The effects of the contracting system of French arms industry

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The French armament industry has inefficient synergy effects, because small and medium enterprises are not very involved in R&D. It suffers from the costs of over runs and lead times. Then, three questions must be solved in order to maintain the strategic independence for each sector, their capacity of growth or decline, their potentiality of specialization or restructuring, and the problem of employment by sector and region. The military R&D has very close relationships with high technology programmes, with some civil programmes and main national industries. They produce some crowding-out effects, with spill overs, he demand-pull effects and an influence on civil R&D.

L'industrie française de l'armement a des effets de synergie inefficaces, car les petites et moyennes entreprises sont peu impliquées dans la R&D. Elle souffre des surcoûts, des délais, puis des surcoûts. Trois questions doivent alors être résolues afin de maintenir l'indépendance stratégique de chaque secteur, leur capacité de croissance ou de déclin, leur potentialité de spécialisation ou de restructuration, et le problème de l'emploi par secteur et par région. La R&D militaire a des relations très étroites avec les programmes de haute technologie, avec certains programmes civils et avec les principales industries nationales. Ils produisent certains effets d'éviction, avec des débordements, des effets d'attraction de la demande et une influence sur la R&D civile.

Military contract system, R&D, Over runs, over costs, high technology, France
Contrats militaires, R&D, Délais de production, Surcoûts, haute tchnologie

The French armament industry has inefficient "synergy" effect, because of the lack of small and medium enterprises which are not sufficiently involved in R&D. This is not the case for FRG with the giant group Daimler Benz which controls aeronautic, military naval construction, electromechanics. The French government has tried to obtain participation in military projects by small and medium enterprises and some good results were obtained last year.

IV.1.2. Cost overruns and lead times

The Cour des Comptes has expressed severe criticism of the management of some military programmes. In a 1988 December report, this financial State Council indicated the quasi-systematic character in military programmes of effective prices much higher than forecast prices. A lot of deficiencies are condemned as :
- under-estimation of technical difficulties,
- non-existence of genuine financial analysis on the development of the products,
- the inefficiency of the public industrial workmasters, such as Arsenals,
- the insufficiency of financial means and
- the wrong analysis of the environment.

The most important deficiencies are the magnitude of overcosts and delays. For land arms, final prices usually exceed by 40 % the initial and forecast prices, and the delays are, on an average, two years. Some specific overcosts are cited, such as :
- the Leclerc tank (21 %),
- 155 Cannon (48 %),
- Murène Torpedo (43 %) and
- fight nuclear submarines (300 %).

Thus, it is not surprising that the Ministry of Finance and the Ministry of Defense are out of tune on the subject of savings on military budget. These figures are contested by the Ministry of Defense, which considered that the Cour des Comptes Report was

would be preferable to eliminate these costly improvements in order to increase the amount of equipment available and, on the whole, to improve security. The question of the choice and characteristics of equipment should be clearly put, since there are obviously budget constraints. Technological monopoly and expertise can lead to market disequilibrium before technology diffusion occurs. It is important to place greater emphasis on manufacturing efficiency, but this policy may endanger technological advances over time, given tightening resources and limited incentives.

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scamped.

- If GIAT is not very competitive and had already received criticism of its management, a recovery plan is running now. Although it was not able to renew the AMX30 tank and then lost international markets to the benefit of Abrams from General Dynamics in Saudi Arabia, the decision was taken by Jean-Pierre Chevènement, Ministry of Defense, to give the GIAT a legal personnality.

- Although the prices are sometimes multiplied by three, this does not happen overall project of submarines, but on some minor components of the programmes. The real figure of overcost is not more than 15 % over 15 years. The Ministry considers that the forecasting over the military programmes is very difficult, because the project is implemented over more than 10 years, with the disturbances and risks of deviation that every similar project is supposedly liable to. Finally the budgetary restrictions endured by the Defense industry are often a cause of overcosts, because they result in delays and reductions of production runs.[1] It is evident that arms costs are very difficult to forecast, because the production procedures are very long and are very involved in high and new technology, which is very difficult to translate into prices.

