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Defence Industry Restructuring: the End of an Economic Exception?

Frédérique Sachwald

Translated by David Lyman Neal

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Institut français des relations internationales

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"The industries linked to defence are an essential component of France's level of technological and industrial development. It has been possible to mobilise this technological potential in the civilian field, and it has been a significant factor in the development of high-performance products..."

[CGP 1993, p.17]

"Now it is civilian research which drives military research"

Jean-Yves Helmer,
delegate-general for Armament [Helmer 1999]

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Abstract

The defence industry is no longer an economic exception; it fits into the logic of the market economy and companies are reacting more and more to competitive pressures. To what extent does this *banalisation* of the defence industry enable it to understand the move towards restructuring in the 90s?

The conjunction of the strategic necessities of the Cold War and of procurement procedures developed by defence ministries has led to barriers between defence industries and commercial activities, which constitute barriers to the purchase of commercial parts and the exploitation of dual technologies. Yet since the late 60s, innovation dynamics have reversed the traditional pattern of spin-offs from military research towards civilian sectors – the paradigm of the *spin-off* has given way to *spin-on* dynamics. Reductions in military budgets and equipment credits constitute the second factor behind the end of the defence industries' exceptional character. Military credits are now more subject to the general principle of budgetary arbitration, which has led to a search for greater efficiency in the production of weapons systems.

This study shows that the search for efficiency, whether it be in terms of production costs or in terms of innovation, argues in favour of greater integration of civilian and military productive capacities. When viewed from this angle, an industrial policy in the defence sector should include a rethinking of the demands which the authorities make on companies – at the national and European level. The scope and effectiveness of the restructuring process depend in particular on this demand-side change, which influences systems manufacturers' strategy of refocusing on defence activities and possibilities for international co-operation on a European or even transatlantic scale.

Résumé

Une version française de ce texte a été publiée dans « Les notes de l'Ifri » (n° 15)

Banalisation et restructuration des industries de défense

L'industrie de défense n'est désormais plus une exception économique ; elle s'insère dans la logique de l'économie de marché et les entreprises deviennent plus réactives aux pressions de la concurrence.

Dans quelle mesure cette *banalisation* de l'industrie de défense permet-elle de comprendre le mouvement de restructuration des années 90 ?

La conjonction des nécessités stratégiques de la guerre froide et des procédures d'acquisition élaborées par les ministères de la défense a engendré des barrières entre les industries de défense et les activités commerciales, qui constituent des obstacles à l'achat de composants commerciaux comme à l'exploitation de la dualité des technologies. Pourtant, depuis la fin des années 60, la dynamique de l'innovation a renversé le schéma traditionnel des retombées de la recherche militaire vers les secteurs civils – le paradigme du *spin-off* a fait place à une dynamique du *spin-on*. La réduction des budgets militaires et des crédits d'équipement constitue le second facteur de banalisation des industries de défense. Les crédits militaires sont désormais plus soumis au principe général de l'arbitrage budgétaire. D'où la recherche d'une plus grande efficacité de la production des systèmes d'armes.

Cette étude montre que la recherche de l'efficacité, que ce soit en termes de coûts de production ou en termes d'innovation, milite en faveur d'une plus grande intégration des capacités productives civile et militaire. Dans cette perspective, une politique industrielle dans le

secteur de la défense devrait comporter une révision de la demande que les pouvoirs publics adressent aux entreprises – aux niveaux national et européen. L'ampleur et l'efficacité du processus de restructuration dépendent notamment de cette évolution de la demande, qui influence la stratégie de recentrage des systémiers sur les activités de défense et les possibilités de coopérations internationales – européennes, voire transatlantiques.

■ Introduction

Even in the capitalist countries, the defence industry has long remained isolated from the logic of the market economy. As a result, industrialists have developed operating modes specific to this sector where the State, which was above all anxious to safeguard national security, dealt with only a few national champions[1]. This configuration, designed to ensure an industrial base for national defence capable of delivering high-tech weapons, did not lead companies to adopt efficient behaviour, particularly with regard to cost control.

From the early 90s onwards, the factors which had justified the defence industries' isolation from market forces were largely called into question. The end of the Cold War meant the end of the direct and permanent threat hanging over the security of the Western countries and brought about a radical revision of defence strategies. This in turn led to sharp cuts in military budgets, including acquisition credits for armies. This first massive and fundamental trend has been amplified by the impact of technological dynamics, which have modified both the characteristics of weapons and industrial production methods.

The evolution of strategic thinking clearly relies on the analysis of threats, but also on the types of weapons made possible by a country's technological capabilities. Information technologies and electronic advances have led strategists to rethink their conception of combat[2]. The Americans have put forward the concept of a *revo-*

1. Exports presuppose prior orders by the State of the exporter's country.
2. These technological fields are often singled out, but many others play a part in the evolution of weapons, for example, new materials.

lution in military affairs to underscore the radical nature of this evolution. The debates around this notion admittedly show that what is involved is an analytical framework, a target designed to federate reflection, rather than a clear strategy designed for rapid implementation [3]. The fact remains that available technologies do orient equipment design towards more accurate weapons, which are often operated by remote control and which are to be used within the framework of increasingly sophisticated networks for gathering and processing information. Thus, weapons have undergone an evolution comparable to that of industrial production overall, which uses fewer and fewer materials and less and less energy while incorporating an ever-increasing amount of information and services.

The importance of cutting-edge technologies in new weapons design presupposes that defence industries are able to rely on solid skills in these fields. Since the end of the 60s, however, it has increasingly been *civilian* industries which introduce innovations in the fields of electronics, information technology and new materials. Defence industry has stopped being a pool of state-of-the-art technological capacities and the main driving force of radical innovation. In this context, the protection of defence industries and the subsidies which they may receive are no longer justified by the argument of civilian spin-offs from military R&D spending.

The aim of this study is to examine to what extent the economic *normalization* of the defence industry enables us to understand the restructuring movement it has undergone in the 90s. The process of normalization of the defence industry means that it has become more subject to the logic of the market economy and that companies have become more reactive to competitive pressures. This perspective enables us to grasp the determinants of the restructuring movement

3. The agitation around RMA reminds us that, just like in other fields, there are intellectual fads in strategic thinking that are based on the consideration of new factors whose importance tends to be blown up; See [Grant 1998, Murawiec 1998, Tertrais 1998].

within the defence sector and to envisage its scope over time, at the national and international level.

The first part explores the respective role of budget constraints and innovation dynamics in the process of normalization of defence industries. The second part analyses the restructuring process under way by incorporating economic determinants on the one hand and the security constraint particular to the defence industries on the other hand. It bases itself on the US experience to take up the case of the European industries.

■ The End of the Military Exception

This first part identifies the two major developments which have challenged the defence industries' status of an exception to the rules of the market economy. National defence efforts have been scaled back in the majority of the industrialised countries. The technological dynamics which quicken the pace of innovation and rely on fields of generic knowledge with multiple uses pay no heed to borders. On the other hand, innovation systems have marked national characteristics, such as the size and degree of isolation of military R&D. Accordingly, the economic role of the defence industries and the various countries' conceptions of the imperatives of defence and sovereignty explain why, although new economic constraints are felt everywhere, national reactions have been more or less rapid.

The Budget Constraint

The End of a Major Conflict

Ever since the end of the Cold War, the NATO countries have significantly cut back their national defence efforts, traditionally measured by the share of military spending out of Gross Domestic Product (GDP). Table 1 shows that the NATO countries and their allies have reduced their defence efforts by around one-third during the 90s. Although Japan has not scaled back its spending, it remains at the

Table 1
Military Spending as a % of GDP

	1985	1990	1995	1997	1997/1990, %
United States	6.4	5.3	3.8	3.4	– 36
France	4.0	3.6	3.1	3.0	– 16
United Kingdom	5.1	4.0	3.1	2.8	– 31
Germany	3.2	2.8	1.7	1.6	– 44
Italy	2.2	2.1	1.8	1.9	– 10
Japan	1.0	1.0	1.0	1.0	0
NATO allies	n.a.	2.9	2.2	2.1	– 25
NATO/Allies in the Pacific/Gulf[1]	n.a.	3.7	2.6	2.5	– 32

n.a.: non available.
1. Pacific: Japan and Republic of Korea; Gulf: Gulf Cooperation Council.
Sources: Department of Defense (U.S.), SIPRI for 1985.

lowest level of all of the countries mentioned in table 1. The US has made particularly deep cuts (– 36%), as a result of which its defence efforts have come closer, in relative terms, to those of its partners. Conversely, France has made relatively small cuts, as a result of which, at the end of the 90s, it has come much closer to the US and has outstripped the UK.

This reduction in defence efforts is remarkable for two reasons. First of all, its scope is remarkable, at the national and international level. Admittedly, this is not the first cut in defence budgets since the end of the Second World War; the advent of an armed conflict logically generates a swelling of military budgets, as was the case with the Algerian war in France and the Viet Nam war in the US. In the context of the Cold War, the Star Wars project had led to a significant increase in the US military budget during the 80s. Accordingly, the end of the Cold War corresponds to a peak in military spending, which underscores the magnitude of the drop recorded in the 90s. This drop has also been amplified at the world level insofar as the conflict concerned the main military budgets, not that of a given country. The end of the Cold War can be analysed as the end of a major conflict, which explains the sharp cuts in military spending that are likely to be lasting.

