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INTERNATIONAL R&D TRENDS AND POLICIES

An Analysis of Implications for the U.S.

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

INTERNATIONAL R&D TRENDS AND POLICIES

An Analysis of Implications for the U.S.

A Publication of

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The mission of the Aerospace Research Center is to engage in research, analyses and advanced studies designed to bring perspective to the issues, problems and policies which affect the industry and, due to its broad involvement in our society, affect the nation itself. The objectives of the Center's studies are to improve understanding of complex subject matter, to contribute to the search for more effective government-industry relationships and to expand knowledge of aerospace capabilities that contribute to the social, technological and economic well being of the nation.

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Executive Summary

The United States is facing strong challenges to its world technological leadership and its posture in international trade. Should existing trends continue, the U.S. could within the decade lose technological superiority to the Soviet Union in the fields of space and national security, and could suffer further deterioration of its already declining world trade position. A matter of particular concern is the indicated erosion of American stature in the commercial aviation market, an area of world trade long dominated by the U.S.

These are the major conclusions of this study of international research and development (R&D) trends and policies, in which the level of a nation's R&D, including the extent to which it is supported by the government, is considered one of the principal indicators of future technological and trade capability. In most of the nations studied, the governments are supporting vigorous R&D programs that are growing annually in funding and scope. By contrast, the growth rate of U.S. government-financed R&D is almost stagnant and the overall rate—federal plus private financing—is among the lowest of major nations.

In terms of total expenditures, U.S. research and development has expanded considerably since 1960, more than doubling from a base of $13.7 billion a year. This single fact, however, is misleading since practically all of the growth took place before 1968. Since that year, outlays have remained at about the same level, which represents a declining R&D capability because of inflation and the increasingly higher costs associated with advanced technology. Since 1966, the growth rate of government R&D funding has plummeted from 9 percent to less than one percent. Substantial annual increases in non-federal funding—mostly from industry—have not taken up the slack.

While the level of effort for R&D remains static in the U.S., substantial increases are being recorded in government support of R&D in other nations. France, for example, is experiencing an annual growth rate of about 13 percent; Japan's growth runs to almost 25 percent and in the Federal Republic of Germany it is 30 to 40 percent. A further influence on future trade is the fact that these and other nations are concentrating the greater portion of their R&D resources in economically-motivated effort, while the U.S. has, of necessity, maintained a broad spectrum with emphasis on defense, nuclear and space research. U.S. funding in these areas has dropped off sharply in recent years, but defense-nuclear-space activity still constitutes more than half of the U.S. total research and development effort.

Productivity growth tends to parallel the level of R&D investment. From 1870 to 1950, the U.S. productivity growth rate exceeded that of Europe by 60 percent and Japan by 70 percent; since 1965, the U.S. has trailed Europe by 35 percent and Japan by 60 percent. Over the past 5 years, U.S. productivity growth has averaged about 1.7 percent annually, compared with 4.5 percent in Europe and 10.6 percent in Japan.

In international trade, the U.S. is no longer the world's largest exporter of manufactured goods; that position was ceded to West Germany in 1970. For the first time in this century, the nation faces for 1971 the distinct possibility of a trade deficit. From a surplus of $5 to $7 billion in the early sixties, the balance declined to a plus-level of only $1 to $2 billion by the late sixties and the trend toward deficit continues.

Trading trends show persistent U.S. deficits—as much as $6 billion in 1971—in raw materials and low-technology manufactures. Thus far, these deficits have been more than offset by annual surpluses in high-technology products, such as aircraft, electronics and automotive products.

Even in the high-technology areas, however, disturbing trends exist. U.S. high-technology exports mounted steadily from $13 billion in 1965 to nearly $23 billion in 1970, but imports in the same category increased at a much higher rate during the same time span, growing from about $4 billion to $13 billion, for a gain of more than 230 percent. The U.S. share of world exports of research-intensive products dropped from a level of 35 percent in 1955 to just under 30 percent a decade later, then stabilized at about that level.

One of the more direct challenges from abroad is in aerospace. An area of especially serious potential impact is the world civil aircraft market. Estimated world sales volume of airline transports is $150 billion in the 1970-1985 time frame and $200 billion or more by 1990. Western European industries are taking hard aim at a greater share of this market and even minor inroads would be a severe blow to a U.S. aerospace industry which has experienced crushing reverses in recent years.

The U.S. is currently supplying about 80 percent of the world market for civil aircraft, while the European nations combined account for only 16 percent. One important factor in traditional U.S. dominance in this area has been the vastly greater U.S. domestic market which is a basic foundation for longer production runs, hence lower unit costs. Another factor has been the U.S. ability to provide high levels of developmental investment. A third has been the wide variety of aircraft types offered by the U.S. The Western European nations are seeking to counter these U.S. advantages by greater employment of the international cooperation approach to R&D. Such an approach permits engagement in high cost R&D projects which would be beyond the means of an individual nation but which become feasible when costs are shared by a number of nations. The market for the end product is broadened by virtue of multi-national requirements and the decreased financing burden to the individual nation permits a wider variety of product developments.

It is Europe in combine, rather than the U.S., which boasts the more extensive range of aircraft offerings for the future. The potential of the threat to American civil aircraft market dominance is exemplified by the commercial supersonic transport: the U.S. abdicated the market and created thereby an estimated trade balance swing of $17.5 billion. Additionally, Western European firms are developing several other types of aircraft for which no American counterpart exists and their challenge must be considered a real one.

A serious threat to American technological supremacy is evident in the Soviet research and development trend. Since 1960, the U.S.S.R. has pursued an energetic R&D program which in terms of percentage increase has been greater than that of the U.S. Although U.S. total expenditures during the 12-year period 1960-1971 doubled, the Soviet effort increased two-and-one-half fold, a fact that takes on added significance when it is realized that the U.S.S.R. program is heavily concentrated in defense, nuclear and space research, where U.S. funding is spread over a much broader spectrum. It is estimated that only about 20 percent of Soviet R&D is related to civilian requirements, indicating substantially stronger Soviet military and space effort.

A Department of Defense study maintains that Soviet spending for military R&D outpaces that of the U.S. by some $3 billion annually; current levels cited are $10 billion and $7 billion respectively. DoD estimates a $2 billion gap in favor of the U.S.S.R. in space research, while another source pegs it at $3 billion. U.S. estimates of Soviet R&D growth rate range from 9 to about 13 percent; even the lower figure considerably exceeds the U.S. growth rate.

Should these trends continue, DoD predicted that the U.S.S.R. could achieve technological superiority by 1980 and that the U.S. "margin of security" would be jeopardized in the 1975-1985 time span.

CONCLUSIONS

• Challenge to U.S. Leadership

U.S. leadership in technology and in world trade is being challenged and the nation could lose its top ranking in both areas during the seventies. The primary reason is diminishing U.S. Government support of research and development at a time when the governments of other nations are accelerating efforts toward specific scientific and technological goals. In defense and space technology, the challenger is the U.S.S.R. In world trade, the U.S. is being challenged by the nations of Western Europe and Japan, who are conducting strong economically-motivated R&D programs, particularly in certain research-intensive industries such as aerospace and electronics.

• Necessity for Government Leadership and Support

Where industrial R&D tends to focus upon product improvement and new product development, a nation's high cost/high risk activity usually stems from national priorities and supporting government policies and programs. Hence, future technological capability hinges in great measure on government leadership and financial support, the determinants as to the nature, direction and level of R&D activity. Government direction is also essential to coordination of policies related to education and training of scientific/technical manpower. The U.S. in particular needs an explicit technological strategy with policies which define national R&D goals and provide levels of support adequate for their attainment.

• Increasing Selectivity and Specialization

Free world nations are generally focusing R&D effort in areas which offer economic and trade growth or social welfare gain. In the face of such measures by other nations the U.S. should consider increasing its selectivity and specialization, to the extent possible, while maintaining its broad front approach to R&D. The U.S. may find it advantageous to concentrate more funding in areas where its present competitive trade leadership is threatened and in selected new technologies—for example, environment control, transportation, pollution control, or water desalination—which offer opportunities for leadership and expanded trade potential. While the relationship of science policy to economic policy can be characterized as complex and unclear, the critical role of research and development in maintaining a strong trade position in technology intensive products has been recognized. Obviously, other major factors such as capital resources, fiscal policy, the quality of management, labor cost, and antitrust policies also come into play.

• Cooperative Ventures

The challenges from abroad and the economic strain of financing R&D could enhance the appeal to the U.S. of the cooperative venture approach to R&D, with its attractive cost-sharing and market-broadening features. At the same time, increasing application of this approach in Western Europe tends to counter some of the competitive advantages long enjoyed by the U.S., particularly in the important civil aviation market. Over the past decade, the framework for European expansion of cooperative R&D has been erected by the establishment of several international organizations and the effective removal of institutional barriers and constraints that had previously precluded such ventures. Although some early joint ventures were failures, the experience gained in organizing multi-national projects augurs greater efficacy in current and future Western European programs. These cooperative efforts are posing an ever-increasing degree of competition to the U.S., who must, if it is to reverse the trend, find new approaches through government policy and industry initiative to counter the combined effort of Western Europe.

• Necessity for Early Action

The long leadtimes associated with R&D in moving from concept to practical application demand immediate policy attention to reversing existing trends in the areas of challenge vital to U.S. productivity, economic strength and world leadership position.

CHAPTER 1

Policy Considerations and the Establishment of R&D Priorities

In this era of explosive technological progress, the posture of any nation is becoming ever more dependent upon their national science and technology capability and the rate at which it is advancing. Science and technology do not advance automatically as a function of the passage of time; the national capability must be fostered by as broad and as vigorous a program of research and development as the available resources will allow.

Although private financing plays a large part in the programs of major nations, R&D has been accepted by many as being in the national interest, and thus, a government responsibility. Its nature and direction are determined by national goals and policies, and its magnitude by the amount of financial support the government can, or is willing to commit.

R&D can be grouped into two primary areas of effort: defense-space-nuclear research and economically-motivated, or trade-oriented, technological advance. Within these two broad categories, there is wide divergence among nations as to relative funding allocations and areas of special priority.

DEFENSE, SPACE AND NUCLEAR INTERESTS

• The U.S. and U.S.S.R.

Defense, space and nuclear R&D is characterized by extremely high costs and high risks, hence only the superpowers, the U.S. and U.S.S.R. have been able to allocate sufficient resources to pursue such programs across the entire spectrum of feasibility. In defense, the continuing quest for weapons superiority has caused each nation to commit exceptionally large sums for R&D. In space, there are multiple motivators: the international prestige that attaches to technological supremacy; scientific gain; the economic potential of applications satellites; and the fact that space research, by its very nature, is an instrument for rapid advancement of a nation's overall technological capability.

In both the U.S. and the U.S.S.R., defense-space-nuclear R&D over the past decade has constituted by far the major portion of the total R&D effort. There is a difference in degree, however. The Soviets have concentrated some four-fifths of their program in the defense-space-nuclear area, paying only minimal attention to civil sector research. The U.S. has pursued a much broader program in which the degree of emphasis on defense-space-nuclear R&D is less pronounced. Thus, although overall Soviet R&D expenditures have not yet reached the U.S. level, spending in this particular area is outpacing that of the U.S. by a considerable margin. Recent internal pressures in the U.S. have tended to widen the gap in favor of the Soviet Union. National policy has decreed increasing emphasis on civil sector R&D, particularly in human resources research, but there has been no compensating increase in overall funding, so defense-space-nuclear R&D has been declining as a percentage of the total.

- **Western European Nations**

Policy considerations regarding R&D priorities among the nations of Western Europe naturally differ greatly from those of the U.S. and the U.S.S.R. In defense, treaty commitments and lack of resources dictate strong reliance upon the U.S. for protection. Similarly, funding does not permit the Europeans to engage in extra-sophisticated space projects such as manned spacecraft or planetary exploration, but, aware of the economic potential of applications satellites, the Western European countries are laying the foundation for future efforts in that area. Nuclear research for the most part is directed toward peaceful applications, particularly energy sources for power needs in coming years.

Many of the major nations have their own independent efforts in defense, space and nuclear R&D Additionally, Western Europeans have banded together in a number of cooperative, cost-and-performance-sharing programs in these and other areas.

In no case, however, does combined spending for independent and cooperative R&D in the defense-space-nuclear area amount to as much as half of the nation's total R&D expenditures. France, which engages in nuclear weapons research as well as R&D on military aircraft, spacecraft and launch vehicles, tops the list with almost half of its total effort devoted to defense, space and nuclear energy. Proportions in other countries range downward to less than one-fifth. By and large, Western European policy is to concentrate R&D resources in economically-motivated projects.

- **Japan**

In the wake of World War II, Japan has risen to become the free world's most rapidly growing economy. One of the reasons is national policy which regards R&D primarily as an instrument for economic growth. Japan is unique among major nations as it has concentrated almost its entire R&D outlays over the past decade in civil sector research. Most of the effort has gone into economically-motivated R&D, particularly in the development of exportable products, a key area of the Japanese economy. A secondary consideration in R&D priority is social welfare research, to which Japan has devoted a greater proportion of its total funding than any other major nation.

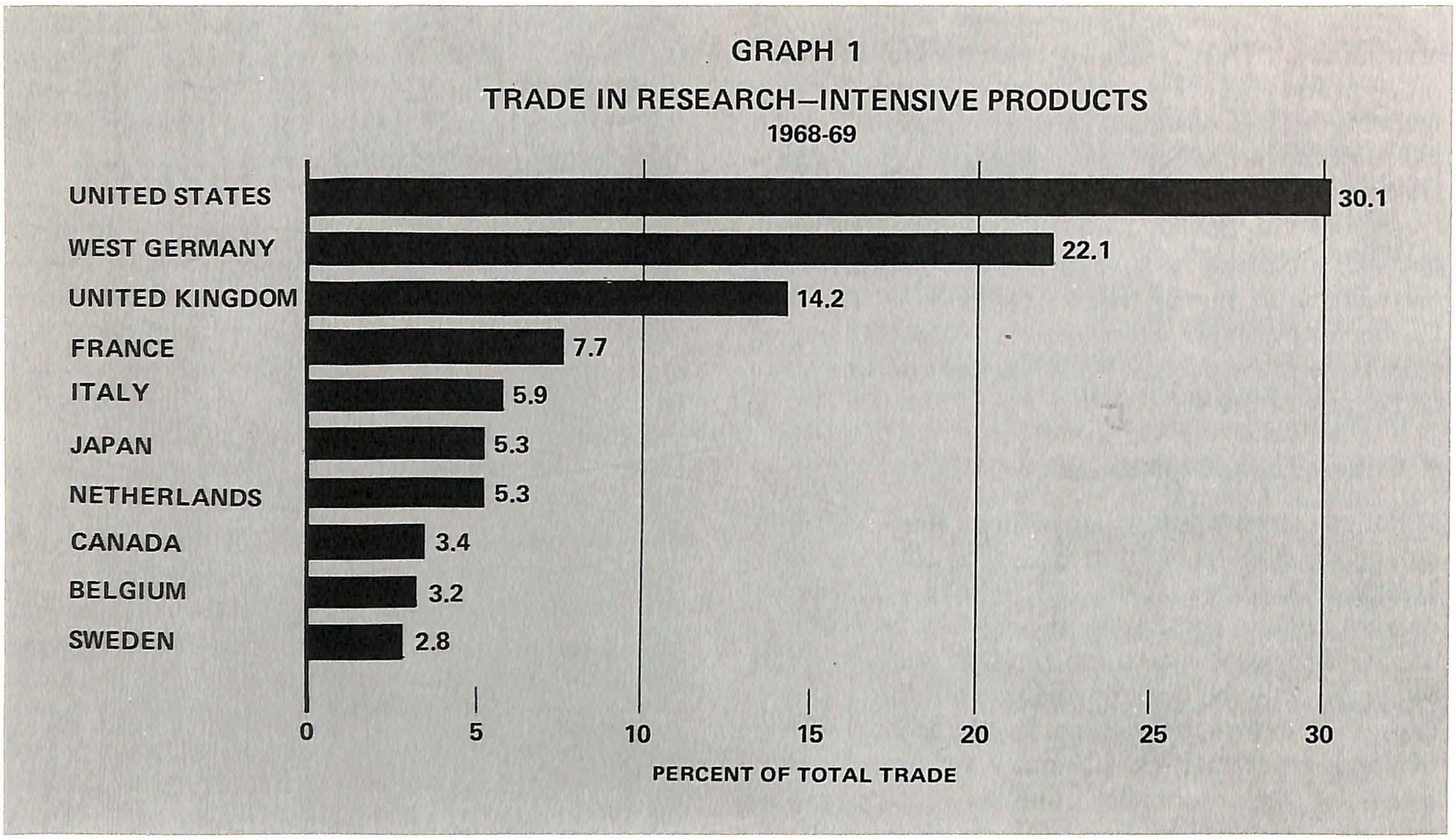
As a result of this national attitude, defense R&D in Japan has been completely subordinated which is reflected in the small home defense force and a policy of importing technology to equip it; independent defense R&D amounts to only one percent of total R&D expenditures. Despite notable successes since 1970, Japan's space R&D has been lightly funded, even by comparison with Western European nations.

