COMPARISON OF INTERNATIONAL TRANSPORTATION R&D

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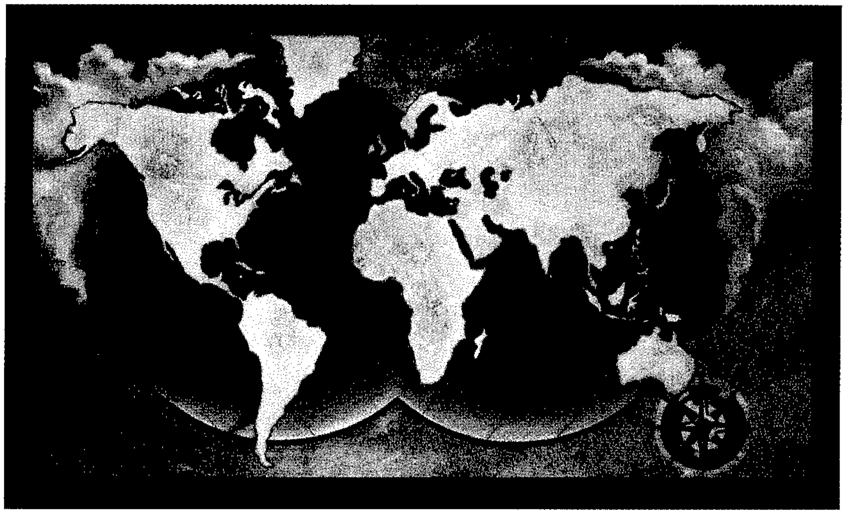

EXPENDITURES AND PRIORITIES

SEPTEMBER 1999

About the National Science and Technology Council

President Clinton established the National Science and Technology Council (NSTC) by Executive Order on November 23, 1993. This cabinet-level council is the principal means for the President to coordinate science, space, and technology policies across the Federal Government. NSTC acts as a "virtual" agency for science and technology (S&T). The President chairs the NSTC. Membership consists of the Vice President, Assistant to the President for Science and Technology, Cabinet Secretaries and Agency Heads with significant science and technology responsibilities, and other White House officials.

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Comparison of International Transportation R&D Expenditures and Priorities

September 1999

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Preface

This report provides a summary of total expenditures on research and development (R&D) in general, and of transportation R&D in particular, by the major performers of transportation R&D within the international community. It also compares these levels to total national wealth and enumerates some of the major transportation-related research projects undertaken by these nations, along with their budgets and time frames. It also discusses several recent national efforts to bolster R&D in 'key' and 'critical' technology fields.

The countries chosen for inclusion in this assessment -- from the continents of North America, Asia, and Europe – currently undertake the vast majority of transportation R&D in the world today. They are also known as the "Group of Seven". They are:

- USA
- Canada
- France *
- Germany *
- Italy *
- Japan
- U.K. *

* In addition to their national programs, these four countries (France, Germany, Italy, and the U.K.) also participate in the multinational R&D activities of the European Community (EC).

Materials for this report were derived from a variety of sources. Information was solicited from transportation, research and academic institutions in the seven countries who were part of the study and their respective representatives in Washington, DC, requesting information from national sources. Web sites pertaining to transportation R&D projects in these nations were consulted. General statistical information on national income, wealth and expenditures were obtained from various printed sources, such as:

- United Nations Economic Commission for Europe
- Annual Bulletin of Transport Statistics for Europe
- OECD in Figures
- Statistical Abstracts of the World and U.S.
- National Academy of Sciences (NAS) Science and Engineering Indicators

The authors hope to expand the countries covered in future versions of this paper. In particular, research is underway for Australia, Netherlands, Spain, Sweden, China, India, Korea, Mexico, Argentina and Brazil.

In addition to some economic and transportation factors which all these nations have in common, each one faces some unique problems depending on its geographical terrain, population density, and budgetary and public policy situation. Each country analyses its own transportation needs, so that those may be met in the most efficient and timely manner. For this reason, each country sets aside some budget for transportation R&D and initiates specific projects in order to meet its unique challenges.

The authors recognize that this paper represents a 'work in progress' that will be improved and expanded over subsequent versions. To that end, they welcome and encourage comments and contributions of all kinds. These can be sent to the following e-mail addresses:

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Chapter 1

Country-by-Country Assessment

A. *Overview*

A key factor of increasing importance in world R&D is that both projects and knowledge are becoming multinational in character. With the growth in international corporations, travel and telecommunications, and growing numbers of foreign students in institutions of higher learning all over the globe, both the practice and the propagation of research are attaining global proportions. As the Congressional Research Service concluded in a recent review: "[W]ith worldwide communications systems, it is virtually impossible to prevent the flow of scientific and technical information."[1]

Industrial firms are turning to global research partnerships to expand their capabilities. Since 1986, over 4,000 known multi-firm R&D alliances for strategic high-technology activities have been created worldwide. Of these, over one-third were collaborations of U.S. firms with European and/or Japanese partners, and most were in information technologies. There is also substantial cross-funding of R&D by U.S. and non-U.S. companies. More than 10% of U.S. corporate R&D funds are spent overseas, and a comparable amount is spent by non-U.S. firms in the U.S. Foreign companies spent $6.5 billion on R&D in the US in 1987 -- that grew to $14.6 billion by 1993. Meanwhile, US corporate spending on R&D overseas also rose dramatically in these years – from $5.2 billion to $9.8 billion. By 1995, foreign-owned companies spent over $17 billion on R&D in the United States, while U.S.-owned companies spent about $13 billion on R&D overseas.[2] In other industrialized countries, the proportion of foreign funding of R&D is considerably higher than this level, and is welcomed and encouraged by some national governments as a public policy priority. Foreign funding of R&D ranged widely from nearly 14% in Britain to only 0.1% in Japan.

The number of foreign-owned R&D facilities in other countries is growing dramatically. In the U.S., the number of such foreign company research facilities more than doubled in just three years -- from 250 in 1992 to 645 in 1995. Of these, 53 were automotive facilities (34 Japanese, 16 European, and 3 Korean).[3] Thus, it is becoming increasingly difficult to isolate any one nation's R&D activities, spending and resources and assess it as an entity separate from the rest of the world.

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1 Wendy H. Schact, "Cooperative R&D: Federal Efforts to Promote Industrial Competitiveness", *CRS Issue Brief*, Congressional Research Service, November 9, 1998, p. CRS-12.

2 Primary source for this section is Chapter 4, "U.S. and International Research and Development: Funds and Alliances," in National Science Foundation, *Science and Engineering Indicators: 1998*.

3 Donald Dalton and Manuel Serapio Jr., *Globalizing Industrial Research and Development*, U.S. Department of Commerce, Office of Technology Policy, October 1995.

However, even though the 'globalization of research' is obvious, each nation still retains to a considerable extent its own R&D priorities, policies, capabilities and history. In fact, it is the uniqueness of each nation's situation that drives the creation of multinational partnerships, which seek to exploit the best available resources, wherever they are, for a common goal. A discussion of the status of both general R&D and transportation-related R&D in individual nations is a necessary background for assessing the position of the U.S. in relation to the other major economies of the world.

B. *Country Summaries*

The 28 member nations of the Organization for Economic Cooperation and Development (OECD) spent a total of $410 billion on R&D activities in 1995. More than 90% of this amount was spent by the 'Group of Seven' nations -- USA, Japan, Germany, France, UK, Italy, and Canada -- and 44% was spent by the United States alone. This is more than double the level of the next country (Japan) and about the same as the next six nations combined. *(See Table 1 and Figure 1)* In only four other countries – Australia, the Netherlands, Spain, and Sweden -- do R&D expenditures exceed one percent of the OECD total for R&D spending.