The scope of the cutbacks in military spending is also remarkable in terms of the way it has been presented to citizens. The end of the Cold War held out the hope of an international context which was more peaceful, and in any case free from a constant threat to the survival of the Western countries. Governments therefore undertook to reallocate part of military spending within national budgets, with a view to distributing "peace dividends". This line of reasoning clearly brings out the principle of arbitration between the different types of spending, and underscores that military spending has become much more subject to this arbitration than in the past – even though national differences persist.

Defence industries are concerned by cutbacks in military spending insofar as the amounts set aside for equipment are indeed affected – as has well and truly been the case[4]. The US budget for the procurement of military equipment was reduced from US$ 160 billion in 1987 to $ 80 billion ten years later[5]. In France, sums spent on equipment plummeted 32% between 1991 and 1998[6].

The Reduction in Production Runs

The reduction in orders for the defence industries has been reflected by a contraction of activity and has led to an unbearable rise in production costs.

Cutbacks in equipment budgets may be seen in the lower turnover figures for companies specialising in defence. Table 2 shows that the arms sales of the 100 leading companies in the sector in 1990 fell by more than 30% between 1990 and 1995. Some of these companies

4. In 1997, equipment accounted for 33% of all military spending in the UK, 28% in France, 17% in the US and 12% in Germany [IISS 1997].
5. In 1997 dollars. These figures include the acquisition of equipment *strictu sensu* and military R&D spending. In 1997, procurement alone came to $ 43 billion.
6. Falling from FF 115 billion to FF 80 billion (Chapter V credits – manufacturing and studies, in constant 1997 francs); the share of "manufacturing" went from 26% of the defence budget in 1990 to 18% in 1998 [Hébert 1998].

Table 2
Arms sales of the 100 largest world producers, classified by region, in billions of constant 1995 dollars

Zone	100 leading firms in 1990			100 leading firms in 1995		
	Number of firms	Arms sales		Number of firms	Arms sales	
		1990	1995		1990	1995
United States	46	129.1	88.1	40	111.6	87.7
OECD, Western Europe	41	71.0	49.0	40	66.5	53.0
Other OECD	7	10.6	7.4	12	11.5	9.1
Developing countries	6	5.6	3.4	8	6.2	4.2
Total	100	216.3	147.9	100	195.8	154.0

Source: [SIPRI 1997].

left the sector between those two dates, but the drop in orders exceeded 21% for the companies present in this sector in 1995. This came as a major shock for the industry, which had grown used to seeing orders increase.

Defence industries incorporate numerous more or less complex assembling operations, yet companies can hardly exploit the potential for economies of scale or learning due to the limited size of production runs. Indeed, the defence industry is relatively small[7]. In 1995, turnover was equivalent to that of the semiconductor sector alone, i.e. $ 151 billion. The computer industry has a turnover of $ 290 billion as against more than $ 160 billion for telecommunications. In the EU, turnover for the automobile sector totals 420 billion ecus, i.e. around 8 times that of the defence industry ($ 53 billion, table 2).

7. It is not easy to differentiate a “defence sector” in economies due to interpenetration with other sectors and the duality of numerous components, see [EEC 1996, Susman, O’Keefe 1998].

Economies of Scale and Economies of Learning

The production techniques of the assembling industries are characterised by considerable potential economies of scale and of learning. The first phenomenon means that the unit cost of production declines with the quantity produced per unit of time. The reduction in the unit cost may be explained by the adoption of a different organisational structure for production as the quantity produced rises. Thus, *mass production* requires special equipment and a specific organisational structure.

Economies of learning are due to the fact that complex assembling operations are progressively better mastered, whether it be by an individual or an organisation: the reject rate declines while speed of execution increases, leading to a drop in unit cost as total production increases. Strong learning economies may generate specific strategies of price-related competition based on winning a large market share, as in the case of semiconductors.

Shrinking budgets have led governments to scale back certain procurement programmes, which lower economies of scale and increases in unit costs. In addition to this first source of cost increases, the defence industries are subject to the general phenomenon of increases in R&D spending (hence overheads). When combined, these two trends lead to such an increase in unit costs that they can no longer be covered by military budgets[8].

In the 90s, the cost of an American F-16 combat airplane, which was developed in the 70s, is around $ 30 million[9]. The combat plane which Japan developed on the basis of the F-16 features improvements over the original model, but the project is far behind schedule and each unit will cost around $ 80 million. The European Eurofighter and the F/A-18 of the US Navy, both scheduled for roll-out at the

8. In other sectors, such as pharmaceuticals or automobiles, companies have adopted strategies which enable them to make up for increases in R&D spending.
9. The source of data on unit costs for combat airplanes is [Grant 1997].

beginning of the next century, will cost around $ 50 million each[10]. The F-22, developed by Lockheed Martin, will cost more than $ 100 million. These estimates show that in the future, apart from the US, no one country will be able to develop a combat airplane on its own. Moreover, in Europe, there is little chance of a reccurrence of a situation in which three different planes (Rafale, Gripen and Eurofighter) are developed at great cost. For its next combat plane, the US has imagined a modular programme: the needs of the three armies will be met by adapting a basic plane. The Joint Strike Fighter is also designed to equip the British Royal Navy so as to achieve a high production level (2,900 planes) and to limit unit costs to around $ 30 million.

Governments will be increasingly inclined to behave like "customers", i.e. they will demand the best value for money and stop systematically opting for performance. Production constraints will therefore lead companies to lengthen production runs. Yet they are no longer able to count on export markets, which are shrinking owing to the strategic context and the lasting economic difficulties of certain importing countries. In these conditions, increasing market share is the only way to lengthen production runs. Companies are thus led to adopt different production techniques, borrowed from commercial industries whose efforts to get a grip on costs and deadlines have become vital in the context of globalisation. US companies and BAe have started working towards these two goals, with remarkable results in terms of profits and share appreciation[11].

Cuts in military budgets are thus a major factor when it comes to integrating defence industries into the logic of the market economy. Technological dynamics constitute the other fundamental factor for the future evolution of defence industries and their economic normalization.

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10. When the four countries in the programme ordered 148 Eurofighters, the price was around $ 55 million [*Air & Cosmos,* 25/09/98, p. 13].
11. Share prices for the top 20 US arms companies quadrupled between 1990 and 1997 – i.e. a considerably larger increase than that of all sectors combined [Delétang 1998].

Technological Dynamics

R&D spending financed by military budgets and the entire system for the procurement of defence equipment contributed significantly to the technological base of the industrialised countries. After the Second World War and up until the 60s, military technologies were more sophisticated than the technologies utilised by civilian industries. Substantial military investments and a lack of commercial pressure made it possible to support basic research efforts, train scientists and develop generic technologies, which were subsequently exploited in various productive sectors.

Starting at the end of the 60s, the tremendous growth of the industrialised economies, combined with the fact that more and more countries are participating in the knowledge accumulation process and competition between firms at the international level, has modified the dynamics of innovation. The stronger relative growth of the civilian sectors constitutes a fundamental change. It has made it possible to invest ever-greater sums in research, culminating in growing technological sophistication of civilian sectors. Innovation dynamics is stimulated by growing competition at the world level. If defence industries want to remain at the technological frontier, they have to take due account of the fact that civilian technologies have often taken the lead. Moreover, the declining relative size of defence markets means that they have become less important from the viewpoint of a whole sector or a technology – e.g. electronics or new materials – a trend which can have a negative impact on the importance companies attach to their specific needs. Admittedly, the arms supply business has traditionally been more profitable than certain competitive markets, but this does not necessarily constitute a long-term guarantee. Companies may fear a field in which turnover is stagnant and fragile, while innovation requires very substantial investments and diversified skills.

The Challenge to the Spin-off Paradigm

During the post-war period and up until the 70s, technological performance often seemed to depend on military spending. According

to the *spin-off paradigm*[12], the volume of military R&D spending determined national technological performances. This schema was based on the case of the US, which remained the unchallenged leader of the free world up until the 60s, both militarily and technologically speaking. In the context of the Cold War, the volume of military spending and the large share of R&D funds earmarked for defence were taken for granted. In the 50s, military research played a key part in the advent of fundamental innovations such as semiconductors, jet airplanes or communication satellites[13]. These innovations, which spread throughout civilian industries, like America's unchallenged lead, gave credit to the theory that military spending generates substantial civilian spin-offs. Military expenditure was thus justified from the point of view of both defence and industrial performance; it ensured the security and power of the US in two different ways. France, which developed an arms industry covering the gamut of defence equipment in order to safeguard its strategic independence, viewed its military R&D spending in much the same way[14].

