fraction classed as radical breakthroughs declined from 36 percent of the total number of major innovations in the fifties to 16 percent in the early seventies.[51] The fact that it required an initiative by the U.S. Department of Transportation to push the automobile industry into a long-term project aimed at developing a new generation of more efficient passenger cars also underlines the reluctance of private industry to devote resources to efforts that have little immediate payoff.

The massive investments in industrial research and development are thus part of a complex system. The industrial R&D enterprise is driven, on the one hand, by the chief corporate objective of increasing profits, and on the other by government needs for weapons systems, space vehicles, scientific studies, and other expertise. It is also highly influenced by broad economic factors such as inflation and uncertain prospects for economic growth, and by more narrow economic factors such as government regulations and tax policies. Governments thus

> **"High levels of inflation and economic uncertainty are steering corporations away from exploratory R&D likely to have its payoff only in the long term."**

have a strong direct influence on industrial R&D because they pay for some of it, and they have an equally strong indirect influence through their general economic and industrial policies.

Science and Development

With less than 5 percent of the world's expenditures on research and development, the developing countries of Africa, Asia, and Latin America are poorly equipped to tackle some of their long-term problems. Even the 5 percent figure greatly overstates the R&D capacity of most Third World countries, for a handful of the more advanced nations, such as Brazil, India, and Mexico, account for the bulk of the developing world's investment in R&D.

The consequences of this maldistribution of resources are manifold. The most obvious is the fact that the world's R&D capacity is overwhelmingly geared to meeting the political, economic, and social needs of the rich industrial countries. The $35 billion invested in the advancement of military technology has little relevance to the needs of the Third World, for example, and even in areas such as health and agriculture, global expenditures are largely aimed at solving problems encountered in the rich, temperate zones.

In 1975, the World Health Organization had this to say about the failure of the world's biomedical research and development enterprise to mount an attack on tropical diseases—maladies that afflict perhaps one billion people in the developing world:

> In the years following the Second World War, several industrialized countries thought fit to make large investments of money and talent in biomedical research. The result has been an explosive increase of knowledge. Some of the highlights are well known—the unravelling of the genetic code, the full description of a protein molecule in all its complexity. . . . These advances have

> as yet hardly begun to be applied to the problems of tropical diseases, where methods of control and treatment have scarcely changed in the past thirty years. It has been estimated that the world's total annual research budget for all tropical infectious diseases is about $30 million per annum; one country alone spends nine times this amount on cancer research. Research in tropical diseases has not yet got off the ground.[52]

The United States Government alone is expected to spend about $670 million in 1979 on research and development designed to raise the productivity of American agriculture. This sum far exceeds the agricultural R&D expenditures of all the developing countries put together. And the vast amount of money that has been sunk into developing synthetic fibers completely dwarfs the resources that have been devoted to improving the production and properties of cotton—a crop on which about 125 million of the poorest people of the world depend for their livelihood.[53]

The lack of R&D capacity in Third World countries leads to their technological dependence on the industrial world. Not only are new technologies developed outside the economic control of the developing world, but the lack of trained scientists and engineers in developing countries can also put poor countries at a disadvantage in negotiations over the import of technology. As Jan Annerstedt has argued, "Those developing countries that do not even have such a minimal R&D capacity to be able to evaluate different technologies are, in a basic sense, in the hands of those who control the technologies."[54]

Research and development is an expensive activity, and, in view of the pressing problems facing most developing countries, investments in R&D often seem irrelevant to national needs. The installation of a thousand irrigation pumps is likely to have a higher priority than the establishment of a plant breeding station, for example. But a few Third World nations have made considerable investments in R&D over the past few years. India's Five-Year Plan calls for the expenditure of about $3 billion on R&D between 1978 and 1983; Mexico spent approximately $360 million in 1978, about 0.6 percent of its GNP; and Brazil spent around $2.5 billion between 1975 and 1978.[55]

"Research and development priorities in developing countries often mirror those in the industrial world."