Table 1[4]

GDP, R&D and Transportation R&D Expenditures, 1995 - Group of 7

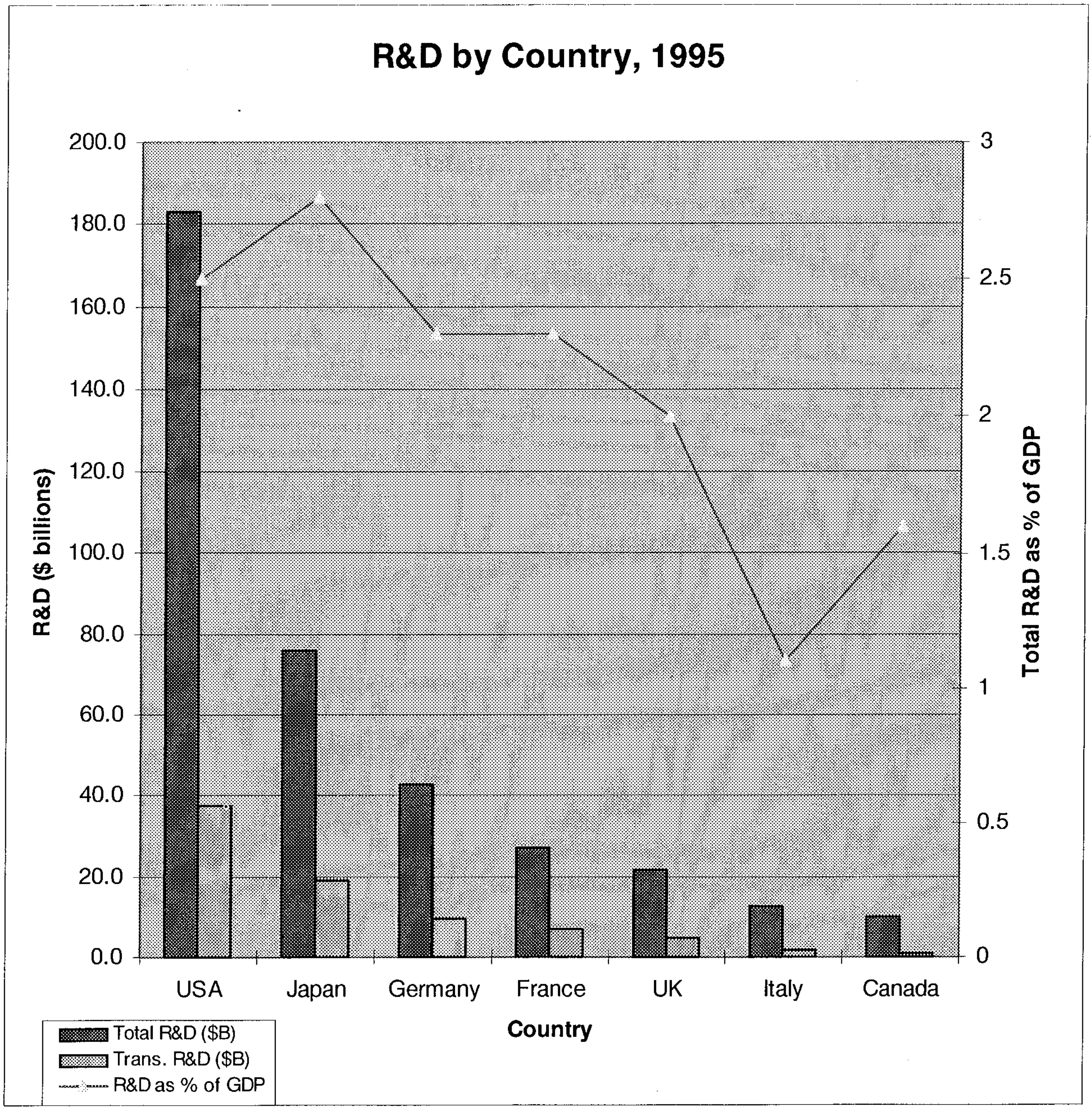
(in 1995 $US unless otherwise noted.)

COUNTRY	Total GDP in ($US) x10⁹	Total R&D in $USX10⁹	Total R&D as % of GDP	Gov't portion of funds in $US x10⁹	Private, foreign & other portion of funds in $US x10⁹	Total Transport R&D in $US x10⁹	Gov't portion of funds in $US x10⁹	Private, Foreign, & other portion of funds in $USX10⁹
USA	7,247	183.0	2.5%	63.2	119.8	37.4	10.4	27.0
Japan	2,782	76.0	2.8%	7.8	68.2	18.9	0.5	18.4
Germany	1,850	42.9	2.3%	6.6	36.3	9.7	0.3	9.4
France	1,202	27.1	2.3%	5.6	21.5	6.9	5.2	1.7
UK	1,120	21.4	2.0%	3.1	18.3	4.7	1.5	3.2
Italy	1,129	12.7	1.1%	2.5	10.2	1.9	0.1	1.8
Canada	634	10.0	1.6%	1.4	8.6	0.8	0.1	0.7

In most of these nations, R&D spending tapered off and even declined somewhat in the early 1990s. By the mid-1990s, however, both the USA and Japan had begun to recover to previous levels. Meanwhile, Canada was the only nation among the top seven to show consistent increases in R&D spending in the past decade. Total R&D spending as a percentage of Gross Domestic Product (GDP) ranged from about 1% (Italy) to more than 2.5% (Japan, USA). In

4 See *Appendix A* for explanation of sources and methodology.

Figure 1


R&D by Country, 1995
R&D ($ billions)
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
3
2.5
2
1.5
1
0.5
0
Total R&D as % of GDP
USA
Japan
Germany
France
UK
Italy
Canada
Country
Total R&D ($B)
Trans. R&D ($B)
R&D as % of GDP

comparison, the levels in Eastern Europe (Russia, Czech Republic, Hungary, Poland, etc.) are around or even below 1%, considerably lower than in the previous decades.

a. USA

Total national R&D expenditures in the United States reached a record high of nearly $206 billion in 1997, with the highest annual growth rate (4.3%) in over a decade. Industry and the Federal government together provided 95% of this amount, with the remaining 5% mostly from universities and nonprofits. According to one recent survey, state governments contribute about $2.4 billion annually to R&D funding.[5]

In 1997, the U.S. ratio of R&D expenditures to total GDP was 2.7%. At the same time, the ratio of non-defense R&D expenditures to total GDP reached an historic high at 2.2%. Total defense R&D has been falling in the U.S., U.K. and France for most of the 1990s. The largest level of non-defense Federal R&D spending, at 18% of the total, is in health.

In 1997, development received the most money ($128.3 billion, or 62%), followed by applied research ($46.2 billion, or 23%) and basic research ($31.2 billion, or 15%). Industry is the lead funder and performer of applied research and development, while the Federal government is the lead funder and academia the lead performer of basic research.

The private sector, spurred by high profits, intense international competition, and the availability of new information technologies, has provided a steadily rising proportion of total R&D for over a decade. In 1997, for example, private companies provided two-thirds of this amount, or $133 billion, and spent three-fourths, or $151 billion. The largest sector increases in R&D spending in the past decade were in electrical equipment (particularly information systems and software) and the pharmaceuticals/biotechnology industries.

In fact, the share of industry R&D performed by non-manufacturing firms – especially software/programming, trade and communications -- rose from 8% in 1987 to 25% in 1995. The six largest manufacturing industries in 1995 in terms of R&D spending (with over 90% of the total) were:

Transportation equipment	17.8%	--	$19.3 billion
Chemicals/pharmaceuticals	16.0%	--	$17.3 billion
Electrical equipment	15.7%	--	$17.1 billion
Machinery (including computer hardware)	8.9%	--	$ 9.7 billion
Scientific/optical/photographic instruments	7.8%	--	$ 8.5 billion
Petroleum	1.6%	--	$ 1.8 billion

In general, these companies are decreasing spending on central research laboratories and shifting their focus to developing new products for the market. In transport equipment, for example,

[5] This figure, for FY 1995, is from a September 1998 Battelle Memorial Institute and State Science and Technology Institute (SSTI) report prepared for the National Science Foundation, *Survey of State Research and Development Expenditures: Fiscal Year 1995*, p. 3. The same report identified $171 million in state spending on transportation R&D in FY 1995, almost equally divided between federal and state government sources. (pp. 7, 9)

motor vehicles R&D increased at an average annual rate of 7.9%, while aircraft/missiles fell an average annual 2.7% in 1991-1995. The industries with highest ratio of R&D spending to total expenditures are: pharmaceuticals, office and computing machines, communications equipment, electronic components, instruments, and aerospace.

The R&D outlays of small and medium firms are increasing at a faster rate than for large firms. But still, 25 U.S. firms spend over $1 billion annually each on R&D. The four largest R&D spenders -- GM, Ford, IBM and Hewlett-Packard -- account for 16% of the total. *(See Table 2)*

Table 2

Leading U.S. Corporate Performers of Transportation-related Industrial R&D in 1996

National Rank	Company	$M R&D Expenditures	% of R&D to Net Sales
1	General Motors	$ 8,900	5.6%
2	Ford Motor	6,821	4.6%
7	TRW	1,981 *	20.1%
11	Chrysler	1,600	2.7%
20	Boeing	1,200	5.3%
23	United Technologies	1,122	4.8%
30	Lockheed Martin	784	2.9%
34	Rockwell International	691	6.7%
39	ITT Industries	535	6.1%
52	Goodyear Tire & Rubber	374	2.9%
55	McDonnell Douglas	355	2.6%
59	AlliedSignal	345	2.5%
67	Northrop Grumman	255	3.2%
71	Cummins Engine	235	4.5%
87	Textron	185	2.0%
98	Johnson Controls	165	1.6%
99	Dana	164	2.1%

* *Includes federal funds.*

Source: National Academy of Sciences, Science and Engineering Indicators, 1998, Appendix Table 4-23.

