NATO Research Fellowship on

Military technologiesand commercial applications: Public policies in NATO countries

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Chapter 1: Introduction

During the ‘90s, the concept of “dual-use” has been widely used, especially in Western countries, to offer a viable solution to the problems faced by the military organisations as a consequence of the so called “military technical revolution”[1] and of the changing international context. It has been a challenge for all the Western Armed forces, after the end of the Cold War, to cope with new conflicts and new security threats.

As it happens sometimes when a concept is so largely used, the meaning of “dual-use” became as vague as those technology policies labelled as “dual-use policies”.

As to its origin, the concept of dual-use comes from the domain of strategic studies where in the '80s concerns about arms proliferation through the international transfers of “dual-use products and technologies” led to set up some national control regimes and, in 1995, a European legislation on dual-use exports controls. Such an origin shows how the concept itself has emerged in connection with the current trends towards globalisation of technology markets and systems of production[2]. Globalisation has entailed some consequences also in the military field (without mentioning those at political and strategic level), where national efforts in Research and Development (R&D) are no longer adequate in order to keep pace with the explosion of commercial technologies in sectors like electronics, informatics or communications. At a time when national economies (and markets) are moving towards integration at global level, even the Western military are increasingly relying on technologies developed in other countries and, sometimes, designed for civilian use.

In such a context, the dual-use concept lost its “static” meaning (i.e. “control over the diffusion of military technology”) and took a “dynamic” meaning (i.e. “development of technologies designed to fulfil both civilian and military needs”).

A “classic” definition of dual-use (or, at least, of how dual-use has been intended in the US) is offered by a 1992 US Department of Defense (DoD) report (see below)

Definitions of dual-use related concepts by the US DoD

- *Dual use technology* refers to fields of research and development that have potential application to both defence and commercial production. Some technologies are important for both DoD and commercial customers. Imaging-sensor technology, for example, has broad application in surveillance systems, video cameras, and robot vision systems that find both military and commercial uses. In fact, at the generic level, most of today's important technologies can be considered dual use.

- *Dual use processes* are those that can be used in the manufacture of both defence and commercial products, such as soldering, process control, and computer-aided design. For defence acquisition, these processes are frequently tied to military standards that may make them defence-unique, resulting in the segregation of defence and commercial production.

- *Dual use products* are items used by both military and commercial customers. Notable examples are global positioning systems used for navigation, aircraft engines, and most medical and safety equipment used by DoD. Some modified commercial products are similar enough to those used by the military to be considered dual use. Some examples are the Air Force's KC-10A Extender aircraft (which is a modified version of the Chevy Blazer). DoD's ability to buy dual use products is limited by the requirements of military specifications and standards and by the degree to which commercial firms are willing to comply with defence purchasing requirements.[3]

From the point of view of defence analysts[4,] the concept of dual-use has been referred to technologies which can be used for both military and civilian purposes (dual-use technologies) or, more widely to a particular relationship which can be established between military and civilian sectors (dual-use relationship). While most technologies are potentially "multi-use", they are mainly developed for specific end uses, especially within government funded laboratories. Thus, a contradiction can be observed between the multi-use nature of many advanced technologies and the separate goals of the organisations which are sponsoring such technologies. This has been called the "paradox of dual-use technologies" and the main goal of a dual-use technology policy should be to intervene in the sensitive field of "dual-use relationships" in order to transform single-purpose technologies in dual-use ones.

To modify the existing "dual-use relationships" is not an easy task. As it has been argued by Jacques Gansler[5]: "... even the technical knowledge developed in connection with one intended use could in principle be applied directly to another use, ... it is a separate challenge to facilitate the movement of ideas, tools and experience from their originator to a new user, or from one user to another. Industrial managers testify to the difficulty and expense of transferring technology even between different parts of the same firm when both parties are eager to do so. The process becomes far more difficult when the attempted transfer must bridge the gap between parties having goals and organisational cultures as different as those of military and commercial institutions.".

Many researchers have discussed about the extent to which the definition of dual-use technology policies can be influenced by the social, economic and political context which determines the "dual-use relationships". It is largely agreed that a dual-use technology policy should address mainly the *social network* within which each technology is developed in order to define a positive "dual-use relationship" and to make technological know-how available for multiple purposes, including both military and commercial ones.

