Defense R&D and national R&D systems: a European outlook

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Defense R&D addresses a highly specific purpose: equipping the armed forces with up-to-date technologies. This R&D responds to the requirements of a monopsony, the government, which acts as the market maker for these products by direct procurement and export authorizations. But defense R&D is also embedded in national R&D systems. The question of the place and role of the defense R&D effort within a national R&D system is of particularly high interest if we take into consideration the possible links and externalities between civil and defense R&D.

A 1998 study of the U.S. national innovation system arrived at two stylized facts on the evolution of R&D efforts there during the 1990s. First, the share of federal funding in R&D was decreasing due to the reduction of defense-related R&D. Second, industry funded a growing part of the R&D effort, thus inducing a high priority given to development rather than basic research.[1] But instead of considering national systems of innovation (NSI) in general, in this article we concentrate our attention on a more specific item and, to some extent, on the core of NSI and technological innovation, namely, the organization of research and development. In particular, we consider "a set of institutions that (jointly and individually) contribute to the development and diffusion of new technologies. These institutions provide the framework within which governments form and implement policies to influence the innovation process." [2] This definition applies both to innovation in general and to R&D in particular.

This article reviews differences in European national R&D systems especially in terms of the place of defense R&D. It is based on annually collected data by the OECD, consistent with the conventions of the so-called Frascati manual.[3] The data contain information on who *finances* and who *performs* R&D. Elements of defense R&D are included, and this allows us to illustrate the place of defense R&D in national R&D systems.

The next section discusses the data, and previous work based on it, and focuses on the evolution of defense R&D in the six European countries who signed the so-called Letter of Intent (or LOI) and who together account for more than 90 percent of defense R&D in the EU.[4] The section thereafter details the role of defense R&D in the French national system of innovation in particular.

European comparisons

We first discuss the role of government in the respective national R&D efforts, then we detail the split of public funding into civil and defense objectives. All monetary amounts are expressed in US$ purchasing power parities (exchange rates are defined by reference to a representative basket of goods and services). But methodological constraints on data gathering are examined first to highlight that and why one cannot directly compare defense R&D across different funding sources for gross domestic expenditure on research and development (GERD).[5]

The U.K. has little public R&D funding, yet a large part of this is dedicated to defense; France has a larger public R&D funding but a relatively small part of this is dedicated to defense. In contrast, Germany has a low level of defense R&D despite a large overall R&D effort, and despite having twice Spain's population, it spends less on defense R&D than does Spain.

Methodology

The OECD collects annual data on R&D from its member states. To be comparable these data must be built on the same definition and data collection method. An OECD meeting with national experts took place in Frascati, Italy, and the resulting manual is therefore called the Frascati manual.[6] But because two types of data gathering are used, namely survey data and budgetary data, the data are not directly comparable.

Several studies using these data to examine defense R&D have already been published.[7] One author uses the data to show the growing defense R&D gap between the United States and Europe. For the 1991 to 2003 period, three results in particular are consistent with our own findings. First, "defense R&D spending in Europe is highly concentrated"; second, "defense R&D budgets fell significantly during the post-Cold War period"; and third, "patterns of defense R&D spending vary amongst the LOI Six countries."[8] (The six countries are France, Germany, Italy, Spain, Sweden, and the United Kingdom.) Our article goes further in that it presents defense R&D not merely on its own terms, but as embedded within the respective national R&D systems. Nevertheless, there are limits to the OECD data, for example in the fuzzy definition of defense R&D and especially the inadequate consideration of dual-use technologies.[9] But no other data source is available for our purposes.

Before presenting the European data, we take a brief look at the U.S. case. In absolute terms, the U.S. defense R&D effort is six times larger than the sum of the efforts of the six members of the European Letter of Intent. The U.S. figure represents 56.9 percent of total public R&D funding; the corresponding figures in the LOI countries range from 3.6 to 31 percent.[10] The U.S. number was even larger in the late 1950s, approximately 80 percent.[11] "Defense-related R&D and procurement programs provided a powerful impetus to the development and commercialization of new civilian technologies in commercial aerospace, semiconductors, computers, and

Table 1: Gross domestic expenditure on research and development (GERD), 2005, by funding source and performance

Panel (a): GERD, 2005, by source of funds in billions $ ppp (and in % of total)