There are indications of a degree of change for R&D in defense, space and nuclear energy. Japan's desire to build up a broader technological base points to substantially larger expenditures for space R&D, along with additional emphasis on civil-potential nuclear energy research and a somewhat more comprehensive defense R&D effort. These gains, however, will come from increased government support as focus on economically-motivated R&D is expected to continue.

TRADE AND TECHNOLOGY

Although a number of factors contribute to trade performance—among them capital resources, fiscal policy and the quality of management—the prime asset for greater productivity and economic growth is a strong technological capability. Hence, research and development plays a major role in shaping future trends, particularly in research-intensive industries, such as aerospace, electronics and chemicals.

The governments of Japan and the Western European nations are taking concrete steps to improve, by extensive economically-motivated R&D, those industries considered vital to a competitive trade position. In each case, the percentage of economically-motivated R&D to total R&D is far greater than that of the U.S. These nations have other advantages relative to competition with the U.S., for instance,



lower labor costs and direct and indirect government incentives to business firms which are designed to stimulate industrial R&D and to encourage construction of modern production facilities.

The effects of increasing foreign competition are reflected in a diminishing U.S. trade balance. According to Secretary of the Treasury John B. Connally, Jr., the "simple fact is that in many areas others are outproducing us, outthinking us, outworking us and outtrading us."[1]

Mounting concern on the part of public officials and industry representatives has led to consideration of a number of proposals for recharging U.S. competitiveness, including:

"—Government subsidies for research and development in computers or other high-technology products in which the U.S. has an advantage over its trading partners (but no help for low-technology industries such as shoes, in which America is less competitive).

—Softer antitrust laws to give U.S. companies more power to compete abroad.

—Tax breaks for exports and investment incentives for companies that sell overseas.

—Realignment of the relative values of the dollar, the yen, the mark and other currencies to make U.S. products relatively cheaper in the world markets.

—A get-tough policy toward Europe and Japan on trade restrictions and defense cost-sharing."[2]

• Deterioration of the U.S. Trade Balance

For the first time in this century, the U.S. faces the distinct possibility of a trade deficit. From a surplus of $5 to $7 billion in the early sixties, the balance

[1] *Time*, May 31, 1971, p. 79.

[2] *Wall Street Journal*, July 6, 1971, p. 1.

TABLE 1

INDUSTRIAL RESEARCH IN HIGH-TECHNOLOGY INDUSTRIES

COUNTRY	TOTAL RESEARCH PERFORMED BY INDUSTRY	RESEARCH IN SCIENCE-BASED INDUSTRIES							
		AEROSPACE		ELECTRICAL		CHEMICAL		OTHER	
		$ Millions	% of Total	$ Millions	% of Total	$ Millions	% of Total	$ Millions	% of Total
France									
1961	538	131	24.3	126	23.4	111	20.6	171	31.7
1964	890	221	24.8	198	22.3	164	18.4	307	34.5
1966	1,184	359	30.3	244	20.6	194	16.4	387	32.7
Germany									
1961	549	–	–	195	35.5	163	29.7	191	34.8
1964	946	–	–	301	31.8	288	30.4	358	37.8
1967	1,420	67	4.7	369	26.0	382	26.9	602	42.4
1970	–	–	–	–	26.8	–	31.5	–	51.7
United Kingdom									
1961/62	1,179	436	37.0	296	25.1	141	12.0	305	25.9
1964/65	1,411	399	28.3	336	23.8	198	14.0	478	33.9
1966/67	1,697	446	26.3	451	26.6	232	13.7	567	33.4
United States									
1961	10,908	3,829	35.1	2,782	25.5	1,396	12.8	2,902	26.6
1964	13,512	5,055	37.4	3,270	24.2	1,716	12.7	3,473	25.7
1966	15,548	5,442	35.0	4,011	25.8	1,959	12.6	4,120	26.5
1970	18,910	5,704	30.2	–	–	–	–	–	–

Source: Based on "R and D in the British business enterprise sector," *Science Policy News,* Science Policy Foundation, Ltd., London, January 1970, p. 78.

declined to a plus-level of only $1 to $2 billion by the late sixties and the trend toward further deficits continues. The situation is largely the result of strong surges in Canadian, Japanese and European exports. A startling development is the fact that the U.S. "is no longer the world's largest exporter of manufactured goods. That position was lost in 1970 to (West) Germany."[3] When the United Kingdom joins the Common Market, total exports from the member countries will amount to more than twice those of the U.S.

[3]Statement of Maurice H. Stans, Secretary of Commerce, before the Joint Economic Committee, June 25, 1971.

• Trade in High-Technology Products

Trade balances can generally be divided into four categories: agricultural products, raw materials, low-technology manufactures (textiles, footwear, iron and steel, etc.) and high-technology products (aircraft, electronics and automotive systems). Trading trends show a small surplus in agriculture, persistent deficits in raw materials and losses of major dimension in low-technology manufactures that by 1970 reached more than $6 billion and continues to mount. The deficits are more than offset by a substantial surplus in high-technology. Surpluses have topped $9 billion annually since 1965.

Clearly, the key to improving the U.S. trade balance posture is expansion of exports in high-technology products, although many problems exist. U.S. exports in the high-technology category have increased steadily from $13 billion in 1965 to $22.6 billion in 1970. Imports, however, in the same category climbed at a much higher rate. During that time span they grew from nearly $4 billion to $13 billion, an increase of more than 230 percent. The U.S. share of world exports of research-intensive products dropped from a level of 35 percent in 1955 to 30 percent a decade later, and then remained relatively stable through 1969.

The relative decline of U.S. technological strength is attributed by Commerce Secretary Stans to a number of factors, some of which are: "(1) the accelerated worldwide transfer of existing technology, (2) relatively lower U.S. investments for civilian R&D and capital equipment than foreign competitors, (3) the growth of foreign government incentives, and (4) increasing cost and risks of major technology breakthroughs, often beyond the capacity of individual companies."[4] Stans further noted that while the U.S. R&D expenditures remain at a high level, two factors modify the relative U.S. effort. First, wage costs in other countries are significantly lower, thus affecting the comparability of R&D dollars expended. Secondly, "it takes a greater R&D effort, at much greater cost, for the leading country to find innovations to stay ahead."[5]

• Productivity and R&D Expenditures

In the United States, total R&D annual expenditures doubled over the past decade, but the most rapid increase was from 1961 to 1966, when the average yearly growth rate approached 9 percent. Since 1966, the annual average growth rate has slowed to about five percent because of a marked reduction in government-funded R&D. This decline in government support contrasts with substantial increases in government funding of R&D in other countries: France, 13 percent annual growth rate; Japan, almost 25 percent; West Germany, 30 to 40 percent.

Shifts in productivity growth rates tend to parallel the scope of R&D investment. From 1870 to 1950, the U.S. productivity growth rate exceeded that of Europe by 60 percent and Japan by 70 percent; since 1965, the U.S. has trailed Europe by 35 percent and Japan by 60 percent. Over the past five years, U.S. productivity growth has been about 1.7 percent annually, compared with 4.5 percent in Europe and 10.6 percent in Japan.

The impact of R&D on U.S. industry is reflected in the percentage increases in sales of new products. For example, even with the slower growth rate since 1967 in aerospace R&D, almost one-third of all aerospace sales in 1974 are expected to come from products which did not exist as production items in 1970.

• Government Incentives

For a number of years, Japan and most Western European nations have actively promoted the expansion of industrial R&D, particularly in areas that offer economic advancement. Canada, for example, extends grants to industrial firms equal to 25 percent of capital expenses on R&D; and, in addition, companies can receive government payments of up to 50 percent of the cost of individual R&D projects. West Germany provides special tax write-offs of up to 50 percent of corporate R&D investment, plus a 10 percent cash investment subsidy. British companies may write off 100 percent of new investments in productive facilities in the year in which the investments were made. Japan allows a 3-year tax holiday for profits on "new and important" products. In addition to these incentives, direct subsidies are being provided by some governments to permit firms to engage in high cost/high market potential programs.

To halt further erosion of its competitive position in the world market, U.S. industry needs such incentives. The U.S. Government is considering a number of possible incentives designed to stimulate development of new technology, among them direct federal assistance in the form of loan guarantees, cost sharing and grants, and such indirect assistance as tax incentives for R&D and capital expenditures and changes in the antitrust laws to permit cost-risk sharing joint ventures.

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[4] Statement by Maurice H. Stans, Secretary of Commerce, before the Subcommittee on Science, Research and Development, House Committee on Science and Astronautics, July 27, 1971, p. 9.

[5] *Ibid*, p. 10.

CHAPTER 2

Organization of Research and Development

INDIVIDUAL NATION R&D STRATEGIES

Varying national strategies for conducting R&D fall into three categories:[6]

- The *broad front approach*, exemplified by the U.S. and the U.S.S.R., involves support of scientific and technological development across a wide spectrum of military, economic and political objectives.
- The *special focus approach* is one in which a nation opts to develop particular competence in specialized areas by concentrating available resources in selected narrow bands of the spectrum. Examples are the United Kingdom and Sweden.
- The *technology import philosophy* is one of broadening the national developmental base by purchase of foreign R&D. Japan is the prime example.

The magnitude and direction of individual nation R&D are influenced by such factors as public versus private financing; public versus private performance of R&D; the level of support in relation to GNP, the R&D growth rate; priority areas of concentration; and the degree of emphasis upon basic research, applied research and development.

FRANCE

• General Trends

France sponsored a particularly vigorous R&D effort in the decade of the sixties and further increases in the support level are indicated for the seventies.

In the sixties, total R&D expenditures more than tripled, from a billion dollar level in 1961 to well over $3 billion in 1970. The French Sixth Plan, covering the years 1971-1975, contemplates an annual growth rate of 13 percent, which by 1975 would elevate the funding level to $5 billion yearly.

As a percentage of Gross National Product, R&D expenditures rose from about 1.5 percent in 1961 to 2.2 percent in 1970. Current plans indicate continuance of the climb, to 3 percent by 1975 and perhaps to 3.5 percent by 1980.

The ratio of government to private funding—roughly 65 to 70 percent government during the sixties—is expected to continue, but recent policy changes indicate an upward revision of the amount of

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[6] Robert Gilpin, "Technological Strategies and National Purpose," *Science*, July 31, 1970, pp. 441-448.

TABLE 2

R&D INDICATORS IN INDUSTRY

COUNTRY	Research Performed By Industry ($ Millions)	% of GNP	% of Total R&D	% Financed By Government
France				
1961	538	0.8	53.9	32.7
1964	890	1.0	51.7	29.0
1966	1,184	1.2	53.9	37.4
Germany				
1961	549	0.7	66.7	14.9
1964	946	0.9	66.0	14.0
1967	1,420	1.2	68.2	17.4
United Kingdom				
1961/62	1,179	1.5	64.0	41.3
1964/65	1,411	1.5	65.4	37.1
1966/67	1,697	1.6	68.6	32.2
United States				
1961	10,908	2.1	75.2	57.2
1964	13,512	2.1	70.4	57.2
1966	15,548	2.0	69.9	53.6
1970	18,910	1.9	70.4	43.2

Source: Based on "R and D in the British business enterprise sector," *Science Policy News,* Science Policy Foundation, Ltd., London, January 1970, p. 78.

R&D performed by industry, currently at the 50 percent level. Government laboratories in France now accomplish a significantly higher percentage of the total R&D than is the case in the U.S., Japan, or other major European nations, a situation which tends to restrict transfer of technology to the industrial sector and concomitantly reduces the prospect of commercial return on R&D.

Along with significantly increased government R&D funding and greater industrial responsibility for R&D execution, there is portent of other changes in recent science policy recommendations by a Commission of the General Delegation on Scientific and Technical Research. Some hitherto neglected areas will receive funding and, although they will continue to be major areas of effort, there will be reduced emphasis in relative terms on aeronautical, nuclear and computer technology programs. Additionally, the government plans to encourage the purchase of foreign licenses, a direct change from the policies of the de Gaulle regime. A larger portion of total R&D will be devoted to development and to economically-oriented technological advancement.

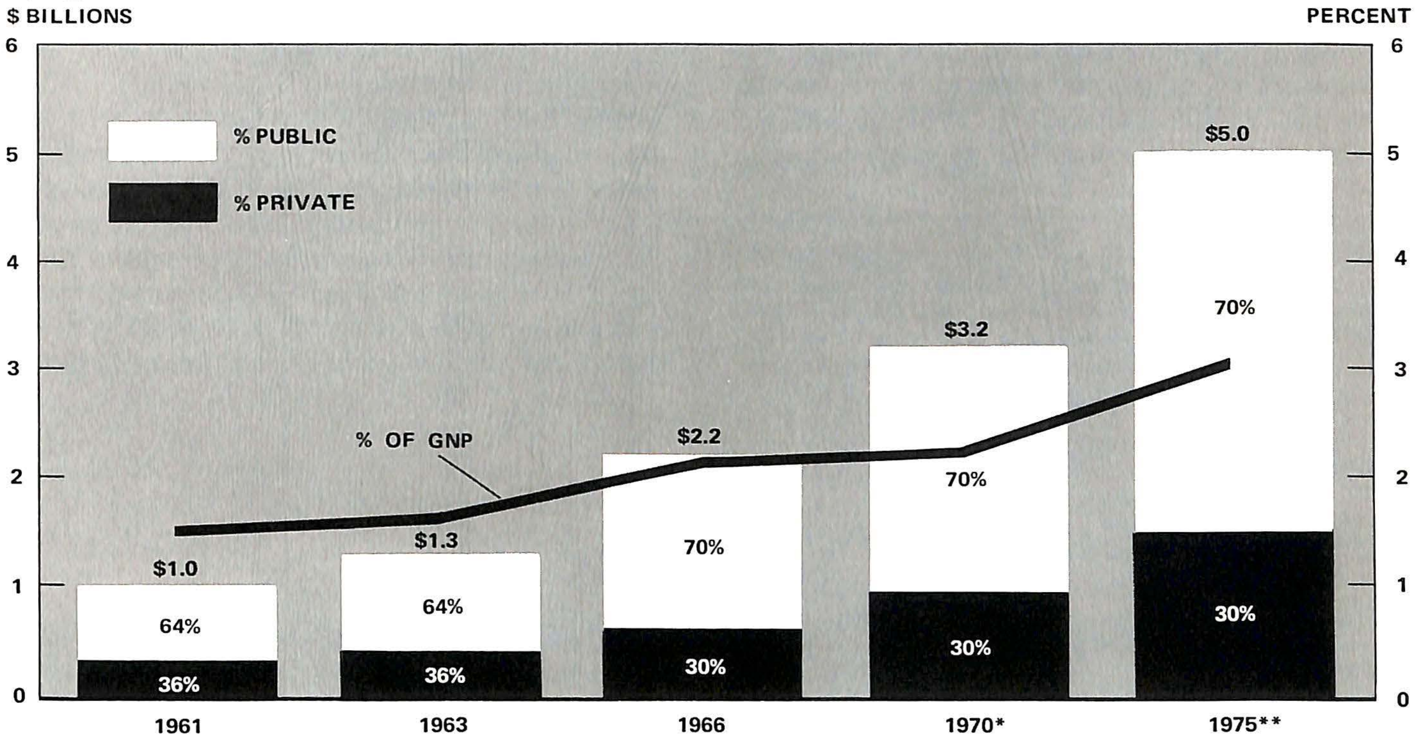
- **Priorities**

France's new policy directions plan a definite shift in favor of such areas as housing, transportation and other urban problems, together with R&D support aimed at improving the international competitive position of French industry.

In the sixties, a decade characterized as a drive for

GRAPH 2

FRANCE
RESEARCH AND DEVELOPMENT EXPENDITURES



*Estimated
**Sixth Plan

Source: *Based on A Study of Resources Devoted to R&D in OECD Member Countries in 1963-1964, OECD, Paris 1967-8, "Research Expenditure in 1970 to 'Preserve Existing Programmes'," Science Policy News, January 1970, and Noah Hardy, "Revamping Priorities: France's new five-year plan gives a boost to research and development," Science News, 1970.*

great power status, France assumed a leading role in multi-national cooperative ventures and sharply emphasized, in its independent R&D, the military, nuclear and space exploration areas. As is evidenced by the following table, France in the mid-sixties devoted a larger percentage of its national R&D resources to those areas than did Japan or other European nations.

In the shifting focus of the seventies, three areas are expected to receive preferential consideration: industrial development, life and human sciences and socio-economic research. It is anticipated that research funds for biology and medicine will increase by about 23 percent a year, and a gain of equivalent order is indicated for the social and behavioral sciences. Support for space and oceanographic R&D will continue. A declining growth rate can be expected in R&D funding in military and nuclear programs. In the latter area, the annual increase may be as little as 5 percent. A reordering of funding for civil aviation is forecast upon the completion of the Concorde SST program. The government will, however, continue to participate in international cooperative ventures.