The socio-political context, or the *social network*, in which the development of advanced technologies takes place is obviously largely dependent on national specificity. The "national system of innovation", as well as the "military system of innovation" and also the size of the Armed forces can influence the innovation process making either more difficult or easier to exploit the opportunities offered by a multiple use of advanced technologies.

The aim of this study has been to compare the process of definition of dual-use technology policies in four NATO countries: the US, the UK, France and Germany. The research has focused more on a comparison between different theoretic and political approaches at national level than on an assessment of the results of the policies implemented in each country. The scientific literature on dual-use policies suggests that it is difficult to transfer theoretical concepts and policy tools from a social context to another, especially because dual-use is a very complex matter. This study is aimed at individuating the existing differences among different national contexts and their origins. As to policy implementation in this field, problems and drawbacks experienced in each country will be analysed and compared with reference to a general model of "dual-use relationships" outlined in chapter 2.

Chapter 2: From Conversion to Civil-Military Integration

In order to make a comparison among different national technology policies possible, we first need to analyse the theoretical frameworks within which such technology policies are defined.

During the ‘50s, both public opinion and policy makers in Western countries (but mainly in the United States) were impressed by the massive impact on everyday life of civilian applications of military technologies, developed during the last years of the World War II. In this context, the relations between civilian and military technologies were considered as totally influenced by the so called "spin-off effect", that is to say a sort of "mechanical" spill over of knowledge from the more advanced military field to the intrinsically less advanced commercial fields. The spin-off effect could be observed within an institutional framework in which:

- military expenditures (mainly military R&D expenditures) were allocated exclusively according to the priorities of the national security;
- military R&D activities (and military production, as well) were totally separated from commercial R&D activities;
- military needs prevailed on commercial needs in the allocation of limited resources (funds, knowledge, people, etc.) within the national economy.

We can observe that the spin-off effect worked effectively in some industrial countries - such as the UK, the US and the USSR - in the final period of the World War II and in the ‘50s[6]. We have also to point out that in the following years a “spin-off ideology” has been defined in order to justify, also in terms of technology policy, the huge spending in military R&D of NATO and Eastern countries during the Cold War period.

Since the ‘60s, a large debate on the need to implement a “conversion”[7] of technological and industrial military activities to civilian needs has taken place in several Western countries, especially in the United States and the UK. Some economists have suggested, for instance, that the US economy has been “overburdened” for decades by military spending. The supporters of conversion policies argued that it was necessary to contain the “crowding out” of industrial and technological resources invested in military, instead of commercial sectors[8]. The economic and industrial performances of Germany and Japan in the following decades seemed to confirm that, for the industrial countries, a low level of military spending (and R&D military spending) makes it possible to achieve a high level of economic development and international competitiveness, especially in high tech industries.

The concepts of “spin-off” and “conversion” refer to two different (and to a some extent aprioristic) interpretations of the existing relations between civilian and military technologies. The former considers the military industries “intrinsically” more technologically advanced than the civilian ones and the process of spill over as “natural” (i.e. taking place without additional efforts or investments); the latter assumes that the commercial use of economic resources is more efficient, in economic terms, than the military one.

The concept of "duality", which emerged in the '80s, aimed at overcoming the problem of understanding what kind of "hierarchy" exists between military and civilian R&D[9]. The dual-use approach basically suggests that some military products can be used for civilian aims, and vice versa. Considering product and process technologies, as well as industrial plants, we can assume that it is possible to produce military goods in commercial factories, or using commercial technologies, and that we can use military developed technologies also for improving, or producing, commercial goods. The final result of a dual-use strategy should be to improve efficiency and effectiveness in the Armed forces, as well as competitiveness in the commercial industry, with a lower level of overall R&D spending.

However, the implementation of a dual-use strategy may raise several problems:

- most of the military products considered for dual-use do not match the cost and quality standards needed in high-tech commercial fields;
- it appeared extremely difficult for the military to buy commercial products without reforming the overall system of military specifications and military procurement rules;
- while a number technologies are already used both in commercial and military industries, it is very difficult to furtherly promote technology transfer.

Actually, the main difficulties in implementing an effective dual-use policy can be found in fully understanding the implications of the concept of dual-use. It assumes that there are two separate fields (and some opportunities to bridge them) but it does not consider as necessary neither to define a hierarchy between them, nor to integrate them. In fact, the dual-use concept assumes as given the "segregation" of the military technological and industrial base from the commercial one.