Is equipment chosen on the basis of lowest cost or under conditions comparable to those that prevail outside France ? It does seem that continual increase in prices is a modern feature of military equipment. The studies which have been carried out on this subject have indicated real rates of growth of prices of 8 per cent and 5 per cent per annum. Military aircraft experience very considerable cost increases, as do fighting ships, and, to a lesser extent, tanks. Development costs are spread over fewer units because of smaller and smaller production runs. It should be noted, however, that it is very difficult to compare the prices of weapons from different generations. These figures are moreover only significant as illustrations, since, in military conflicts, an unsuitable weapon is an obsolete weapon with a low degree of effectiveness. Under these conditions, although the price of an aircraft has increased five-fold in five years, if this aircraft is capable of destroying more than five aircraft of the previous generation, its effectiveness is beyond dispute. The key question is whether the General Staffs are over-concerned with technology and as a result, anxious to have the best aircraft, end up unwittingly reducing the country's defense capability by reducing the amount of equipment available, by

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[1] Libération, "Chevènement défend pied à pied les dépenses militaires", Mercredi 10 Mai 1989

renewing the equipment less often, or by drastically reducing operating costs. The requirement of defense independence implies that when projects arise at intervals, there are overhead costs involved in maintaining teams and facilities in the periods between projects.

Unit costs of military products are often very imprecise : from 40 to 50 million francs for the Leclerc tank, 65 to 100 million francs for HAC helicopter, 120 to 150 million francs for the Mirage 2000 aircraft, 220 to 350 million francs for the Rafale aircraft, about 1 billion francs for the light frigate, 2 billion francs for the SNA submarine, 11 to 13 billion francs for the nuclear submarines SNLE and about 14 billion francs for an aircraft carrier, without arms costs, ammunition or other additionnal equipment. From the forecasting of costs, there were over-runs of 26 per cent for the Leclerc tank, 19 per cent for the new generation SNLE and 13 per cent for BAMO (ocean anti-mines equipment) and the unit price of the French-German helicopters will exceed 70 million francs. There are new delays on the orders of AMX 30 B2, DATCM Mistral Missiles and light armoured vehicles.

There are some reductions on budget credits which disturb the normal functioning of the programme and increase the total cost. The scale economies are reduced. This is the case for munitions and armaments for Air and aircraft carriers and supervision fregates for the Navy.

The costs of the new submarine-launched ballistic Triomphant missiles, with six submarines built for the période 1994 to 2007, were evaluated by the Loi de Programmation at 70 billion francs, with 20 billion between 1987 and 1991. During 1988, an overcost of 10 billion francs is estimated by the Maître d'Oeuvre and the Parliament is very afraid that it might be only the first over-cost. Explanations of the over-costing are based on the difficulty of working with the economic complexity of entirely new technologies. The report of the Parliament considers that : "Peut-être les états-majors ont-ils leur part de responsabilité. Ils cherchent souvent à minimiser le coût des programmes les plus coûteux afin d'en assurer le lancement par l'autorité publique...le surcoût a pour conséquences l'étalement de plusieurs programmes : S4, M5 et dans une moindre mesure, celui du porte-avions nucléaire...Cet effort montre que le programme SNLE-NG reste, dans l'esprit du gouvernement, totalement prioritaire"[1]

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[1] Assemblée Nationale, Première Session Ordinaire de 1988-1989, Tome IV, Défense. Espace et Forces Nucléaires" par Freddy DESCHAUX-BEAUME. 13 Octobre 1988. p. 12.

Table 62 - Comparison of the objectives of French military "Programmation" and payment allocations for 1988 (billion current francs)

Section	Programmation	Payment allocations
Common	26.4	26.1
Air	23.2	22.9
Land	22.4	22.1
Navy	20.6	20.4

A comparison of the programmation objectives with concrete payments allocations shows the government's lack of political will to respect its commitment. Every service received less money to give a total shortfall of 3.7 billion francs for 1989 alone. A revision of the programmation must be decided at the end of 1989. In May 1989, three hypotheses was evoked in order to solve the dissenssion between the Ministry of Defense and the Prime Minister.

- The first possibility is to increase military investment by only 6 percent for 1990 and 1991 and 5 percent for 1992 and 1993, with a reduction of the total investment by 20 billion francs and with the execution of the main equipment programmes.