- **Industrial R&D**

In focusing priority attention on strengthening French industrial competitiveness, the government will continue to support its highly-developed industries, such as the electronics industry, which has been a primary recipient of public funding during the last

TABLE 3

FRANCE
ALLOCATION OF TOTAL R&D EXPENDITURES
(Percentage Share)
1963-1964

COUNTRY	Atomic, Space & Defense	Economically-Motivated	Welfare and Miscellaneous
France	45	41	14
Germany	17	62	21
Japan	—	73	27
Sweden	34	50	16
United Kingdom	40	51	9
United States	62	28	10

Source: OECD. *The Overall Level and Structure of R&D Efforts in OECD Member Countries*, Paris, 1967, p. 57.

decade. At the same time, France will take measures to broaden the scope of industrial development by placing new emphasis on advancements in chemistry, metallurgy and mechanics. Government aid to industry is expected to increase from the present level of about $30 million to a range of $270 to $360 million by 1975.

- **Scientific and Technical Manpower**

In comparison with other major countries, France ranks among the lowest in per capita R&D manpower, a situation which the new plan seeks to correct by stressing the need for increasing the number of scientists, particularly those in industrial occupations. The proposed goal is to channel into industrial research about 70 percent of the 1971-1975 science and engineering graduates. Also under consideration are recommendations for increasing employment flexibility and mobility.

GERMANY (FEDERAL REPUBLIC OF)

- **General Trends**

The Federal Republic of Germany experienced an extraordinary R&D growth during the sixties, reaching the billion dollar level early in the decade, doubling it by the mid-sixties and climbing to the $3 billion level by 1969. But even this impressive growth rate pales by comparison with the greater momentum of the period since 1969 and the plans for the remaining years of the seventies.

The accelerating R&D effort gained new impetus with the ascension to the Chancellorship of Social Democratic Party leader Willy Brandt in October 1969. In his inaugural policy statement, Brandt made it clear that West Germany proposed to promote fundamental research on all fronts.[7] Stressing the im-

[7] *Science Policy News*, January 1970, p. 90.

portance of European cooperation, Brandt maintained that an integrated European scientific community could measure up to the U.S. and the U.S.S.R.

In 1970, the Federal Minister for Education and Science presented these guidelines:

- An integrated policy for science and education;
- An integrated policy for science and technology, directed toward economic growth and practical applications of research in such areas as consumer goods, communications and transportation;
- An international science policy, embracing international cooperation, stressing the benefits to be derived from improving Western Europe's position in world affairs and from promoting economic integration for strengthening the competitive posture of the EEC nations.[8]

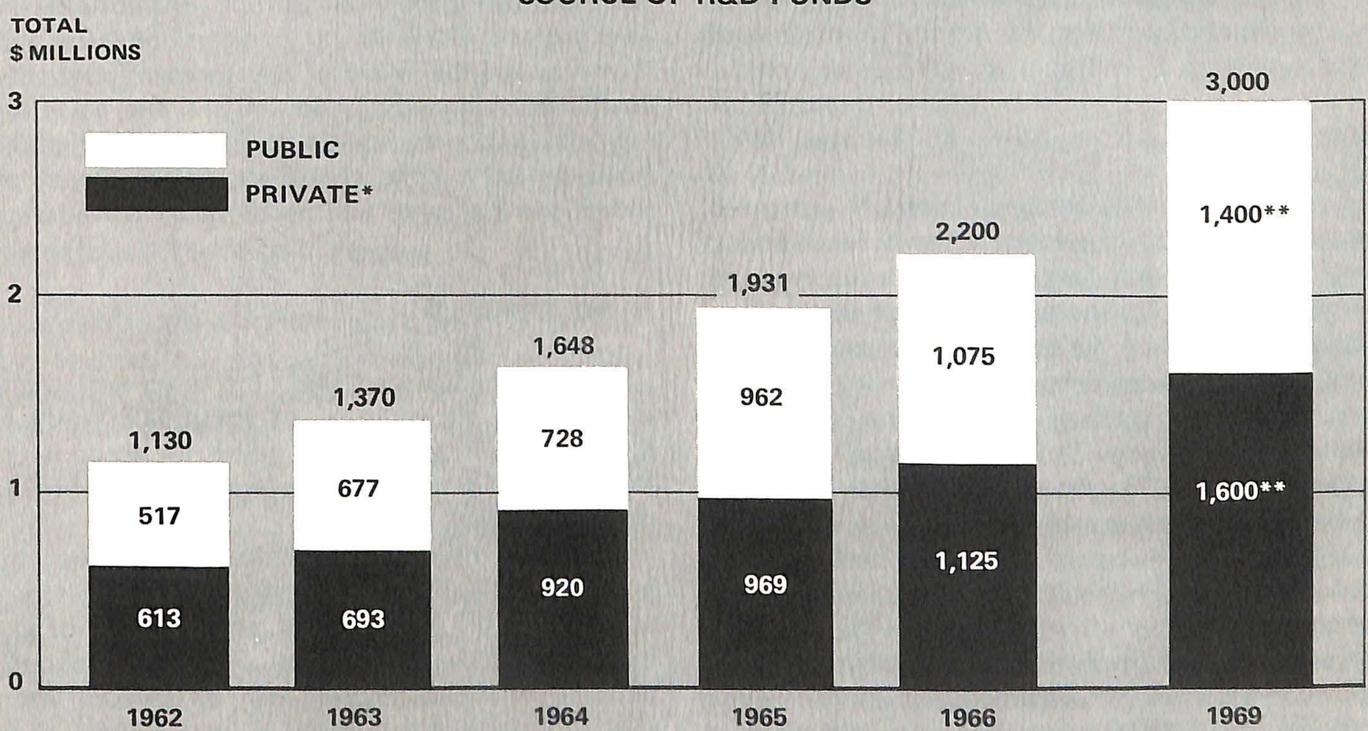
Germany's policies have been backed by solid financial support. Estimates of the budget for the Ministry for Education and Science[9] show an increase from 4.7 percent of the total federal budget in 1969 to 6.7 percent in 1971, and is forecast to rise to almost 10 percent by 1974. Government support of science grew at the rate of 10-15 percent annually in the mid-

[8] *Science Policy News*, July 1970, pp. 102-3.

[9] The Ministry for Atomic Energy was established in 1954, expanded in 1962 to include space research activity and renamed the Federal Ministry for Scientific Research. In October of 1969, it became the present Federal Ministry for Education and Science.

GRAPH 3

GERMANY
SOURCE OF R&D FUNDS



*Primarily Industrial

**AIA Estimates

SOURCE: UNESCO. Science policy and organization of research in the Federal Republic of Germany, p. 58, and Science Policy News, 1970.

sixties and in more recent years at 30-40 percent, compared with increases in the total federal budget approximating 12 percent. Current plans indicate growth rates in government funding for education and science up to 50 percent.[10]

Along with science and education, industrial research expenditures have been climbing steadily, with growth rates approaching 25 percent annually. From the early sixties to the end of the decade, the ratio of R&D expenditures to GNP increased from 1.4 to 2 percent and may reach 2.5 percent in 1972. The overall West German R&D effort is comparable to that of France, with the exceptions that private sources finance more (about 50 percent to France's 30 percent) and a greater percentage of German R&D is industry-performed (about 70 percent, which matches the U.S. pattern). In contrast to the centralization of scientific and technological policy in the United Kingdom and France, the German Federal Ministry does not have responsibility for industrial applications of technology.

Of the government-funded science and education allocation, more than one-third goes to general education and institutions of higher learning. The remainder is accounted for by nuclear research, aerospace research, data processing and new technologies, and expenditures for the general promotion of science.

• Priorities

As outlined by the German Federal Ministry for Education and Science, priority areas include atomic energy, data processing, space exploration, marine research and "new technologies"—a catchall grouping which embraces such fields of interest as environmental research, water desalination, communications and transportation systems.

While atomic energy activity remains a priority area, as it has been in the recent past, expenditures will increase at a lesser rate through 1974. As in the U.K., France and Japan, R&D on fast breeder reactors has been and will continue to be a prime focal point.

Because of the necessity for selectivity, West Germany will continue to explore space on a cooperative basis. The nation has made the most of the limited space funding available by participating with the U.S., the U.K., France and other European countries on a joint effort basis in highly technical space projects that would have been too costly for independent conduct.

The joint venture approach also extends to defense-related R&D, particularly military aircraft developments. This factor, together with continuing commitment to direct procurement of U.S. and U.K. military hardware, relegates independent defense-related R&D to a relatively low priority (less than 15 percent of the total R&D budget).

In 1971, funding for aerospace activity increased about 50 percent over the previous year and the plan contemplates continuing increases of substantial order over the next several years. The emphasis is on basic national programs, together with contributions to such joint aerospace ventures as the European Space Research Organization, the European Launcher Development Organization and the French/German Symphonie applications satellite.

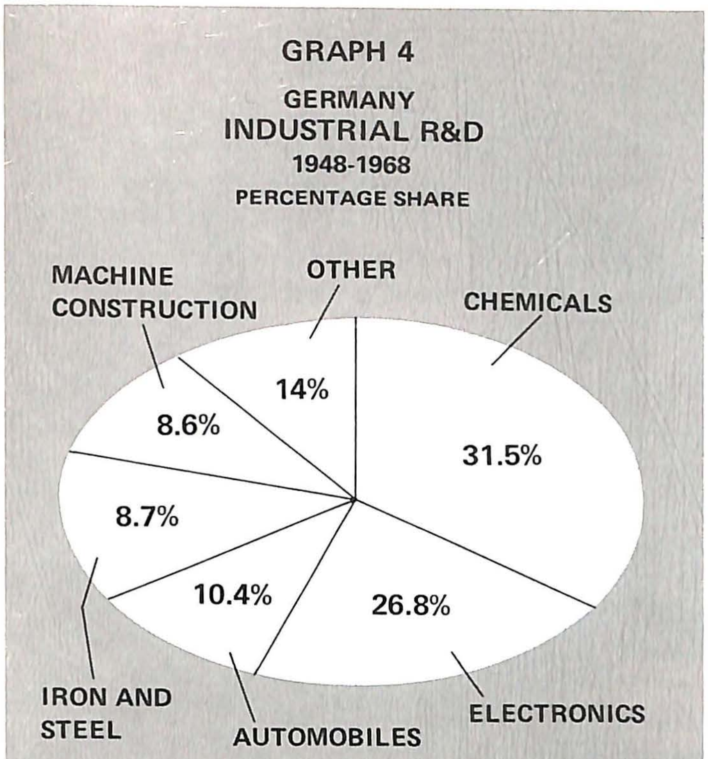
In computer technology, the government determined in 1967 to promote and support the development of the West German computer industry, challenging U.S. domination of that field not only in Germany but throughout Europe. Promotional measures include low interest loans to computer manufacturers and the award of development contracts by the Science Ministry. Additionally, the government has effected a strong policy of buying first from home industry, although preferential treatment is not independent of price and performance consideration.

• Industrial R&D

Industrially-financed R&D increased over the past decade from expenditures of about \$250 million to more than \$1 billion. Five industries accounted for 86 percent of both the financing and the performance of total industrial R&D.

The high degree of competence and the strong competitive position of West German industry are reflected in the fact that the nation's share of world exports in research-intensive products is about 22 percent, which compares with 30 percent for the U.S., 14 percent for the U.K. and 7.7 percent for France. In most areas. German industrial technology can be considered comparable to that of U.S. industries; although there are lags in aerospace and electronics capability, but efforts are being made to

[10] *Science Police News*, November 1970, pp. 33-34.



Source: Department of State. International Science Notes, No. 25, September 1970, p. 10.

close the gap.[11] Government-sponsored R&D in both fields has increased sharply since 1967.

- **Scientific and Technical Manpower**

According to the Denison report, which systematically examined U.S. economic expansion, education is the single most important factor in economic development. Elsewhere it has been suggested that the technological gap between the U.S. and Europe "is due primarily to a paucity of higher education, and thus to a relative weakness of science and research."[12]

West Germany's R&D progress in the sixties, impressive as it was, was nonetheless restrained to some extent by an insufficiency of scientific and technical manpower. As recently as 1964, the nation had fewer per capita qualified scientists and engineers engaged in R&D than did France, Japan, the U.K., the Netherlands and Sweden. In 1966, Germany's student corps amounted to 7.5 percent of the population from ages 20 to 24, compared with 43 percent in the U.S. and 24 percent in the U.S.S.R. Consequently, the number of students ranked below all major industrialized nations except Italy and the U.K. This situation portended later shortages of scientific and technical personnel, which the country is now experiencing.

JAPAN

- **General Trends**

Like the major European nations, Japan steadily increased its commitment to R&D in the sixties, particularly in the latter years of the decade, when expenditures reached an annual growth rate of about 20-25 percent. R&D funding climbed from about $500 million in 1960 to roughly $3 billion in 1970. Under Japan's philosophy of importing technology in certain areas, a good portion of the funding went for purchases of foreign R&D, an expenditure that doubled from 1964 to 1969 to a level just under $400 million.

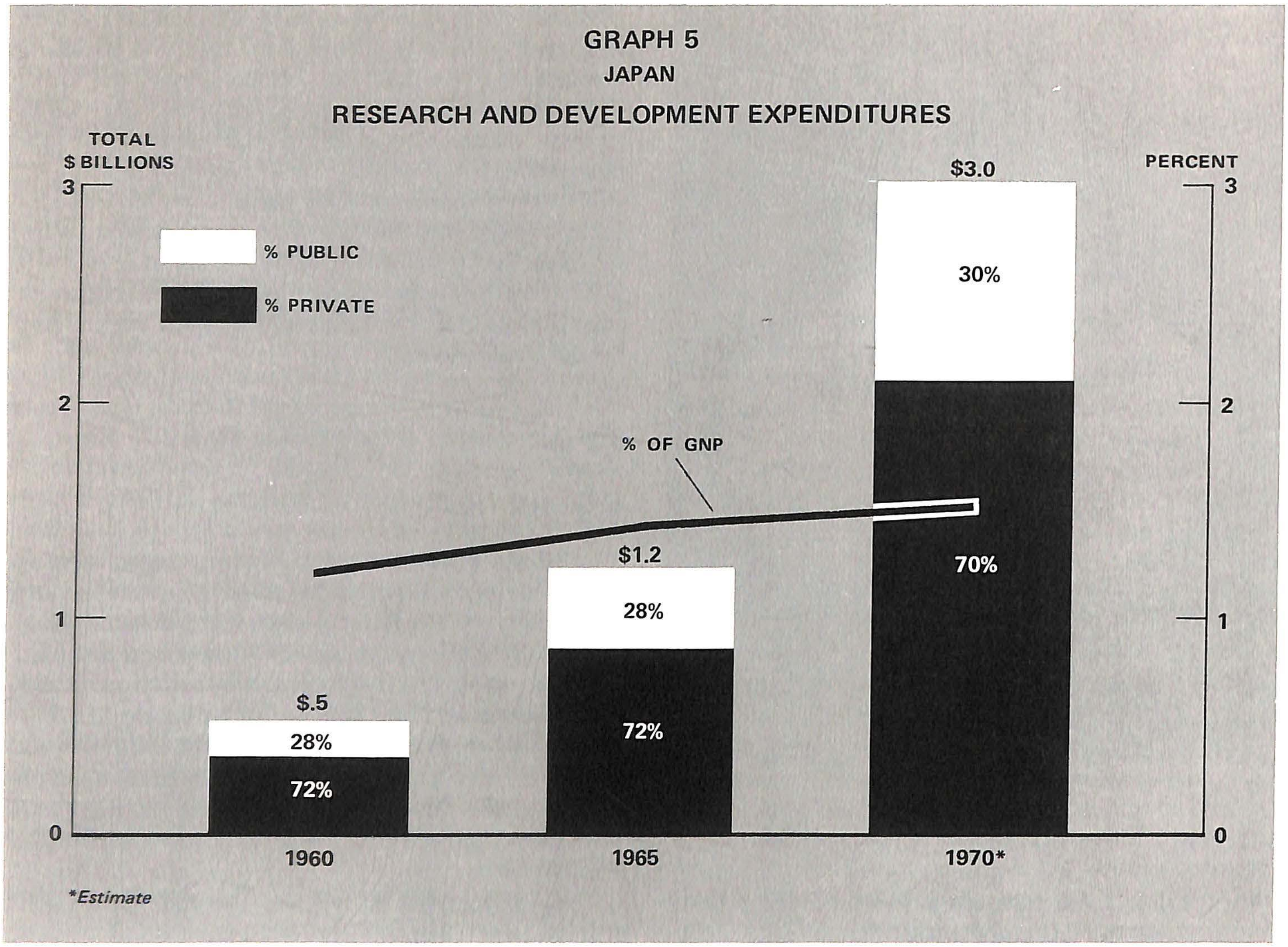
For Japan, R&D growth as a percentage of GNP has been less impressive as it rose only 0.3 percent during the decade and still remains below 2 percent. Nonetheless, the funding expansion is significant in view of the fact that Japan devotes only a small proportion of its R&D effort to military purposes. Defense research accounts for only one percent of total R&D expenditures and less than 4 percent of government research expenditures.