To overcome this conceptual problem, the Office of Technology Assessment of the US Congress, but also scholars like Jacques Gansler, have developed in the '80s an innovative concept in the military field: the civil-military integration (CMI). The CMI approach suggests that technological and industrial policies should be mainly aimed at integrating military and commercial activities within a unified technological and industrial base.

According to Gansler (1993) there are three broad processes supporting the "integration" perspective:

- the increasing availability of cheaper high tech commercial components, often more advanced than the military ones;
- the chances offered by innovative systems of production - particularly, the *flexible manufacturing system* - in order to integrate several productions, or several production lines, in the same plant;
- the high level of commonality currently existing in high tech sectors among military and civilian needs, as well as the large number of experiences of "spin-on" (technology transfers from commercial to military fields) which can be increasingly observed in the most advanced industries.

It is quite clear the framework in which such a CMI strategy can be effectively implemented is largely influenced by the need to reduce the size of the largest Western Armed forces, while improving at the same time their "quality".

Coming to policymaking, the theoretical concepts of spin-off, dual-use or CMI have been used to define strategies basically different. During the '50s and the '60s, the emphasis on the space race or on other very large military and civilian technological projects was strictly related, both in the United States and in Soviet Union, to the "spin-off ideology" which promised large benefits to the commercial industry in terms of spill-overs.

As an example, Japan developed in the last decades an original dual-use approach to the national technological and industrial policy. The Japanese Ministry for Trade and Industry (MITI) has the task of coordinating the industrial strategies of the largest Japanese industrial corporations, but at the same time it is concerned with the acquisition of a national capacity to produce advanced weapon systems. Actually, the Japanese specificity in this field is mainly related to the ability of most Japanese dual companies to produce commercial and military products in the same plants and, sometimes, in the same line of production[10].

On the other hand, in the United States the Clinton Administration presented in 1993 an innovative "conversion strategy" which led to a dramatic shift in the DoD technology policy, pointing out the need for an increasing dual orientation of the Armed forces. Several programmes were launched and a number of governmental agencies were involved in this “strategy”. Before the results of this “conversion” policy could be assessed, the US Congress withdrew, at the beginning of 1996, its support to the DoD dual-use policy and the DoD agencies already involved in it are currently refocusing their R&D activities on military-unique objectives. In the US political debate, the dual-use, as well as the CMI, approach have been criticized as been not suited to cope with basic military needs and potentially dangerous for maintaining the current US military capacity.

Concluding this brief description of the concepts related to dual-use, we can observe that the concepts related to dual technology policies are rapidly evolving, especially in main Western countries. This makes it increasingly difficult to define coherent and effective technological policies. The existence of different national frameworks for military or dual R&D, as well as the variety of industrial and technological cultures in the main NATO countries, leads to different national “models” for dual technology policies.

Chapter 3: Innovation and Military Spending in Four NATO Countries

In this chapter, data referring to some basic science and technology as well as defence spending indicators for the four countries considered in this study[11] will be briefly compared.

Table 1. Defence budget R&D as a percentage of Total Government Budget Appropriations for R&D, 1990-96

Country	1990	1991	1992	1993	1994	1995	1996
USA	62.6%	59.7%	58.6%	59.0%	55.3%	54.1%	54.7%
UK	43.7%	43.9%	40.7%	42.0%	38.9%	40.8%	n.a.
France	40.0%	36.1%	35.7%	33.3%	33.1%	30.3%	29.0%
Germany	13.5%	11.0%	10.0%	8.5%	8.6%	9.1%	n.a.
Total OECD	40.2%	37.6%	36.2%	36.2%	33.8%	32.6%	n.a.
Total EU	23.1%	21.0%	19.5%	18.8%	17.9%	16.9%	n.a.

Source: OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.

Table 1 shows the share of total government spending for R&D is devoted to military R&D[12]. This indicator is basically correlated to the size of national military R&D systems (including research laboratories, experimental centres, other research facilities and manpower) compared with other government funded research institutions (National Research Councils, civilian laboratories, etc.). Thus, we can see that the US, the UK and France have a very strong military R&D base supported by a significant share of total government expenditure for R&D. Obviously, also the overall size of the military R&D base does matter. In 1995, in the US the total gross domestic R&D spending was worth $179.1 billion, about $64.7 billion of which has been covered by the government (about $35 billion for military R&D).