- The second possibility is to decide on a constant annual growth rate (5 %) of military credits for the period. Then, the total military investment would be 443 billion francs, with an overall reduction of 30 billion francs and a delay of some programmes.

- The third possibility is to decide on a reduced (4 %) constant annual growth rate of military credits, with a reduction of 40 billion francs in relation to initial objectives and the renunciation of some arms systems.

The Prime Minister, Michel Rocard, wants the rationalization effort improved in order to reduce costs, although the nuclear priority must be maintained with a nuclear capacity representing 2 % of the two superpowers. He has publicly spoken of "dossier en état de sinistre avancé" for the Rafale aircraft and he is not really satisfied by the Hades programme. His disputes with the Ministry of Defense on this

subject are well-known. The final decision may be taken by the Parliament, in the Autumn Session.

IV.2. Effects on the industrial structure

These effects are very important : growth/decline, specialization/restructuring, employment/restructuring.

IV.2.1. Growth/decline

Given the size and volatility of the international market, low demand and the entry of many new competitors the likely return from arms exports is not great, particularly in terms of opportunity costs. While defense spending represents a relatively small portion of the overall French Gross National Product, its impact on the French economy's innovativeness and manufacturing sector is more than proportionate, because of first, the decisive importance of military decisions on some industrial sectors ; second, the influence and the size of military R&D ; and third, the particular role of military exports on France's trade balance.

Since 1950, the French arms industry has profited by an exceptionally advantageous situation. In the 1950s, as a response to NATO commitments, France's Dassault built 225 aircrafts paid for by U.S. government contracts on behalf of the French air force and later copies of them were sold to Israel and India. The development of the commercially successful Mirage series and of Dassault as an international producer of advanced fighter aircraft are directly derived from the know-how, design, tooling materials of these contracts. After the end of the Algerian War and in order to sustain an advanced weapons industry, a very open door arms sales policy (ventes tout azimut) was pursued for strategic and economic reasons. Then, the French arms industry profited from the failure of its Allies to contest its aggressive sales efforts and its relatively independent strategy became an important quality for the buyers. Now, these advantages are in decline, with simultaneously, the emergence of European and Third World competitors and the reduction of the political advantages of an independent strategic policy.

IV.2.2. Specialization and restructuring

There are few incentives towards integration of civil and military engineering and production. Even firms working in both fields have tried to specialize in defense products, because of "unique" military requirements and the special weapons markets. Integration would have negative effects on French trading performance, because of, first, the technical and non-economical nature of modern weapons, second, the unfair advantage of firms which have defense contracts and third the failure of conversion attempts. Sometimes military and civil products are substitutes, especially when critical bottlenecks appear. Although some recommendations have been produced by the public authorities in order to improve "commercial practice" in the whole defense arena, the results of this exercise are not very valuable. Integration would be the result of a State decision, for which there seems to be little basis, at present. Ideally, integrated civil and defense productions benefit from economies of scale, introduce cost consciousness and improve commercial performance through continuous competition. In this kind of argument, civilian enterprise management is supposed to be stronger than military production habits. Unfortunately, after a substantial improvement at the beginning of dual production, gradually the advantages of military contracts tend to pervert the normal functioning of enterprises involved in a competitive market.

IV.2.3. Employment and restructuring

In 1981, there were 300000 workers in the French arms industry (1,25 per cent of active population and 6 per cent of industrial workers, buildings and public works excluded) of which only 80,000 were in export production. There were respectively 81000 and 43500 employees in the aeronautical and electronics industries.

In 1989, there are 270000 workers in the French arms industry and less than 70000 (77500 in 1987) in export production. There are plans for a reduction of employees of GIAT and elimination of 1200 jobs in Dassault. If every job created up-stream were included, then more than 400000 jobs are directly dependent on the arms industry. DGA employs 73500 persons. For the SIRPA, there were 730000 jobs directly or indirectly concerned with the defense industry. The general turnover of arms industries exceeds 100 billion francs, but in a more *stricto sensu* definition, specific arms market turnover was 65, 73 and 77 billion francs in 1986, 1987 and 1988 respectively, with 43 and 34 billion francs of exports in 1986 and 1987.