Japan still ranks behind the U.K., France and West Germany and far behind the U.S. and the U.S.S.R. in various comparative measures of R&D. The Japanese, however, have effectively concentrated their efforts in areas offering contribution to economic growth, as is evidenced by the GNP rise from less than $50 billion in 1960 to almost $200 billion in 1970 and a gain in exports from $4 billion to about $20 billion in the same period.

The trend toward further R&D expansion, bolstered by growing government support in selected areas, has led some analysts to predict that Japan will climb to third place in R&D expenditures by the late

[11] Department of State, *International Science Notes*, pp. 10-13.

[12] J.-J. Servan-Schreiber, *The American Challenge*, p. 75. Servan-Schreiber attributed Europe's economic weakness as stemming not only from the education factor, but also largely as a result of the failure to apply modern methods of management.



seventies. The Japanese effort, however, may be retarded by certain restricting influences, among them (1) limited government financing, which undermines the ability to undertake sophisticated projects where costs and risks are high; (2) student disruptions of university research programs, which some observers say have slowed the development of Japan's research capability by as much as five years; (3) an apparent attitude of distrust between the academic research community and the government; (4) concentration on technological development at the expense of basic research; and (5) continued heavy reliance on the purchase of foreign R&D.

• Organization of R&D

The Japanese approach to R&D differs markedly from that of other countries. The government plays a relatively minor role, providing only about 30 percent of the R&D financing, while industry funds much of the remainder. This unique situation gives rise to three key factors:

- Lacking significant government support in such areas of endeavor as defense, space and atomic energy, the Japanese have confined their R&D largely to economically-motivated advancements.
- Because of industry's dominant role, the direc-

tional focus has been almost exclusively on development, rather than basic and applied research.

- The philosophy of importing technology has limited the advancement of independent R&D capability. Although the latter policy is expected to continue, there is growing evidence that in coming years Japan's R&D program will be strengthened and redirected toward increased government support and greater allocation of resources to basic and applied research.

• Priorities

Areas of future priority include atomic energy, space exploration and marine science. Additionally, the level of defense research expenditure is expected to increase to some degree. Japan's proposed defense budget for 1972-1976 includes some $480 million for research and development.

While space research appears to be of interest to the Japanese, expenditures ($100 million over the past 10 years) have been slight compared with those of other major nations. The trend, nonetheless, is upward as indicated by space funding increases from $15.6 million in 1967 to about $20 million in 1968 and $26 million in 1969. It is estimated that by the mid-seventies Japan will spend between $500 million and $1 billion on satellite and launch vehicle programs.

Initially, the Japanese space effort was divided between a university program and a government program with differing objectives. Seeking more efficient direction, the government established a Space Activities Commission in 1968 and in the following year set up a Space Development Corporation. The Japanese had originally intended to pursue a "go-it-alone" policy in space research, but limited funding and a series of failures brought a decision to request American technical assistance.[13] The space program scored its initial success in 1970, when Japan became the fourth nation to orbit its own spacecraft with its own launch vehicle.

The atomic energy research program has been a minor one in comparison with Western-nation efforts, and in the development of first generation nuclear reactors Japan relied extensively upon imported technology. Recently, however, spurred by industrial energy needs which are currently being met with imported fuels, Japan has embarked upon development of a fast breeder reactor and an advanced converter reactor. Government interest in atomic energy is reflected in increased R&D spending as illustrated in the 1969 budget allocation which was 40 percent higher than the previous year. Larger commitments are indicated for the future, as it is estimated that by the year 2000, atomic energy will supply most of the Japanese power requirements. Special emphasis is also being placed on development of nuclear-powered ships.

• Industrial R&D

While industry in Japan finances most of the R&D it performs, the government provides indirect aid such as tax incentives and long-term loans at low interest rates.

The leading performers of R&D are the electrical engineering and chemical industries where the former accounts for about 25 percent of the total, the latter 22 percent. The ratio of research expenditures to sales is highest in the pharmaceutical industry (3 percent); the communications industry, including electronics and electronic measuring instruments (2.9 percent); and the electrical appliance industry (2.3 percent).

Japanese ratios of R&D funding to sales are lower than the U.S. all-industry average of 4 percent and significantly lower in the high-technology industries, such as aerospace (19 percent in the U.S.) and electrical equipment/communications (8 percent). In the latter cases, however, the differences stem largely from U.S. Government financing of industrial R&D directed toward space and defense requirements. Adjusted to consider only the industry-funded portions, U.S. and Japanese ratios are roughly equivalent.

• Scientific and Technical Manpower

The R&D scientific and technical manpower force in industry, numbering some 200,000 in 1968-1969, constitutes about 1.3 percent of the total work force, a level below the U.S. figure, but somewhat higher than the U.K. and significantly greater than the corresponding ratios for France and West Germany. In addition, it is estimated that the money spent per

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[13] On July 31, 1969, the U.S. and Japan reached an agreement allowing U.S. aerospace firms "to make available a wide range of space equipment and technology to Japanese companies," under the condition that any technology would be used solely for peaceful purposes and could not be re-exported directly or indirectly to third countries. *Business Week*, September 13, 1969, p. 52.

research worker is less than half that spent in advanced Western countries.[14]

SWEDEN

• General Trends

Among the smaller nations of Europe, Sweden's R&D commitment in relation to population ranks very high. R&D expenditures in 1969 totaled about $320 million, or about $40 per capita, roughly the same level on a per capita basis as France and West Germany.

Seeking to make the most of limited resources, Sweden has opted for a selective and specialized approach to R&D, focusing on advancements in electrical equipment and nuclear energy. The nation has established independent capabilities in those areas and it is further advancing its general capability by means of cooperative programs. The country has teamed with the U.K. in development of a fast breeder reactor and is a participant on the governmental level in the work of such international organizations as the European Organization for Nuclear Research (CERN), the International Atomic Energy Agency (IAEA), the European Nuclear Energy Agency (ENEA) and the European Space Research Organization (ESRO).

R&D is approximately 50 percent state-supported and 50 percent industry-supported, with combined public and private investment amounting to about 1.3 percent of the GNP. Industry performs roughly 60-65 percent of the R&D and more than half of the total effort is in the economically-motivated category, the remainder being devoted for the most part to defense and nuclear research.

The establishment in 1962 of the Science Advisory Council, staffed by representatives of industry, universities and research institutes, provided central coordination for the development and evaluation of national research resources and requirements. Although no resolutions or published statements emanate from the Council, it can exert influence on the direction of government science policies.

• Priorities

The atomic energy program continues to be one of the largest of the government-sponsored R&D efforts. By necessity, principal emphasis is on nuclear electric power generation. Estimates indicate a 5 percent per year increase in electricity consumption and even with expansion of hydroelectric power systems, conventional sources are not expected to meet anticipated demands. Nuclear power stations appear to be the most feasible answer to the problem.

Defense-related R&D constitutes about one-fifth of the total effort. Much of the development work for defense systems is contracted to industry, particularly in aircraft, vehicle and electronics programs.

Commitments to space remain relatively small as total funding, including R&D, amounts to only $3-$4 million annually. A newly emerging priority area is environmental protection, to which Sweden has allocated increasingly large sums in the last few years.

• Industrial R&D

Industrial research leaders are the electrical, transport equipment (including aircraft) and chemical industries. Industry performs little basic research and focus is on development, with the single exception of the pharmaceutical industry which, as in other nations, devotes more resources to research than to development.

The all-industry average of R&D outlays as a proportion of total sales amounts to about 1.3 percent (compared with 4 percent in the U.S.), but considerably higher ratios are found in the research-intensive industries. For example, in the electrical industry, where Sweden has developed particular technical competence,[15] the ratio is 8.6 percent, higher than the U.S. ratio of 8 percent in electrical equipment/communications. The high ratio for the Swedish electrical industry stems largely from government support through defense contracts, although even without such support the industry would rank first among Swedish industries.

Although Swedish firms are generally small relative to many others in Europe, several are internationally competitive, largely as a result of technical sophistication and selective specialization.

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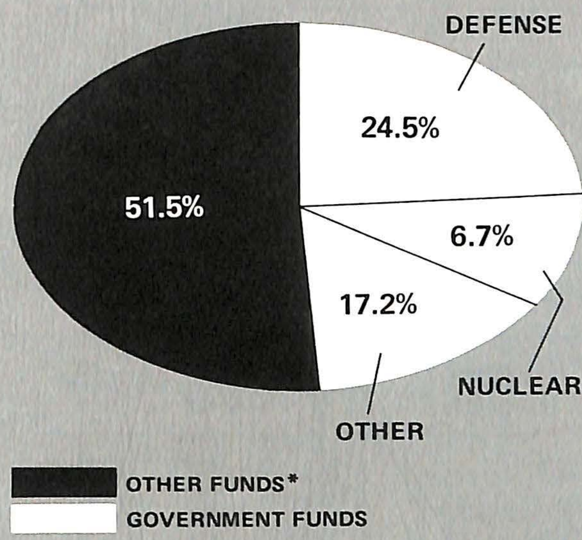
[14] *Science Policy News*, May 1970, pp. 115-116.

[15] Specialized products where Sweden accounts for a high proportionate output include iron powder, carbide tools, separators and telephone exchanges.

GRAPH 6
SWEDEN
SOURCE OF R&D EXPENDITURES
1963-64
(PERCENTAGE SHARE)



**Industry, academic and other non-profit.*

Source: OECD. Gaps in Technology, p. 123.

TABLE 4

SWEDEN
R&D OUTLAYS IN INDUSTRY
1967

Industry	% of Total Sales	% of Industrial R&D
Electrical machinery and electronics	8.6	25
Transport equipment	5.6	23
Chemicals	4.9	3
Non-electrical machinery	N.A.	16

TABLE 5

U.S.S.R.
SCIENCE AND R&D EXPENDITURES
1960-1970

	Soviet expenditure for science:				Official U.S. estimates of Soviet R&D expenditure:	
	All-union Budget expenditure for science	Total Budget expenditure for science (All-union + Republican)	Total science expenditure (Budget + other) excl. cap. invest. for science	Total science expenditure including capital investment for science	Soviet military R&D and space expenditure	Total Soviet R&D and space expenditure
			Billion rubles, current prices		*Billion U.S. $, constant (1966) prices*	
1960	1.9	2.3	3.3	3.9	..	7.8
1961	2.2	2.7	3.8	4.5	..	..
1962	2.5	3.0	4.3	5.2	..	..
1963	3.0	3.5	4.9	5.8	..	..
1964	3.5	4.0	5.4	6.4	..	..
1965	3.7	4.3	6.0	7.1	..	13.9
1966	..	(4.6)	(6.5)	7.7	..	..
1967	..	..	(7.2)	(9.0)	..	..
1968	..	..	(7.9)	..	..	17.7
1969	..	(6.3)	(9.0)	..	14.8	..
1970	..	..	(10.2)	(11.0)	16-17	(21.3)

() = planned or estimated rather than actual expenditure. .. = not available.

Source: SIPRI, "U.S. estimates of Soviet expenditure for military research.", p. 303.

- **Scientific and Technical Manpower**

The number of science and engineering graduates in Sweden compares favorably with other Western countries. From 1960 to 1967, graduates from institutes of technology increased from less than 800 to more than 1100. Sweden has the highest level of education in Europe and the number of qualified scientists and engineers engaged in R&D, as a percentage of total population, exceeded that of France and West Germany.[16]

[16] OECD, *Gaps in Technology*, p. 120.

UNION OF SOVIET SOCIALIST REPUBLICS

- **General Trends**

The Soviet R&D picture is hazy, but a few facts are clearly discernible:

- Since 1960, the Soviets have pursued an exceptionally energetic research and development program which in terms of overall percentage increase has been greater than that of the U.S.
- By contrast with the near-stagnant growth rate of U.S. research and development, Soviet growth is continuing at a high level.

TABLE 6

U.S.S.R.
TRENDS IN SCIENCE EXPENDITURES AND R&D

	Average annual percent increase		Average annual percent increase
A. Official U.S. estimates of total Soviet R&D and space expenditure (at constant prices):		A. Total Soviet science expenditure, including capital investment for science (at current prices):	
1960-70	10.6	1960-70	10.9
1960-65	12.3	1960-65	12.7
1965-70	8.9	1965-70	9.1
B. Official U.S. estimates of Soviet military R&D and space expenditure (at constant prices):		B. Soviet science expenditure, excluding capital investment for science (at current prices):	
1960-70	"about 13"	1960-70	12.0
1970 statement: "this vigorous rate of growth" —about 13—"appears to be continuing."		1968-70	13.6
1969 statement: "about 10 percent a year . . . during the last few years."		1964-68	10.0

Source: *Congressional Record*, July 31, 1971, p. E8677.

• The Soviet level of spending has not yet reached U.S. proportions, but where U.S. expenditures are spread across a broad spectrum, the U.S.S.R. effort is heavily concentrated in defense, nuclear and space research.

Estimates of U.S.S.R. total expenditures for R&D are in the same general range as those for the U.S. One credible report projects Soviet R&D funding for 1971 at approximately $20 billion versus an estimated $28 billion for the U.S. The respective levels in 1960 were $8 billion and $14 billion.[17] Thus, the Soviet effort has increased two-and-one-half fold in the 12-year period while the U.S. outlay has doubled. But only a small percentage of Soviet R&D—perhaps 20 percent—is related to civilian requirements, which indicates a military/space endeavor substantially stronger in the U.S.S.R. than in the U.S.

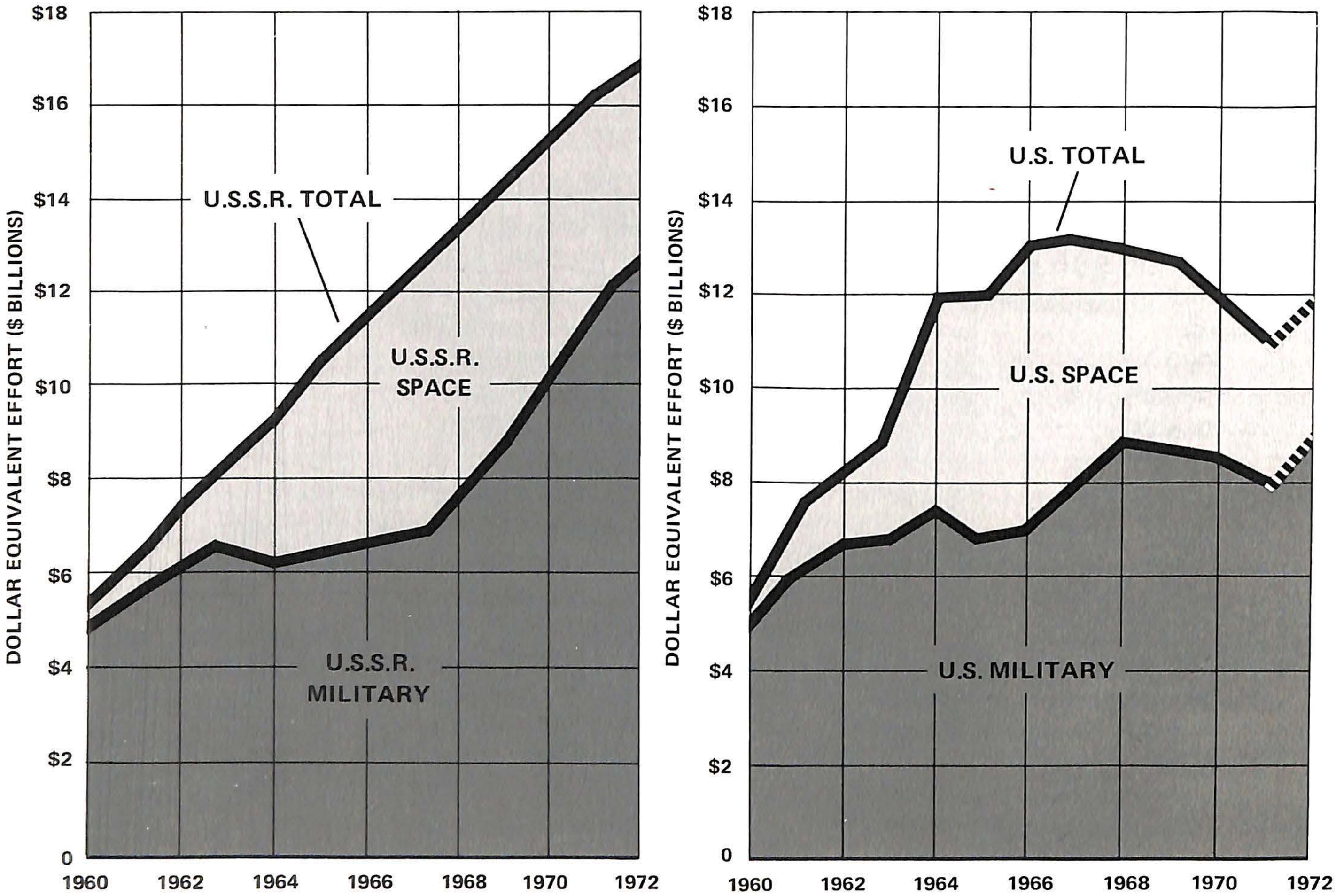
A detailed assessment of the comparative U.S./U.S.S.R. research and development posture becomes clouded by a number of factors, principally the question of whether expenditures constitute a valid measure of relative capability. This question arises because of the differences between a competitive economy and a centrally planned economy, the

[17] *Aviation Week & Space Technology*, April 12, 1971, p. 23.