	Business sector	*Government sector*	*Other nat. sources*	*Non-national sources*	*Total*
France	21.4 (52.6)	15.5 (38.2)	0.8 (1.9)	3.0 (7.3)	40.6
U.K.	14.8 (42.1)	11.5 (32.8)	2.1 (5.9)	6.8 (19.2)	35.2
Germany	42.7 (67.6)	17.9 (28.4)	0.2 (0.3)	2.3 (3.7)	63.1
Italy	7.2 (39.7)	9.2 (50.6)	0.3 (1.7)	1.4 (8.0)	18.1
Spain	6.2 (46.3)	5.8 (43.0)	0.7 (5.0)	0.8 (5.7)	13.4
Sweden	7.4 (65.7)	2.6 (23.5)	0.3 (3.1)	0.9 (7.7)	11.3

Panel (b): GERD, 2005, by sector of performance (billions $ ppp)

	Business sector	*Government sector*	*Higher ed. sector*	*Private, non-profit sector*	*Total*
France	25.5 (62.5)	7.2 (17.6)	7.6 (18.6)	0.5 (1.3)	40.7
U.K.	21.7 (61.6)	3.7 (10.6)	9.0 (25.6)	0.8 (2.2)	35.2
Germany	43.7 (69.4)	8.9 (14.1)	10.4 (16.5)	0.0 (0.0)*	63.1
Italy	9.1 (50.4)	3.1 (17.3)	5.5 (30.2)	0.4 (2.1)	18.1
Spain	7.2 (53.9)	2.3 (17.0)	3.9 (29.0)	0.0 (0.1)*	13.4
Sweden	8.4 (73.8)	0.5 (4.7)	2.4 (21.2)	0.0 (0.3)*	11.3

Note: * $ ppp are not zero but rounded to one decimal place, hence small percentages do result in the parenthetical expression.
Source: OECD (2007/2).

computer software."[12] If so, it should be worthwhile studying the role of European defense R&D efforts in their own national R&D system.

National R&D systems in Europe

Research capabilities, both private and public, are a key element of the future success of the economy in industrialized countries. In 2000, the European countries decided in Lisbon to undertake an unprecedented R&D effort to make Europe the most productive and competitive knowledge economy in the world. The quantitative target is for R&D expenditure to reach three percent of GDP in 2010. For the six LOI countries, only Sweden has met the target (in fact, it has exceeded it). Worryingly, some of the other countries are showing a decreasing R&D spending trend for the past decade: by 2005 France was down to 2.13 percent and the U.K. to 1.78 percent.[13]

These differences in national R&D efforts are even more striking when partitioned by source of funds as well as by sectors of performance, showing different institutional arrangements to deal with R&D.

Table 1, panel (a) shows significant differences from one country to another. Due to its size, Germany spends the most, followed by France and the U.K. The German business sector alone spends as much on R&D as all of France does. The business sector provides two-thirds of R&D funding for Sweden and Germany but only one-half in France and Spain, and a little less than that in the U.K. Government funding is particularly important for France (more than one third) and for Italy and Spain. Britain shows an unusual pattern in that an important share of R&D funding comes from abroad. Table 1, panel (b) shows the distribution of GERD by the sector in which R&D is carried out (the sector of performance). In this regard, the LOI Six are more comparable than the distributions of funding but two groups of countries nonetheless stand out: Italy and Spain show a relatively low share of R&D carried out in the business sector and with a comparatively high share in higher education; in contrast, Germany, France, and the U.K. show that business performs about two-thirds of R&D performance and the government and higher education shares are relatively balanced. Sweden stands apart with about three-quarters of GERD performed by the business sector and very little by the government sector.

Some initiatives are taken to enhance both the quantitative effort of R&D at the European level and in terms of international collaboration. The most well-known and, in budget terms, important initiative are the Framework Programs for Research and Technological Development which helped to structure the European Research Area, but in the past the defense field was explicitly excluded from this funding. The seventh Framework Program, starting in 2007, includes a cooperative program on "security" for the first time. But the budget is only €1.4 billion for the period 2007-2013. Another initiative, specific to the defense sector, should also be mentioned: the relatively new European Defense Agency (EDA) which already has launched multinational programs for Research and Technology (R&T).[14] None of these initiatives apply automatically to all participating member states.