Funds for R&D in Third World countries come predominantly from government sources. Of the $484 million spent on R&D in India in 1977, for example, $387 million was provided by the central government, $41 million by state governments, and only $56 million by private industry. One reason for the relatively low share of corporate investment is that the modern industrial sector is usually dominated by subsidiaries of foreign multinational corporations, which perform most of their R&D in centralized laboratories in their home countries. Even when multinationals do carry out research overseas, it tends to be relatively low-level work designed to adapt existing products to local markets.[56]

Third World nations are not the only countries affected by this pattern of expenditure. In Canada, where a substantial portion of the firms are foreign-owned, industrial R&D spending is markedly depressed. Only about 40 percent of Canada's R&D is performed by industry, and less than 1 percent of the nation's GNP is devoted to research and development. A Canadian Government study recently lamented:

> One consequence of foreign subsidiaries doing relatively little innovative R&D and being engaged mainly in adapting products to the Canadian market is that they have little to export. Also a heavy dependence on foreign R&D leaves Canadian industry vulnerable to foreign decision-making, both by the parent company and by its government.[57]

Research and development priorities in developing countries often mirror those in the industrial world, a feature that can make programs marginal to national needs. Rogerio de Cerqueira Leite, Professor of Physics at the State University of Campinas suggests, for example, that in Brazil "scientific and technological research (except in agriculture and health) is rarely related to social and economic needs, and research is often undertaken for reasons of prestige rather than necessity." In India, the Departments of Atomic Energy and Space now account for more than one-third of all government R&D expenditures, more than is spent on agriculture, forestry, and fisheries. And in neighboring Nepal, the government candidly states in its paper prepared for the August 1979 U.N. Conference on Science and Technology for Development that "the few research institutions that are fairly well equipped with laboratory facilities are mostly engaged in research of their own institutional interests and often of marginal relevance to the broader needs of the country."[58]

Yet there have been some successful efforts in the Third World to develop technologies that have been neglected by the industrial world. Perhaps the best known is Brazil's ambitious program to produce ethanol from sugar cane. Launched in 1975, the program aims to produce sufficient ethanol to meet one-fifth of Brazil's automotive fuel requirements by 1980. Substantial R&D funds have been invested in the program—in spite of the fact that it came under domestic criticism because no industrial country had considered the technology worth major investment—and Brazil is now widely regarded as a world leader in the technology.[59]

In Malaysia, a government-sponsored program has helped maintain the market for natural rubber in the face of stiff competition from synthetic materials. The program, which involves R&D on rubber production and processing, has "shown how modern technology can maintain the competitiveness of natural [products] against materials produced by large chemical firms and backed by modern integrated marketing and technology," according to Charles Weiss, Science and Technology Adviser to the World Bank. Malaysian rubber technology is, in fact, so advanced that Malaysian experts have recently been advising other Third World governments on rubber production.[60]

There is, however, a limit to the ability of many Third World governments to launch such major innovative R&D programs. That limit is set mostly by shortages of capital and expertise, both of which are widely available in industrial countries. A major attempt to harness some of these resources for an attack on Third World food production problems has been launched in recent years with the establishment of a network of agricultural research institutes throughout the developing world. The network is funded by private foundations, the Food and Agriculture Organization, international agencies such as the World Bank, and bilateral aid agencies such as the U.S. Agency for International Development.

The network grew out of the work of the International Wheat and Maize Improvement Center in Mexico, and the International Rice Research Institute in the Philippines. Established with support from the Ford and Rockefeller Foundations, these institutes spearheaded the development of the high-yielding varieties of wheat and rice that formed the basis of the so-called Green Revolution. Nine other research institutes have now been established, and their work includes improving livestock production, developing machinery suitable for use on small farms, raising yields of crops such as potatoes and millet, and developing techniques for farming in semiarid areas. The eleven institutes of the network are spread throughout Africa, Asia, and Latin America, and their combined annual budget is close to $100 million.[61]

A similar attempt to mobilize R&D to combat tropical diseases has recently been launched by the World Health Organization. Like the international agricultural research network, the tropical diseases program will perform most of its work in the developing countries themselves, and local researchers will be trained. And yet another international effort is now being discussed for an R&D program on cotton production and the improvement of cotton textiles. The idea is to do for cotton what the Malaysian R&D program has done for natural rubber, and the effort would be jointly financed by the World Bank and the cotton-producing countries themselves. These efforts have focused considerable resources on critical and long-neglected problems, and there are perhaps other areas, such as the development of small-scale renewable energy technologies, that could benefit from such international programs.[62]

A different approach to the application of international R&D resources to development problems has recently received much attention. This is the concept of technological cooperation among developing countries, an idea that was the focus of a major United Nations conference held in Argentina in 1978. While such cooperation will mainly involve the sharing of information on already-developed technologies, the regulation of technology transfer between nations, and the growth of international engineering consultancy among Third World countries, there are many opportunities for joint R&D efforts as well.