GRAPH 7

U.S. AND U.S.S.R. TECHNOLOGICAL EFFORTS IN MILITARY AND SPACE

1960-1972



Source: *Air Force Magazine, August 1971, p. 30.*

difficulty of accurately converting rubles to dollar equivalent, and the problem of isolating and identifying Soviet expenditures. Other factors which complicate R&D comparison are the distinct differences between the two nations in management, facilities, equipment, performance and manpower.[18]

The most detailed information on Soviet funding is contained in a report by the U.S. Department of Defense. Accepting the qualification that expenditures do not constitute a *precise* measure of capability, this report at least serves as a base point for an assessment of the general magnitude, growth and direction of Soviet R&D.[19]

The major point of the DoD report is that Soviet spending for military R&D outpaces that of the U.S. by some $3 billion annually; the current levels cited

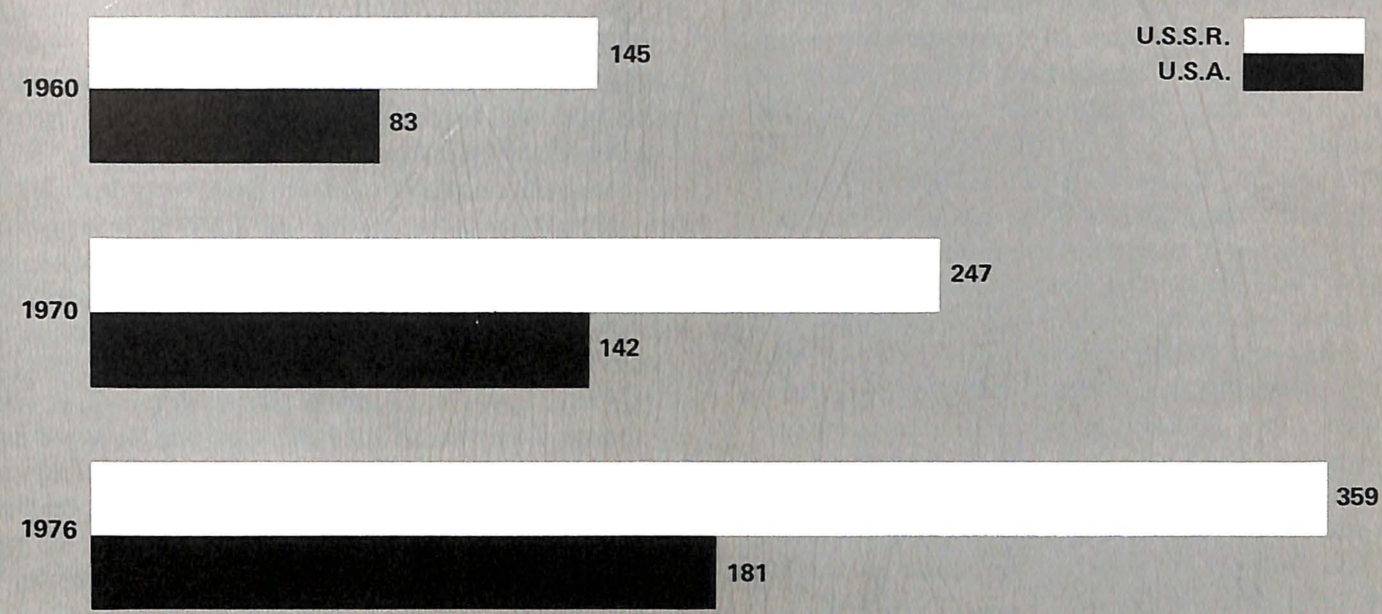
[18] Elmer B. Staats, Comptroller General of the United States, "Comparison of Military Research and Development Expenditures of the United States and the Soviet Union," *Congressional Record*, July 31, 1971, p. E8608.

[19] The GAO study concluded that although "the DoD methodology with its limited data base may be useful in indicating trends and the apparent magnitude of the Soviet Union military R&D threat, we have reservations as to its usefulness in quantifying relative efforts or spending gaps between the countries," Elmer B. Staats, Comptroller General of the United States, "Soviet Military Research and Development," *Congressional Record*, July 31, 1971, p. E8610.

GRAPH 8

A COMPARISON OF U.S.S.R. AND U.S. GRADUATES IN ENGINEERING AND THE NATURAL SCIENCES

(Thousands)

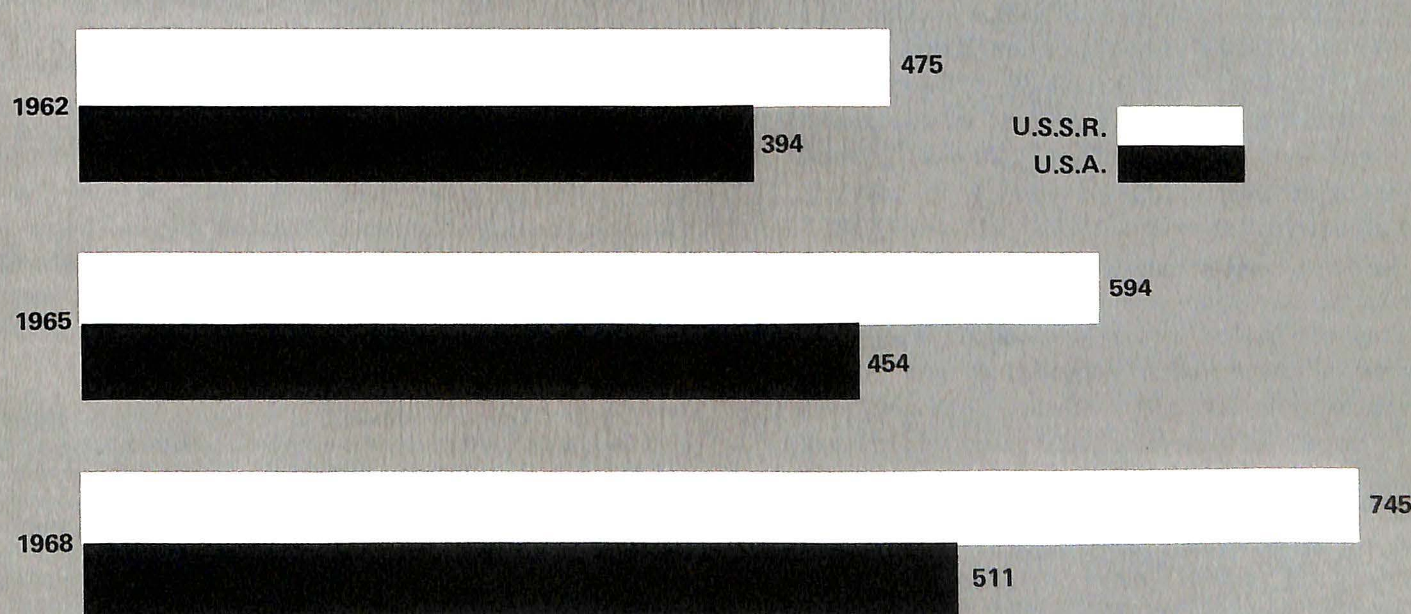


Source: John S. Foster, Jr., "Excerpts Concerning Soviet Military," Congressional Record, August 4, 1971, p. E8746.

GRAPH 9

A COMPARISON OF U.S.S.R. AND U.S. SCIENTISTS AND ENGINEERS IN R&D

(Thousands)



Source: Michael Boretsky, The Technological Base of Soviet Military Power, Washington 1970, p. 224.

are $10 billion for the U.S.S.R. and $7 billion for the U.S. A recent General Accounting Office study interjects a modification; the U.S. figure, it states, should be higher by at least $1 billion, to account for defense-related costs not included in the annual RDT&E (Research, Development, Test & Evaluation) budget. Even with the modification, a very substantial gap exists in favor of the U.S.S.R.

Estimates of the average annual growth rate in Soviet R&D range from 9 to about 13 percent, depending upon how the various sectors of the overall program are grouped. Even the 9 percent figure considerably exceeds the U.S. growth rates for both total R&D and for the government-funded portion.

DoD predicted that, should these general trends continue, the Soviet Union could achieve technological superiority by the end of this decade and that the loss of U.S. leadership "would require enormous expenditures over many years"; and that the U.S. "margin of security" would be jeopardized in the 1975-1985 time span.

- **Priorities**

The level of effort in military and space R&D was roughly the same for the U.S. and the U.S.S.R. in the years 1960-1968.[20] A DoD comparison of the relative military and space *outputs* during those years indicates that both countries had developed about the same number of systems; that the U.S. had a two to three year technological lead in military systems; and that the U.S. had advanced its technological edge in space programs.[21]

According to DoD, Soviet military projects, since 1968, have received top priority. Growth in R&D support has been applied almost entirely to defense work while space R&D remained at an "essentially constant level." Even without extra growth, however, Soviet space funding is estimated at $2 billion to $5 billion per year more than the U.S.

Another source allows that the DoD estimate of Soviet space R&D errs on the conservative side, in that the $5 billion annual expenditure covers only the "civil" area of space exploration and that overall space funding, including military programs, probably approached $7 billion in 1968. Moreover, the military portion of the space effort has increased over the past two years by about 10 percent.[22] Accepting this estimate, which puts total Soviet military/civil space funding at about $7.5 billion a year, it is necessary to add U.S. military space funding ($1.5 billion in FY 1972) to civil expenditures to come up with a comparable figure of $4.5 billion[23] total U.S. space spending, or a $3 billion gap in favor of the U.S.S.R.

The Soviets appear to be planning further acceleration of space research in the 1971-1975 time period, as part of a projected general expansion of science and technology. Soviet leaders are emphasizing space exploration as an instrument for increasing rates of scientific and technical progress.[24]

Military, space and nuclear applications will probably continue to be priority areas of the Soviet R&D program, although their support, as a percentage of the total, may dip slightly below the indicated 80 percent. There appears to be some reordering of national priorities with increased industrial R&D in fields other than military and space technology.[25]

- **Industrial R&D**

Transfer of innovation to civil use is facilitated in the U.S., where industry performs about 70 percent of all R&D; but the Soviet Union does not enjoy this ease of technology transfer. A 1969 OECD study of U.S.S.R. science policy summed up the matter, pointing out that the "spin-off to civilian industry in the Soviet Union is considered to have been small because all invention and innovation of military application, while in principle available for civilian use, is surrounded by a somewhat impenetrable security blanket. Consequently, the strain produced by this substantial R&D effort has been much greater for the

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[20] *Air Force Magazine*, August 1971, p. 30.

[21] "Soviet Military Research and Development," *Congressional Record*, July 31, 1971, p. E8611, and "FY 1972 Defense RDT&E Program: Research and Development in U.S. Defense Posture," *Defense Industry Bulletin*, Summer 1971, p. 2.

[22] "DoD Downgrading Soviet Space Efforts by Default," *Space Business Daily*, August 11, 1971, pp. 190-192.

[23] "Soviets To Accelerate Science/Technology 1971-1975," *Space Daily*, February 22, 1971.

[24] *Aerospace Facts and Figures*, 1971/72.

[25] ". . . areas of science and technology to be expanded include theoretical and applied mathematics and cybernetics, nuclear physics, solid-state and semiconductor physics, quantum electronics, low temperature physics (for creating new materials and materials processing, improvement of energy conversion, mastering the use of fast-neutron reactors, solution of thermonuclear fusion problems, and nuclear and radiation processes), electronics, radio-engineering and computing techniques." "Soviets to Accelerate Science/Technology 1971-1975," *Space Daily*, February 22, 1971, pp. 230-231.

Soviet Union economy than for the richer United States economy."[26] For this and other reasons, several studies conclude that Soviet civil-use technology lags behind that of the U.S. by as much as 25 years in some areas and by perhaps 5 to 7 years in others.[27]

The scientific and technological level of the civilian sector is a matter of some concern to the future of the Soviet economy. A major drawback in the relative position of industrial R&D in the Soviet Union is the lack of computer capability, which is more pronounced in general civilian usage than in the higher priority space and military applications.

• Scientific and Technical Manpower

Scientific and technical education has long been a matter of prime attention in the Soviet Union where the number of higher education graduates in the fields of engineering and the natural sciences sharply increased during the 1960's.

According to a U.S. Department of Commerce study, Soviet R&D manpower in 1962-1968 experienced an average annual increase approaching 8 percent which compares with less than 4 percent per year for the U.S. The study shows that in 1968, the U.S.S.R. employed 745,000 qualified scientists and engineers in research and development, compared to 511,000 for the U.S. The trend is clearly toward a wider gap in favor of the U.S.S.R.

UNITED KINGDOM

• General Trends

Since the early sixties, the U.K. has pursued a financially adequate and technically sound R&D program, but the resulting economic gain has fallen short of expectations. Analysis points to two reasons for the shortcoming: failure to establish a consistent national strategy, and ineffective commercial exploitation of technological advances. Britain, says one observer, constitutes "a classic case of failure to translate high scientific achievement into rapid innovation, development and marketing. Its weakness, like America's success, has been in management skills and in the absence of a market of sufficient scale in which to apply its knowledge."[28]

R&D expenditures increased from about $1.8 billion in 1961-1962 to about $2.7 billion in 1967-1968; as a percentage of GNP, research and development funding rose only slightly during that period, to 2.7 percent. Over the last decade, the proportion of R&D supported by the government has declined gradually to the 50 percent level.

British expenditures for R&D in the mid-sixties represented by far the largest effort in Western Europe. In the years since, however, a relatively slow U.K. growth rate, coupled with the R&D upswing in France and West Germany, have brought the three nations to roughly the same spending level.

• Priorities

Over the last two decades or more, U.K.'s attempts to develop areas of special competence have met with repeated setbacks. In the computer field, for instance, British technology was more advanced than that of the U.S. in the late forties, but it was the U.S. that took over market domination, because of foresight in the variety of potential applications, strong financial backing and aggressive marketing techniques. Among the European nations, Britain was first to undertake development of nuclear systems in both defense and civil applications. The U.K. established a sound technology base, producing the world's first nuclear power station and the first fast breeder reactor. But again, U.S. production and marketing capability captured the commercial benefit. In the late fifties, the U.K. initiated a comprehensive defense program, but lack of selectivity, insufficient funds and a rash of related problems brought on a series of cancellations.

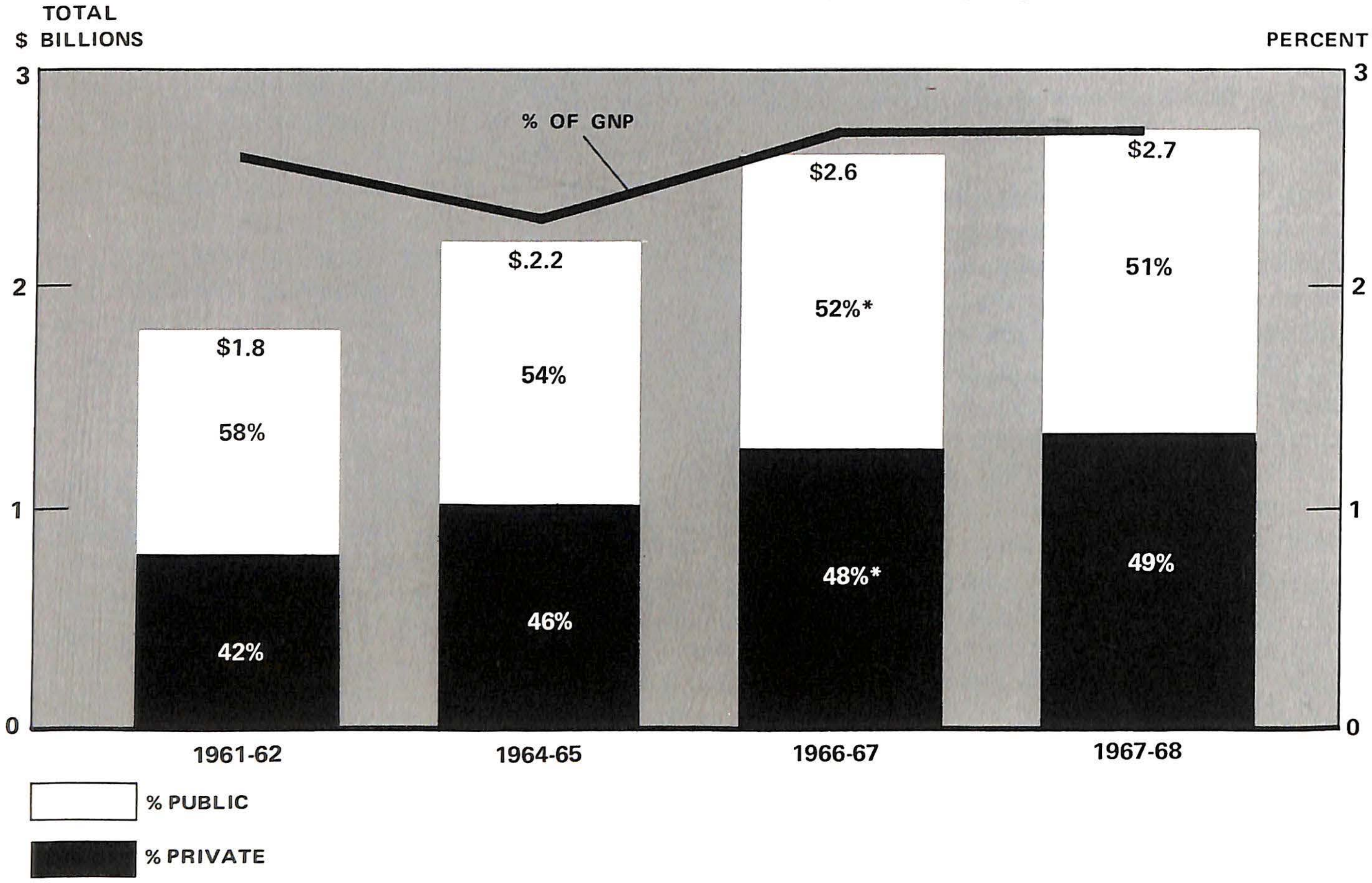
The relatively small market potential in a country the size of the U.K. necessarily restricts R&D efforts of a purely national character. This consideration, along with management and organizational problems

[26] GAO Staff Study, Congressional Record, July 31, 1971, p. E8612.