Despite efforts to develop European collaboration within the Research Areas, the organization of national R&D efforts shows large differences, and it is noticeable that countries with stronger efforts in terms of the R&D share in GDP (Germany and Sweden) are also those where private funding and private sector R&D work are prominent. At the opposite end of the scale, Italy and Spain depend heavily on public efforts.[15]

Defense R&D

As compared to other studies, the definition of defense R&D used in this article is quite restrictive, but this allows us to give a clearer view of its publicly funded share and also of its evolution throughout the last decade. Table 2 presents data on Government Budget Appropriations or Outlays for R&D (GBAORD) dedicated to defense, i.e., public funding of defense R&D wherever it is performed.

In relative terms, the main defense R&D efforts are made by the United Kingdom and France, both of whom also have the largest defense budgets in Europe.[16] Sweden and Spain have show a significant share of GBAORD dedicated to defense. The numbers for Germany and Italy are surprisingly low. For the latter, this may be due to the fact that defense R&D is supported by the Ministry of Industry. Comparing the numbers for 1995 with 2005, the tendency is decreasing for all except Spain (the explanation being that in Spain defense R&D was switched from the Ministry of Industry to the Ministry of Defense with the advent of the Eurofighter Typhoon program).[17]

Comparing the numbers in Tables 1 and 2, defense R&D budgets are particularly important in the national R&D efforts of France and Spain, due to the high shares of public funding in GERD associated with the significant shares of defense R&D in GBAORD. The United Kingdom is in the same situation especially for its important defense share in GBAORD. In contrast, Germany has both comparatively low public funding of GERD and a low share of defense R&D in GBAORD. Its defense R&D effort is comparatively smaller than those of its European counterparts.

In monetary terms, defense R&D is highest in the United Kingdom and France, Spain being third and significantly above Germany (although the Spanish numbers are not consistent with the data published by EDA in 2006). Italy and Sweden lag far behind in monetary terms, the former because it has a small share of defense R&D in GBAORD, and the latter due to the small size of its economy. The Swedish GBAORD is only about one quarter of Spain's and a mere 13 percent of Germany's. Generally speaking, the Letter of Intent effort is increasing in the later years of the period studied, reflecting the end of the post-Cold War peace dividend era.

Comparing 1995 and 2005, the level of defense R&D has been roughly stable for France, Italy, and Sweden. But Italy and Sweden show a sharp drop during the late 1990s and a similar recovery since then. The United Kingdom and especially Spain have shown continuous defense R&D growth, and Germany a slight decrease. As indicated, some of these trends can be explained by external factors such as changes in ministerial responsibilities and boundaries. Except for the Spanish case, the results appear to be globally consistent with the statistical survey of the EDA.[18] The EDA figures also show that only ten percent of the R&T of its participating member states is conducted under European collaboration. While Europe's main industrial groups are well-integrated, they still are organized along national lines so as to benefit from national funding. Even if a program is nominally conducted under European collaboration, a nation-state based prime contractor has difficulties to transfer knowledge and components from one country to another. Thus, room remains for a higher level of integration in the defense R&D area.

Table 2: Defense budget R&D as a percentage of total government budget appropriations or outlays on research and development (GBAORD) and defense budget R&D (in billion $ ppp)

	1995 (%)	*2000* (%)	*2005* (%)	*1995* ($)	*2000* ($)	*2005* ($)
France	30.0	21.4	20.8	4.1	3.2	3.9
United Kingdom	36.5	36.2	28.3	3.3	3.8	4.1
Germany	9.1	7.8	5.8	1.4	1.3	1.1
Italy	4.7	0.8	3.6	0.3	0.1	0.4
Spain	10.4	26.2	16.4	0.3	1.3	1.6
Sweden	20.9	7.1	17.4	0.4	0.1	0.4

Source: OECD MSTI 2006/1 and 2007/2.

The French case

The role of defense in the national R&D system

The French Ministry of Defense performs, by itself or through contracts with other organizations, both public and private, the R&D needed for equipping its armed forces. (French defense R&D means as funded by the French Ministry of Defense.) Claude Serfati showed that since the late 1950s, defense *grand programs* played an essential role in building and developing the French national system of innovation.[19] Figure 1 shows the links between public and private actors of the national effort of R&D. A significant amount of R&D is paid by the public sector but performed by the private sector and vice versa.