An important collaborative project undertaken by the members of the Andean Group of countries—Bolivia, Colombia, Ecuador, Peru, and Venezuela—has produced a novel technique for concentrating copper ores, for example. The project, which grew out of the desire of those countries to manage their own natural resources, has led to the establishment of a prototype production plant to test the technique. Similar projects have also been launched by the Andean Group to survey the forest resources of the region and to develop new technologies for using tropical forest products.[43]

Technological cooperation among developing countries is regarded by many Third World leaders as a promising way to achieve mutual self-reliance, to break some of the Third World's dependence on the technologies of the rich countries. Joint R&D projects are expensive, however, and they are unlikely to be undertaken unless an economic payoff is reasonably certain. There is thus considerable scope for the support of Third World cooperative projects by the rich countries and by international agencies such as the U.N. Development Programme.

Important as they are, international R&D programs are no substitute for efforts within individual nations. New varieties of crop plants produced by the international agricultural research network often require further changes to meet specific local conditions, for example, and a nucleus of trained scientists and engineers is important for the screening and adaptation of technology imports. No country in history has advanced simply by importing other nations' technologies. While it may be relatively simple to establish an R&D institute in a developing country, however, it is far more difficult to build links between researchers and those in dire need of new technologies, such as small farmers and small-scale manufacturers.

The experiences of India and China with two very different approaches to R&D illustrate some of the difficulties of developing programs in the Third World. During the sixties and early seventies, China developed a highly decentralized R&D system in areas such as crop production and health. While a few regional institutes conducted basic and applied research, much of the work in developing and testing new plant varieties and pest control techniques was performed by workers in the communes and production brigades. Many scientists

"**Most of the problems now facing Third World nations require political and social reforms that will allow the poor to benefit from existing technologies.**"

were also sent into the rural areas to work alongside the farmers. The system is widely credited with tailoring new technologies to local needs, but it has also been heavily criticized for neglecting laboratory work. Most of the scientific delegations that visited China in the mid-seventies commented on the poor quality of research facilities, for example.[64]

India, on the other hand, has built up a strong R&D capacity in a range of areas. Its scientific institutions are performing advanced work in atomic energy, space research, and heavy engineering, for example, but critics have pointed out that such efforts have not been of much benefit to the rural areas in general and to the rural poor in particular. Both nations are now trying to overcome these drawbacks. In recent years, China has taken bold steps to beef up its research facilities, while the Janata Party government of Prime Minister Moraji Desai has begun to focus R&D on the rural areas.[65]

Building up research and development capacity in the Third World is likely to be critical for the long-term economic and political prospects of developing countries. It is not sufficient by itself to guarantee future social and economic progress, however. Most of the problems now facing Third World nations require not research and development but political and social reforms at the national and international level that will allow the poor to benefit from existing technologies. It is always easy for a government to put off making tough political decisions with the excuse that more research and development is needed to explore all the dimensions of a problem. But research and development cannot settle questions of social justice.

Science Policies and Priorities

The priorities reflected in the global research and development budget and the arrangements for funding and performing R&D were essentially laid down in the postwar years, in the corrosive atmosphere of the Cold War and in an era of abundant resources and cheap energy. Now, as the world faces dwindling reserves of oil and gas, rising demands for food and fiber, and deteriorating biological systems, such unproductive tasks as developing more devastating weapons and restyling consumer products still claim the bulk of R&D funds around the world.

14 Thus, the United States has the ability to survey virtually every square meter of the Soviet Union, yet the world's scientists have barely begun to survey the complex ecosystems of fast-disappearing tropical rain forests or the malignant spread of the world's deserts. The nuclear arsenals of the superpowers contain enough explosive power to reduce to rubble most of the cities on the globe, yet the more challenging task of providing clean, safe power for those cities has received far less scientific attention.

Driven by the political and commercial motivations of governments and corporations in the industrial world, the global research and development system is poorly attuned to the needs of the developing countries in general and to the requirements of the poorest people in those countries in particular. Not only does the lack of R&D capacity in Third World countries perpetuate their dependence on imported technology, but it also means the technologies produced are overwhelmingly geared to the economic environment of the industrial countries —they are capital-intensive, labor-saving, and adapted to large-scale enterprises.