The spin-off paradigm was fundamentally challenged by the proliferation of innovations of civilian origin, not only in the US but also in Europe and Japan. From the 60s onwards, the military's share of R&D spending declined in the US, and America's share of total R&D expenditure declined. Thus, America's share of military R&D spending out of total R&D spending for all OECD countries dropped from 33% in 1960 to 17% in 1970 and 12% in 1980, before rising slightly owing to the military expenditure approved during the Reagan administration [Alic *et al* 1992]. In these conditions, it became more and more difficult to view America's R&D spending as the major source of innovation. This trend has been reinforced by the efforts which the

12. According to the expression coined by [Alic *et al* 1992].
13. In certain cases, the prospect of massive military procurement played a more important part than the military R&D spending itself. This was the case for the development of semiconductors, for which the initial research was conducted by private US firms using private funds [Mowery, Rosenberg 1989, Alic *et al* 1992].
14. For an affirmation of this concept, see [CGP 1993].

Table 3
Military Spending as a % of Government R&D Spending*

	1985	1990	1995	1997
US	67.6	62.6	54.1	55.0
France	32.5	40.0	30.0	27.7[p]
United Kingdom	51.0	42.5	37.0	n.a.
Germany	11.9	13.5	9.1	n.a.
Italy	9.9	6.1	4.7	n.a.
European Union	n.a.	22.8	16.4	n.a.
Japan	n.a.	5.4	6.2	5.8

* Funds for defence R&D as a % of total R&D budget funds.
[p]: provisional.
n.a.: not available.

Source: OECD science and technology indicators, various years.

other industrialised countries were making to catch up, but the decline in military R&D spending as a percentage of national innovation is a general trend. It came well before the reduction in military spending in the post-Cold War era, which merely reinforced the phenomenon (table 3).

The reduction in the military's share of R&D did not stem first of all from budget restrictions, but rather from the increase in research investments made in the civilian sectors. This trend in government funds (table 3) was amplified by the rise of research investments by private companies. Starting in the 70s, the private sector was the source of a growing flow of innovations. International comparisons further showed that Japan and Germany, which invested relatively little in military R&D and whose innovation systems were not based on the spin-off paradigm, were particularly dynamic in various civilian sectors, so much so that they competed successfully with American companies, including in the US[15].

15. The phenomenon gave rise to a wave of concern as to America's competitiveness and various studies on this topic (in particular [Dertouzos *et al* 1989], which was particularly influential).

The challenge to the spin-off paradigm, which had often been accepted as a sort of postulate[16], gave rise to studies designed to evaluate the role of military R&D in the innovation system. In an initial phase, these studies showed that research projects carried out within the framework of military programmes could turn out to be very costly owing to the extremely demanding performance requirements and a lack of commercial constraints[17]. These same characteristics could complicate or even preclude transfer to civilian sectors. In these conditions, the positive externalities of the defence sector with regard to innovation could never be effectively exploited. The added costs paid by the army in connection with equipment programmes could therefore not be justified by quasi automatic civilian spin-offs. When viewed from this angle, the allocation of innovation resources between civilian and military research may have to be reexamined.

In a second phase, as certain civilian sectors became particularly innovative, the debate shifted towards the issue of *dual technologies*. The aim was no longer to measure the spin-offs from military innovation, but rather to assess to what extent the overall innovation process could be made more efficient. This approach to the problem drew the lessons from the dynamism of the civilian sectors to try and reduce innovation costs for military budgets or even to enhance the performance of weapons systems. The underlying hypothesis was practically reversed, as the source of the spin-offs was more likely to be civilian than military[18]. This is especially true of the body of information technologies, which have become central factors in modern-day economies.

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16. [Alic *et al* 1992] stresses this trend for the US. A 1993 report by France's Plan (planning body of the French Government) largely bases its analysis of research funding on this postulate of spin-offs, while making rapid allusions to the progress made by civilian industries [CGP 1993].

17. These programmes are subject to the *great project syndrome* as analysed by literature on innovation – particularly in the French case – namely, strong ambition in terms of innovation, which allows the requirements of various sources to find expression and gives priority to technical exploits over deadlines and cost considerations. This tends logically to lead to delays and cost overruns.

18. This marked a shift from the spin-off paradigm to the hypothesis of spin-ons from the civilian sector.

Table 4
Demand for Electronic Components in Europe,
in US $ billions

Sectors	1997	1998	2002
Computers	57.2	63.4	95.1
Communications	61.6	65.6	76.4
Industry	32.2	34.5	47.9
Consumer electronics	23.8	25.0	30.6
Aerospace and military	20.52	20.5	20.2
Transport	9.7	11.2	18.0
Total	209.7	225.5	296.5

Source: Gartner Group, quoted in *Les Echos*, 17/09/1998.

Even though, historically speaking, semiconductors, computers and telecommunications owe a great deal to the research efforts and orders of the US Department of Defense, civilian sectors have become the leaders with regard to innovation – and not only in the US. This evolution is due both to the relative size of civilian orders on the one hand and military orders on the other hand, and to the incentives generated by competition in commercial sectors. It is particularly interesting to track demand for electronic components since they constitute a growing share of the value added to weapon systems. Table 4 shows that military demand is not very dynamic compared to the other sectors; in Europe, its share of the total is expected to fall from 9.8% to 6.8% by the year 2002.

Growth in civilian sectors has been driven by the penetration of new products such as mobile telephones, where growth tops 20%, and by the increase in the value of electronic components in certain capital goods, such as cars[19]. In the future, the growing tendency to include sophisticated navigational systems in cars will continue to increase demand for electronic components.

19. At the rate of 17% per year up until the beginning of the 21st century [*Les Echos*, 17/09/1998].

Rethinking Technological Duality

From the industrial point of view, a technology is dual if it is likely to be applied for the development of both military and civilian products or processes. The term is somewhat vague; for example, it does not indicate whether the origin of the technology is military or civilian [20]. In fact, the majority of technologies can be used in different applications; they have multiple uses. Thus, what matters is not identifying technologies which are supposedly intrinsically dual [21] but rather determining to what extent the potential for duality can actually be tapped. Military procurement officials are primarily interested in companies' ability to use technologies developed by civilian industries to limit military R&D costs. Viewed from this angle, what matters is assessing to what extent adapting to commercial markets results in arbitrations unfavourable to military requirements.

Two Innovation Cultures

Technologies of the various productive sectors rely on a largely common base and lend themselves to various adaptations [22]. The source of the divergence between civilian and military production is not in fact intrinsically technological, but rather stems from the unfolding of the innovation process.

Table 5, which is based on analyses of innovation economics, makes it possible to identify the key elements which determine the unfolding of the process and the results in terms of product type, production methods and costs. The starting-point is the innovator's motivation. In the commercial sector, companies are motivated by potential profits – innovation is a fundamental means of protection against price-based competition. This in turn explains the concern to innovate in order to

20. This origin is important for envisaging the types of policies for the promotion of dual technologies. See below.

21. For an attempt to characterise the degree of duality of a list of technologies, see [CGP 1993, Appendix 5].

22. Strictly military technologies, such as those used in the materials for stealth planes, are relatively rare.

Table 5
Civilian and Military Innovation: Two Cultures

	Civil/Commercial	Military
Impetus for the project	Market-driven, opportunistic introduction of new projects	Needs expressed via military procurement
Definition of innovation[1]	Successful introduction of a new product, process or service on the market	Introduction of a new product, process or service in the defence field
Nature of response to demand	Rapid incremental improvements punctuated by more fundamental new conceptions	Improvements in major qualitative leaps
Interactions between R&D and production	Integrated management of R&D, production, and consumer service	R&D and production work carried out sequentially
Product life cycle	Measured in years or even months	Measured in decades
Priorities of production methods	Organisational structure/techniques aimed at cost savings, quality and flexibility	Organisational structure/techniques aimed at performance of functions and product longevity
Production characteristics	■ Short deadlines and high volumes (consumer markets) ■ Imperative release dates for seasonal products	■ Long deadlines and low volumes ■ Frequent postponement of introduction dates
Dissemination of technologies	Success based on proprietary technological advantage (sharing in case of network effects)	In the name of security, the authorities can demand that technologies be shared with a second source, or restrict dissemination

1. The definitions given, and in particular that of commercial innovation, make it possible to distinguish innovation from invention. A number of inventions never become innovations in the sense of market successes.

Source : Adaptation on the basis of the outline proposed by [Alic *et al* 1992].

respond to demand, as it is expressed or as the company attempts to perceive and encourage it. The success of innovation is not decided in company laboratories, but rather on markets downstream of the R&D phase. Thus, (successful) innovation integrates all of the characteristics of the new proposal made by the firm, not only the strictly technical aspects but also design, marketing and price.

This explains the choices and constraints in terms of production processes in table 5: integration of research with design of production methods and commercial aspects[23], capacity for minor changes in products and production techniques according to demand; search for volume.