Companies have a variety of ways to access external technologies. These include: outright purchase, licensing, joint ventures, minority equity, joint development, contract, and funding exploratory research. It can often be both cheaper and faster to find an external source than to develop the technology internally.

The successful application of new technologies is critical for many manufacturing industries in maintaining competitiveness. In fact, a 1996 study by the U.S. Council on Competitiveness made the following observation about the U.S. motor vehicle industry:

> "It is no secret that U.S. companies' share of the world market for motor vehicles declined during the last quarter century: however, the industry has rebounded in recent years. The success and strength of foreign competitors actually led to a 'revolution' of sorts in U.S. laboratories and production facilities. R&D has played a major role in the changes, in terms of both the automobile production process and the product itself." [i.e., adopting concurrent engineering, introducing computers into the design/development/production process and electronic components into the vehicles]. "The overriding goal of the changes has been to reduce production costs and time-to-market. Success is evident: where it once took five or more years for a new car to go from drawing board to showroom, it now takes only two to three years". [6]

The Federal share of U.S. R&D spending in 1997 was just under $63 billion, representing less than 5% of all public spending in the nation. *(See Table 3)* The Federal government provides 30% of all R&D spending in the country, which compares to a peak of 46% in the mid-1980s. In fact, the level of Federal R&D spending has fallen at an average annual rate of 2.3% in the past decade. In contrast, however, the Department of Transportation's R&D budget has grown an average of 7% annually in real terms since FY 1992. This is primarily due to the expansion of support for the Intelligent Transportation Systems (ITS) program. Among the factors re-shaping Federal R&D are: declines in defense spending, public pressure for lower government spending and balanced budgets, and an increase in collaborative and partnership

Table 3

R&D Spending by Federal Agency, FY 1997

Agency	($ billions)	% of Federal R&D
Defense	$33.0	47%
Health & Human Services	$12.2	18%
NASA	$ 9.2	14%
Energy	$ 5.9	10%
National Science Found.	$ 2.3	4%
Agriculture	$ 1.4	2%
Commerce	$ 1.1	2%
Others (including DOT)	$ 3.0	3%
Total Federal	$68.1	100%

Source: NSF, Science & Engineering Indicators, 1998, p. 4-23.

[6] In National Science Foundation, *Science and Engineering Indicators 1998*, p. 4-14.

activities. However, the Federal government remains an important source of R&D funding, particularly from a few large agencies. The Department of Defense still provides over three-fourths of all Federal R&D funds going to industry, while the Department of Health and Human Services (HHS) is the source of more than one-half of all Federal R&D funding for universities. Other major recipients include the Federal laboratories and Federally-funded research and development centers (FFRDCs), which obtained over $26 billion of their FY 1997 funds from the Federal government. The only performer of R&D not receiving less Federal support in recent years is academia, which still received 60% of their R&D funding from Federal sources in 1997.

Meanwhile, the Federally-funded share of industry R&D has fallen from about $29 billion in 1987 to only $21 billion in 1997. The Department of Defense now accounts for less than one-half of all Federal R&D for the first time since 1981. The number of cooperative and international R&D partnerships has in fact been steadily expanding since the early 1980s. The Technology Reinvestment Project (TRP) invested over $2 billion in public and private funds in 288 projects in the early 1990s. The Advanced Technology Program (ATP) has received $1.4 billion since FY 1990 to promote economic growth and employment in the U.S. by awarding funds to support the development of 'enabling technologies' that can lead to new products and services. Among the transportation-related projects funded by ATP in FY 1998 are the development of composite railroad cross ties and several alternative energy projects, including fuel cells, flywheels, solar power and advanced battery proposals.[7]

b. Japan

The U.S. and Japanese national S&T efforts reveal both remarkable similarities and significant differences. In both nations, R&D spending has been steadily growing over the past two decades, except for a slight decline in the early 1990s. Both nations spend between 2.5% and 3% of their GDP on research and development, although the Japanese levels tend to be slightly higher. In contrast, however, the U.S. spends a much higher (although declining) proportion of its resources on defense-related R&D, and the U.S. government provides a larger (although also declining) share of total national resources for R&D, than in Japan. In 1994, for example, about 20% of U.S. R&D spending went to defense, while in Japan the level was only about 1%.[8] The U.S. has also traditionally supported basic research at a higher level. However, support for both basic research and the role of universities in R&D has been increasing in Japan since a 1992 Cabinet Decision to double the government's R&D budget and improve the equipment and facilities at universities and national research institutes. This decision led the Japanese government to enact the Science and Technology Basic Law in November 1995 and to approve the Basic Plan for Science and Technology in July 1996. The Basic Plan calls for the government to spend a total of $155 billion on research and technology between 1996 and 2000. Among the priority R&D topics identified in the Basic Plan are: the human brain, global materials, supersonic air transport, and earthquakes.[9]

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7 See http://www.nist.gov/www/press/g98-74.htm for the complete FY 1998 list.

8 *The Science and Technology Resources of Japan: a Comparison with the United States*, NSF, 1997, p. 7.

9 National Science Foundation, Tokyo Office, *Japanese Government Science and Technology Budget, Fiscal Year 1997*, INT 97-27, June 30, 1997, *passim*.

Within the Japanese government, the four most influential agencies in R&D policy are: the Prime Minister's Council for Science and Technology (CST); the Science and Technology Agency (STA); the Ministry of International Trade and Industry (MITI); and the Ministry of Education, Science, Sports and Culture (Monbusho). The CST, chaired by the Prime Minister, consists of the heads of research and economic agencies as well as representatives from industry and the universities. They advise the Prime Minister on long-range research goals and assist in coordinating science-related programs across the government. The three agencies with the largest levels of government R&D funding are: Monbusho (49%); STA (26%); and MITI (12%). The Defense Agency accounts for only 6% of government R&D funding.

Table 4

Japanese Transportation-related Research Institutes and Their Government Affiliation

Government Affiliation	Research Institutes
Ministry of Construction	Public Works Research Institute Building Research Institute
Ministry of International Trade & Industry (MITI)	Industrial Research Institute
Ministry of Transport	Port and Harbor Research Institute Ship Research Institute Aeronautics Research Institute
National Police Agency	International Association of Traffic & Safety Sciences
Science & Technology Office	National Aerospace Laboratory Japan Marine S&T Center National Space Development Agency
Japan Highway Public Corporation (JHPC)	JHPC Research Institute
Japan National Railways	Railway Technical Research Institute
University of Tokyo	Institute of Industrial Sciences

Most of Monbusho's funds support both the basic operations and research activities in the Japanese university system, while STA supports a number of large national laboratories and science facilities. Research institutes related to transportation can be found in several agencies. STA includes institutes for aerospace, space and marine science and technology. Under the Ministry of Transport are maritime, navigation and traffic safety institutes. The Ministry of Construction includes the Public Works Research Institute, which covers such topics as seismic design and materials durability.[10] Important Japanese transportation research institutes are listed in *Table 4*. Even though the Japanese government is active in R&D, it remains the case that Japanese industry funds about three-fourths of all national R&D and employs nearly 70% of all Japanese research scientists and engineers. In 1994, in fact, industrially-funded R&D was 1.9% of Japanese GDP and only 1.5% of U.S. GDP.[11] Funding is

[10] The Japanese government recently announced plans to merge the Ministry of Construction and the Ministry of Transport in 2000.
[11] *Ibid.*, p. 25.

focused almost exclusively on manufacturing, as opposed to the service sector of the economy. In 1993, for example, $37.5 billion of the total industrial R&D funding of $39.3 billion was devoted to manufacturing. The largest expenditures were in communications equipment, motor vehicles, electrical machinery, and chemicals. *(See Table 5)*

Table 5

Japanese R&D Funding by Selected Industry, 1983 and 1993
(in millions of constant 1987 $US)

Industry	1983	1993
Communications equipment	4,209	6,145
Motor vehicles	2,884	4,633
Electrical machinery	2,293	4,208
Chemicals	2,429	4,042
Office machinery & computers	1,008	3,477
Non-electrical machinery	1,984	3,475
Pharmaceuticals	1,219	2,728
Aircraft	221	305
Shipbuilding & repair	58	79
Other transport	131	76
Total, transportation	3,294	5,093
Total, all Industries	**22,851**	**39,252**

Source: OECD, 1995.