For 2004, the whole of public sector R&D funding represents nearly half of the total R&D funding (Figure 1). But in terms of where R&D is performed, its share is significantly lower (at €13.3 billion, it is just above one-third of the total). Two-thirds of public funding of R&D performed by the business sector is coming from defense (€1.7 billion defense R&D vs. €0.9 billion civilian R&D). Of R&D performed in-house by the public sector, defense represents approximately 10 percent (€1.2 billion vs €10.7 billion). And of the total government-funded defense R&D, €1.7 billion flows into the private sector, and only €1.2 billion stays within the government

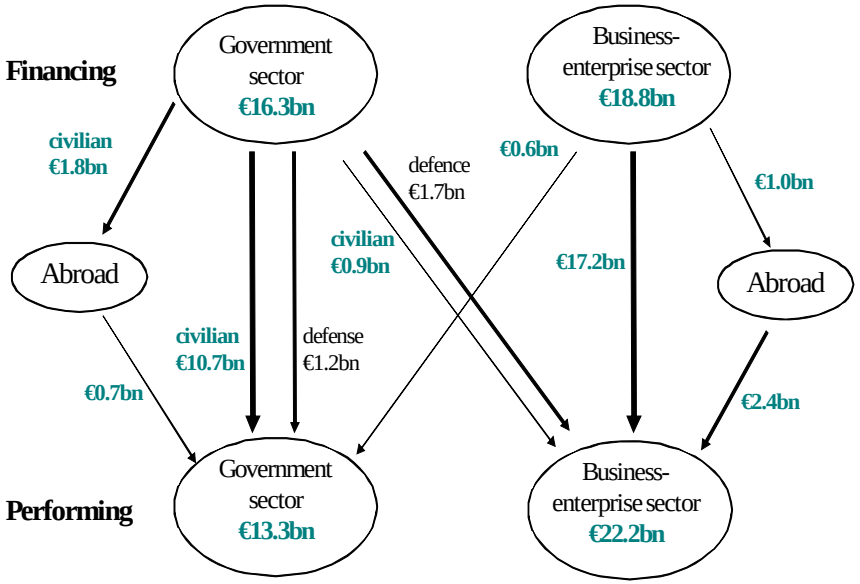

Figure 1: The French system of research and development
Source: French Ministry of Research data, 2004

sector. Thus, defense R&D constitutes a key link between public and private R&D efforts.[20]

Despite the recent defense R&D increase due to the 2003-2008 Military Programming Law that gave priority to equipment procurement, as compared to the early 1990s, the share of defense R&D in national R&D has declined (see Table A1 in the appendix). The share of defense R&D is U-shaped for the period 1992-2005, the bottom phase occurring in 2001. The level attained in 2005 is still far lower than the level attained in the mid-1990s, even when measured in nominal euro terms.

This quantitative change was accompanied by a structural change in the objectives of public funding. Traditionally, the French national system of innovation was both highly concentrated and publicly managed.[21] Nowadays, this is less true.[22] The strategy of the *grand programs*, both civil and defense, is no longer a priority and funding of bottom-up initiatives from the industrial sector and especially from small and medium enterprises (SMEs) are increasing. The growing role of complementary funding for private initiatives like the OSEO group, the Agence Nationale pour la Recherche and other institutions dedicated to the new *pôles de compétitivité* have changed the basic role of the public sector; its orientation and management activity is decreasing and it increasingly performs strictly a funding role.[23]

These new types of interventions carry strategic implications for defense R&D, even if not directly funded by the state. Since 2005, the French government identified 71 research clusters, each accompanied by a ministerial committee: out of the 7 "global competitiveness clusters," the Ministry of Defense (MoD) participates in the 5 committees dedicated to software, aeronautics, and nano and biotechnology. Among the 10 "globally-oriented competitiveness clusters," the MoD is present in 3 committees, and it also participates in 5 of the 54 other "competitiveness clusters."[24] This permits the MoD to keep in touch with the leading edge of technology, even if it is not (yet) specific to the defense sector. It is of major importance to identify possible disruptive technologies and other solutions are being explored, such as the use of venture-capital in strategic sectors.[25]

The major part of useful defense technology still comes from direct investments by the MoD. Nevertheless, since the early 1990s not only did the amount of defense R&D change significantly but so did its distribution. Table A2 shows two major trends. First, total R&D spending by the French Ministry of Defense decreased from 1992 to 1998 and then remained stable until 2001. From this date onward, an increased effort has taken place, but still not enough to bridge the gap. Second, the distribution of defense R&D funding between in-house performance and contracts given to firms and other research institutes also changed.[26] While both types of spending were reduced, the cut was 44 percent for internal research, but only 20 percent for research contracts performed outside the Ministry. Private firms therefore carried out a growing share of defense R&D. This finding is consistent with the new French arms procurement strategy, the *délégation générale pour l'Armement*, to give more responsibility to the business sector even in terms of research and development.[27]