Motives for innovation are very different in the defence sector. Indeed, they are due to a large extent to requests by the army. However, the army does not express its needs directly through a defence market. In general, defence officials constitute an intermediary who interprets needs and offers to subsidise research efforts in a given field if they are likely to meet these needs. Thus, what matters for companies is convincing others in an initial phase of their capacity for innovation, and then possibly responding to a bid concerning production[24]. On the other hand, what counts is not selling on a market, but rather convincing an administration for which price is a decision-related element that traditionally carries less weight. In all cases, production runs are limited, which precludes substantial economies of scale. Consequently, price control is ensured by procedures rather than market discipline.

The emphasis placed on strictly technical performance is conducive to experimentation and the development of costly features – even if improvements are relatively minor. The little weight given to cost variables in arbitrations does not encourage companies to introduce cost-saving pro-

23. Marketing is increasingly integrated in the innovation process. Whether it be in the automobile sector or in the agrofood industry. Companies seek to find out what clients are looking for via constant surveys.

24. The exact procedures vary from one country to another, depending in particular on whether companies which supply defence equipment are nationalised or not.

duction techniques. These different factors combine to yield products that are extremely sophisticated as well as costly production methods.

This summary of the traditional characteristics of innovation processes in the civilian and military sectors makes it possible to grasp the origin of the notion of dual technologies. Technologies which are separate and incompatible to a certain extent have developed progressively from a largely common basis for cultural and organisational reasons.

Specialisation and Divergence of Technologies

The scope of the divergence of civilian and military technologies depends first and foremost on the type of functions considered. Thus, it is logical to note that the potential for duality is higher with aviation and electronics than with munitions, armoured vehicles or submarines. Technological divergence also depends on the life cycle of the products and processes considered.

When an innovation first appears on the market, it only partly meets users' needs and is technically incomplete. Accordingly, there is a phase of experimentation during which various companies' entry onto the market makes a selection with regard to functionalities and design which end up dominating the market [Geroski 1995]. During the next phase, the market expands sharply, allowing for product standardisation and the application of more efficient production techniques [Vernon 1966, Abernatly 1978].

During the *experimentation* phase, knowledge of the future potential of an innovation is still very incomplete, which is why various types of information are sought via multiple experiments. The *rationalisation* phase begins when the technology starts to become better known. In this second phase, the different types of users have identified their interests and develop the technology according to their own needs. During this specialisation process, military uses on the one hand and civilian uses on the other tend to diverge. Thus, a technology's potential for duality tends to diminish as it matures.

The hypothesis of a life cycle of duality makes it possible to explain how military spending on R&D and equipment has been instrumental

in the development of generic technologies in the past. On the other hand, the more military expenditure finances specific developments and equipment, based on proven technologies, the more sharply its productivity falls off in terms of innovation and civilian spin-offs [Nelson 1993]. This could indeed be the case since basic or upstream research tends to represent a falling share of military spending.

The hypothesis of the divergence between civilian and military applications throughout the life cycle indeed corresponds to certain developments. In aeronautics for example, military research has made major contributions, but the advent of the supersonic era for military airplanes has led to a major divergence with the development of commercial models[25].

This hypothesis is not always as relevant, as illustrated by the case of CMOSs (Complementary Metal-Oxide Semiconductors). CMOS technology constituted a major advance in comparison with bipolar transistors in common use in the 60s. These semiconductors, which were complex to manufacture, were gradually perfected by the Japanese industry for use in watches (their energy consumption is very low). Demand was stimulated by consumer electronics, which helped to make CMOSs the dominant technology for components with a favourable cost/performance ratio. They went into everyday use in military products where weight and bulk are important variables [Alic *et al* 1992]. In this case, the convergence of interest in the technology was asserted after the civilian industry had standardised the component and lowered its cost. This example suggests that the life cycle hypothesis should no doubt be supplemented with a possibility of (re)convergence for a very high level of standardisation – which is logically more frequent with components than with finished products. It is the case in particular for a number of electronic components[26].

25. European and American attempts to manufacture supersonic commercial planes, relying in particular on military developments, have by and large ended in failure – from the point of view of the products' relevance (both technical and economic) for civilian markets [Mowery, Rosenberg 1989].
26. In 1995, France has stopped its funding of the development of military electronic components by terminating the Paceo programme.

The CMOS example suggests moreover that military research does not necessarily participate in the development of a new technology, even an important one, and even in a field which is highly relevant to the defence industries. It is interesting to note that this example comes from Japan, which did not develop a defence industry after the Second World War. This case may therefore suggest that technological breakthroughs occur in fields where a country is making significant research efforts – whether it has civilian goals, such as economic power, or military ones. In the case of France, the nuclear sector, both civilian and military, could serve as an illustration.

In reality, the contribution of military R&D spending to innovation is largely due to the fact that what is involved is public expenditure, i.e. expenditure that is not subject to the decision-making process of private companies, motivated by the profit they could derive from proprietary technologies. In the case of the US, the positive externalities of this government spending have been amplified by a mechanism for dissemination to different companies[27]. Nevertheless, innovation economics and the studies conducted in different countries have shown that these dissemination mechanisms have also been very effective in civilian fields [Ergas 1989, Nelson 1993]. These dissemination efforts are designed to optimise the public benefit nature of the research, i.e. its simultaneous and diversified use by different players[28].

Stimulating Innovation in the Defence Industries

For some ten years now, the authorities responsible for military procurement have been aware of the erosion of systems founded on the spin-off paradigm (implicitly or explicitly). The US and British authorities

27. See [Mowery, Rosenberg 1989]. For the role of research in computer science and software in American universities, see [Mowery 1996].
28. Owing to the question of additional costs, knowledge is not public property in the purest sense of the term; very often, exploitation of knowledge entails investments which are specific to each new user.

in particular have taken several initiatives to rationalise procurement procedures and stimulate the flow of innovation in the defence industries. These initiatives include *inter alia* policies of promoting duality or integration of civilian and military technologies (see box below). Available studies on the results of some of these initiatives underscore the usefulness of duality for the defence industry but also point to difficulties with regard to implementation [OTA 1995, Richardson 1996].

The Paths of Technological Duality

There is no definition of technological duality or policies to promote the integration of civilian and military technologies[1]. However, at the end of the 90s, proponents of this integration generally deemed it appropriate to include all methods, including the use of civilian commercial off-the-shelf equipment and the adaptation of civilian products upstream of the development process[2]. In fact, the various approaches imply a state of mind, a voluntary pro-duality approach, for they often presuppose collaboration.

The US Congressional Office for Technological Assessment [OTA 1995] has adopted a definition for the integration of civilian and military technologies which encompasses the various methods: the process of merging the Defense Technology and Industrial Base (DTIB) and the larger Commercial Technology and Industrial Base (CTIB) into a unified National Technology and Industrial Base (NTIB). This process concerns at the most general level a sector as a whole, but also impacts on companies and even production units. At the end of such an integration, the production technologies, processes or units stemming from this common base can be utilised to meet the needs of the different types of manufacturing. To clarify this conception of extreme integration, the OTA adds that decisions relating to the utilisation of the resources of this common base are founded on the technical, legal and economic reasoning generally employed by commercial enterprises.

1. See in particular [Gummet, Reppy, 1988, Alic *et al* 1992, Cowan, Foray 1995, OTA 1995, Richardson 1996, Molas-Gallert 1997].

2. Non-Developmental Items (NDIs).

The preceding analysis underscores that tapping a potential for duality of civilian and military technologies not only depends on technical characteristics, but also on the markets targeted and the capacity of the organisations concerned to implement this potential. The issue of duality may thus be tackled on the basis of the analytical frameworks developed to study technology transfers-whether between two companies or within a given company[29].

Technology transfers between civilian and military uses entail adaptations, including in firms' organisation[30] which is consistent with the analysis in table 5. As a result, the process is necessarily costly and risky. The scope of adaptation depends on the degree of specificity of the military equipment. Accordingly, the potential for duality depends to a large extent on the procurement policies and procedures for military equipment applied by defence officials. The role of procurement policies is all the more important as the promotion of dual technologies (or dual innovation) has been moderately successful[31].

Dual innovation, through projects which attempt to take due account of commercial and military needs, is only conceivable with certain technologies and for specific cases. Military technological trajectories remain specific to a certain extent, particularly at the level of strictly military equipment and with certain subsystems. Notwithstanding, defence industries are relying to an ever-greater extent on dual technologies and multi-purpose components. The "civilian" content of military equipment is tending to increase – in particular through some of the electronic components they incorporate. Accordingly, it does not seem wise to make the promotion of duality a central goal of innovation policy as a whole. The development of dual technologies is one

29. For example, a multinational seeking to use its technological resources on the world scale.
30. See for example the invention of the microwave oven by Raytheon and of a videophone system by GEC – Marconi [Gruneberg 1995].
31. Which does not mean that this type of policy was irrelevant [Pages 1998].

means of increasing the pace of innovation in military equipment and should be focused on those systems for which this approach seems most relevant.