Total Japanese industrial funding for transportation R&D equaled about $5 billion dollars in 1993, or about one-eighth of industrial expenditures. Nearly 90% of this total was for motor vehicles. In contrast, about one-fourth of all U.S. industrial funding in 1993, or $22 billion dollars, was devoted to transportation, most of which was for aircraft. *(See Table 6)*

Table 6

U.S. and Japanese Industrial Funding for Transportation R&D: Amounts and Proportion of all Industrial Funding, 1993

	U.S.		Japan	
Sector	$ billion	% of total	$ billion	% of total
Aircraft	$13.9	14.4%	$ 0.3	0.8%
Motor vehicles	$ 8.0	8.3%	$ 4.6	11.8%
Shipbuilding & repair	$ 0	0	$ 0.1	0.2%
Other transport equipment	$ 0.3	0.3%	$ 0.1	0.2%
Total	**$22.2**	**23.0%**	**$ 5.1**	**13.0%**

Source: OECD, 1995.

c. *Europe and Canada*

i. *Multi-national*

Along with their own individual research programs, the member nations of the ***European Community***[12] also contributed toward an ambitious common, community-wide research effort. The most recent activity, termed the *Fourth Framework Programme for Research and Technological Development*, received about $14 billion in funds during the years 1994 through 1998 for a wide range of scientific and technical fields.[13] About $1 billion was directed towards transportation in three specific categories: transport ($260 million); transport technologies ($500 million); and telematics ($275 million). The categories receiving the most funding under the Fourth Framework are information and communications (28%, or about $4 billion); energy (18%, or about $2.5 billion); and industrial and materials technology (16%, or about $2.2 billion).

The transport category focuses on integrating the various modal and national segments into a coherent trans-European transportation network. Thus, research in this area emphasizes improving the compatibility of various modes and national segments, as well as optimizing the operations of the network. Transport technologies seek to improve vehicle design tools and traffic control and management systems for aviation, maritime, rail and highway transport. The goals of this effort are to improve the capacity, safety, quality, speed, comfort and environmental friendliness of transport in Europe. Finally, telematics represents the combination of information system and telecommunications technologies to improve services and the quality of life in transport and other areas such as public administration, education, and health care. Much of the

[12] EU members included in this study are: France, Germany, Italy, and the U.K.
[13] Points of contact for the research areas can be found in the Internet at *http://www.cordis.lu/inco/src/contprg.htm*

transport telematics activity directly supports the development of Intelligent Transportation Systems (ITS) in Europe.

In addition to these transportation projects, several other Fourth Framework categories of research are also applicable to transportation. The 'Information Technologies' category earmarked about $2 billion for software, electronic components, microprocessors, and computer-assisted manufacturing. 'Advanced communications technologies' ($700 million) supported research in high-speed and cordless networks, photonics, and communications security. Other areas with transportation applications include advanced materials ($600 million), the environment ($600 million), and clean and efficient energy technologies ($1 billion). Notably, the Fourth Framework also includes specific program categories and funds dedicated to international cooperation, dissemination of results, and the training of teachers and researchers in these fields.

Under the *Fifth Framework Programme for Research and Technological Development*, or FP5, announced in early 1999, a total of 13.7 billion euros ($14.6 billion at $1.10 US = 1 euro) is being budgeted for the years 1998-2002. FP5 includes four *thematic programmes*, three *horizontal programmes*, and support for a *Joint Research Center*. These items, with their projected budgets, can be seen in *Table 7*.

Table 7

Fifth Framework Programme Funding
(in US$ millions at $1.10 US = 1 euro)

	Thematic Programmes	
1.	Quality of life and management of living resources	$2,654
2.	User-friendly information society	$3,960
3.	Competitive and sustainable growth	$2,975
4.	Energy, environment, and sustainable growth	$2,337
	Horizontal Programmes	
1.	Confirming the international role of Community research	$523
2.	Promotion of innovation and participation of small/medium enterprises	$400
3.	Improving human research potential & socio-economic knowledge base	$1,408
	Joint Research Center	$310
	Total	**$14,567**

Transportation-related projects are listed primarily under the 'Competitive and sustainable growth' thematic programme. The four *key actions* identified under this programme are:

- *Innovative products, processes and organizations*
- *Sustainable mobility and intermodality*
- *Land transport and marine technologies*
- *New perspectives in aeronautics.*

Each key action is supported by a collection of socio-economic and research objectives and targeted research actions. In addition, the third and fourth key actions include technology platforms that will be used for integration and validation of the outputs. For example, two of the technology platforms under 'Land transport and marine technologies' are advanced power train systems with minimized environmental impact, and a new generation of environmentally friendly modular trains. Three *generic technologies* will help develop the scientific and technological base and human capital to support these key actions. They are:

- *Materials and their production and transformation*
- *New materials and production technologies in the steel field*
- *Measurements and testing.*

Other transportation-related projects can be found under 'User-friendly information society' (see 'Travel and tourism' items) and 'Energy, environment and sustainable development'. Further information on FP5 is available on the Internet at http://www.cordis/lu/fp5/home.html.

In addition to these EC initiatives, the 14-nation ***European Space Agency*** spends about $3 billion annually on technology development and space-related research in such areas as launchers and telecommunications. The results of these efforts are then available to member nation's aerospace companies. Among the recipients of these funds are Aerospatiale (France), Daimler-Benz Aerospace (Germany), and British Aerospace (U.K.). These three companies are also the largest partners in the **Airbus Consortium**, which is now one of the two largest commercial jet aircraft manufacturers in the world and receives significant government support. Finally, the European Research Coordination Agency (***EUREKA***) initiative was launched in 1985 to enhance European competitiveness in high technology fields. Since that date, the more than 20-member nations have allocated up to $10 billion annually to a wide range of projects, including transportation. At the present time, EUREKA is funding 44 transport projects for a total of 182 million euros ($200 million) for such topics as: alternate fuel motor and marine vehicles, Intelligent Transportation Systems, advanced materials, and materials recycling.[14]

In the area of transportation policy, on 1 December 1998 the European Commission adopted a Common Transport Policy (CTP) for Sustainable Mobility: Perspective for the Future. This is an action program "to encourage the development of efficient and environmentally friendly transport systems that are safe and socially acceptable"[15] for the years 2000-2004. This

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[14] See *http://eureka.belspo.be*; then click on *Project Portfolio*; then click on *Transport*. 1 euro = $1.10 US.

[15] Quotation is from the Internet site of the European Commission's Transport RTD Programme Directorate General VII (DG07) at http://europa.eu.int/en/comm/dg07/ctp_action_prog/ctpen.htm.

statement is based heavily on the previous CTP Action Programme 1995-2000, whose strategic objectives remain valid. The five major goals are:

1) liberalizing market access, especially to rail service and port facilities;
2) ensuring integrated transport systems across Europe through encouraging *Public Private Partnerships* (PPPs) and development of *Trans-European Transport-Networks* (TENs);
3) ensuring fair and efficient pricing within and between transport modes by applying the concept of charging for marginal social costs;
4) enhancing the social dimension by emphasizing how transportation can help improve accessibility for weaker regions of the EU and disadvantaged population groups; and
5) making sure all EU member states apply the competition articles and public aid to industries fairly.

Additionally, the CTP stresses improving transportation safety while reducing environmental impacts, protecting consumer rights while improving transportation service quality, and negotiating transportation agreements with the potential future EU member states in Central and Eastern Europe.

ii. France

Over the past decade, the government of ***France*** has maintained support for civilian R&D even as defense research has been scaled back. In particular, the government funds large-scale, multi-year research programs in areas of national importance. The 1997 state research budget identified the following six priority topics for government support as having the greatest economic and employment potential: (i) electronics and information technology; (ii) road and air transport; (iii) chemistry; (iv) agro-food industry; (v) industrial product and process innovation; and (vi) medical research, especially infectious diseases, genetics, microbiology, and biotherapies. [16]

The French government supports an extensive network of world-renowned national research centers that specialize in high-technology. These are coordinated through the *National Center for Scientific Research (CNRS).* In transportation, these facilities include the *National Institute for Transport and Safety Research (INRETS)* and *the Laboratoire d'Economie des Transports (LET).* The government also assists industry through such policies as R&D tax credits, cooperative pre-competitive government/industry projects, and regional technology transfer centers. In addition, there is extensive transportation R&D supported by such companies as Peugeot/Citroen and Renault (motor vehicles), Dassault Aviation and Aerospatiale (aircraft), and SNECMA (aircraft engines). It should also be noted, however, that the French government owns much or most of these latter four companies.