The changing role of the defense industrial base in the French R&D effort

R&D funded by the Ministry of Defense is increasingly carried out by private firms. However, this funding is concentrated on a small number of companies, about 110 to 120 firms each year. Even if the number of SMEs financed directly by the Ministry remains stable over the period, the funding they received has been reduced. This can be explained in part by the transfer of responsibilities to large industrial prime contractors. Certain R&D contracts for SMEs are still maintained by the Ministry to secure access to disruptive technologies and to develop specific areas of interest.

Table A3 shows that defense R&D funding is a significant part of firms' total R&D expenditure, and its contribution is roughly stable (around 7 percent) since the late 1990s. Even if highly concentrated, the defense sector represents a significant source of funding for the business sector.

About one-quarter of firms' R&D in France is carried out by the few firms whose research is directly financed by the Ministry of Defense. These firms also account for about one-third of R&D outsourcing. This includes all industrial prime contractors and some very innovative SMEs. This is likely to have an important effect on driving the whole defense industrial base, as shown by its share in R&D and in particular in

Table 3: Distribution of defense funding toward firms by industrial sector

Sector	*Share of funding (%)*
Aerospace	48.8
Medical, precision, and optical instruments	17.4
Telecommunications	14.3
Weapons and ammunition	13.1
Parachemistry	3.3
Services	0.7
Other	2.4
Total	100.0

Source: Ministry of Research data, 2004.

the research outsourced by firms. These one hundred firms represent 10 percent of the sales of innovative firms, 23 percent of their R&D performed, and 33 percent of their outsourced R&D. The comparisons show that these firms are leaders of innovative networks. They are also highly concentrated in terms of the industrial sectors in which they operate (Table 3). The aerospace sector obtains nearly half of defense R&D funding. Together, the four main sectors (aerospace, instruments, telecommunications, and weapons) absorb more than 90 percent of the total.

Despite the significant overall funding decrease during the 1990s, defense funding steered toward industrial firms is still significant. The findings presented in this article demonstrate the growing role of industrial firms in the French defense R&D system as well as in the technical definition of defense equipment. Industrial skills and technical competencies seem to move from the Ministry to the main prime contractors. This evolution is due to internal as well as external factors, such as shrinking budgets, defense equipment cost escalation, and international cooperation led by European prime contractors.

The distribution of R&T credits (*études amonts*) among prime contractors illustrates the major role taken by Lead Systems Integrators such as EADS and Thales that capture almost half of the funding (Table 4). This is due both to the recent acquisition and merger activity within the French defense industrial base and to the new acquisition strategy of the French arms procurement agency, DGA, that tends to globalize contracts. It should also be noted that small and medium enterprises receive a steady share (10-11%) of the *études amonts* funding.

Conclusion

While limited in scope, the data used for this article permit us to extract stylized facts regarding patterns of national R&D systems in selected European countries. One finding is to show up the diversity of national R&D systems and the even greater diversity in defense R&D. There is no general link between the role of public effort in total R&D spending and priorities given to defense concerns.

The two European leaders in defense R&D are France and the United Kingdom, consistent with their overall defense effort and their strategic and international objectives. But their national R&D systems are quite different. The U.K. has little public R&D funding yet a large part of this is dedicated to defense (comparable to the United States); France has a larger public R&D funding but a relatively small part of this is dedicated to defense. In contrast, Germany has a low level of defense R&D despite a large overall R&D effort; despite having twice Spain's population, it spends less on defense R&D than does Spain.

As regards France, the trend in defense R&D is rising since the late 1990s but it has not yet closed the gap to the early 1990s, even in nominal terms. The data show the effect of the new strategy of the French defense procurement agency favoring industrial firms as from the late 1990s. Increasingly, France relies on the private sector to perform R&D, even for the defense sector. In 2004, two-thirds of publicly funded but privately performed R&D came from the Ministry of Defense; it plays therefore a major role in the relation between public and private R&D efforts.

Table 4: Main contractors in terms of R&T (études amonts)

	1998	*2003*
Alcatel	2	3
Dassault Aviation	6	3
Aérospatiale/Matra	8	-
Eurocopter	2	-
EADS	-	22
Giat industries	3	3
Sagem	3	3
Snecma	5	4
SNPE	3	1
Thomson	25	-
Thales	-	27
SME	10	11
others	33	23
Total	100	100

Source: Fromion (2005).