The most promising approach when it comes to integrating production systems is not developing dual technologies but rather recognising that henceforth civilian technologies and components frequently have such a dual nature. The preceding analysis of innovation dynamics suggests relying on technology transfers from the civilian to the military sectors that are as direct as possible[32], i.e. favouring the integration of non-specific components in weapons systems. There are already a great many useable "commercial" components; opportunities would be more numerous if military specifications were only to be used in case of genuine need.

During the 90s, it has become increasingly clear that maintaining the civilian-military segregation depended to a large extent on the specifications imposed by officials in charge of procurement. This in turn explains the reforms of procurement policies designed to favour the purchase of components available on markets. Thus, the DoD has increased its civilian purchases, but progress has been slow in light of the potential[33]. According to certain analysts, a more radical change would take a genuine revolution in the conceptions and methods of DoD procurement officials[34]. Over and beyond national specificities, an analysis of innovation processes effectively indicates that the evolution of demand is the primary driving force behind the integration of civilian and military productive capacities.

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32. To take up the typology of technology transfers used above (figure 2).
33. According to one study, the value of COTS purchases could rise from some 15% to nearly half of the total [OTA 1995]. The existence of a significant and desirable margin was confirmed during the author's interviews with senior DoD officials (September 1998).
34. Ever since the end of the 80s, the necessary cultural evolution of the organisational structures concerned has been underscored more and more forcefully; see in particular [Gansler 1987, Alic *et al* 1992, Gouré 1998].

■ The Scope of Defence Companies

Since the defence industry is more subject to economic constraints than before, firms need to review their strategy and their organisation. Hence the restructuring period which began in the US at the end of the 80s. In the late 90s, European companies are experiencing a similar evolution. The latter is more complex owing to the political fragmentation of the "market".

By relying on the aforegoing analysis of the budget and technological constraints, this second part reviews the economic determinants of the necessary restructuring and introduces national security considerations which remain fundamental. It shows that the latter, although they must be taken into consideration, should not prevent economic evolution, since falling back on national champions or excessively rigid industrial structures would be counter-productive, from the viewpoint of military capacity itself.

Economic Analysis of Corporate Boundaries

Strategic analysis emphasises the fundamental role of resources and competences in firms' external growth decisions. Traditional economic analysis focuses rather on the consequences of these decisions for competition. But consolidation does not always aim at increasing the market power of the companies involved. However, in cases where two companies decide, for example, to merge with a view to pooling their technological skills, the authorities may well wonder how this consolidation will impact on competition. Accordingly, the perspective of market power is relevant both at the start of the analysis of a consolidation process and to appreciate the impact on the dynamics of competition.

The Strategic Adaptation of Resources

The boundaries of companies evolve depending on the resources and skills they need to implement their strategy. When a gap appears between the necessary resources and the resources available to a firm, it

modifies its scope. It may opt to invest in the creation of new resources; for example, a pharmaceutical company can hire researchers to acquire skills in the field of biotechnologies. Yet this approach takes a long time to pay off, hence the frequent reliance on external growth-mergers, acquisitions and inter-company agreements. Thus, as biotechnologies have affirmed their role in the development of drugs, pharmaceutical groups have progressively adopted various strategies of co-operation with specialised firms.

The most obvious resources and skills are technical and financial. In the case of the defence industry, the above analysis showed that the relationships which systems manufacturers have gradually developed with their government customers are both a guarantee of success and an obstacle to redeployment on *commercial* markets. As in other productive sectors, the notion of skills must therefore be understood in a broad sense, which includes, in particular, marketing and organisational skills.

The aforegoing analysis of innovation dynamics suggests that companies specialising in defence must rely more and more on technologies which they do not possess or which they develop less rapidly than companies present on commercial markets. This is, in particular, the case with electronics and information processing[35]. The need felt by systems manufacturers to integrate skills in these fields has been one of the driving forces behind the wave of acquisitions which the sector has experienced in the US. In the 90s, systems manufacturers have bought up specialised companies to gain access to skills in the field of defence electronics[36].

Adaptation of resources has also been necessary with respect to production methods. Costs are traditionally high in the defence industry in comparison with commercial sectors. As mentioned above, in the

35. Defence electronic companies are in a specific position from this point of view.
36. Systems manufacturers have in particular bought up the electronic divisions of civilian defence companies (IBM, General Motors, Chrysler, Texas Instruments, etc.).

90s, lower volume has tended to exacerbate this trend by reducing even further opportunities for exploiting economies of scale. In response, companies have, on the one hand, sought to increase their scale of production and, on the other, adopted production techniques which commercial sectors had already experienced[37].

The ability to offer products on both civilian and military markets also holds out the prospect of restructuring production operations in order to benefit from joint expenditure and various synergies. Thus, economies of dimension[38] go hand in hand with a certain diversification into civilian industries. However, implementation depends on genuine integration of productive capacities, as was mentioned in the first part. This issue is not entirely specific to the defence industry; effective integration concerns mergers and acquisitions in general, as well as the operations of multinational companies. Here, the problem is two-pronged: firms have to correctly assess the prospects offered by civilian-military integration both from the point of view of markets and from the organisational angle.

The Search for Market Power

The traditional objective of competition policy is to prevent companies from using market power to the detriment of the consumer. Now it is also increasingly to prevent existing competitors from blocking market entry, which over time would threaten the dynamism of the innovation process[39].

In the defence sector, the market structure is highty concentrated on both the supply side, with a small number of large companies as sys-

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37. On this transposition of conception methods from the civilian to the military sectors, see in particular [Grant 1997] and "Lessons from the commercial sector", A. Nicoll, *Financial Times*, 3/9/1998.
38. Economies of scale and economies of product range for several different products.
39. This was the basis in particular for the proceedings which the US Department of Justice brought against Microsoft in 1997.

tems manufacturers, and the demand side, because the State is the primary customer in the producing countries – exports being a non-negligible yet much less central eventuality. Accordingly, the customer has an incomparably greater capacity for information and negotiation than the consumer on a competitive market[40].

The recent consolidation in the US was initially encouraged the DoD before it became such a matter for concern that they banned the merger between Lockheed Martin and Northrop Grumman in March 1998[41]. In 1993, the Clinton administration served notice on DoD contractors that the new budget and strategic situation implied excess capacity. As a consequence, restructuring was necessary to ensure an efficient and profitable industrial base which would be capable of incorporating future technological and strategic evolutions. The administration has offered financial incentives to ease the process of restructuring[42]. However, the administration has by and large left it up to companies to implement this consolidation[43].

The DoD became concerned about competition-related issues once the consolidation movement had gained momentum in the early 90s[44]. This movement began in the second half of the 80s but slowed down between 1988 and 1991 before gaining momentum in 1992 to

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40. The aim here is not to refer to a market with perfect competition but simply to numerous markets for consumer products, or even industrial products where customers are many and dispersed.

41. The European Commission and the US authorities examined the case of the Boeing-McDonnell Douglas merger, but the problems posed concerned competition in the civilian airplane plane sector.

42. Between 1994 and 1997, the DoD refunded US$ 850 million to industrialists, who had justified restructuring costs of US$ 1.4 billion [Delétang 1998]. These subsidies, justified by possible cost reductions for the DoD, were contested from a liberal point of view, see in particular [Korb 1996].

43. On the role of the different actors, including investment banks and consulting firms, see [Markusen 1998].

44. A working group set up in 1993 to deal with the matter made recommendations on the process of following up and reviewing consolidation between DoD contractors *(Defence Science Board Task Force on Antitrust Aspects of Defence Industry Consolidation)*.

1994 and resulting in mega-mergers in 1995-1997[45]. It included at least two types of operations. In an initial phase, companies primarily present on civilian markets sold off military units to groups which were initiating a strategy of specialisation and growth in the defence sector. This was, in particular, the case of Xerox (1984), Ford (1990), IBM (Federal Systems, 1994), Westinghouse (1996), General Motors (Hughes, 1997) and Texas Instruments (1997). Simultaneously defence companies acquired firms specialising in relatively light weapons. In a second phase, consolidation led to mergers between the major groups. The number of companies placing two-thirds of all arms orders in the US fell from 17 in 1989 to 8 in 1995 [DoD 1997]. Since it bought up the Hughes units, Raytheon, for example, controls the air-air missile market [Grant 1997].

The consolidation process for US companies specialising in the defence sector is horizontal in its strategic intentions and in its overall configuration. Nevertheless, its very scope implies that as operations proceeded, the sector has also experienced a certain amount of growth in terms of vertical integration[46].

At the end of the 90s, the major US groups specialising in defence are prime contractors of the Department of Defense. They have swallowed up certain companies working as sub-contractors. This was particularly the case in the fields of electronics and information processing, in accordance with the resource-based approach developed above. Viewed globally, consolidation has refocused the main groups on defence, while diversifying their capacities within the sector (both horizontally and vertically). Even though the vertical integration effect has been indirect, the DoD has insisted on reviewing its impact in terms of competition.