[16] *International Plans, Policies, and Investments in Science and Technology, April 1997,* Technology Administration, U.S. Department of Commerce, p. 13.

iii. Germany

Germany has the highest level of R&D spending of the European nations. It is particularly supportive of basic research and 'cutting-edge' areas such as information, biotechnology and micro-systems. Two separate coordinating bodies largely reliant on government funds – the *Fraunhofer Society* and the *Max Planck Institute* – dominate scientific and engineering research. They manage a large number of research institutions throughout Germany and in other countries, including the US. The major government supporter of R&D is the *Bundesministerium fur Bildung und Forschung* (Federal Ministry of Education, Science, Research and Technology), or the *'bmb+f'*.

In recent years, the Federal government funded significant research into magnetic levitation (TransRapid) and conventional high-speed (Inter-City Express, or ICE) rail service. Among the current major thrusts for German transportation research are the application of artificial intelligence (AI) to road transport informatics (RTI), and the development of models and simulations of freight and logistics activities within the European community. For example, the goal of the "AI Techniques for Traffic Control" project is to develop a set of innovative tools that can effectively support real time traffic control and supervisory operations. Among the topics being investigated are: decision making and planning for traffic control actions, validation methods for sensor-acquired data, and using AI to enhance data acquisition. The prototype was designed and developed using both simulations and offline experimentation with real data supplied from roadside sensors.

The potential of new information and communication technologies to establish integrated pan-European freight and fleet management systems is being investigated. The objective of a second major project, "Freight and Logistics Efforts for European Traffic," is to evaluate existing transport, fleet, vehicle and freight management systems in terms of operational goals and strategies, market requirements (by regions/sectors), and social, economic and cost benefits. From this evaluation, a proposed system design, set of specifications and standards and implementation scenario for a pan-European fleet management system will be developed.

The German government is also committed to reduce road and air traffic volumes. It offers attractive alternatives to its citizens and industry alike, because there is a growing demand for mobility. Transport and traffic plays a crucial role in Germany, because it is a central transit point in a now-integrated Europe. The growing traffic volumes that result, however, are posing threats to the environment. In order to develop innovative and sustainable solutions, the aims of German R&D in this area are:

- to create the scientific and technological conditions for an integrated overall transport system;
- to make more effective use of the existing transport infrastructure and to reduce unnecessary traffic;
- to reduce the environmental impact and the consumption of resources associated with traffic;
- to cope with traffic in conurbations (major urban areas); and
- to increase road safety.

In pursuit of these goals, Germany is supporting the *MOTIVE* project (Mobility and Transport in Intermodel Traffic). The purpose of MOTIVE is to make more effective use of the existing traffic infrastructure, optimize the use of modes of transport, and reduce environmental pollution. MOTIVE will enable travelers to select the optimum route and the most suitable mode of transport by means of modern information and communication technologies. MOTIVE will link public with private transport and also takes into account the need to park vehicles, i.e., availability of parking facilities at a given location.

In addition, the bmb+f funds the *Mobilitatforschungsprogram* (Mobility Research Program), a comprehensive approach to enhancing transportation options. Among its goals are improved efficiency and safety, reduced emissions, and improved mobility in conurbations. Eight such regions have received funding for related projects under this initiative.[17]

iv. Italy

Italy has realized that transport is fundamental for economic and social development in a modern country. Recent estimates suggest that transportation accounts for about 5% of all value added in the national economy.[18] Therefore, the Italian National Research Council (CNR) had undertaken a multi-year research program entitled *Progetto Finalizzato Transporti 2* (PFT2), or 'Special Projects in Transportation Research'. PFT2 funds research into advanced tools for transport system planning and control, and for innovative technologies in the field of vehicles and infrastructures, in order to direct different national bodies toward common and specific objectives. It includes governmental, industry and academic participants. The program began in 1992, and its budget for the period 1992 to 1999 is 257 billion liras (about $226 million), of which about 60% is from the CNR and 40% from industry.

The PFT2 has been subdivided into six research areas, or subprojects (SP), as shown below:

SP1: Mobility management and planning tools
SP2: Vehicles
SP3: Technological support systems and infrastructures
SP4: Urban and metropolitan systems
SP5: Freight transport
SP6: International programs

SP1: "Mobility management and planning tools" deals with transport planning and management problems. It will provide scientific support to decisions pertinent to transport systems and industries. SP1 projects include: development of decision support systems and geographic information systems for local and regional transport and land use planning and transit system operations; and national manuals for transport planning, environmental impact studies, and financial assessment of infrastructure projects.

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17 Additional information on this program is available on the Internet (in German) at http://www.bmbf.de/deutsch/arbeit/aufgaben/leitproj/mobil.htm

18 "Special Project on Transportation Research: General View", presented at the CNR "Infomobility" conference, Rome, June 22-23, 1998, p. 1.

SP2: "Vehicles" and SP3 "Technological support systems and infrastructures" are chiefly directed to foster innovation in high technology sectors of strategic importance to transport and economy. SP2 projects focus on surface vehicle and vehicle subsystem prototype development, and improved naval and aeronautical design methods. Specific topics include: improved internal combustion and alternative propulsion systems (electric, electric/solar, electric/fuel cell, electric/petrol); electronic subsystems to control vehicle functions (adaptive cruise control, drive by wire, active suspension and engine mounts, robotized gearbox, electronically controlled differential); and on-board rail track diagnostics system.

Under SP3, projects include: multi-sensor surveillance systems for terminals, unattended premises, and highway-rail grade crossings; millimeter band radar for ground traffic surveillance at airports; and rail, subway and highway modeling and simulation tools.

SP4: "Urban and metropolitan transport systems" and SP5: "Freight transport" both study specific problems and analyze solutions providing research support to reduce the current social and economic costs of transportation. SP4 concentrates on improved software and information systems for transport network design, operations and analysis. Specific projects include: improved measurement of the energy efficiency and environmental impact of transport operations; traffic and transit fleet management systems; and artificial intelligence system for signalized traffic control.

SP5 seeks to develop and distribute improved hardware and software tools for firms engaged in freight transport and logistics. Among the activities are: development of software to calculate the costs of various shipping options; identification and analysis of multimodal corridors; and improved automated systems for intermodal ports and terminals.

Finally SP6: "International programs," is devoted to promoting Italian participation to international research, particularly in a European context. These international projects include: a prototype video system for vehicle position location (LAKE, or Lane Keeping); a mobile laboratory (MOBLAB) in a van for developing computer vision systems; low-cost, massively parallel computer architecture for real-time image processing (PAPRICA); a demonstrator car prototype (ARGO); and a highway macro-simulator (PLAN) for assessing vehicle platooning.

Results from these research areas are distributed through national and regional workshops and conferences, as well as publications and the Internet.[19] PFT2 researchers also participate in related European research programs, such as the European Commission (EC) initiatives (see below); and FANTASIE (Forecasting and Assessment of New Technologies And Systems and their Impact on the Environment).

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19 See h*ttp://www.iasi.rm.cnr.it*

v. *Britain*

Recent British government initiatives promoting technology-based economic competitiveness have included biotechnology (*Biotechnology Means Business Program*), the environment (*Environmental Best Practices Program*), civil aeronautics *(National Strategic Technology Acquisition Program*), and computing (*Microelectronics in Business and Parallel Applications Programs*). In addition, the government's *National Technology Foresight, LINK, Small Firms Award for Research and Technology (SMART)* and *Advanced Technology Programs* are examples of public/private research partnerships designed to assess and support the development of significant emerging technologies.

Much of the British transportation-related research has centered on the planning and evaluation of road, rail, air and marine transport systems from a technological, economic, social and ergonomic viewpoint. In aviation, the range of research projects includes airport choice modeling, airport planning and design, economic and environmental impacts, and safety. Among the current active aviation research projects are the following:

- Decision support system for airport terminal design;
- The development of a user friendly environmental impact model for airports;
- Airport access considerations, including the impact of congestion on passenger terminal flows;
- An evaluation methodology for the level of service at the airport landside system;
- The application of a "Hub-and-Spoke" network for air transport system planning; and
- The International Civil Aviation Organization (ICAO) airport coding implications of operation at hot and high airfields.