The gross domestic expenditure for R&D in the other three countries is hardly comparable with the US figures: Germany spent in 1995 a total of $36.2 billion for R&D (about $13.4 funded by the government of which $1.2 billion for military R&D); France spent in 1995, $27.5 billion for total gross domestic R&D (between $10 and $11 billion have been funded by the government, of which about $3.5 billion for defence R&D), and the UK in 1995 spent $21.4 billion for R&D ($7.1 billion by the government of which about $2.9 billion for military R&D). The total expenditure for military R&D of the three main European countries roughly accounts for one fifth of the US R&D military spending. It is mainly for this reason that we will not compare the four countries in absolute terms, but we will use some indicators in order to point out the national specificity of each country. From this point of view, table 1 shows that not only the US technology base, but also the French and British technology bases, are strongly "military oriented" and are potential targets for "dual-use" technology policies, aimed at obtaining some advantages transferring to civilian fields the results of such a large effort in military R&D.

Table 2 provides data on total national effort in support of R&D activities (in term of shares of GDP), and shows that there is little difference between the four countries, which it is not surprising these countries being among the most industrialised and technologically advanced in the world.

Table 2. Gross domestic expenditure in R&D as a percentage of GDP, 1990-96							
Country	1990	1991	1992	1993	1994	1995	1996
USA	2.81%	2.84%	2.78%	2.64%	2.53%	2.58%	2.54%
UK	2.23%	2.18%	2.11%	2.13%	2.15%	2.11%	2.05%
France	2.41%	2.41%	2.42%	2.45%	2.38%	2.34%	n.a.
Germany	2.75%	2.61%	2.48%	2.43%	2.33%	2.28%	2.26%
Total OECD	2.38%	2.31%	2.25%	2.20%	2.13%	2.16%	n.a.
Total EU	1.99%	1.96%	1.94%	1.94%	1.88%	1.84%	n.a.
Source: OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.							

Data in table 3 and 4 gives us additional information about the contribution of the industry to the total national R&D effort (as percentage of GDP and gross domestic R&D expenditure). To some extent, it is possible to assume that the industry (or better, the commercial industry) has to compensate for the resources devoted by the government to non-industrial purposes (including defence). Thus, we can explain a quite high level of industry funded R&D in the US as result of the large support to military R&D but it is hardly possible to give the same explanation for the European countries.

Table 3. Total business enterprise R&D as a percentage of GDP, 1990-96							
Country	1990	1991	1992	1993	1994	1995	1996
USA	2.00%	2.07%	2.01%	1.88%	1.80%	1.85%	1.85%
UK	1.51%	1.42%	1.42%	1.44%	1.38%	1.34%	n.a.
France	1.46%	1.48%	1.51%	1.51%	1.47%	1.44%	1.43%
Germany	1.96%	1.81%	1.70%	1.62%	1.54%	1.51%	1.50%
Total OECD	1.64%	1.59%	1.54%	1.47%	1.42%	1.45%	n.a.
Total EU	1.29%	1.25%	1.23%	1.21%	1.17%	1.15%	n.a.
Source: OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.							

Table 4. Total business enterprise R&D as a percentage of Gross domestic R&D, 1990-96							
Country	1990	1991	1992	1993	1994	1995	1996
USA	71.0%	72.8%	72.2%	70.9%	71.0%	71.8%	72.7%
UK	68.0%	65.6%	65.4%	65.6%	65.2%	n.a.	n.a.
France	60.4%	61.5%	62.5%	61.7%	61.8%	61.6%	n.a.
Germany	71.9%	69.3%	68.5%	66.8%	66.0%	66.1%	n.a.
OECD	68.9%	69.0%	68.2%	66.8%	66.8%	n.a.	n.a.
EU	64.6%	63.4%	63.1%	62.1%	61.9%	n.a.	n.a.
Source: Our calculations based on OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.							