Notes

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1. Mowery (1998).

2. Following Metcalfe (1995), as cited by Sharif (2006).

3. OECD (2002).

4. EDA (2006).

5. OECD (2002).

6. The latest version is OECD (2002).

7. James (2006) for the United Kingdom; Molas-Gallart for Spain (1999); and Sachwald (1999) and Guichard (2004) for France. The quotes that follow in the text are taken from James (2006).

8. James (2006, p. 226, Table II).

9. See Molas-Gallart (1999).

10. OECD (2007).

11. Mowery (1998).

12. Mowery (1998, p. 640). In a recent book on defense technology, Ruttan also underlined the development of general purpose technologies induced by World War II and the Cold War (Ruttan, 2006, p.185).

13. On the U.K., see Hall and James in this issue.

14. The R&T aggregate is specifically used in the defense area and corresponds, roughly, to both basic and applied research.

15. In the 1980s the share of private R&D funding was increasing to the detriment of government funding in every OECD country studied (France, Germany, Japan, the United Kingdom, and the United States). But no clear-cut evidence in terms of R&D execution was found. See Mowery (1998).

16. EDA (2006).

17. Molas-Gallart (1999).

18. EDA (2006).

19. Serfati (1998 p. 21).

20. Also see Daffix and Jacquin (2007).

21. Mustar and Laredo (2002).

22. Foray (2001).

23. OSEO is a holding company with public status. Its mission is to provide assistance and financial support to French SMEs and VSEs in the most decisive phases of their life cycle: start up, innovation, development, business transfer, or buy out. By sharing the risk, it facilitates the access of SMEs to financing by banking partners and equity capital investors.

24. Ministry of Defense, PLF2008 (2007).

25. See Bellais, in this issue.

26. Bellais and Daffix (2005).

27. See Bellais, in this issue.

References

Bellais, R. 2009. “Defense innovation at any (out of control) cost? The stalemate of today’s R&D policy and an alternative model.” *The Economics of Peace and Security Journal*, Vol. 4, No. 2.

Bellais, R. and S. Daffix. 2005. “Evolutions de l’effort public et privé de recherche-développement et capacités d’innovation des firmes,” pp. 87-110 in R. Bellais, ed., *Economie et Défense*. Paris: Editions Descartes.

Daffix, S. and Y. Jacquin. 2007. “Quelques repères statistiques sur la R&D de Défense en France.” *Ecodef*. No. 48, (October) pp.1-4.

[EDA] European Defense Agency. 2006. *National Defense Expenditure in 2005*. http://www.eda.europa.eu/genericitem.aspx?area=Facts&id=179 [accessed 15 December 2007].

Foray, D. 2001. “On the French system of innovation: between institutional inertia and rapid changes.” Working paper 01/03. Paris: IMRI, Dauphine University.

Fromion, Y. 2005. “Rapport d'information n˚2150 sur la recherche de défense et de sécurité.” Paris: Assemblée nationale.

Guichard, R. 2004. “Eléments pour un repositionnement de la R&D de Défense au sein du système d'innovation français.” *Revue d'économie industrielle*, No. 108, 4ième trimestre, pp.7-20.

James, A. 2006. "The Transatlantic Defense R&D Gap: Causes, Consequences and Controversies." *Defense and Peace Economics*, Vol. 17, No. 3 (June), pp. 223-238.

[MESR] Ministry of Research. Various annual editions. *La recherche et développement en France*. Paris: MESR.

Ministère Français de la Défense. 2006. *Annuaire statistique de la Défense*. Paris: Ministry of Defense.

Molas-Gallart, J. 1999. "Measuring Defense R&D: A Note on Problems and Shortcomings." *Scientometrics*, Vol. 45, No. 1, pp. 3-16.

Mowery, D. 1998. "The changing structure of the U.S. national innovation system: implications for international conflict and cooperation in R&D policy." *Research Policy*, Vol. 27, pp. 639-654.

Mustar, P. And P. Laredo. 2002. "Innovation and research policy in France (1980-2000) or the disappearance of the Colbertist state." *Research Policy*, Vol. 31, pp. 55-72.

[OECD] Organization of Economic Development and Cooperation. Various years. *Main Science and Technology Indicators*. Paris: OECD.