The primary public source of transportation R&D funding and support in Britain is the *Department of the Environment, Transport and the Regions (DETR).* In July 1998, the DETR published its policy document *"A New Deal for Transport: Better for Everyone,"* which seeks to safeguard the environment and develop "an integrated transport policy to fight congestion and pollution."[20] According to the document, 'integrated transport policy' refers to integrating transportation: within and between modes; with the environment; with land use planning; and with other public policies in education, health and economics. Among other measures, it advocates a greater emphasis on walking, cycling and transit; focusing highway funds on maintenance rather than new construction; and improved safety and accessibility.

The DETR manages a number of separate research initiatives at both the national and international level. For example, the *LINK* program in Inland Surface Transport research is also supported by the Engineering and Physical Science Research Council, the Economic and Social Research Council, and the Department of Trade and Industry. The *Seedcorn* program funds innovative research ideas that promote the Department's broad policy objectives. The *Programme for Mobility and Transportation in Europe (PROMOTE)* is evaluating vehicle telematics such as communications, driver and vehicle information systems, tolling, and selective

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[20] DETR, "A New Deal for Transport: Better for Everyone – A Summary of the Government's White Paper," July 1998, p. 3.

airbag arming. DETR also participates in the EC's research programs, the COST (European Cooperation in the Field of Scientific and Technical Research) initiative, and the Transport Research Programme of the OECD. Specific DETR goals promoted by its research program are improved safety, congestion mitigation, minimized environmental impacts, and cost-effective infrastructure maintenance and renewal. DETR's current budget for transport R&D is approximately $65 million annually.

A recent (1997) study paper from the Department of Trade and Industry's Office of Science and Technology, *The Role of Technology in Implementing an Integrated Transport Policy*, describes three new technology initiatives that will enhance accessibility, improve the environment, and offer the potential for export products. The first initiative, the *Clear Zones* concept, will run demonstrations of implementing complementary technologies for communicating traveler information, moving people and goods, monitoring traffic and environmental changes, and conserving energy in up to six city centers.

The development of a 'global vehicle' that will be able to meet strict environmental and safety requirements, contribute to an enhanced quality of life, and help sustain the competitiveness of a major manufacturing sector poses a formidable challenge to the world community. The U.K. response to this challenge, the *Foresight Vehicle LINK* initiative, is the second technology initiative. It provides up to $8 million of government funding (to be matched by industry), to help government, the private sector and the academic community to work together to develop a range of desirable automotive technologies. Governmental participants include the Engineering and Physical Sciences Research Council, the Department of Trade and Industry, the Ministry of Defence, and the DETR. Among the projects supported by this initiative are: environmentally friendly propulsion systems; new lighter-weight materials that can reduce vehicle weight and the resulting fuel usage and emissions; the replacement of mechanical subsystems with lighter and more reliable electronics-based components; and telematics systems that give the driver information that can increase journey efficiency and allow smoother traffic flow. This program is essentially an umbrella for cooperative, pre-competitive automotive technology activities in the U.K. for the purpose of focusing resources on areas where the country can make real technological advances. It also complements other European and international transportation technology programs in which Britain participates.

The third technology initiative, *Informed Traveller*, promotes more efficient intermodal travel. This initiative will make available real time traffic and transport alternatives information to drivers and shippers so that they can make rapid decisions about changing routes or even modes of travel. For example, a driver heading downtown may be persuaded to park the vehicle and take transit upon being informed in real time that there are no parking spaces at the destination. This information should be available in homes, offices and vehicles, as well as in public places such as terminals and shopping locations.

vi. Canada

Most R&D in ***Canada*** is privately funded. One recent estimate suggests that the private sector performs about 62% of all Canadian R&D, the universities about 22%, and the Federal government about 12%. [21] In the government sector, much responsibility for research in highway transportation remains at the provincial level. However, as a sign of the importance of science and technology to economic growth, the Canadian government announced a three-year *Technology Partnerships Canada* (TPC) in March 1996. TPC provides up to $250 million (US) annually to encourage commercialization of high technology products and processes. Among the target areas for TPC are aerospace, environmental technologies, advanced manufacturing, materials, and biotechnology. Additional federal assistance is available through the *National Research Council of Canada*, which focuses on biotechnology, construction, manufacturing, and information and telecommunications; and the new *Canada Foundation for Innovation*, which supports improvements in the research infrastructure at Canadian hospitals and universities.

Some surface transportation research and development is coordinated through the *Transportation Association of Canada (TAC),* whose members include representatives from Federal, provincial and municipal government agencies and the transportation manufacturing, construction and service industries. TAC also maintains on the Internet a searchable database of Canadian surface transportation R&D projects.[22] The *Transportation Development Center (TDC)* in Montreal is Transport Canada's primary research institute. It emphasizes topics of national interest and federal responsibility. Among its multi-year transportation R&D projects are: improving aircraft winter operations; transferring accessible technologies, especially in transit, to operators and equipment manufacturers; evaluating the safety of tanker cars; and assessing incidents of truck driver fatigue.

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[21] *International Plans, Policies, and Investments in Science and Technology, April 1997,* Technology Administration, U.S. Department of Commerce, p. 18.

[22] See *http://www.tac-atc.ca/rdqbe.htm.*

Chapter 2

Critical Technologies

As can be seen, the 'Group of Seven' nations devote a considerable measure of the R&D efforts and resources to advancing transportation technologies. Much of this activity is channeled into motor vehicle and aerospace research, both for economic competitiveness and national security reasons. *(See Appendix A for a breakdown of revenues and R&D spending by major international transportation firms.)*

Due to the high technology content and national security implications, aerospace tends to spend a higher proportion of revenues on R&D, and receives a higher proportion of governmental funds for this purpose. On the other hand, the sheer volume of R&D in the motor vehicle industry dominates all transportation R&D activity. When combined, the major vehicle manufacturers have spent over $40 billion annually on R&D in recent years *(see Table A-1)*.

In addition to transportation, however, other key technology areas also receive considerable governmental support and national attention in these and other industrial and industrializing nations. The reasons for the selection of these technology fields are similar to those that sway transportation research decisions as well – international economic competitiveness and national security.

Several recent reports in the U.S. have drawn considerable national and public policy attention to these technology areas, and have sparked an ongoing debate on the best means for selecting and supporting R&D projects. Among these important reports are: the biennial *National Critical Technologies Reports* from the Office of Science and Technology Policy (OSTP) (1991, 1993, 1995); the U.S. Department of Commerce's Council on Competitiveness, Endless Frontier, Limited Resources: U.S. Policy for Competitiveness (1996); and the RAND Critical Technologies Institute's Critical Technologies in a Global Context: A Review of National Reports (May 1997).

The reason for this intense interest in the subject is stated clearly in the executive summary of the 1995 National Critical Technologies Report:

> "The development and use of technologies remains a driving force in U.S. economic prosperity and national security. Maintaining the strengths and competitiveness of the U.S. technological enterprise, therefore, continues to be vital. In the current climate of intensifying global competition, rapid technological change, and geopolitical uncertainties, the need for identifying critical technologies for concentration of effort becomes even greater." (p. v).

The report, submitted to the President by OSTP and the National Critical Technologies Review group, identified seven key *technology categories*, each of which in turn contained several *technology areas*. These are shown in *Table 8.*

Table 8

National Critical Technology Areas

Technology Category	Technology Area
Energy	Energy efficiency Energy storage, conditioning, distribution and transmission Improving generation
Environmental Quality	Monitoring and assessment Pollution control Remediation and restoration
Information and Communication	Components Communications Computer systems Information management Intelligent complex adaptive systems Sensors Software and toolkits
Living Systems	Biotechnology Medical technology Agriculture and food technology Human factors
Manufacturing	Discrete product manufacturing Continuous materials processing Micro/nanofabrication and machining
Materials	Materials Structures
Transportation	Aerodynamics Avionics and controls Propulsion and power System integration Human interface

Source: 1995 National Critical Technologies Report, p. vi.