Table 63 - Employment in the French Defense sector in 1988

Type	Sectors	Employment
State	Technical services	24650
	Shipyards	28200
	Land arsenals	16900
	Aeronautical workshop	2850
Enterprises	Nuclear	10600
	Air and Space	73100
	Mechanic, metallurgy, shipyards	50200
	Electronics	57700
	Others	16800

Table 64 - Direct employment in the French arms industry in 1987

Activities	**Employment**	
	1987	**1988**
General task of DGA	25000	24650
Industrial activity of DGA	48500	47950
CEA	10000	10600
Public enterprises	108500	99500
Private enterprises	108500	98300
Industrial tasks only	275500	256350

IV.3. Effects on France's R&D

The military R&D expenditure has very close relationships with high technology programmes, some civil programmes and principal national industries.

IV.3.1. High technology programmes

Some analysts argue that military R&D has significant spin-offs for the civilian sector, that research in the military field yields civilian applications as a by-product (radar, computers, electronics for example). Spin-offs are also used as an argument for European participation in the Strategic Defense Initiative (SDI) developed by the government of the United States. In this version, SDI would produce goods directly useful to the civilian sector and would be the occasion to get insight into modern U.S. technology. The other school of thought considers that spin-offs are very low and become lower and lower. For example, integrated circuit or silicon ships were developed by commercial firms without any military funding. If early development such as radar, jet engine or transport aircraft or more recently semiconductors, fiber optics, lasers, nuclear power, satellite communications, composites materials are presented as successful technology transfers, these efforts to stimulate development and expand markets, represent quite limited contributions, taking into account the importance of civil transfers to military products. The growing importance of new materials, lasers, sensors, advanced energy devices, computers will inevitably lead to a growing overlap of defense and non-defense technologies.

Table 65 - Main areas of French military R&D

Technological areas	Contents
Computers and automation	Computers Data processing Guidance, navigation Robots, automatics Big computers with vectorial calculations
Telecommunications and detectors	Telecommunications Radar Sonar Pipes and hyperfrequency apparatus Signal treatment
Environment and general physics	Optics Thermics, Acoustics, Measurement Earth science Basic physics ans plasmas Infrared applications
Quantic electronics	Lasers sources Lasers propagation Lasers applications Non linear optics
Semi-conductors and components	Semi-conductors Materials for electronics Components Solid-state physics
Fluid mechanics and physics	Aerodynamics Hydrodynamics Noise and vibrations
Chemistry and Energy, propulsion	Electrochemistry Chemistry Thermic materials Ergols propulsion Electrotechnics Detonics
Materials and technology	Technology Structure arithmetic
Biology and Human Sciences	Chemical-Pharmacology Biology-Physiology Ergonomy Psychology Sociology

IV.3.2. Military R&D spin-off

Military spending is mainly unproductive in terms of opportunity costs. The conversion of resources to the civilian sector is seen as likely to improve the performance of the national economy. The countries with the highest military burdens compete less well in world markets. Correlation does not establish causality. It depends on the nature of R&D, on the will to seek civil applications, on the secrecy of military R&D, etc. Civilian spin-off effects of military R&D have been considerably exaggerated and the civilian spin-off effects on military R&D are not often analysed. There is considerable evidence that many new technologies now being sought in the military-security sphere were initially generated in the commercial sphere.

Table 66 - Spin-offs military vs civil

Military R&D	Civil R&D
Nuclear energy	Nuclear reactor Nuclear propulsion of oil tankers
Propulsion	Urban bus Helicopters
Aerospace	Knowhow Engines
Electronic	Air traffic Landing systems
Optronic	Laser Sprectroscopy
Information	Computers
Miscellaneous	Meteorology

Table 67 - Main categories of outlays of military R&D in constant francs 1981 (Ministry of Defense)

Outlays	1981	1982	1983	1984	1985	1986
Basic (Capital)	**3.4**	**3.6**	**3.4**	**3.9**	**4.3**	**4.3**
- Conventional	1.8	1.9	1.8	2.1	2.4	2.3
- Nuclear	1.6	1.7	1.6	1.8	1.9	2.0
Basic (Personnel)	0.3	0.3	0.3	0.3	0.3	0.3
Developments						
- Conventional	3.6	3.8	3.1	3.6	3.8	3.9
- Nuclear	6.0	6.2	5.7	5.6	4.8	4.7
Total R&D	**13.3**	**13.9**	**12.5**	**13.4**	**13.1**	**13.3**

IV.3.3. Economic importance of military R&D

Military R&D is very important for some industrial sectors.