The report of the working group which examined this issue concluded that the degree of vertical integration reached in 1997 did not

45. For lists of operations, see in particular [Grant 1997, DoD 1997, Markusen 1998].
46. This same issue has been discussed when BAe bought GEC's military operations.

constitute a threat to the competition process, while considering that it should be monitored [DoD 1997]. Three main aspects have to be monitored. The groups of systems manufacturers have incorporated capacities for production of sub-systems and parts, which they may be tempted to favour at the expense of more competitive rival suppliers. The latter could possibly be pushed into bankruptcy, thereby reducing the number of competitors.

Secondly, the DoD intends to see to it that vertical integration of the major groups is not used to increase entry barriers. In particular, it is necessary to ensure that certain sub-systems necessary for competition between DoD contractors are supplied on good terms. If this is not the case, certain systems will gradually be monopolised by the group which possesses a given high-performance system. When reviewing the merger between Lockheed and Martin Marietta, the DoD thus underscored the fact that the latter company supplied the LANTIRN, a navigational and target acquisition system critical for airplane hardware. It asked Lockheed not to modify this system in a way which could discriminate against other corporate customers. Similarly, the subcontracting activities of Northrop Grumman (in particular for Boeing and Lockheed) in the sensitive area of airplane electronic hardware were one of the main considerations behind the ban on the merger with Lockheed Martin[47].

The third important aspect concerns industrial property. In the event that a systems manufacturer buys up the supplier of a rival, the latter may worry that the sensitive information in the hands of the supplier will be misused. The fear is that the integrated company might use its rivals' innovations and ideas via information which has come to the knowledge of its component unit. Such fears tend to isolate subcontracting units and hinder the competition process.

Recent experience with consolidation in the US highlights the constraints to which the consolidation process is subject in the

47. A. Nicoll, "Further consolidation possible", *Financial Times*, Survey 3 September 1998.

defence industry. Its limited size implies a trade-off between economies of scale and the desire to retain a certain degree of competition. For certain products, the US authorities have already agreed to have only a single supplier: General Dynamics for tanks, Northrop Grumman for bombers, and Raytheon for air-to-air missiles. This trend underscores the importance of the objectives of reducing production costs. However, it should be noted that these examples concern weapons with declining strategic value or relatively widespread technologies. In these cases, it may be easier to control the competition process indirectly, through sub-systems and parts, or possibly through imports. Moreover, it would appear that as far as components and systems of medium technological intensity are concerned, competition remains keen, including between US and European companies[48].

This point brings us to the problematic issue developed at length above; potential competition will indeed be better safeguarded if the customer has access to civilian and/or foreign production capacities. This in turn presupposes that the reform of procurement procedures pays off. The analysis of the innovation process conducted in the first part identified the role of these procedures as obstacles to transfers of potentially dual technologies; the economic approach in this second part underscores its role as a barrier to entry.

Thus, industrial economics identify two roles for public authorities with regard to the competitive dynamics of the defence industry. They must ensure the classic trade-off between the exploitation of economies of scale on the one hand and the maintenance of a sufficient degree of competition on the other hand. The latter depends not only on decisions of bodies responsible for competition policy, but also on Defence Ministry decisions making it possible to limit the importance of barriers to entry – which brings us back to the considerations concerning the procurement and innovation policies mentioned in the

48. Messier-Dowry (Franco-British) is the world leader for landing gear on military planes, while Germany dominates the market for diesel submarines [Grant 1997].

first part. The interdependence between the maintenance of a keen competitive process and a procurement policy was also underscored by French leaders within the framework of the DGA reform [Helmer 1996].

Which Structures for the European Defence Industry?

Economic analysis has made it possible to identify the determinants of the change in the scope of companies. We now examine to what extent the economic and technological dynamics are compatible with the goals assigned to national defence.

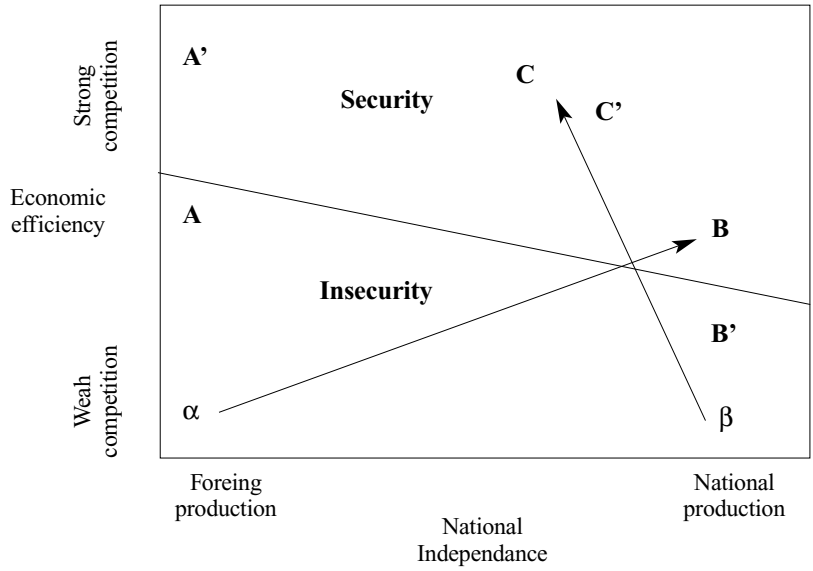
A Framework for Economic and Strategic Analysis

The issue rationalisation of the arms industry cannot be stated in the same terms as for other sectors insofar as national production capacities would guarantee the possibility of conducting a truly independent defence policy. Accordingly, the nationality of defence firms has traditionally been viewed in terms of sovereignty.

Figure 1 depicts the trade-off between the goal of independence and the constraint of economic efficiency. The choice of the degree of competition as an indicator of efficiency is based on the traditional economic reasoning recalled above. The analysis of the first part emphasises the incompleteness of this approach and highlights the need to add the degree of innovation as a second variable of economic efficiency. The discussion which follows suggests that incorporating this variable modifies the conditions of the trade-off shown in figure 1.

Situation α represents "De Gaulle's nightmare"; [Moran 1990] this nightmare which came to pass between 1964 and 1966, when the US administration asked IBM and Control Data not to sell France technology critical for the development of nuclear weapons. US companies controlled these technologies and their refusal to pass them on halted work on the hydrogen bomb for a while. As France wished to get out of this type of situation, it developed the means to set up a

Figure 1
Evolution of the Structure of the defence Industry: Economic Factors Versus national Security



Source: modification of the figure proposed by [Moran 1990].

relatively comprehensive defence industry. Thus, defence efforts in the 60s and 70s may be schematised by the arrow which goes from zone α to zone B. The US is usually in a B-type situation and would certainly not accept exclusive control of cutting-edge technologies by a foreign country[49].

The boundary between national security and national insecurity is drawn in as a diagonal because, for a low degree of competition, it is better to depend on national suppliers (situation B) than foreign sup-

49. This fear existed at the end of the 80s for certain electronic parts and this concern constituted one of the arguments in favour of partial government financing of the SEMATECH R&D consortium (development of hardware for semiconductor production).

pliers (situation A). If they are essentially foreign, arms suppliers must be sufficiently numerous and diverse (situation A'), so that the purchasing country may consider that its security is guaranteed despite the ever-present possibility of unfavourable international events. This reasoning may be illustrated by the oil embargo decided by the OPEC producers in 1973. In the short run, the concentration of production and exports made this embargo a serious threat, at least as far as the economic security of the oil-consuming countries was concerned. In the longer term, various economic mechanisms made it possible to diversify supply and moderate demand for oil, leading to a lessening of the threat of an oil cartel – considering the industrialised countries as a whole, the situation evolved from A to C.

The accelerating pace and cost of innovation, identified as a fundamental factor in the evolution of the defence industries in the first part, may be shown in figure 1. The diversity of technological skills and the breadth of the R&D investments needed to develop the new weapons systems now surpass the capacities of most countries. Even though up until the 80s, a country like France, for example, could support a B-type situation, maintaining exclusively local supplies could lead to a shift towards the zone of insecurity, to B' or even β, which represents the liberal economist's nightmare, symmetrical to De Gaulle's nightmare[50]. This line of reasoning may be illustrated by two examples, one British and the other French.

At the end of the 70s, the British Nimrod project was aimed at developing a system similar to the AWACS. The team of British companies involved had sound technical skills and the design envisaged had its own qualities. It was therefore conceivable that Nimrod could become a credible piece of equipment to rival the American AWACS [Moran 1990]. Nevertheless, the project failed because changes in terms of targets (Soviet planes) and techniques led to difficulties beyond the capacities of the British team, causing a series of delays and cost overruns. At the time of the Falklands

50. Scale constraints have the same type of effect: if the scope of the national market is insufficient, concentration will be too high.

war, the British Royal Navy found itself facing the Argentine planes without an efficient air surveillance system – situation β on figure 1. This dramatic episode weighed heavy in the decision to scrap the Nimrod programme, after nine years of work and US$ 1.6 billion of expenditure. British officials opted for dependency on a foreign system, but one whose performances were known and reliable. In this case, the search for greater security led to a decision to give up the idea of independence, via a move from a β-type situation to an A-A' type situation.