[27] U.S. Congress, Joint Economic Committee, "New Directions in the Soviet Economy," testimony by Michael Boretsky, 1966, Part II A, p. 149. Richard W. Judy, "The Case of Computer Technology," *East-West Trade and the Technology Gap*, edited by Stanislaw Wasowski, New York, 1970. Gertrude Schroeder, "Soviet Technology: System vs. Progress," *Problems of Communism*, September-October 1970.

[28] Christopher Layton. *European Advanced Technology: A Programme for Integration.* London, 1969, p. 60.

GRAPH 10
UNITED KINGDOM
RESEARCH AND DEVELOPMENT EXPENDITURES



**AIA Estimates*

Source: British Information Services, New York; "Statistics of Science and Technology 1970," Science Policy News, January 1971, p. 45, and "The Overall Level and Structure of R&D Efforts in OECD Member Countries," OECD, Paris 1967, pp. 14 and 57.

and a continuing decline in defense funding, has forced the U.K. to turn to collaborative efforts, particularly in aviation where the most notable example is the joint venture with France on the Concorde. The U.K. is also engaged in international cooperative projects involving several advanced engines, military aircraft, helicopters and spacecraft.

• Industrial R&D

Private industry, public corporations and research associations perform about 70 percent of all R&D in the U.K. A breakdown of the focus of effort shows that some 75 percent of the work is development, about 21 percent applied research and 4 percent basic research which is similar to the pattern in the U.S. About two-thirds of the total industrial R&D is concentrated in electrical products, aerospace and chemicals.[29] In 1966-1967, industrial research programs amounted to about $1.7 billion.

Where government is playing an increasingly larger role in supporting industrial R&D in France and West Germany, the reverse is true in the U.K. The percentage of R&D performed by industry has increased since 1961-1962, as has the percentage of company funding, while government financing has declined steadily to about 30 percent. Most of the decline in government support of industrial R&D has resulted from sharp reductions in defense spending; but the greatest impact of the decline has been felt in the aircraft industry. In 1961-1962, defense-related R&D accounted for about 90 percent of all government-supported industrial R&D; by 1966-1967, the percentage had dropped to 75.

In both absolute terms and as a percentage of GNP, research and development by the British industrial sector approximates that of France and West Germany. Those nations, over the last decade, however, have increased industrial R&D activity at a more rapid pace than the U.K.

[29] See Table 1, Industrial Research in High-Technology Industries, for a comparison of industrial research in France, Germany, Japan, the United Kingdom and the United States.

UNITED STATES

• General Trends

In contrast to the general increased emphasis among major foreign nations, U.S. research and development in recent years has declined in terms of growth rate, remaining at a relatively constant level as regards dollar expenditures.

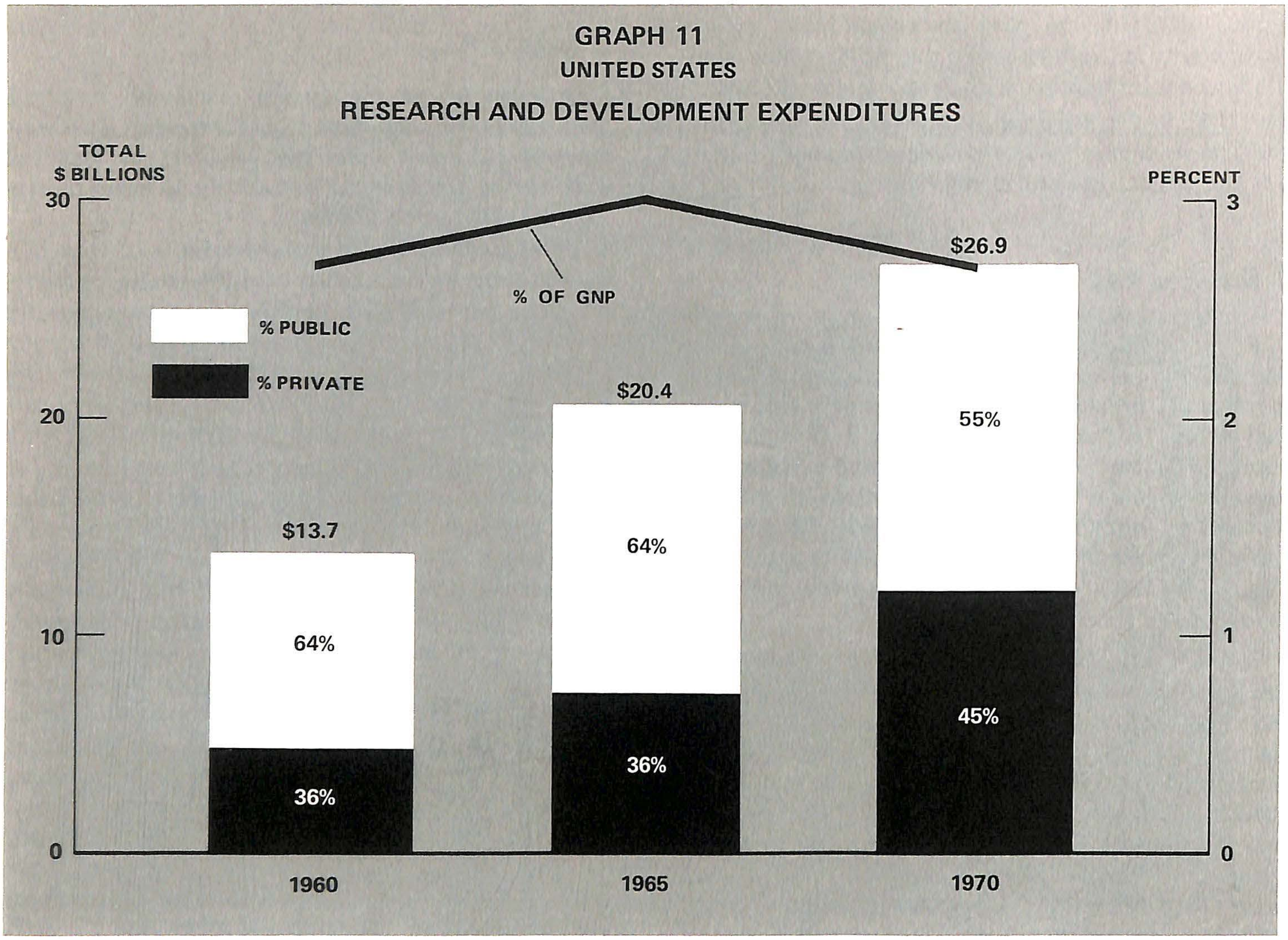
The U.S. experienced explosive R&D activity during the early and middle years of the sixties, but since 1966 the overall R&D growth rate (based on *constant* 1966 dollars) has dropped to less than one percent per year, because steady increases in industry-funded R&D were unable to offset declining government support. The growth rate in non-federal funding, which is primarily from industrial sources, grew consistently at 9-10 percent annually. Federal growth, on the other hand, has declined in terms of actual *current* dollars.

In terms of expenditures, R&D has expanded dramatically since 1960, from $13.7 billion annually to about $27 billion, but those statistics are not indicative of the current trend. While outlays doubled from 1960 to 1968, they have since remained at approximately the 1968 level. A constant financial level is, in effect, a decline in the level of R&D effort, because of the inflation factor and the higher costs associated with increasingly sophisticated technology.

Current trends are more apparent in a comparison of R&D activity with the national economy. From 1961 through 1966, percentage increases in R&D funding outpaced the annual growth rate of GNP. The research effort, as a percentage of GNP, reached a peak of 3 percent in the mid-sixties, then trailed off to about 2.7 percent in 1970.

Reduced federal support has had its primary impact in applied research and development associated with defense and space programs funded by the Department of Defense, NASA and the Atomic Energy Commission. Decreasing support of defense and space research is one of several factors influencing not only the level of federally-funded R&D but also its shifting scope and nature. Other influences include general budget constraints, the reordering of national priorities, a growing apathy toward technological advance, and the lack of long-range scientific and technological objectives.

Because government and industry together account for more than 95 percent of the total U.S. research and development funding, the relative share expended by each exerts a strong influence on the direction of the national research effort.



Government expenditures for R&D more than doubled from 1960 to 1968, increasing from nearly $8 billion in 1960 to over $17 billion in 1968. Since 1968, however, actual expenditures have declined by about one billion dollars. Industry expenditures during the decade more than doubled also, rising from $5 billion to about $11 billion. As a percentage of the total, the federal share reached a high point of 65 percent in 1963-1964, then declined to 55 percent in 1970. The industry trend moved in the opposite direction, from a low of 31 percent in 1963-1964 to 41 percent in 1970. Since industrial R&D focuses upon developmental work, the respective changes in degree of financing have implications in the distribution of funds among basic research, applied research and development.

The trend toward diminishing governmental leadership in R&D has a negative effect on the initiation of high risk/high cost technology programs which cannot be independently financed by industry. This is true not only of defense and space projects but also of domestic programs, where the markets are small, dispersed or underdeveloped. Uncertainty as to the degree of federal support for R&D in defense and space, and the seeming lack of program direction, underline the need for establishing national science policies and priorities.

• Priorities

Until 1965, combined R&D expenditures by DoD, NASA and the AEC accounted for some 90 percent of all federally-financed R&D. In fiscal year 1970, the figure dropped to 82 percent and the downward trend continued in the FY 1971 and 1972 budgets.

In another view of shifting emphasis, defense R&D in 1960 amounted to 50 percent of all federally-funded research and development. By 1972, it is projected to drop to 34 percent. Over the same period, human resources R&D will have increased from 27 percent to 42 percent.

In short, although defense and space remain among the priority areas, they are being cut back in favor of such domestic programs as health, housing and education. As in Europe and Japan, urban transportation and energy requirements are areas which appear likely to receive priority attention in the future.

• Industrial R&D

Historically, industrial research and development differs from that sponsored by the Federal Government in that a considerably larger portion of the total is devoted to development (about 80 percent, compared with the federal 65 percent) and a lesser effort goes into basic research (about 4 percent compared with 11 to 14 percent.) The applied research share is approximately the same in either case.

U.S. industry finances slightly less than half of the national R&D activity, but it performs more than 70 percent. Estimates indicate that R&D financed by industry will increase 6 to 10 percent per year through 1974, while an annual increase of only 1.2 percent is projected for federal financing of industrial R&D.

Five major industries—aerospace, electrical equipment/communications, motor vehicles, chemicals and allied products, and machinery—account for about 80 percent of all industrial R&D. In terms of performance of R&D, the leaders are the aerospace industry and the electrical equipment/communications industry, who together accomplish about 56 percent. These industries have well-above-average ratios of R&D expenditures to net sales. In 1968, the all-industry average was 4 percent, aerospace more than 19 percent, electrical equipment/communications about 8 percent. Aerospace, however, has a slower growth rate and a recent survey by the McGraw-Hill Department of Economics suggests that the aerospace industry may relinquish its leadership position to electrical equipment/communications by 1974. Despite that possibility, the aerospace industry continues to be highly innovative; sales of new products (items not being manufactured in 1970) are expected to account for 31 percent of total 1974 sales, compared with an all-industry average of 16 percent.

• Scientific and Technical Manpower

Changes in federal support of various activities have had a feedback effect on the desirability of pursuing certain careers. The feedback was particularly evident as regards scientific and engineering careers in the post-Sputnik era. Today, a new directional shift is emerging, fed by wide national interest in environmental and social problems.

The number of scientists and engineers employed in research and development activity increased significantly from the mid-fifties to the mid-sixties, rising from roughly 240,000 in 1954 to almost 500,000 in 1965. Expansion continued thereafter, but at a slower rate, to some 550,000 in 1969. Similarly, the number of natural science and engineering graduates climbed rapidly from 1955 through 1960, then began a gradual leveling-off. There has been a lack of consideration of the long-term balance among the various fields of science. This implies future imbalances, due to the leadtime required in establishing capabilities and in providing incentives to pursue certain disciplines. The maintenance of a skilled scientific manpower base demands further provisions for the retraining and transfer of existing personnel resources. The current lack of mobility within the aerospace industry and constraints on the transferability of capabilities to other industries have become critical issues.

CHAPTER 3

Challenge to the U.S. Aerospace Industry

While the U.S. is experiencing a marked slowdown, aerospace technological activity is on the rise among other major nations, a contrast which signals the emergence of new trends in aerospace trade and technology and the potential erosion of the dominant position long held by the U.S. industry. This statement is not to suggest an immediate deterioration of American aerospace supremacy, but rather a gradual encroachment by other nations into the traditional markets of an already depressed U.S. industry. Prime challengers appear to be the Western European nations acting in concert with commercial aviation as the focal area of challenge.

BACKGROUND TO THE EUROPEAN CHALLENGE

European aerospace activity, characterized by increasing accent during the last decade on R&D and coupled with growth of international cooperation, has laid a foundation from which the European nations could mount a strong challenge to future U.S. commercial sales, particularly in developing markets such as Asia, Africa and South America.

Current European investment in aerospace R&D amounts to less than 20 percent of comparable U.S. investment, but the difference is narrower in the commercial sector. Neither funding nor technological shortcomings are considered the key factors in the gap that exists between the U.S. and Western Europe; rather it is disparities in production and marketing techniques. Planned attention to these areas, together with the advantages of cooperative venturing, can provide a substantial boost to the competitive strength of Western Europe. Advantages of cooperative programming are outlined in a statement by France's Union Syndicale des Industries Aeronautiques et Spatiales:

"Cooperation makes it possible to undertake programs that would be beyond the means of a single country. Financing is broken down to dimensions that can be digested by each partner. As these programs are also subject to inter-governmental agreements, the danger of breaking-off contracts is eliminated. In this way, existing facilities for research, development, testing and production, the real capital of the partners, can be orchestrated and used to the greatest possible efficiency. A further significant advantage is that production batches are larger, as programs are designed to meet the requirements of all the countries involved, and this means that unit prices are finally lower. . . . With increasing experience to draw upon, and by constantly striving to improve ways and means, cooperation should make it possible for the aerospace industries of Europe to expand internal markets, develop activities, and consolidate their position on the international market."[30]

A recent paper by the Transportation Products Division of the U.S. Department of Commerce adds that "integration of requirements, resulting in common specifications for aerospace equipment, can provide production runs competitive with the scale of the U.S. aerospace industry."[31]

Total aerospace employment in Western Europe at roughly 500,000 is about half the U.S. figure; however, sales in 1970 at only $3.4 billion were only 15 percent of the $25 billion recorded by the U.S. producers. Total European aerospace sales, however, are comparable to U.S. aerospace exports, which constitute 14 percent of the total U.S. aerospace sales.

RESEARCH AND DEVELOPMENT

Due to the long leadtime required to bring a high-technology development to fruition, current R&D decisions have a decided impact upon the future position of a nation's aerospace industry. No other industry places such heavy reliance on R&D for continued growth and maintenance of competitive posture. The necessity for R&D to "feed" the product line is illustrated by the estimate previously mentioned that 31 percent of all U.S. aerospace sales in 1974 will derive from items not in production status in 1970.