Table 68 - Main sectorial outlays of military R&D in 1985 (percentage of total)

Sectors	% total military R&D
Nuclear	21
Electronic	28
Land Vehicles	3
Shipbuilding	5
Aircraft	17
Engines	15
Ammunitions and others	11

The main characteristics are :

- For the computer sector, the leadership of the military area is declining and often civil products are more complex than military products. Military computer R&D is sometimes important for development, but not for fundamental research.

- Without military purchases, naval shipyards would be in a deep economic crisis. The civil spin-off of military naval R&D is very small except for composite materials and very rarely in electronic equipment.

- The relations between military and civil aeronautic products are very ambiguous, because of the dual applications of these products. But it is very difficult for a country to build an aerospace sector without military purchases.

- There is no spin-off from nuclear weapons programmes which could profit the civilian nuclear industry and results are so extremely secret that access is not permitted for civilians.

- Military R&D represents more than 12 per cent of the military budget, a third of the R&D State budget and more than a fifth of the national effort in R&D. In 1988, more than 24 billion francs went to private or public industrial enterprises for military R&D. In 1989, DGA will entrust 60 per cent of its military R&D to enterprises, 15 per cent to the universities and 25 per cent to itself. For Aerospatiale, R&D outlays represent 23 % of turnover and the military programme, entirely financed by public funds, financed 75 per cent of the total R&D. More than 20,000 highly skilled workers are employed in military R&D, but this figure seems very low in comparison with international data.

- Military products are very voracious of R&D and especially of electronics (40 per cent of the new Leclerc tank is devoted to electronics). Actually, R&D represents 30 per cent of the price of military products and this percentage is clearly growing.

The economic role of R&D is not the same in every country. The United States is very proud of its high technology and it seeks a lot of new directions for research. France discovers what the best avenues of research are, and tries to finance only the most promising innovations, because it is not possible for her to waste her R&D resources and thus only a few technical possibilities are tested. But, ever since the post-war reconstruction period, France's relative weakness in exploiting the results of R&D and its relative slowness

in applying new technology in the economy have been apparent. Too often, new technology costs money in France but earns money elsewhere. Although most analysts have failed to find evidence of a similar direct productivity impact of State R&D expenditures, they nevertheless consider that public R&D may nevertheless have a considerable indirect impact (positive or negative) on total factor productivity if it influences private R&D investment decisions. There are three main hypotheses : the crowding-out, spillover and demand-pull effects.

- **The crowding-out effect** is predicated on the assumption that military and civil R&D employ similar types of resources, such as engineers, scientists or equipment. In the USA, it has been proved that federal R&D spending had a determinant influence in the starting salaries of engineers and scientists. In France, no study exists on this hypothesis. But, when military and public R&D become a main State objective, then government can try to attract high skilled manpower and to do so improve the wage rates of graduating scientists and engineers in the short run, even though the supply of graduates is much more elastic in the long run. In France, State R&D personnel are sometimes public servants ; so that, if higher wage rates are perhaps an incentive, it is not always possible to raise them, because of public servant status. To increase operations and maintenance, procurement and construction is easier than to increase salaries, except for indirect and non-cumulative payments such as bounties or special subsidies. The crowding out effects may occur when very specialized engineers are requisitioned by military sectors, thus provoking bottlenecks for civil production or when limited financial resources are allocated directly to arms production. In France, these effects certainly exist, but it is not obvious that they are very important, taking account of the high degree of complementarity between military and civilian R&D in the present structure of defense in France.