All of these technology groups either directly or indirectly benefit transportation. Even the 'Human Factors' area under 'Living Systems' receives considerable transportation R&D funding. The 1995 report judged the U.S. to be at least tied or ahead of Japan and Europe in each of these technology areas. However, it did note that our relative standing was declining in many of these areas, including: aerodynamics, avionics and controls, propulsion and power, materials, structures, communications, and computing systems. These are some of the key technologies to assure a competitive transportation industry. In addition, Japan and Europe were judged to be leading in several specific transportation-related areas, such as high-speed rail and magnetic levitation, and highway infrastructure.[23]

The 1996 report of the Council on Competitiveness, Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness, also acknowledges the importance of a strong R&D capability to assure the nation's "economic well-being and national security."[24] The report assesses the state of U.S. R&D in six industries judged to be of especial significance to national competitiveness. They are: aircraft, automobiles, chemicals, electronics, information technologies, and pharmaceuticals. In aircraft, the Council observed that increasing competition, especially from the European Airbus Consortium, is creating a new emphasis on improving value for the customer through lowering costs and improving the quality of the product. In fact, Boeing worked closely with potential customer airlines in the U.S., Japan and Britain (United Airlines, Japan Airlines, All Nippon Airways, and British Airways) from the start in developing the new 777 model. This is creating pressure for component and sub-component manufacturers to increase their R&D on their own portions of the finished product. This trend is affecting non-U.S. contractors such as the Japan Aircraft Development Corporation, which manufacturers about one-fifth of the airframe for the new Boeing 777 model, and the French engine manufacturer SNECMA, which collaborated with GE to develop new engine models for the 777. It is also driving more R&D into the short-term 'development' side and less into longer-term 'research'. Unfortunately, this has happened at the same time that government funding for aircraft and aerospace R&D has been falling dramatically.[25]

The report describes similar patterns in the automobile industry. Increasing international competition is forcing the 'Big Three' to increase their R&D spending. However, most of this growth has been directed toward the short-term 'development' side and improvements to the manufacturing process itself, rather than longer-term 'basic' research. Component and sub-component suppliers are being pressured to assume more of the burden for R&D to improve their products. The report notes that electronics component manufacturers spend about 7-8% of total sales on R&D; even non-electronics component makers are spending about the average for the industry of 4% of total sales on R&D. The major companies are also increasingly being drawn into R&D collaborations to share costs and deal with complex technical issues, such as the United States Council for Automotive Research (USCAR) consortium. Among other activities, USCAR oversees the industry's involvement in the Partnership for a New Generation of Vehicles (PNGV), which includes the Federal government and more than twenty universities as partners. The industry is also increasing their involvement with universities by supporting a number of research centers and funding individual projects. In fact, a number of foreign

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23 1995 *National Critical Technologies Report*, pp. vii-xiv, 108.

24 p. 1.

25 *Ibid., Appendix A: Aircraft*, passim.

automotive and components manufacturers are also establishing R&D facilities in the U.S. and increasing their own funding of research at U.S. universities. As of 1996, there were over 50 of these foreign-affiliated automotive research institutions in the U.S., and the number is growing.[26]

The Council's primary conclusion was that the most effective means for the U.S. to pursue key technological advances in the future was through partnerships, that is, "cooperative arrangements engaging companies, universities and government agencies and laboratories in varying combinations to pool resources in pursuit of a shared R&D objective."[27] In turn, this can only be accomplished when there is a shared agreement on the specific roles and responsibilities of the various partners, including the Federal government and national laboratories, in such partnerships. In addition, the level of support for R&D must increase, particularly from industry.

The Critical Technologies Institute at the RAND Corporation contributed to this dialog in 1997 with a White Paper entitled Critical Technologies in a Global Context: A Review of National Reports.[28] This report reviews recent national 'key' or 'critical' technology reports from the U.S., Japan, Germany, France, and Britain, including the following:

US	National Critical Technologies Report, 1995.
Japan	Future Technology in Japan Toward the Year 2020, 1995.
Germany	Delphi-Bericht 1995 zur Entwicklung von Wissenschaft und Technik, 1995.
France	Les Technologies Cles pour l'Industries Francaise a l'Horizon 2000, 1996.
Britain	Winning Through Foresight: A Strategy Taking the Foresight Programme to the Millenium, 1996.

There were a number of similarities among these efforts. All of the reports noted the significant contribution of R&D to economic competitiveness and growth and market share for national industries, and stress the importance of governmental support for certain key technologies, especially those considered 'high risk'. Among the specific technologies mentioned in nearly every report were: high-density data storage and high definition displays; telecommunications and data routing; network and system software; sensors; pollution control technologies; design engineering tools such as computer-aided design (CAD) and computer-aided engineering (CAE); micro/nano-manufacturing; semiconductor manufacturing; and materials. At the same time, there were also importance differences in the methods and results of these studies. This could be seen in the criteria used to pick key technology areas, the specific lists that resulted, and the relationship between social demand and technology 'push'. The RAND study does most clearly reveal, however, that interest in choosing 'critical' technologies and improving government support for their development is evident in all of these nations.[29]

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26 *Ibid.*, *Appendix B: Automotive*, passim.
27 *Ibid.*, p. 3.
28 Caroline S. Wagner, WP-117, May 1997.
29 *Ibid.*, passim.

Chapter 3

Issues

A. *Increasing Globalization of R&D*

It is becoming increasingly difficult to separate one nation's unique non-military S&T assets and advantages from another nation. There are several reasons for this:

- Expansion in international travel and communications – foreign nationals account for about one-half of US graduate students in certain key technology and engineering fields; commercial aviation, long-distance phones and the Internet make sharing data easy; publications and conferences are increasing.

- Large corporations are increasingly becoming multi-national or international themselves -- a company with manufacturing facilities on several continents (Ford, GM, Toyota) will undertake R&D in a number of nations simultaneously and share the results within itself across national boundaries and with other institutions as part of deliberate technology sharing strategies. Meanwhile, auto companies are continuing to merge into true multi-national corporations: recent example include Daimler Chrysler, the Renault Nissan alliance, the purchase of Rolls Royce by Volkswagen, and the purchase of British and Swedish manufacturers (Aston Martin, Jaguar, Volvo) by Ford.

How does this reflection change our perception of the situation? Is it in fact true that it is no longer easy to disentangle U.S. R&D 'assets' and 'advantages' from those available to other nations as well? Is it still possible to take measures to enhance the inventory of key 'U.S.' technologies in transportation and other critical fields without letting these become available to others?

B. *The U.S. Position viz a viz our International Competitors: Where Do We Stand?*

How does the U.S. 'stack up' to our major international competitors? Are we generally ahead, tied with, or behind them in our access to and application of key technologies? Are there identifiable and desirable foreign transportation-related technologies to which we want to establish better U.S. access?

C. *Successful Value-capturing*

What is the best approach to take to identify those specific transportation-related foreign technologies that would benefit the U.S.? To actually obtaining access to these technologies?

Is there in fact a desire or need to do this in an organized way? If so, what is the best role for the government? For industry? For academia?

D. Continuing the Process

How should we continue this process of focusing on transportation-related technologies?

Appendix A

Transportation R&D Estimates and Table 1: Sources and Methods

The primary source for the national GDP and total R&D expenditures for 1995 are from Chapter 4 and Appendix Tables 4-42, 4-45, 6-1 and 6-2 from the NSF, *Science and Engineering Indicators: 1998.* All dollar totals were adjusted to 1995 dollars.

The estimates for transportation R&D expenditures in Table 1 for 1997 (unless otherwise indicated) were derived from a variety of sources. First, major corporations in motor vehicles and aerospace and their 1997 revenues were identified from the 1998 Fortune magazine list of the "Global 500" companies. Second, R&D expenditures for a number of these companies were identified, particularly for the aerospace firms. Third, an estimated average factor for R&D as a percentage of revenues of 4.7% was developed for motor vehicle companies, based on the identified factors that ranged between 2.8% (Fiat) and 9.3% (Nissan); this factor was used to estimate R&D expenditures for companies for which specific amounts could not be found. This information is presented in Table A-1. Adding the R&D expenditures for the largest motor vehicle and aerospace companies provided the bulk of the non-governmental expenditures column.

Using 1995 data for GDP and total R&D and mostly 1997 data for transportation R&D does cause a slight discrepancy in viewing *Table 1* as a whole. It is hoped that future editions of this table will be standardized on a common year. However, it was thought useful to display the most recent data available in each category of information.

Additional information on national R&D policies and funding was obtained from contacting the science and commercial counselors at the EC Liaison Office and the Embassies of Canada, France, Germany, Italy, Japan and the UK in Washington; as well as officials from various research and transport ministries, research institutes and universities, and Internet sites in these countries. In addition, parallel information was sought from similar sources for Chinese, Indian, Russian, Dutch, Australian, and Swedish R&D. It is hoped that this information can be included in later versions.