The high technological input required of aerospace programs results in exceptional cost levels and therefore requires a unique degree of support, public and private, and high-technology goals demand consistent government funding. In the U.S., the U.K., and the European Economic Community (EEC), the respective governments provided 85 to 90 percent of the total funding in the early and mid-sixties, largely due to heavy investments in military programs, and for space programs, in the case of the U.S. The disparity in total aerospace funding was great, as is shown in the following table listing overall R&D expenditures and the relationship of public and private funding.

Although overall U.S. spending was vastly greater than that of the Western European nations, the EEC countries held a substantial edge in rate of increase from 1960 to 1967, largely because of the significant growth of the French and West German aerospace industries; the EEC gain amounted to 383 percent, compared with 189 percent in the U.S. As a percentage of GNP, EEC funds for aerospace R&D rose from 0.1 percent to about 0.3 percent; the U.K. remained level at about 0.6 percent and the U.S. increased from 0.7 to 1.3 percent.[32]

As regards R&D funding for civil aircraft programs during 1960-1967, U.S. total investment was again far greater than the combined investment of the Western European nations, but here the gap is narrower than it is in terms of overall R&D. In addition to relative total investment, the table below shows that European firms rely to a considerably larger extent on governmental support of civil aviation projects.

Due to the growing emphasis in the European Community, particularly in France and West Germany, on the development of a competitive aerospace industry, the governments in these countries are continuing to increase public funding for civil aircraft programs. By contrast, U.S. industry provides more than 90 percent of the support for projects of this type. Industry-financed aerospace R&D is still on the uptrend in the U.S. Prior to 1967, average annual expenditures for the 7 years of the decade were less than $500 million; since then the annual figure has exceeded $1 billion every year and industry-funded R&D for the years 1967-1969 more than equaled the total for the preceding 7 years.

A comparison of average annual increases in total aerospace R&D against those of the industry-funded portion shows that only in the U.S. did industrial spending gain at a more rapid rate than total aerospace R&D.

A breakdown of funding allocations among military, space and civil programs shows, as might be expected, that space research represented the greatest area of disparity in the 1960-1967 period. During that span, the U.S. was funding three manned spacecraft projects and was conducting an across-the-board unmanned space exploration program involving

[30] L'Industrie Aeronautique et Spatiale Francaise, Union Syndicale des Industries Aeronautiques et Spatiales, Paris, 1971.

[31] Cohen, Richard E., "Implications of Expanded Common Market to Future of U.S. Aerospace Industry," U.S. Department of Commerce, June 1, 1970.

[32] SORIS, Vol. 1, pp. 24-24b.

TABLE 7

TOTAL R&D EXPENDITURE OF THE AEROSPACE INDUSTRY
1960-1967

Country	Total ($ Millions)	Public Funds ($ Millions)	Private Funds ($ Millions)
EEC Countries	2,708	2,336	372
United Kingdom	3,301	2,791	510
United States	39,633	35,339	4,294

Source: SORIS. "The Aeronautical and Space Industries of the Community Compared with those of the United Kingdom and the United States." Vol. 1, p. 42.

TABLE 8

R&D FUNDS FOR CIVIL AIRCRAFT PROGRAMS
1960-1967

Country	Total Investment ($ Millions)	Public Funding ($ Millions)	Private Investment ($ Millions)
EEC Countries	820	477	343
United Kingdom	738	428	310
United States	4,629	335	4,294

Source: SORIS, Vol. 1, p. 27.

scientific/applied satellites and lunar/planetary probes; the Western European nations, on the other hand, confined their efforts to a few unmanned earth satellites. Where space accounted for almost half the total R&D in the U.S., the respective EEC and U.K. allocations amounted to about 11 and 5 percent.

Assuming an R&D growth rate of 3.4 percent per year for the U.K., 15 percent for the EEC and 6 percent for the U.S., which correspond to recent growth rates in the respective industries, the EEC would significantly narrow the gap by 1980 to a ratio of about 1:4. The following page presents the estimates of SORIS.

The projected increase in EEC aerospace R&D and the leveling trend in the U.K. and U.S. aerospace industries, along with Europe's emphasis upon civil and military programs, are indeed indicative of a changing trend in the world aerospace market. The next section highlights some of the major aspects of future market potential.

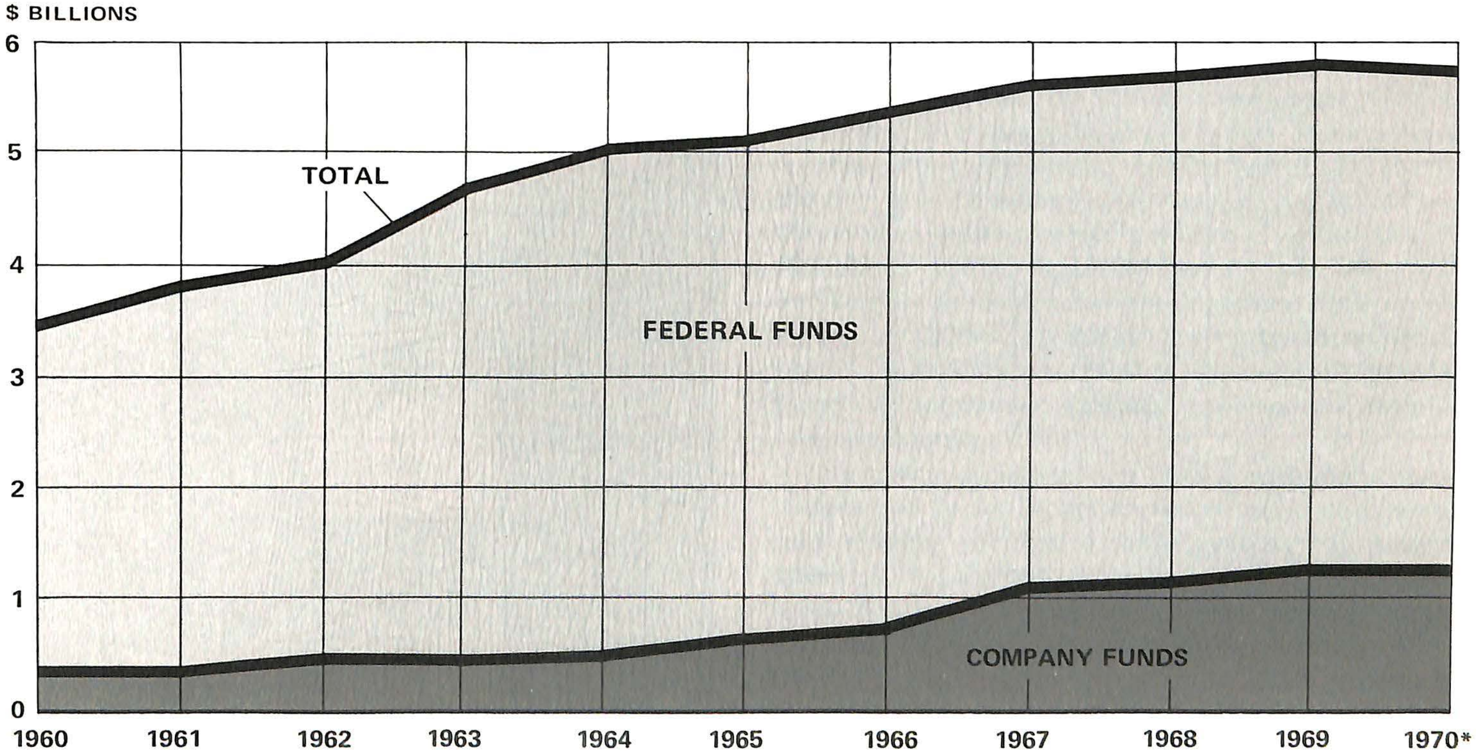
CIVIL MARKET POTENTIAL

The world market for airline transports is estimated to be at least $150 billion in the 1970-1985 time frame and at $200 billion or more by 1990. It is in this area of tremendous potential that European industry is most directly challenging traditional American dominance and there is concern in U.S. aerospace circles that the challenge is a serious one; even relatively minor inroads by the Europeans would constitute a severe blow to a U.S. industry which has

GRAPH 12

U.S. AEROSPACE R&D

1960-1969



*AIA.

Source: AIA. Aerospace Facts and Figures, 1971/72, p. 69. Note slight difference in AIA and SORIS R&D expenditures.

TABLE 9

AVERAGE ANNUAL INCREASE IN R&D EXPENDITURE
1960-1967
(Based on Constant 1967 Prices)

Country	Percent Total Expenditure On Aerospace R&D	Percent R&D Expenditure Of The Aerospace Industry
EEC Countries	20.6	16.5
United Kingdom	3.7	3.4
United States	14.3	15.6

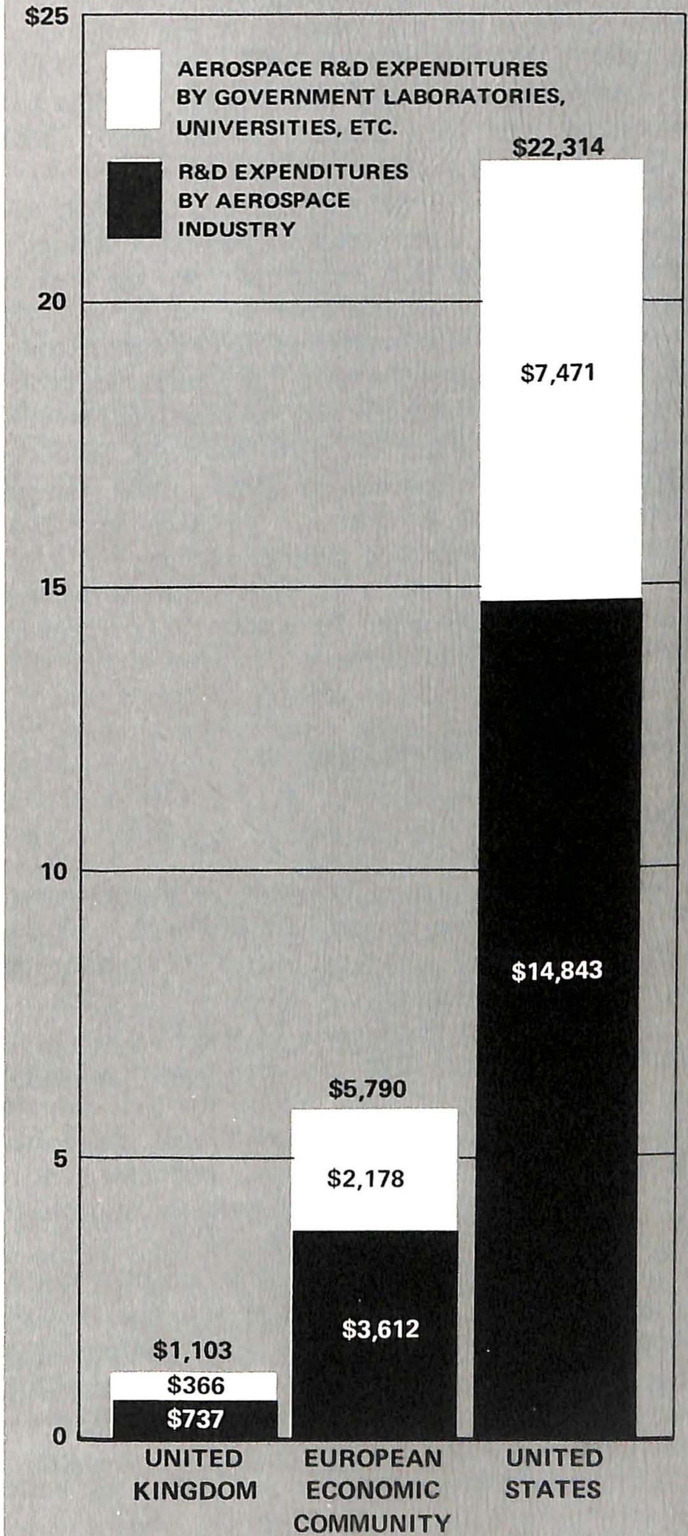
Source: SORIS, Vol. 1, p. 95.

TABLE 10

R&D IN THE AEROSPACE INDUSTRY BY PROGRAMS
1960-1967

Country	Total		Military		Space		Civil	
	($ Millions)	(%)	($ Millions)	(%)	($ Millions)	(%)	($ Millions)	(%)
EEC Countries	2,708	100.0	1,586	58.5	302	11.1	820	30.3
United Kingdom	3,301	100.0	2,186	66.2	177	5.4	938	28.4
United States	39,633	100.0	15,271	38.5	19,733	49.8	4,629	11.7

Source: SORIS. Vol. 1, p. 41.



Source: SORIS, Vol. 1, p. 96.

experienced crushing reverses in recent years. There are indications that the inroads may be more than minor. One example is the situation brought about by American abdication of SST development. It had been estimated that the American SST would produce $13 billion in export sales during 1975-1990, aside from domestic sales. In the absence of an SST, not only are the export sales lost but it is further estimated that U.S. carriers will spend $5.6 billion to buy the French/British SST. U.S. purchases of the Concorde would be reduced to only $1.1 billion if the American SST was to be available later. Thus, the trade balance swing on that single project is a very substantial $17.5 billion.

Currently, the U.S. supplies about 80 percent of the Free World market for civil aircraft, while Western Europe combined accounts for only 16 percent. A major factor in this dominant position is the vastly greater U.S. domestic market, which is a basic foundation for long production runs, and hence lower unit costs. Other factors include aggressive marketing techniques and exceptional technological competence, which embraces such considerations as a high degree of product reliability and the ability to design aircraft of maximum profitability in a broad range of aircraft types.

The attitudes and policies, however, of European nations, underlined by strong government financial assistance to industry in civil aviation developments, is changing the pattern. Intensified R&D has increased the European technological capability and cooperative ventures offer a potential solution to the traditional problem of inadequate market: "The European countries, working together, now constitute a market that approches the American market in size. It can therefore provide the large production runs which American industry has claimed as its own unique advantage."[33]

International cooperation on the part of European nations has an additional impact since developmental cost sharing permits a wider variety of aircraft offerings. It is Europe rather than the U.S. which now holds the lead in types of aircraft available to the market. The most dramatic example is the supersonic transport, where France and the U.K. have an airplane in advanced development while the U.S. has abdicated the market. In addition, states one observer, U.S. dominance "is being nibbled away at the lower end of the transport spectrum. There only

[33] *Aerospace Daily*, May 25, 1971.

Europe is developing the lower-medium and short-haul transports incorporating the new technology that will make current equipment obsolete and uneconomic. The A-300B twin-engine Airbus, the Mercure, the Fokker F-28 and VFW-614 are all aimed at segments of the transport market where there are currently no American competitors. In the twin-jet executive aircraft field the European preponderance is even heavier. Nor is there a single U.S. STOL aircraft competing with the British Skyvan and Islander, the Israeli Arava or the Dornier models."[34]

The challenge to American dominance is also spreading to "sectors of the industry where in the past the Europeans had little sales impact beyond their limited domestic needs or in specific portions of world export."[35] Examples include the helicopter, civil aircraft engine and aviation electronics fields.

These concentrations of effort do not foreshadow an abrupt reversal of U.S./Europe positions in international aerospace sales, but collectively they suggest the possibility of some changes in the relative ratios and respective competitive postures. Said William M. Allen, chairman of the Boeing Company: "I believe that any remaining claim to this national advantage (technology, production and management), if it still exists, is likely to be shortlived."[36]

A necessary first step toward a successful European challenge is solidification of the European market. The member states of the EEC (Belgium, Federal Republic of Germany, France, Italy, Luxembourg and The Netherlands) meet only 15 percent of their aeronautical needs, while the U.K. and the U.S. hold about 72 percent and 97.9 percent, respectively, of their national requirements. The EEC's aerospace industry supplies only 3.8 percent of the equipment in use in the Western world, against an EEC market that represents more than 10 percent of the world market.[37] EEC officials are taking steps to solidify their market. A major forthcoming boost to the EEC's position in that respect is the impending inclusion in the Common Market community of the U.K., which will not only substantially broaden the market but also make available an additional source of facilities and financing.

Given a solid internal market, the European nations could then attack areas of particular interest: penetration of the U.S. market and the developing markets of Asia and Latin America. European firms already export a relatively large percentage of their products, including civil and military aerospace products. For example, French exports accounted for 36 percent of total sales in 1970 and U.K. exports amounted to 44 percent in 1969; these figures compare with 14 percent for the U.S. in 1970. However, U.S. aerospace exports represent a large share of all non-governmental sales by the aerospace industry, having increased from about 50 percent in 1968 to 74 percent in 1970.

• European Policies and Programs

France

A major aim of France's current five-year financial plan (1971-1975) is to speed transformation of the nation's aerospace industry into a self-supporting segment of the economy.

During the last three years of the fifth financial plan, covering 1966-1970, the government provided an annual average of $180 million for civil aircraft R&D, most of which the Anglo-French Concorde claimed. Substantial amounts were also allocated to the co-op A-300B Airbus and Mercure short-haul transport projects.