After having considered some indicators of the main "input" of the R&D process, i.e. the amount of money spent for R&D by the government or by the industry, table 5 and 6 provide us with two indicators of the output of the overall innovation process: the ratio between the number of patents applications and population and the ratio between the patent applications by residents and the total of patent applications (the sum of resident and non-resident patent applications). The OECD has named the former indicator "inventiveness coefficient" and the latter "rate of technological autosufficiency", arguing that they can offer an acceptable measure, respectively of the ability of one country to produce "innovation" (at least that innovation which can be translated into a patent application) and of the capacity of one country to produce "innovation" at home, reducing the need for importing technologies. As shown in these tables, Germany is a very good "producer" of innovation, while the US have a quite high rate of "autosufficiency" in applications for patenting. According to both the indicators, the UK, and even more France, do not seem to have a very innovative technological base. France has performed systematically at a lower level than the European Union's average. On the other hand, it is worth to note that all four countries have an "inventiveness coefficient" lower than the OECD average: this is mainly due to the very high rate of Japan: 25.6 in 1994.

Table 5. ***Inventiveness coefficient*** **(resident patent applications/10.000 population), 1990-96**							
Country	1988	1989	1990	1991	1992	1993	1994
USA	3.1	3.3	3.6	3.5	3.6	3.9	4.1
UK	3.6	3.5	3.4	3.3	3.3	3.2	3.2
France	2.3	2.3	2.3	2.2	2.2	2.2	2.2
Germany	5.3	5.1	4.9	4.1	4.3	4.4	4.6
Total OECD	5.8	6.0	6.2	6.0	5.6	5.6	5.5
Total EU	2.4	2.3	2.3	2.2	2.4	2.4	2.5
Source: OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.							

Table 6. ***Autosufficiency ratio*** **(resident/national patent applications), 1990-96**							
Country	1990	1991	1992	1993	1994	1995	1996
USA	0.51	0.51	0.52	0.50	0.50	0.53	0.52
UK	0.26	0.24	0.21	0.22	0.21	0.21	0.20
France	0.19	0.18	0.16	0.17	0.16	0.16	0.15
Germany	0.38	0.36	0.32	0.35	0.35	0.36	0.36
Total OECD	0.46	0.44	0.41	0.41	0.38	0.37	0.35
Total EU	0.28	0.25	0.21	0.21	0.21	0.20	0.19
Source: OECD, *Main Science and Technology Indicators 1996/2* and *1997/1*, Paris 1997.							

Finally, after having considered inputs and outputs of the innovative process, table 7 and 8 offer some data about the military spending in the four countries. Table 7 shows total defence expenditures (according to NATO definitions) as percentage of the GDP: a widely used indicator of one country’s financial burden related to defence. Table 8 provides some data on military procurement: the indicator proposed here is the percentage of “equipment expenditure” (i.e. mainly weapons acquisition) on the total defence spending.

Table 7. Defence expenditures as percentage of GDP (current prices), 1985-96							
Country	Average 1985-89	Average 1990-94	1992	1993	1994	1995	1996
USA	6.3%	4.9%	5.1%	4.8%	4.3%	4.0%	3.7%
UK	4.5%	3.8%	3.8%	3.6%	3.4%	3.0%	2.9%
France	3.8%	3.5%	3.4%	3.4%	3.3%	3.1%	3.0%
Germany	3.0%	2.2%	2.1%	2.0%	1.8%	1.7%	1.7%
Total NATO	4.7%	3.7%	3.7%	3.6%	3.3%	3.0%	2.9%
Total NATO Europe	3.2%	2.7%	2.6%	2.6%	2.4%	2.3%	2.3%
Source: NATO, *Financial and Economic Data relating to NATO Defence*, Press Release - December 1996.							

Table 8. Percentage of the total defence expenditures devoted to procurement, 1985-96							
Country	Average 1985-89	Average 1990-94	1992	1993	1994	1995	1996
USA	25.6%	25.1%	22.9%	22.0%	29.2%	27.8%	25.9%
UK	24.8%	21.0%	18.1%	26.0%	24.9%	22,0%	22,1%
France	n.a.	n.a	40.9%	39.7%	38.6%	35.0%	34.6%
Germany	19.6%	13.5%	13.3%	11.1%	10.9%	11.4%	12.0%
Sources: NATO, *Financial and Economic Data relating to NATO Defence*, Press Release - December 1996; for France, SIPRI, *SIPRI Yearbook 1997 Armaments, Disarmament and International Security*, Cambridge Univ. Press, 1997.							

Defence expenses are declining in NATO countries both in absolute values and as percentage of GDP. The same trend affects the four countries considered, even though, while the US, France and the UK have a percentage higher than the NATO average, Germany has one of the lowest levels of military spending (in terms of percentage of GDP) in NATO. Within the defence budget, also the share devoted to weapons acquisition is lower for Germany than for the other three countries. This confirms that Germany is not oriented to sustain a large military industrial and technological base, but rather to maintain a medium-size cost-efficient military system.