The information on Tables 1 and A-1 represent a 'work in progress'. For example, smaller component and sub-component manufactures are not totally included, although certain additions were made to the totals to reflect this item in part (such as the portion of General Electric's corporate R&D for jet engines and locomotives). Insufficient information on maritime and transit R&D is included. Considerable additional research and refinement is needed: all comments and offers of advice and assistance are enthusiastically welcomed.

Table A-1

Major Transportation Companies Revenues and R&D Expenditures

Company	1997 Revenue ($B)	1997 R&D Exp. ($B)	R&D % of Rev.	Notes
USA				
General Motors	178.2	8.4	5.6%	(a)
Ford	153.6	6.5	4.6%	(a)
Chrysler *	61.1	1.7	2.7%	(a)
Boeing	45.8	1.9	5.3%	(a)
Lockheed Martin	28.1	0.8	2.9%	(a)
United Technologies	24.7	1.2	4.8%	(a)
AlliedSignal	13.8	0.4	2.5%	(a)
Goodyear	13.2	0.4	2.9%	(a)
Rockwell International	11.8	0.7	6.7%	(a)
TRW	10.8	1.2	11.1%	(a)
Johnson Controls	10.3	0.2	1.6%	(a)
Textron	10.5	0.2	2.0%	(a)
Northrop Grumman	9.2	0.3	3.2%	(a)
ITT	7.5	0.5	6.1%	(a)
Genuine Parts Co.	6.6	0.3	4.5%	(a)
Cummins Engine	6.3	0.2	3.4%	(a)
Total		*24.9*		
Japan				
Toyota	84.1	6.5	6.3%	(a)
Nissan	53.5	3.6	9.3%	(a)
Honda	48.9	2.0	5.2%	(a)
Mitsubishi Motor	30.4	[1.4]	[4.7%]	(b)
Mazda	16.6	[0.8]	[4.7%]	(b)
Isuzu	14.7	[0.7]	[4.7%]	(b)
Denso (components)	13.6	[0.6]	[4.7%]	(b)
Suzuki	12.1	[0.6]	[4.7%]	(b)
Fuji (Subaru)	10.6	[0.5]	[4.7%]	(b)
Total		*16.7*		
Germany				
Daimler Benz *	71.5	3.4	5.2%	(b) (c)
Volkswagen AG	65.3	[2.9]	[4.7%]	(b)
BMW	34.7	[1.6]	[4.7%]	(b)
MAN AG (trucks)	13.3	[0.6]	[4.7%]	(b)
Total		*8.5*		

* Now *Daimler Chrysler*, a U.S.-German firm.

Company	1997 Revenue ($B)	1997 R&D Exp. ($B)	R&D % of Rev.	Notes
France				
Renault	35.6	1.5	4.3%	(d)
PSA (Peugeot-Citroen)	32.0	[1.5]	[4.7%]	(b)
Aerospatiale	9.8	2.3	24.0%	(e)
SNECMA	4.3	1.4	33.0%	(f)
Total		*6.7*		
UK				
British Aerospace PLC	11.9	0.8	6.1%	(a)
Rolls Royce	6.2	0.9	14.0%	(g)
Non-aerospace transport		1.2		(h)
Total		*2.9*		
Italy				
Fiat Auto SpA	53.5	1.6	2.8%	(a)
Total		*1.6*		

Notes to Table A-1

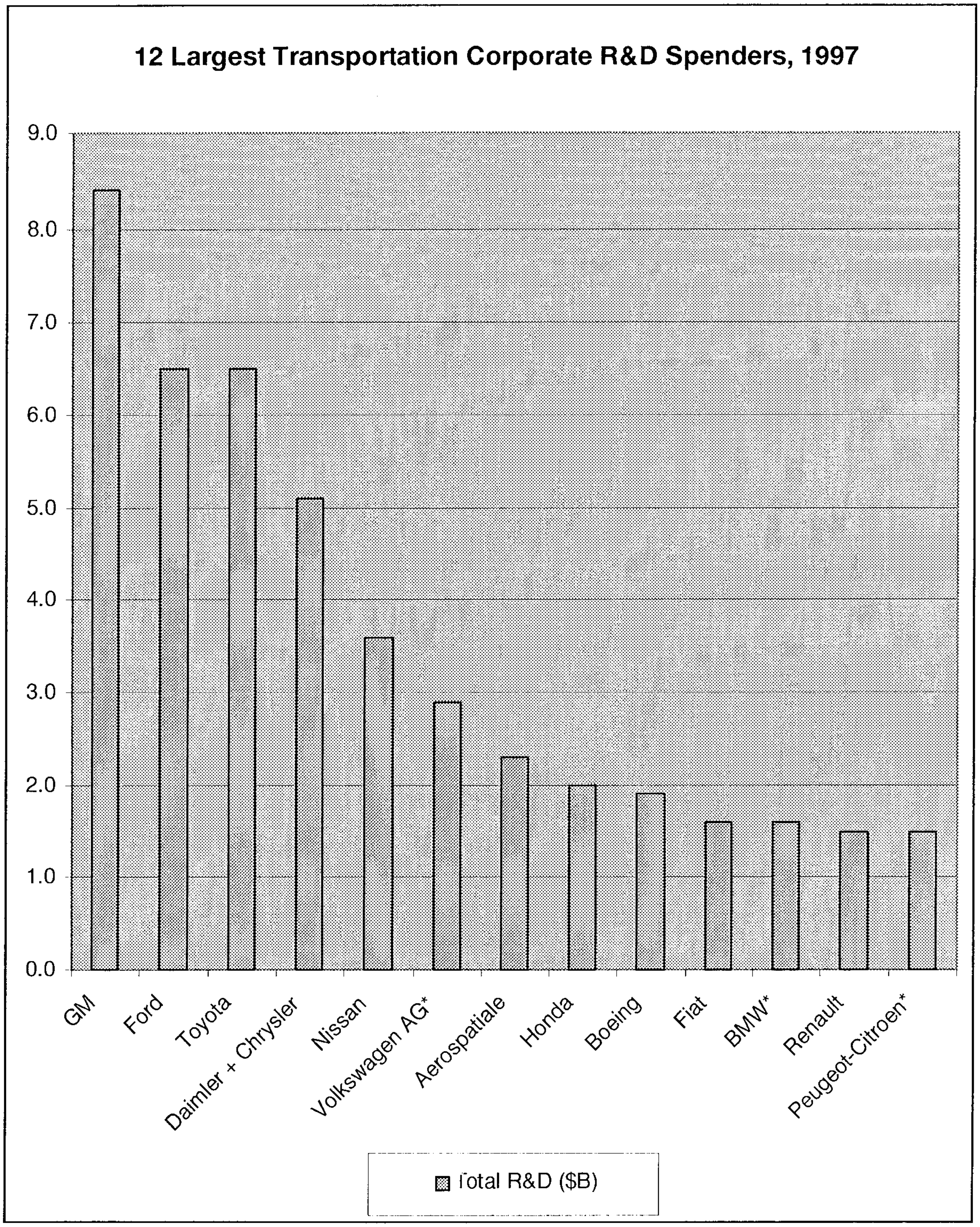
An additional 10% was added to the *Total* for each nation's non-governmental R&D to reach the amounts shown on *Table 1.* This is to account for R&D performed by smaller companies.

1997 Revenue figures are from the 1998 Fortune magazine "Global 500" list of the world's largest companies. See *http://www.pathfinder.com/fortune/global500/500list2.html.*

(a) R&D data is from R&D Magazine, October 1998, Section S.
(b) These R&D expenditure estimates were created using the 4.7% R&D to revenues factor.
(c) Daimler-Benz includes the former Deutsche Aerospace (DASA), Germany's largest aerospace company.
(d) R&D data is from the Renault Internet site. Renault is government-owned.
(e) R&D figures are from 1992; source is GAO, European Aeronautics: Strong Government Presence in Industry Structure and Research and Development Support, GAO/NSIAD-94-71, March 1994, p. 5. Aerospatiale is government-owned: R&D funding is primarily governmental.
(f) Data is from 1992; source is GAO, *op. cit.* SNECMA manufactures jet engines and is government-owned: R&D funding is primarily governmental.
(g) Data is from 1992; source is GAO, *op. cit.* R&D expenses are primarily for aircraft engines.
(h) R&D data is for 1995; source is UK Office of National Statistics, Annual Abstract of Statistics: 1998 edition, p. 260.

The twelve largest transportation corporate funders of R&D in 1997 are shown on *Figure A-1.*

Figure A-1



* These amounts are derived using the average 4.7% factor of R&D to total revenue. All other amounts are based on research as described in *Appendix A*.