In the sixth plan now in effect, civil aviation spending is expected to increase to an annual level of about $210-$220 million. This plan contemplates that civil programs will account for 55 percent of the aerospace industry's total business by 1975, compared with 75 percent military in 1968.

The French government has established six basic

[34] *Aviation Week & Space Technology*, May 31, 1971, p. 21.

[35] *Ibid*, p. 57.

[36] The following official attitudes represent current thinking in the European aerospace industry. For example, Forster-Steinberg, corporate director of international operations for Germany's Messerschmidt-Balkan-Blohm complex, stated "Europe is technically a developed area. So why should this area with a fairly big gross national product not produce the same goods—perhaps in a more specialized way. This doesn't mean that America isn't going to sell a lot of aerospace programs during the years we are going to work here. But we hope also with our industry to sell you a few good programs."
Aerospace Daily, May 18, 1971.
Diepen, representing Association Internationale des Constructeurs de Materiel Aerospatiale (AICMA) "Put it the other way around. If Europe cannot develop its own aircraft industry or continue its industry, that could be the beginning of becoming an under-developed country and it would not be a customer of the U.S. any more. That's a long-term view, but there's something in it."
Aerospace Daily, April 9, 1971.

[37] *Aerospace Daily*, April 7, 1971.

TABLE 11

U. S. AEROSPACE SALES AND EXPORTS

	1968	1969	1970
Total Sales ($ Billions)	29.0	26.1	24.8
Total Exports ($ Billions)	3.0	3.1	3.4
Exports as a Percent of Total Sales (%)	10	12	14
Non-Government Sales ($ Billions)	5.9	4.3	4.6
Exports as a Percent of Non-Government Sales (%)	51	72	74

goals for achievement in the years of the sixth plan:[38] (1) continuation of existing civil programs, including developmental completion of the Concorde, Airbus and Mercure and the launching of production and marketing efforts; (2) development of advanced versions of the civil aircraft designs; (3) development initiation of a new 22,000 to 26,000 pound thrust civil aircraft engine; (4) expansion of the aircraft equipment and aviation electronics segments of the industry; (5) plan programs for the short-term future in such areas as V/STOL aircraft; and (6) increase the civil aviation R&D effort to expand the technology base for the 1980's.

United Kingdom

Its resources stretched by heavy spending on the Concorde and the RB.211 advanced technology engine, the U.K. is not currently in a position to expand its aerospace effort. Other than the Concorde, the industry is without a major airframe project, and, according to an industry official, "there is not a single significant airframe project in sight, supported by government funds, for some years to come."[39]

[38] *Aviation Week & Space Technology*, May 31, 1971.

[39] *Ibid.*

Government policy appears to be concentrated on studies toward later development of a V/STOL system and toward initiating talks with other European interests on the possibilities of joint ventures in the V/STOL area.

Federal Republic of Germany

In an effort to increase its competitive standing in the aerospace marketplace, West Germany has streamlined its aerospace industry by consolidating a great many companies into four major complexes which collectively have 95 percent of the nation's aerospace productive capacity. The industry hopes to double its capacity in the next 10 years.

West Germany has some special problems. A shortage of manpower forces the nation to import labor from other European countries, and restrictive trade barriers work to the detriment of export sales. In addition, the aerospace industry is heavily reliant on government contracts, which accounted for 85 percent of the workload in 1970.

Nonetheless, the 50,000 employee industry has attained a high level of technical competence and consensus holds that the country can become competitive in world aerospace markets, either by itself or

TABLE 12

AEROSPACE SALES
U. S., CANADA, AND MAJOR AEROSPACE INDUSTRIES OF EUROPE
1965-1970

COUNTRY	YEAR	TOTAL SALES ($ Millions)	EXPORT SALES ($ Millions)	EXPORT/TOTAL SALES (%)
CANADA	1965	394	250	63
	1966	533	255	48
	1967	610	366	60
	1968 est.	654	447	68
	1969 est.	649	395	61
	1970 est.	565	429	76
FRANCE	1965	975	333	34
	1966	1,095	382	35
	1967	1,249	392	31
	1968	1,138	372	33
	1969	1,165	406	35
	1970	1,270	457	36
GERMANY	1965	190	18	9
	1966	157	18	11
	1967	327	32	10
	1968	419	32	8
	1969	414	42	10
	1970	546	—	—
UNITED KINGDOM	1965	1,576	418	27
	1966	1,621	608	38
	1967	1,596	562	35
	1968	1,574	703	45
	1969	1,656	731	44
	1970	—	667	—
UNITED STATES	1965	20,670	1,618	8
	1966	24,610	1,673	7
	1967	27,267	2,248	8
	1968	28,959	2,994	10
	1969	26,126	3,138	12
	1970	24,848	3,400	14

Source: France, Germany and the U.K. from *Interavia*, 5/1971, the U.S. from AIA, *Aerospace Facts and Figures 1971/1972*, and Canada from D. H. Chopping, "Canada Going for Intercity STOL," *Interavia*, June 1971, p. 690. European statistics cover aircraft and engine manufacture and exclude aircraft equipment.

as a partner in consortiums.[40] The industry is seeking revision of international trade regulations to remove barriers that now restrict Germany's share of the world aviation market to only one percent. The country is committed to a strong effort in civil aircraft development and is a partner in the A300B airbus and VFW-614 short-haul transport projects which should assist in bringing the military-civil work balance to a 50-50 level.

Italy

Like other Western European nations, Italy is engaged in a strong effort to upgrade the status of its aerospace industry. A major step was the consolidation in 1971, of the aviation divisions of three firms into one major aerospace company called Aeritalia, which is expected to receive solid financial support.

The aerospace industry employs 25,000 workers and had a 1969 sales volume of $265 million, largely in licensed production. As for directions for the future, a government commission recommended in 1970 that the aerospace industry be further consolidated and that emphasis be placed on commercial projects in general and on business aircraft and STOLs in particular.[41]

• Non-European Nations

Although the primary challenge to the U.S. aerospace industry is expected to come from Western Europe, evaluation of the civil market potential must also consider the policies and programs of the major non-European aircraft-producing nations.

Canada

The Canadian aerospace industry is most heavily engaged in export sales. Between 1961 and 1970, exports in relation to total sales jumped from about 40 to 76 percent. Despite major reductions in overall sales and in personnel, exports rose in 1969 and 1970. A large proportion of the industry's work is performed under contract to U.S. aerospace companies.

The Canadian government provides certain incentives, for example, remission of customs duties in connection with some programs. Since 1965, with the introduction of the Program for the Advancement of Industrial Technology, the government has provided direct assistance to both military and civil projects. There are, in addition, indirect aids, such as tax incentives which encourage R&D, duty-free entry of aircraft and engine components not available in Canada, and export promotions.[42]

The Canadian aerospace industry has developed particular competence in V/STOL technology which it expects to capitalize on through export sales. Following the recommendations of The Science Council Report of October 1970, the government decided to support future development of a Canadian STOL transport system.

Japan

Japan's aerospace industry has progressed considerably since its rebirth in 1952. The value of aircraft production increased almost every year after the resumption of operations and in 1969 it reached $274 million. Employment in that year numbered 25,000.[43]

Japan has developed few aircraft because of the technology import policy. As a result, production has been almost entirely of American-designed military aircraft built under license agreements. Recently, however, the Aircraft Industry Council, an advisory group to the Ministry of International Trade and Industry, recommended government support for the immediate development of a medium short-haul jet and for later development of STOL aircraft. The Council also recommended that the jet be developed on a joint venture basis with an American manufacturer.[44]

Union of Soviet Socialist Republics

The extent of the Soviet challenge in the commercial sector is difficult to assess. Traditionally, the U.S.S.R. has not found a wide market outside of the Communist Bloc. Now, however, the Soviets have a commercial airplane, the Tu-144 SST, which has no

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[40] *Aviation Week and Space Technology*, May 31, 1971.

[41] *Ibid.*

[42] U.S. Department of Commerce, *World Survey of Civil Aviation: Canada 1970*, June 1970, pp. 1-48.

[43] The Society of Japanese Aircraft Constructors, *Directory of the Aircraft Industry in Japan*, September 1970.

[44] *Aerospace Daily*, June 25, 1971.

TABLE 13

AEROSPACE EMPLOYMENT
U. S., CANADA, AND MAJOR AEROSPACE INDUSTRIES OF EUROPE
1965-1970

COUNTRY	YEAR	TOTAL EMPLOYEES (Thousands)
CANADA	1965	28
	1966	34
	1967	37
	1968	37
	1969	34
	1970	28
FRANCE	1965	96
	1966	100
	1967	101
	1968	101
	1969	97
	1970	102
GERMANY	1965	29
	1966	31
	1967	33
	1968	38
	1969	40
	1970	42
UNITED KINGDOM	1965	251
	1966	247
	1967	255
	1968	242
	1969	238
	1970	228
UNITED STATES	1965	1,133
	1966	1,298
	1967	1,392
	1968	1,418
	1969	1,354
	1970	1,159

Source: France, Germany and the U.K. from *Interavia*, 5/1971 and the U.S. from AIA, *Aerospace Facts and Figures 1971/1972*, and Canada from *Interavia*, 6/1971.

American counterpart and only one other rival in the world. The U.S.S.R. has, in addition, developed a variety of other commercial aircraft, including the Yak-40 STOL, the Tu-134 medium-haul transport and the Il-62 long-range transport. Soviet authorities have been noncommittal about seeking SST sales in the West, stating only that they would concentrate on meeting home demand before contemplating other sales activity.[45] Another source, however, states: "Nobody who spends much time . . . talking to the Aviaexport salesmen can doubt the Russian determination to break into the international market beyond the territories of its political satellites."[46]

MILITARY AEROSPACE TECHNOLOGY

In military aerospace technology, national security rather than product marketability is the basic consideration. The strong U.S. defense posture is due in considerable measure to the nation's long-acknowledged aerospace technological leadership, the loss of which would naturally have serious defense implications. Only the Soviet Union is in a position to mount a challenge. A disturbing indicator, however, is the R&D trend, in which the U.S.S.R. leads by a substantial margin in both annual defense R&D expenditures and growth rate. According to DoD, continuance of the upward Soviet trend and the downward U.S. trend could result in Soviet ascendancy to world technology leadership by the end of the decade. This possibility has economic as well as defense implications as such an eventuality would demand tremendously heavy "catch-up" expenditures.

Neither individually nor collectively can the Western European nations assume aerospace technological leadership in the near term. Like the U.S., they are trending downward in the more demanding area of military technology in favor of civil aerospace effort. They can, however, exert an economic influence on the U.S. aerospace industry. For some time, the industry has supplied the military forces of politically-aligned nations with aerospace products, principally aircraft and related equipment. During 1966-1970, these military exports reached significant proportions. In the peak year they amounted to more than $1.1 billion or about 38 percent of all aerospace exports. In 1970, military aerospace exports declined to less than $900 million and 26 percent of the total.[47] Despite the concentration on civil aircraft, the Western European nations are still engaged in a number of cooperative military aircraft and missile projects; but, on an independent basis, all are attempting to strengthen their national aircraft equipment industries. To the extent that emerging European products may supplant U.S. imports, as part of the market solidification process, they constitute a further threat to overall U.S. aerospace sales.

SPACE TECHNOLOGY

The competition for world supremacy in space technology is limited primarily to the U.S. and the U.S.S.R. Achievements of the past decade, and particularly the last three years, clearly give the current edge to the U.S. But here again the Soviet Union is putting forth a strong challenge.

In manned space flight, the U.S. focus for the coming decade is on a prototype space laboratory in 1973-1974, followed by hardware development of a space transportation system, or shuttle. Emphasis in unmanned activity is directed toward advanced scientific observatories, more comprehensive planetary exploration, and additional effort in applications satellites, particularly those of the earth resources survey variety, which offer vast economic potential.

The Soviets have already launched a prototype of a long-duration manned space platform and, despite a tragic setback in 1971, have indicated plans to continue in that direction. In addition, the U.S.S.R. contemplates "continued fundamental scientific investigations of the moon and the planets of the solar system," together with further advancement of weather and communications satellites and introduction of an earth resources survey satellite program.[48]

Thus, the projected programs of the two nations will proceed along parallel lines; the degree of accomplishment and rapidity of progression will depend to a great extent upon funding levels. The recent U.S. trend has been downward, but the sharp reductions of recent years are not necessarily indicative of the future pattern. They reflect the pre-

[45] *Aerospace Daily*, June 25, 1971.

[46] *Aviation Week & Space Technology*, May 31, 1971.

[47] *Aerospace Facts and Figures*, 1971/72.

[48] *Space Daily*, February 22, 1971, and April 7, 1971.

planned curtailment of Apollo expenditures after a peak in the latter sixties, although the overall drop has been greater than the predicted downturn. Soviet science expenditures have been at a considerably higher level than the U.S. and from all indications will go higher; because space is a priority element of a policy of accelerating scientific and technical progress advocated by the CPSU Central Committee of the Soviet Union in its latest 5-year plan (1971-1975).[49]

France, Japan and the People's Republic of China are the other nations which have designed and launched their own satellites and booster vehicles. The latter two nations did not orbit their first payloads until 1970 and have not yet attained a high degree of space research sophistication. Both chronologically and in terms of accomplishment, France is the "third nation," having launched several satellites since 1965. Until this year, France also led all nations except the U.S. and U.S.S.R. in annual space expenditures.

The U.K. and West Germany are the other leading nations in independent space research; both have orbited their own satellites with U.S. launch vehicle assistance. Surpassing France this year, West Germany now leads the European nations in space funding at a 1971 level of $91 million, a massive boost from about

TABLE 14

SELECTED WESTERN EUROPEAN SPACE EXPENDITURES

(Millions of Dollars)

1966-1971

Country	Year	Government	ESRO[1]	ELDO[2]
FRANCE	1966	45.1	7.4	19.9
	1967	71.7	9.4	21.2
	1968	88.0	10.2	23.7
	1969	75.8	10.6	19.5
	1970	65.0	11.5	22.3
	1971	66.2	12.4	22.5
GERMANY	1966	18.0	8.7	18.4
	1967	35.0	11.0	22.9
	1968	42.0	12.3	25.6
	1969	50.7	12.8	21.1
	1970	54.5	13.3	25.2
	1971	91.2	16.3	25.2
UNITED KINGDOM	1966	29.4	9.7	32.4
	1967	30.7	12.2	22.9
	1968	7.2	11.7	25.6
	1969	48.0	12.2	21.1
	1970	48.0	12.2	1.3
	1971	41.4	15.6	4.8

Source: *Aviation Week & Space Technology*, March 8, 1971, p. 53.

[1]European Space Research Organization.

[2]European Launcher Development Organization.

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[49] *Space Daily*, February 22, 1971, April 7, 1971.

$55 million in the previous year.

In addition to their national programs, France, West Germany and the U.K. are engaged in cooperative space projects, along with several other European nations. The European Space Research Organization (ESRO) is a co-op for spacecraft development while a companion group, the European Launcher Development Organization (ELDO) concentrates on launch vehicle development. ESRO's focus for the decade is on applications satellites, including planned joint development with the U.S. of an air traffic control satellite. Generally, the European space program, confined to unmanned systems and funded at relatively low levels, constitues no challenge to U.S. leadership in space technology.

SUMMARY OF THE AEROSPACE CHALLENGE

The U.S. slowdown in technological activity, contrasted with an uptrending pattern among competitive nations, is an indicator that the U.S. may find it increasingly more difficult to maintain its leadership in the three primary areas of aerospace effort: defense, space and civil aviation.

- In defense, Soviet R&D expenditures are outpacing those of the U.S. by a substantial margin, the gap being variously estimated at $2 to $3 billion a year. Continuation of this trend could bring about early loss of U.S. military superiority and create a serious national security problem in the 1975-1985 span.
- In space, the U.S. holds the technological edge, but the Soviet capability is well established and the level of R&D effort in coming years will determine the outcome. The $2 to $3 billion a year gap in favor of the U.S.S.R. is foreboding and a comparison of growth rates indicates a widening rather than a narrowing of the differences.
- In world civil aircraft sales, the U.S. still dominates the market with some 80 percent of the volume, but Western European nations are making a strong bid for a greater share. The U.S. has lost some of its traditional marketing advantages and this, coupled with more vigorous support of R&D on the part of Western European governments, indicates a shift in relative positions and possibly a change of major dimension.

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Abbreviations

AEC:	Atomic Energy Commission
AIA:	Aerospace Industries Association
ARC:	Aerospace Research Center
CERN:	European Organization for Nuclear Research
DoD:	Department of Defense
EEC:	European Economic Community
ELDO:	European Launcher Development Organization
ENEA:	European Nuclear Energy Agency
ESRO:	European Space Research Organization
GAO:	Government Accounting Office
GNP:	Gross National Product
IAEA:	International Atomic Energy Agency
NASA:	National Aeronautics and Space Administration
NORDFORSK:	The Nordic Council for Applied Research
OECD:	Organization for Economic Co-operation and Development
R&D:	Research and Development
RDT&E:	Research, Development, Test and Evaluation
SIPRI:	Stockholm International Peace Research Institute

AIA
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