- **The spillovers of military R&D** generate knowledge which can be cheaply or costlessly exploited by civilian R&D and which increase the productivity of the civil sector. The larger the stock of knowledge-capital, the smaller the quantity of civil R&D needed to produce marginal improvements in products and processes. But, it is possible that in some instances the value of the spillover is negative, when the applications of military technologies, such as Concorde for example, have been a financial disaster for public utilities, their customers and the citizens. For five or six years, French governments have been trying to develop spillovers. The study of Schankermman and Pakes on the value of patent rights in the U.K., France and FRG during the post-1950 period indicates that there

is a dense concentration of patent rights with very little value... The general picture of a sharply skewed distribution of the value of patent rights emerges clearly in all three countries. Basic research certainly offers the greatest prospects for generating beneficial knwledge. Because of secrecy and the highly classified nature of much public-supported activity, the special development of hardware and the differences between military and civil types of thinking, there is very little potential for the commercialization of military R&D.

- **The demand-pull effects** can result in the demand for technology producing innovation. Military R&D stresses the role of market and production opportunity in innovation. It is often difficult to know if there really is a demand-pull effect (short run theory) or a technology-push effect (long run theory, which insists on the role of supply factors in explaining variation in research activity). Because of the "military-industrial complex", it seems that in France the technology-push effect in military R&D is predominant.

Table 69 - Outlays of military R&D in million current francs (by the Ministry of Defense)

Year	Outlays	% Public Budget R&D
1976	5,05	28,3
1977	5,95	29,2
1978	7,55	32,4
1979	9,35	34,3
1980	11,35	35,7
1981	17,67	39,0
1982	17,86	35,5
1983	20,31	33,7
1984	22,98	33,2
1985	23,62	31,5
1986	25,78	34,7
1987	30,75	38,3

Indices of R&D prices indicate that R&D is clearly cause of and subject to inflation. It is interesting to note, that notwithstanding the differences between countries general index prices, it appears that countries with substantial military R&D had more inflation in their index of R&D prices. We can therefore consider that military R&D, because of the urgency and importance of its objectives, is not very influenced by economic constraints and becomes a clear source of inflation.

Table 70 - Index of R&D prices (from Eurostat)

Years	FRG	France	Italy	the United Kingdom
1980	100	100	100	100
1981	105.4	113.7	120.6	112.3
1982	109.9	128.2	141.0	121.7
1983	113.7	141.1	162.3	130.0
1984	117.0	151.6	180.3	136.8
1985	120.1	161.3	197.5	146.3

Proponents of military programmes maintain first, that there have been substantial technological spin-offs (for example, on jet engines, computers and nuclear power) and second that State funding in R&D would not have been available for civilian R&D (so the military programmes must be seen as net additions to the civilian effort rather than substitutes).

IV.3.4. Military R&D vs civil R&D

The defense and civil research organisations are independent of each other, but there exists a lot of links between them. For example, the "Office National d'Etudes et de Recherches Aérospatiales (ONERA) which is under the control of the Ministry of Defense works with civil aeronautics as well as military aeronautics ; thus basic research is applicable to all types of helicopters or aircraft. It is the same with the "Bassin d'Essais des Carènes", the civil part of CEA and with the "Centre National d'Etudes Spatiales" which are respectively the only naval hydrodynamics, nuclear and space authority establishments in France. There are some agreements between military R&D Centers and "Centre National de la Recherche

Scientifique" (CNRS) or "Centre National d'Etudes des Télécommunications" (CNET) which are respectively the most important fundamental and telecommunications research agencies in France.

More than 60 per cent of R&D expenditures are incurred in the industry, and thus technology transfer from the military sector to civil activities is easily feasible. In 1984, DRET created a "Mission Industrie" to inform small and medium-sized enterprises of defense research results and to ensure that these results are applied in both civil and military sectors, trying at the same time to detect new technologies, originating in this kind of enterprise, which could be integrated into future weapons systems. This Mission has been in touch with 1200 enterprises and 15 per cent of these contacts produced effective exchange of technologies. There is now a wide variety of initiatives from the Ministry of Defense to enlarge the base of innovation.

Now France needs :
- An adequate level of scientifically and technologically skilled management, aware of the economic, social and cultural issues involved,
- a market large enough to provide an adequate return on investment in R&D and production,
- international cooperation and restructuring.