While it is easy to point to the mismatch between the priorities reflected in the world's investment in R&D and its most urgent problems, it is far more difficult to reorder those priorities. The global R&D system is a product of vested interests, whether they be corporations seeking higher profits, government agencies seeking greater political power, or university scientists seeking larger research budgets. The R&D proposals contained in the yearly budget of the U.S. Government are among the most intensely analyzed and bitterly contested items, for example, even though R&D constitutes less than 6 percent of total government outlays.

When the various actors in the R&D system perceive a common interest, major new initiatives can be launched with dispatch. The Manhattan Project, which led to the atomic bomb, and the Apollo Program, which culminated in the 1969 moon landing, are the most celebrated examples. But such problems as providing clean and safe energy, "**When the various actors in the R&D system perceive a common interest, major new initiatives can be launched with dispatch.**"

reducing poverty, and building sustainable agricultural systems demand actions that cut across a range of vested interests. And unlike the building of bombs and space vehicles, they involve more than the simple marshalling of science and technology to attain a single objective.

Yet there are many steps that can and should be taken to channel R&D resources into socially productive areas. Governments have considerable flexibility in reordering their own R&D programs and considerable power to influence the priorities of private industry through a mixture of incentives and regulations. Universities constitute a major source of scientific and engineering expertise, but aside from agricultural extension services, they channel little of this knowledge into the solution of problems in their surrounding communities. In the Third World, R&D institutions are in dire need of aid from the industrial world—greater intellectual support from its scientists as well as greater financial support. And finally, while governments and multinational corporations may dominate the funding and performance of R&D, they do not hold a monopoly on human ingenuity; appropriate technology groups in rich and poor countries are developing technologies that have been neglected by major R&D enterprises, but usually such groups are poorly funded and lack official support.

Government R&D priorities have indeed been changing over the past decade, as the share of funds devoted to military science and technology has declined in most countries, and as outlays on programs related to energy, health, and similar areas have increased. Such trends have been most marked in the United States. Yet spending on military R&D by the U.S. Government still exceeds that on energy, health, environmental protection, agriculture, transportation, basic research, and the social sciences combined.

While there has been considerable talk of stepping up energy R&D funding, few governments have yet channeled much effort into energy conservation and the development of renewable resources. No country has accelerated its support for solar technologies as rapidly as the United States has, for example, but even there government spending on all solar R&D—including direct use of sunlight, wind power, small-scale hydroelectricty, and biomass—amounts to less than

2 percent of the government's R&D budget. Since the availability of adequate, safe, and environmentally acceptable supplies of energy will be critical to the long-term economic prospects of all nations, governments still have a long way to go in reordering their R&D priorities.

The recent debate in the industrial world on the need to stimulate innovation by private industry usually boils down to a discussion of how government policies can help foster industrial R&D and remove some of the barriers that hinder the development and marketing of new products. Rarely does anybody ask what this surge of innovation would produce, aside from the hoped-for increase in productivity. The unspoken assumption is that market forces will determine the mix of goods and services, and that the role of government policy is to help industry produce more of everything more cheaply.

Market forces cannot always be relied on to produce the most desirable mix of goods and services, unfortunately, nor can they be expected to ensure that production processes are environmentally and socially acceptable. One of the prime motivations of corporations is making a profit, and if there are more profits to be made in finding a marginally better aspirin tablet than in developing a new drug to control leprosy, it is not difficult to predict where corporate funds will be invested. Similarly, it is far cheaper for factories to dump their wastes into rivers and streams or vent them into the atmosphere than for them to develop and install costly pollution-control equipment. In the absence of government regulations, the unalloyed profit motive would not be a socially acceptable allocator of resources.

Government regulations are often criticized for dampening innovation, however. Corporate executives have complained that the drive to meet regulatory requirements and product-performance standards has forced industry to switch a substantial fraction of its R&D away from the development of new products. While this may be true, the reprogramming of R&D resources has produced many socially beneficial innovations, such as less-polluting automobiles.

Corporate expenditures on pollution control and on energy conservation have been among the fastest-growing areas of industrial R&D in recent years. In the United States, for example, spending on pollution-control R&D rose by 50 percent and that on energy conservation doubled between 1976 and 1978.[66] A substantial chunk of those expenditures resulted from the automobile industry's efforts to meet government-imposed efficiency and environmental standards. Certainly, the whole area of government regulations may be ripe for reform, for most regulations have been imposed piecemeal and they constitute a confusing phalanx of requirements. But a combination of incentives and regulations will be necessary to force industry to channel its R&D resources into socially beneficial areas.