Should the inability of French planes to fly at night in the Gulf War be analysed in the same way? Has the development and production of combat planes with solely national capacities led to technological backwardness which is harmful to France's defence (B'/β type situation)? A look at operations on the Gulf War theatre would tend to indicate this because the French planes were not able to carry out night penetration missions. However, the analysis of the military experts shows that this under-equipment of French planes was due to the prevailing French strategic doctrine rather than a technological incapacity. This doctrine was based on the defence of the national territory and use of nuclear weapons. In this perspective, projection missions away from the national territory were neglected; unsuitability to air combat in the Gulf War was due to a conceptual, not a technological gap [Saint-Simon Foundation 1991]. But strategic options have long-term consequences on equipment choices; during the Kosovo war, France was still under-equipped with planes capable of carrying out all-weather missions.

The fact remains that France's insistence on maintaining both a doctrine of strategic autonomy and a national arms industry could give rise to fears that β-type insecurity situations might arise. The reason why France has not found itself in this situation is that the nation has accepted for longer than the other Western countries to bear the costs of independence (going from α to B entailed higher defence spending). The Rafale is a case in point. France preferred to develop a plane on its own rather than participate in the European Eurofighter consortium, both to respond as best as possible to the

specific needs of the French army and to support the national industrial base[51]. The Rafale is a high-tech plane, but one whose development has fallen behind schedule and whose cost is particularly high. Cost overruns and budget difficulties have led to postponements of orders and reductions in the number of planes actually ordered by the army.

Ever since the end of the 80s, innovation dynamics have kept the cost of maintaining a relatively comprehensive weapons research and production apparatus beyond France's financial reach. Yet French policy-makers have been reluctant to recognise this evolution and have pursued numerous arms programmes. The contradiction has been temporarily resolved by lengthening programme deadlines and by reducing order levels, so much so that France seems to be engaged in a "prototype logic" [Hébert 1998], in which the national resources earmarked for military equipment only suffice to maintain skills in the various relevant technological fields without being sufficient to bring in income-generating orders. This logic is not sustainable; it is necessary either to make choices and abandon certain fields, or indeed to move on to the production phase on a non-negligible scale.

The trade-off between independence and security of Figure 1 must be supplemented by consideration of opportunities for inter-company co-operation. European producers are already co-operating via joint ventures such as Eurocopter specialising in helicopters or Matra-BAe Dynamics, which groups together the missiles activities of the two partners.

Co-operation agreements make it possible to go beyond the national/foreign control dichotomy. Indeed, they make it possible to

51. From this point of view, there is a need to supplement consideration of the competitive process with the problematic of *capture*. National champions have the capacity to influence public decision-makers (due to their technical expertise and to the jobs they represent), including to secure choices which meet above all their own objectives.

combine the maintenance of national companies with economies of scale and access to the necessary technological skills. The introduction of inter-company agreements is capable of facilitating the shift from zone B to zone C (on figure 1), not only through the existence of national and foreign companies competing on a given market but also through the co-operation of national producers in a given niche. For co-operation to be effective, it must lead to genuine co-ordination, which has not been the case for the co-operation without effective integration of production capacities implemented in Europe[52]. At present, European co-operation arrangements are clearly often in a C'-type situation (rather than C), where the desire to maintain national positions simultaneously reduces the amount of capital available for other countries and the degree of competition. Effective agreements should, on the contrary, make it possible, in exchange for limited loss of control by national companies, to increase the degree of competition and capacity for innovation. In this perspective, agreements constitute a means of taking root in the safety zone – of moving from B' to C' or C. This reasoning may be extended to the transatlantic co-operation taken up below.

Prospects for European Companies

Economic analysis and the US experience shed light on the prospects which are opening up for European companies and the policies which are likely to favour restructuring of the industrial defence base. This restructuring process comprises several aspects: evolution of the scope of defence companies, rationalisation of production capacities, and the governance issue (private/government, national/foreign). The following considerations underscore just how interdependent these various aspects are.

52. The constraint of *juste retour* (just return), which establishes a linkage between the division of production between partners and orders placed by their respective States, is regularly incriminated and its abandonment is advocated, including in the founding principles of OCCAR.

National Restructuring

The restructuring of the US defence industry during the 90s followed a classical logic. The process may be compared to the one experienced in several sectors during the 80s and 90s, combining a refocusing on core competences and an increase in market share. Given the relatively limited size of the defence industry, the "core market" covers the entire industry and is not limited to sub-sets, as for example with the chemical industry[53]. During the refocusing process, a number of companies left the defence sector (e.g. Ford or IBM), while others became integrated in larger sets as a result of mergers or acquisitions (for example, E-Systems, Northrop or Grumman). The companies which have remained in the sector have begun a process of rationalisation, which entails site closures, rationalisation of production methods and a restructuring of commercial networks [Delétang 1998]. They have already sharply cut their staffing levels: the US DoD estimates that the defence sector shed 39% of its jobs between 1989 and 1997[54]. The consolidation movement has been limited to the national territory, whereas in numerous sectors increases in market shares and production scales have been accompanied by a sharp increase in the degree of internationalisation[55]. In the defence industry, this increase still by and large takes the form of exports, as the multinationalisation of companies remains limited.

Companies have refocused on defence at a time when their "trade" is in the process of being redefined to take account of the increasingly central role of military electronics[56]. As in other sectors, electronics advances have rendered the functions of systems more complex and

53. The distinction persists between systems manufacturers and component suppliers which may be specialised in a sub-market or even a niche.
54. Between 1987 and 1997, defence-related industrial employment fell from 3.9 million to 2.1 million – i.e. a drop of 45% [Grant 1997, SIPRI 1997].
55. Hence the theme of globalisation of company strategies and organisational structures; see in particular [Sachwald 1993, 1994, 1997].
56. Military electronics are said to account for some 45% of the Pentagon's equipment budget [Grant 1997].

enhanced their efficiency. The quantity of aeronautical, spatial or naval platforms should therefore increase less rapidly than the electronics-based content of systems. Accordingly, the strategies of systems manufacturers have aimed at incorporating the skills of electronics experts by buying up specialised companies; the refocusing on defence has been accompanied by a certain diversification of the skills of the companies [57].

In an initial phase, reductions in arms sales have thus not led to a movement of diversification of companies towards civilian activities, as was sometimes envisaged. Refocusing on military activities can nevertheless lead to the acquisition of some civilian activities, as part of the units purchased. Moreover, the underlying tendency seems to be towards diversification in civilian sectors to make up for the drop in military budgets and to exploit technological dynamics. The impact of the contradictory movements generated by military reorientation is not yet clear. According to table 6, the underlying trend indeed seemed to be a certain diversification, visible in the reduction of the military's share of turnover between 1998 and 1993-1996 in aeronautics (Boeing, Aérospatiale, BAe), but also for certain defence electronics companies (Raytheon, Rockwell, Thomson). Consolidation operations offset this trend to a certain extent because defence companies bought up specialised units from civilian groups [58]. Raytheon exemplifies this evolution, with the acquisition of military units from Hughes and Texas Instruments. BAe is a special case on the other hand; before it bought GEC's military activity, the increase in turnover from the defence sector was due to the sale of its automobile activities to BMW. In the United States, after the consolidation phase, firms seem to follow various strategies with respect to diversification [Markusen 1998].

57. This movement, in conjuncture with the search for electronics-related skills, was evoked earlier.

58. Loral increased the military share of its turnover from 69% in 1988 to 97% in 1995, in particular by acquiring units specialised in defence, such as Ford Aerospace and Federal Systems (IBM). Loral was itself bought up by Lockheed Martin in 1996.

Table 6
Military Share of Corporate Turnover in the Defence Sector[1], as a Percentage

Name of company In 1996	1988	1993	1996 (1997)[2]
Lockheed Martin	Lockheed, 79 (Martin Marietta, 75)	Lockheed, 77 (Martin Marietta, 69)	70 (+ Loral, 70)[3]
Mc Donnell Douglas	56	62	69 (merger)
British Aerospace	54	37	72
Northrop Grumman	Northrop, 78 (Grumann, 82)	Northrop, 88 (Grumman, 84)	83
Hughes Electronics	40	45	40 (bought)
Thomson-CSF.	77	70	64
GEC	35	22	26
Raytheon	67	49	33 (+ Hughes + TI, 59)
Boeing	27	15	18 (+ Rockwell + Mc Donnell, 46)
DCN	100	97	98
United Technologies	25	20	14
TRW	26	31	34
DASA/Daimler Benz Aerospace	n.a	29	38
General Dynamics	84	94	92
Litton	60	91	89
Mitsubishi Heavy Ind.	15	10	10
Aérospatiale Groupe	49	32	23
Finmeccanica (IRI)	n.a.	28	25

1. The order corresponds to the classification of defence industries based on turnover for 1996 (in dollars).

2. 1997 reports the estimate on the basis of turnover for 1996, taking account of major mergers which occurred in 1996/ 1997. Example: + Loral indicates that Lockheed Martin bought up Loral; the share of military turnover is adjusted by incorporating Loral. These estimates are slightly below the level reached in 1997 owing to other acquisitions (65% for Raytheon for example), see [SIPRI 1998].