But the concrete conditions do not match these requirements and European programmes are not able to bring long term solutions to the latent crisis. Eureka and the Common Research Programme adopted in 1987 strengthen the integration apparatus. These programmes are specifically civilian, but in practice, they give priority to work on dual technology, both civilian and military. Military applications are clearly, for the European Commission, a desirable objective which will develop the common interests of EEC countries. Some French people think that these programmes encourage a specialization on civilian and industrial technologies for the FRG and on basic research and military technologies for France. Some developments such as the decision of CGE and CEA to concentrate their investments on military lasers to the detriment of civilan applications, on which Siemens will concentrate, could confirm this hypothesis. There is concern for naval shipyards and engineering.

- Moreover, non defense firms exploit technology and achieve economies of scale. Often, large arms enterprises tend to be risk minimizers rather than innovators. The problem of measuring the

contributions of military R&D is very difficult, because of the unavailability of direct and relevant measures of the output of the R&D process and the need to use indirect measures such as aggregate productivity growth which reflect imperfectly the contribution of R&D investments.

- Technology transfers between military and civilian sectors involve adapting technological information from a technical priority to an economic priority. There is a widening gap between defense and commercial planning processes, due largely to increased emphasis on short term returns for enterprises. The distinction between military and civilian technologies is fairly clear for nuclear missiles and submarines but less obvious for helicopters or computers. These military products are distinguished from their civilian products by greater ruggedness, higher costs and specialized components. When there is a dual-use technology, then the government must take account of the COCOM list which forbids free trade with the USSR. The United States and its Allies explicitly recognized the liability and potentialities inherent in the flow and use of civilian technology for military purposes. Military secrecy, special military requirements which are not relevant to civilian applications, emphasis in military programmes on product innovation over process innovation, the "megalomania" of military products (which produces "baroque" civil technology), businesses' segregation of military work, pricing practices are very important barriers to the diffusion of technology from the military to the civilian sector. While there are some applications where the results are not so good in commercial terms, such as Concorde, applications such as liquid crystals, portable satellite communication links, night vision equipment and carbon fibres are successful examples of civil spin-offs. The underlying military technologies have separated into civilian and military streams ; production for military products does not result in the development of cost-effective production practices or highly competitive processes. Sometimes, military R&D has clearly negative effects on economic development, for example, in France, when military choices stopped the development of the transistor and small computer industries. While the military sector systematically surveys civilian programmes with respect to the take-over of potential technologies, the reverse process rarely occurs because of secrecy. Although civilian R&D priorities rarely influence military R&D programmes, the reverse is frequently the case.

- On the positive side, military interest in a new technology improves its development and it is possible to think that its incorporation into final civilian products is quickened. Government

assumes the risks of introducing the new technology by a guaranteed and high priced market. But secrecy and specialization in defense firms reduce this positive effect. The loss of the scientific and engineering resources devoted to military sectors is only partially offset by the possible civilian applications of some new technology. Incentives to improve productivity are weak within the defense sector. The long-run consequence for the economy is to encourage growth along technological lines that have their origins in military priorities. Military spending for research and development has dominated the national R&D programme and thereby influenced the direction of technological changes.

- Kurt Rothschild suggested that the receptiveness of spin-offs from the military to the civilian sector is dependent on the state of the economy ; it is very low during an economic depression and high during a boom phase. This analysis may be interesting for the USA, but for France it seems inadequate. During recession phases, civilian R&D tends to be reduced because of the lack of opportunities and of financing. Military R&D maintains a sufficiently high level of expenditures, in order to allow the scientific teams or centers to follow their tasks. During the boom phase, there are some substitution effects which are not often in favour of civilian R&D. In this case, spin-off is widely considered as a non-planned, accidental product, because military R&D is not geared towards civilian industries or towards the military products departments involved or in tight connection with civilian departments.

- The problem of confidentiality occurs from the first start-up phase and is most important in the R&D process. The process itself of dividing the R&D process into phases is possibly a way of reducing the effects of uncertainty. By putting at risk the smallest levels of resource expenditure in the earlier and more uncertain phases, managers aim to avoid catastrophe. Now, military R&D reduces the importance of uncertainty for private firms, although the division between Civil and Military R&D is far more marked than in the past.

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