As far as building up R&D resources in developing countries is concerned, a vast amount of rhetoric, discussion, and debate about technology transfer has preceded the August 1979 U.N. Conference on Science and Technology for Development. Yet the industrial world has done little to help establish the Third World's R&D capacity. The flow of general foreign aid from rich to poor countries has been dismally low; with a few notable exceptions—such as Sweden and the Netherlands—it has not come close to the 0.7 percent of GNP that was set as a target for the U.N. Second Development Decade. Specific support for science and technology projects in the Third World has been correspondingly low.[67]

Two new agencies, Canada's International Development Research Centre (IDRC) and the Swedish Agency for Research Cooperation with Developing Countries, have taken a constructive approach toward increasing R&D capacity in developing countries, however. They have operated chiefly by relying heavily on local expertise and by training people in Third World countries to manage their own programs. And similar objectives have been incorporated in a proposal put forward by the Carter Administration for a U.S. Institute for Scientific and Technological Cooperation (ISTC). To be drawn partly from the existing Agency for International Development, the proposed institute would work with institutions in developing countries and would also attempt to focus more American research on Third World problems.

Political obstacles encountered by IDRC and by the proposed ISTC have cast doubts on the future of both initiatives, however. IDRC has come under fire within Canada for putting too great a share of its resources overseas rather than into Canadian universities, and critics have maintained that some of its projects have not been cost-effective.[68] Its budget has been frozen at the 1978 level and, according to some reports, the Centre may be folded into Canada's official development agency. As for the ISTC proposal, it was rejected by the U.S. Senate largely on the grounds that a new initiative, costing some $25 million, should not be launched in a period of financial stringency. While that vote may be reversed, it is nevertheless an unfortunate sign to the Third World of the way the political winds are blowing in Washington.

In view of the apparent reluctance of the rich countries to support the expansion of science and technology programs in the Third World, some commentators in developing countries have been discussing proposals for a mechanism that would guarantee a flow of R&D funds into poor countries. Possible mechanisms include earmarking a specific proportion of official development aid to build up science and technology institutions, establishing a fund linked to the imbalance in trade of technology-intensive goods between rich and poor countries, and taxing the international arms trade.[69] The industrial countries have generally dismissed such proposals out of hand as being either unworkable or politically unacceptable. But the arguments for increasing aid flows and for enabling Third World countries to decide how the money should be spent cannot be ignored indefinitely.

Many innovative technologies that rely on renewable energy resources, and that are suitable for use on small farms, in small-scale industries, and by community organizations, are being developed by groups outside the traditional R&D establishment. Such appropriate technology groups are reaching people who have been left out of the development process in the past, and are working on technologies that have been ignored by government and corporate researchers. They have proliferated in rich and poor countries alike in recent years, but their work has won little recognition from funding agencies.

There have been a few signs of interest by some governments recently, however. In the United States, a National Center for Appropriate Technology has been established to channel federal funds to such groups, and the Department of Energy has set up a program to provide funding for proposals costing less than $50,000 apiece—proposals that are unlikely to be funded by traditional grants and contracts from an agency used to dealing with multi-million dollar projects. An international agency, Appropriate Technology International, has also been established in the US to support the work of appropriate technology groups in developing countries. And in Britain, the Intermediate Technology Development Group, an organization founded by E. F. Schumacher, has recently received a small government grant to aid small-scale industrial development in the Third World. Such initiatives are likely to be stepped up as the need to channel R&D into areas neglected by traditional science and technology agencies becomes more widely recognized.

Reordering the world's R&D priorities by channeling more money into neglected programs, new organizations, and Third World laboratories will not be sufficient, by itself, to solve the world's problems, however. Many tasks are too urgent to wait for R&D to provide solutions and many cannot be solved by science and technology alone. Indeed, when new knowledge is used to bolster and extend the power of governments, corporations, and ruling elites, it can aggravate the social injustices that lie at the root of many of the world's most urgent problems.

Nevertheless, there are many areas in which R&D can play a key role in determining how society responds to the problems that will present themselves in the decades ahead. The world's research and development program now reflects the needs of the fifties and early sixties. Major changes are needed to make it more relevant to the needs of the eighties and nineties.

Notes

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2. Extrapolation of trends reported by Ruth Leger Sivard, *World Military and Social Expenditures 1978* (Leesburg, Va.: WMSE Publications, 1978), and national data.

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4. Estimates based on data in later sections.

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9. U.S. figure calculated from OMB, *Special Analysis L*; developing country estimates from Annerstedt, "Indigenous R&D Capacities."

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