Chart 1 summarises some of the data provided by the above tables. The four indicators described above are displayed on the four axes of the chart. The first and third axes show two indicators of military spending: the percentage of government R&D budget devoted to military R&D in 1995 and the percentage of GDP devoted to defence spending in 1996. The second axis shows an indicator of R&D input: the percentage of GDP devoted to R&D in 1995. Finally, the fourth axis shows an indicator of R&D output: the rate of national "autosufficiency" in terms of patents, 1996 data.

Some basic differences among the four countries can be drawn from chart 1. The shape of each country's "diamond" can give some information about how the national systems of innovation (in terms of input and output) interacts with the level of military spending. For instance, Germany appears to have a low level of military spending together with a good innovative performance. On the other hand, it is difficult to assume the existence of a correlation between a low military spending and a good innovative performance, though it has been frequently suggested by several defence economists. Particularly, when considering the US experience where relatively high levels of defence spending have always been matched by the ability to exploit - in terms of technological performance - the high levels of public and private investments in R&D.

The French and the British "models" appear less clearly defined: military R&D spending has a relevant role in their national systems of innovation but it can be hardly assessed -

at least considering the indicators here available - if it has been a burden or it has boosted their national technological performances. Chart 1 gives also some additional information about the "dual-use" potential of the four countries, and seems to suggest that Germany can rely on its civilian technology base for a dual-use potential, which can be exploited also for military needs. On the other hand, the US have to deal with the need of transferring technological knowledge from their huge military technological and industrial base to the commercial sectors.

Chapter 4: the Science and Technology (S&T) Policy in the United States

The S&T strategy of the Clinton Administration

The constant quest for technological superiority over the Soviets has dominated the priorities of the US government in terms of Science and Technology (S&T) policy during the Cold War; as a consequence, government research and development (R&D) investments have been mainly devoted to military R&D, including nuclear weapons development.

Until ten years ago, the idea that military R&D, which benefited from huge Federal investments, was the leading-edge technological drive of the national system of innovation was based on the belief that advanced military technologies could have been used also in the civilian field (i.e. that the spin-off effect could work). As already observed, some significant transfer of military technology to the commercial market has occurred but it can be hardly argued that the military R&D and the spin-off effect have played a crucial role in the US post-war economic development.

On the other hand, in the 80s, some economic analysts pointed out that the US civil technological base was becoming weaker if compared to the increasing competitiveness of European and Japanese hi-tech firms, and that one reason could be the absence of significant inducements from the government. At a time when a new arms race began, involving the US and the USSR, and large amounts of money were spent in military R&D, it seemed necessary to many that this should also contribute to strengthen the overall US technological base[13]. Then, dual-use emerged in the political debate as a needed move for exploiting the US military technological potential.

A first step, aimed at making available some of the expertise and infrastructures of the defence R&D to the private sector, was undertaken by the Congress in 1980 passing the *Stevenson-Wydler Technology Innovation Act.* This Act provided for the legal basis for establishing joint projects (Co-operative Research and Development Agreements - CRADA) involving Federal laboratories and private firms. The CRADAs (which, however, became effective only in 1986 with *the Federal Technology Transfer Act*) also made it possible, for the first time, to transfer technologies developed by Federal laboratories, many of which were devoted to military activities, to commercial firms, enhancing their ability to compete in international markets.

A second initiative came in 1982 with the *Small Business Innovation Development Act* (SBIR), which allocates funds from the Department of Defense's (DoD) Research, Development, Test & Evaluation (RDT&E) Office for the introduction and transfer of government-sponsored technologies in small and medium firms. Expanded in 1992 with the *Small Business Technology Transfer Program Act* (STTR) the programme is aimed at sustaining the technological capacity of firms with less than 500 employees. The programme has allowed to conduct explorative research and advanced research in small and medium firms using DoD funds and structures.