3. Estimates based on turnover for 1995, because Loral was bought up in April 1996.

Source: SIPRI Yearbook, several years, and author's estimates for 1997.

In Europe, since the end of the 80s, defence industries have experienced a national trend towards national concentration, which has been accompanied by the signing of co-operation agreements at the European level[59]. Thus, the arms sector has become very concentrated in Italy, where Finmeccanica controls 70% of production, and in Sweden where Celsius controls 50% [SIPRI 1996]. In Germany, the aeronautical industry has been restructured around DASA (Daimler Benz Aerospace).

As in the US, certain predominantly civilian groups have sold off their military units. In the United Kingdom, Ferranti and Thorn-EMI have left the sector, whereas Lucas Industries has sharply reduced its arms sales. Thomson CSF has bought up Thorn-EMI's defence electronics activities in the fields of missiles and optics. Considering itself to be a second-rate player in defence electronics, Siemens sold off this activity in 1997 to a consortium made up of DASA and BAe[60]. The two aeronautical groups are counting on this operation to reinforce their systems manufacturing skills[61]. It corresponds to the logic of procurement of the electronic skills of prime contractors mentioned in the case of the US.

In France, the consolidation movement only began in 1996-1997. Governments implemented very large-scale reforms, where budget cuts went hand in glove with the professionalisation of armies, the reform of the DGA (the French arms procurement agency) and the restructuring of the defence industry[62]. This latter must be viewed from a European perspective, which implies, in particular, the priva-

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59. The small countries, in particular Belgium and the Netherlands, have also experienced an internationalisation of their defence industries; Sweden relaxed the rules for control of defence companies by foreigners in 1992 [SIPRI 1993].

60. Each of these two companies is to take over the units situated on its territory, in Germany and the United Kingdom respectively.

61. A. Nicoll, "Siemens' sale creates fresh cross-border fighters", *Financial Times*, 31 October 1997; N. Bayle, "DASA absorbe sa portion de Siemens", *L'Usine Nouvelle*, 5 February 1998.

62. On the interdependent nature of these evolutions, see in particular the presentation of the DGA reform by the Delegate-General for Arms [Helmer 1996].

tisation of major players such as Thomson-CSF and Aérospatiale[63]. Although the State's share has fallen below 50% with the recomposition of the capital of the companies, whose partners are respectively Alcatel and Matra Hautes Technologies, it remains the main shareholder and retains decisive clout.

Europeanisation and Globalisation?

Although the rationalisation of European defence industries on a continental scale has been on the agenda since the early 90s[64], European companies have increased the share of activities carried out in co-operation, but without introducing real rationalisation measures making it possible to reduce excess capacity. European co-operation schemes have traditionally opted for one of two arrangements[65], either consortia to develop and produce a weapons system which met a given need or teams of systems manufacturers trained to respond to a call for bids [SIPRI 1993]. These forms of co-operation with constant structures have now been supplemented by a few specialised joint ventures and some transborder acquisitions [EEC 1996, Serfati 1996, SIPRI 1998]. Genuine European restructuring is viewed as increasingly urgent by industrialists, by the governments of the producer countries[66] and by the Commission [EEC 1996, 1997a, 1997b], but remains incomplete.

The major issues set out earlier have taken on special forms in this debate on continent-wide restructuring. The question of the scope of companies has been posed in particular through the opposition between

63. BAe and DASA which have been considered as the unavoidable partners of French companies in European restructuring, have made such privatisation a prerequisite.

64. Cooperation between governments has been examined for much longer.

65. In addition to the two categories mentioned, the host of licensing agreements concluded with US companies should be added.

66. In December 1997, the German, French and British governments jointly asked industrialists to present a plan for restructuring the aeronautical and defence industries by March 1998. In July 1998, after this first report, the governments gave their agreement in principle to the formation of a single European company-European Aerospace Defence Company.

a major group which would have encompassed the majority of European aeronautical and defence activities, and specialised regroupings in more targeted activities. The question of ownership comes up in most debates, including about possible transatlantic undertakings or joint ventures.

The analysis conducted in this study suggests that setting up a single European company, grouping together aeronautic, spatial and defence activities[67], would be a bad solution. It has been considered because the Europeans were impressed by the size of the US companies which have suddenly emerged from the consolidation process. As in other sectors, the race for market share and leadership has fuelled the concentration process. Thus, between 1995 and 1997, Raytheon made several acquisitions to follow the movement set in motion by Lockheed. According to Peter d'Angelo, Financial Director of Raytheon, competitive logic made it necessary to increase the size of companies[68], Yet economies of scale and the accumulation of capacities for systems integration are not the only relevant factors to be considered from the perspective of creating an efficient industrial defence base, i.e. one which is both competitive and innovative.

The ongoing and efficient introduction of innovations in weapons systems henceforth depends to a certain extent on a better integration of civilian and military industrial bases. Economic efficiency (*inter alia* with regard to innovation) presupposes a certain degree of competition. However, a very large European company grouping together aeronautical and defence activities would probably be both protected from competition and relatively impermeable to the innovation dynamics of civilian industries[69]. This in turn explains the idea that what

67. See for example the list of activities which according to the President of the DASA Directorate should have been grouped together [Bischoff 1998].
68. "*The market redefined what it took to remain a top player; you must adapt or suffer the consequences*" quoted by [Grant 1997, p. 6].
69. In general, even in commercial sectors, industrial history has shown that very large companies generate rigidities and a culture likely to make them lose some innovative capacity – this has been the case with IBM and General Motors for example. Moreover, effective integration of various companies into a single one is a very delicate undertaking.

is needed is several companies in the aeronautical and defence sectors rather than a single large European company. The economic viability of these companies and their ability to meet Europe's defence needs could be ensured by various strategic options: more interactions with civilian activities, increasing exports and partnerships with American companies[70].

■ Conclusion: Public Policies and Corporate Strategies

During the 90s, European defence industries primarily restructured on the national level. In the case of the UK, the establishment of a single large group was accompanied by the control of a major American parts manufacturer – Tracor, bought up by GEC. Simultaneously, US groups restructured their operations and sought to improve their access to European markets. In this connection, plans for a grand European company grouping together aeronautical and defence activities on a continental scale have been shelved. This failure could in fact represent an opportunity for Europe's industrial defence base. Due to the absence of one single European champion, more flexible and more competitive solutions may be envisaged.

As far as Europe is concerned, the stakes are high because a cutting-edge industrial base is one of the components of a common security policy. The aforegoing analyses tend to underscore the authorities' fundamental role in setting up this European industrial base, by modifying the incentives to which companies respond instead of applying a traditional industrial policy. They do not need to dictate their strategy to companies because they control demand through acquisition policies. The challenge for those in charge is to tackle this question

70. These strategic options can be interdependent. Thus, Thomson-CSF and Racal Radio formed a joint venture in September 1998 to serve the *world* market for military digital access networks (*Europolitique* 21 October 1998).

with a view to not only enhancing the performance of the national industry but also favouring the emergence of a European industrial base.

This paper has defended the idea that defence industries have to a certain extent entered the economic mainstream. This trend, whose scope needs to be evaluated more precisely, points to two concluding remarks concerning the setting-up of a European industrial defence base.

The breathtaking restructuring in the US has illustrated the fact that, when defence companies are obliged to operate under conditions closer to those of companies in the commercial sector, they tend to develop similar strategies. This may also be the case with the European companies. A look at other sectors indicates that European defence companies are likely to simultaneously focus on core competences and adopt internationalisation strategies which will include Transatlantic operations.

Taking a closer look at options for integrating the civilian and military industrial bases could be a promising avenue for European industry. Easier access to "commercial" components would, in particular, increase the production scale of the European groups. More extensive civilian-military integration would also make it possible to tackle the question of internationalisation more dispassionately[71]. If the continent-wide regroupings taking place in Europe lead to high-tech companies which combine military skills and some commercial activities, States could have more faith in the existence of an industrial base capable of supporting their defence efforts in the future[72]. This would allow them to downplay their role as producers and concentrate on their role as customers. Such a change could be very

71. This is what figure 1 suggests as it clearly indicates that the threat to national independence is greatest when there is a monopoly of supply, a situation which is less frequent and of shorter duration in civilian sectors.
72. Civilian-military integration is easier when it comes to components – moreover, it is developing, just as internationalisation is increasing.

favourable in terms of defining European equipment, an essential component of a common defence and security policy.

Thus, the restructuring of defence industries in Europe implies rethinking the concept of this sector that has made it an exception to the rules of the market economy. The conjunction of the strategic necessities of the Cold War and acquisition procedures gradually fine-tuned by defence ministries have isolated defence industries and limited both purchases of commercial components and exploitation of dual technologies. Positive trends have already emerged, but the inertia of industrial systems and organisations is such that civilian-military integration will have to be considered as a veritable innovation process by which both the contours of the defence industry and corporate behaviour will be reshaped.

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