[OECD] Organization of Economic Development and Cooperation. 2002. *The Frascati Manual*. Paris: OECD.

[OECD] Organization of Economic Development and Cooperation. 2007. *Main Science and Technology Indicators*. Paris: OECD.

Ruttan, V. 2006. *Is War Necessary for Economic Growth? Military Procurement and Technology Development*. New York: Oxford University Press.

Sachwald, F. 1999. "Banalisation et restructuration des industries de défense." *Les notes de l'Ifri*, No.15. Paris: IFRI.

Serfati, C. 1998. *Les industries européennes d'armement, de la coopération à l'intégration?* Paris: La documentation française.

Sharif, N. 2006. "Emergence and development of the National Innovation Systems concept." *Research Policy*, Vol. 35, pp. 745-766.

Appendix

Table A1: Distribution of national R&D funding

	National expenditure on R&D	*Business sector*	*Gov't sector (civilian)*	*Gov't national (defense)*	*Defense/ national expenditure*	*Defense/ total gov't sector*
1992	26,229	12,769	9,136	4,324	16.5%	32.1%
1993	27,002	13,307	9,620	4,075	15.1%	29.8%
1994	26,995	13,468	9,529	3,998	14.8%	29.6%
1995	27,563	13,916	10,184	3,463	12.6%	25.4%
1996	28,091	14,373	10,337	3,381	12.0%	24.6%
1997	28,005	15,025	10,320	2,660	9.5%	20.5%
1998	28,724	15,865	10,423	2,436	8.5%	18.9%
1999	29,885	16,618	10,760	2,507	8.4%	18.9%
2000	31,438	17,166	11,738	2,534	8.1%	17.8%
2001	33,570	18,897	12,163	2,510	7.5%	17.1%
2002	34,759	19,082	12,897	2,780	8.0%	17.7%
2003	34,395	18,505	13,061	2,830	8.2%	17.8%
2004	35,136	18,831	13,395	2,910	8.3%	17.8%
2005	37,125	20,156	13,861	3,108	8.4%	18.3%

Note: Data in € millions
Source: [MESR] Ministry of Research, several years

Table A2: Distribution of the defense R&D budget by R&D-performing sector

	1992	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Defense expenditure on R&D	4,323	4,075	3,999	3,464	3,381	2,660	2,436	2,507	2,533	2,509	2,781	2,829	2,910	3,108
intramural R&D	1,973	2,005	1,945	1,589	1,585	1,013	774	777	777	848	874	993	1,075	1,175
Extramural R&D	2,350	2,070	2,054	1,875	1,796	1,647	1,662	1,730	1,756	1,661	1,907	1,836	1,835	1,933
of which performed by:														
- the government sector	163	158	222	206	242	230	362	299	234	206	278	205	130	119
- the higher education sector	17	16	19	26	25	14	11	8	7	6	7	8	7	6
- the nonprofit private sector	4	5	8	8	8	0	0	0	0	0	0	0	1	1
- the business sector	2,149	1,874	1,788	1,618	1,500	1,386	1,273	1,407	1,497	1,432	1,604	1,608	1,680	1,790
- the foreign (abroad) sector	17	17	17	17	21	17	16	16	18	17	18	15	18	17

Note: Data in € millions
Source: [MESR] Ministry of Research, several years

Table A3: Total expenditure of firms' R&D by sector of funding

	*Total expenditure**	*| financed by: | (a) firms*	*(b) government*	*of which: (a) defense*	*(b) abroad*
1991	16,567	11,395	3,423	n/a	1,750
1992	17,664	12,588	3,136	2,133	1,940
1993	17,957	13,221	2,897	1,874	1,840
1994	17,890	13,352	2,681	1,788	1,858
1995	17,979	13,778	2,351	1,626	1,850
1996	18,471	14,195	2,331	1,500	1,945
1997	18,612	14,785	1,994	1,386	1,834
1998	18,972	15,497	1,824	1,273	1,651
1999	20,004	16,183	2,174	1,407	1,646
2000	20,971	16,962	2,259	1,497	1,749
2001	22,591	18,680	2,110	1,432	1,800
2002	23,605	18,871	2,498	1,604	2,236
2003	23,021	18,318	2,444	1,608	2,258
2004	23,562	18,545	2,620	1,680	2,396

Note: Data in € millions
Source: [MESR] Ministry of Research, several years
* Total expenditure includes R&D performed by firms plus R&D outsourced by firms toward government sector and abroad