Other measures have been approved by the US Congress in order to enhance the collaboration between Federal R&D infrastructures and commercial firms, but it is only under the Clinton Administration that the S&T policy came to a turning point. One obvious consequence of the end of the Cold War was a reduction of defence budgets, down to $116 billion of savings in the '90s in the US DoD budget (most of such savings, about 85%, went to reduce the public deficit), and severe cuts in military procurement. In order to soften the negative impact of such cuts on the military industry, the US government provided $17 billion for helping military personnel and military industry workers who were going to be laid off, as well as for the development of new high-tech industries. Almost half of that amount was devoted, anyway, to military technology initiatives[14]. The idea underpinning the Clinton administration policy was that orienting military R&D and defence industry toward the development of dual-use technologies and products would have allowed the government to have an affordable technological base for its military procurement, while strengthening the national economy.

In February 1993, President Clinton introduced this strategy to the general public, publishing a report on *Technology for America's Economic Growth. A New Direction to Build Economic Strength*, which emphasised the need to promote the development and introduction of technological innovations in the commercial fields in order to promote economic growth in the US. The document underlines that: "international competitiveness depends less and less on traditional factors such as access to natural resources and cheap labour. Instead, the new growth industries are knowledge based. They depend on continuous generation of new technological innovations and rapid transformation of these innovation into commercial products the world wants to buy"[15].

A second document, *Science in the National Interest*, released in August 1994, stressed the need to involve the government in the promotion of technological innovation in the commercial sectors. Both documents point out that, as a consequence of the new international environment, it is now possible for the US government to follow a more comprehensive approach to scientific and technological development. This can be achieved, on the one hand, by supporting the economic growth of the country and promoting the technological innovation in the private sector through direct investments in civilian R&D; and on the other, by meeting security requirements more effectively and at lower costs than in the past, using in the military sector the management criteria developed in the commercial sector.

The US Administration identified three basic goals. The first goal was to assure the US with long-term economic growth, creating new jobs and enhancing environmental protection. This should be attained: by fostering private investments in civil R&D; by promoting education and vocational training; by creating far-reaching information networks; and by improving transports and Federal infrastructures.

The second goal was to make the government more efficient and responsive to the needs of the citizens by reducing wastes of resources, maximising the benefits of resources allocation and changing the government procurement policy.

The third goal consisted in maintaining the world's scientific leadership in the fields of fundamental sciences, mathematics and engineering; enhancing research activities in the universities and endorsing the role that Federal laboratories can play in the field of space and environmental sciences.

The Clinton Administration aimed at strengthening the US economy by getting rid, at least partially, of the financial burden of the Cold War. At the same time they did not have to give the impression that the new approach to military spending could undermine the US political and military leadership. Taking into account the political hostility of the Republican Party, and the disagreement of many defence contractors, about any reduction in defence spending, the initiative of President Clinton was designed considering the potential benefits of a dual-use policy for the defence procurement itself. A dual-use strategy could allow the DoD to share the financial burden of military R&D with the private sector and would make available to the DoD dual-use products developed by commercial firms, reducing costs and enlarging the industrial base for defence systems. Furthermore, instead of relying on occasional spin-off or spin-on effects, the DoD would have benefit from a more systematic approach to the integration between the commercial and the military sectors.

The new S&T policy of the Department of Defense

Following the same approach of President Clinton, the then Secretary of Defense, William Perry, presented in September 1994 its *Defense Science and Technology Strategy*. The document emphasised the need to cope with reduced defence budgets while maintaining high technological standards in the US Armed forces. The basic assumption of this strategy is that a new policy for DoD's R&D investments can both strengthen the national technological base and reduce procurement costs for the military. On the other hand, emphasising the role of technology transfer and developing dual-use technologies do not match the other primary task of the DoD technology policy: "support a well-defined set of defence-unique, defence-funded capabilities".

The DoD recognises the need to account for the decreasing advantages of a separate military R&D: "with declining defence budgets, especially for acquisition, affordability has become even more important. Meanwhile [...] the rapid growth of certain high technology industries has reduced the once central role of defense spending as a driving force for innovation. DoD's ability to take advantage of commercial product development cycles in dynamic industries has been hindered by its increasingly cumbersome, time-consuming acquisition process"[16].

This is the core concept that underpins the need of a new technology policy and its primary component: the procurement reform.

Restructuring the procurement process is not an easy task. On the one hand, the DoD has to identify and develop those technologies that are suitable to satisfy the requirement of the military operational concepts and the *Joint Warfighting Capability Objectives* (see box below). On the other hand, S&T planners should be able to foresee the potential implications of new scientific developments for future or current operational concepts.

Operational Concepts and the Joint Warfighting Capability Objectives

The "Joint Vision 2000", a document produced by the US Joint Chief of Staff, defines the new doctrinal and strategic framework for the Military Services and the procurement policy. The operational concepts outlined in this document are:

- Dominant Maneuver
- Precision Engagement
- Full Dimensional Protection
- Focused Logistics

These concepts, that come together to create the so-called "full spectrum dominance" rely on the development of technological innovations in twelve main fields:

- Information Superiority
- Precision Force
- Military Operation in Urban Terrain
- Joint Readiness
- Chemical/Biological Agent Detection
- Counterproliferation
- Combat Identification
- Joint Theater Missile Defense
- Joint Countermine
- Electronic Warfare
- Real-Time Logistics Control
- Information Warfare

The 1996 edition of *Defense Science and Technology Strategy*, lays emphasis on the conflicting imperatives of the DoD: "we must address the joint warfghter's needs, maintain a broad-based program spanning al defense-relevant sciences and technologies to anticipate future needs, support the unique needs of the military Departments, preserve long-range research, and do it within limited budgets"[17].

In other words, there are at least four issues that have high priority in the process of defining the DoD S&T policy:

- affordability,
- a dual-use-oriented industrial and R&D base,
- an accelerated transition pace from the development phase to the insertion of new technologies in military systems, and
- maintaining a strong technological base.

The new orientation of the DoD is also emerging in the new approach of the DDR&E Office towards the implementation of the DoD S&T policy. Currently, the main task of the DDR&E Office, acting under the supervision of the White House's Office for Science and Technology Policy, is to verify that military programmes would match the requirements set by the military, as well as the guidelines of the overall S&T strategy of the Administration.

A number of documents define the framework within which the DDR&E Office (as well as other military Departments and Defense Agencies) can operate: the *Defense S&T Reliance* linked to the *Joint Warfighting S&T Plan*, the *Defense Technology Area Plan* and the *Basic Research Plan.* The main scope of the Reliance is to avoid useless duplications of projects and to evaluate the consistency of those under way with the more general *Defense Planning Guidance.*

A Defense Agency playing a key role in the implementation of the dual-use strategy has been in the last years the Defense Advanced Research Projects Agency (DARPA), whose name was changed in 1993 into ARPA, underlining the fact that the new S&T policy was not going to be military-dominated.

The structure of the DoD's S&T programme is based on three categories of R&D funding (see next table):

- Basic Research, aimed at developing knowledge in scientific or engineering fields, which will not necessarily lead to innovations (if any at all) of interest for the military. Almost 50% of basic research funded by the DoD is performed by universities. Basic research is mainly financed by government agencies and only for a lesser degree by industry and universities. It is therefore relevant that, as shown in the table below, Federal investments in basic research have only slightly decreased over the last years;
- Applied Research, which investigates the potential applications of experimental concept emerged in the first phase;
- Advanced Technology Development, which investigates the potential military uses of technologies developed in the two previous phases.

DoD Science and Technology Budget (constant FY97 $millions)

Categories	FY94	FY95	FY96	FY97	FY98
Basic Research	1,257	1,227	1,116	1,080	1,138
Applied Research	2,954	3,080	2,915	2,873	2,782
Advanced Technology Development	4,110	3,964	3,663	3,769	3,293

Source: Statement by Dr. A. Jones (DDR&E) to the Subcommittee on Military Research and Development, February 27, 1997.

In selecting projects that the DoD is going to fund there are some guiding management criteria that the Agencies have to follow:

1 - Transition technology to address warfighting needs

Two issues are here implied. The first one is that the introduction of new technologies in weapon systems should be speeded-up in order to assure the superiority of the US forces and to avoid technological drawbacks. The second issue is that a closer interaction between those who develop weapon systems and those who use them has to be assured. Co-operation between scientists and warfighters within the Advanced Concept Technology Demonstrations (ACTD) is being reported by the DoD as a particularly effective programme, which has produced important cost savings.

2 - Reducing costs

This means both reducing acquisition and life cycle costs. Affordability remains a high priority in any decisions of the DoD on investments. Recent studies have underlined the fact that up to 80% of maintenance costs could have been avoided with larger investments during the initial design phase if more funds had been made available. Further saving could be made by using the best commercial products, practices and processes available on the market. Modelling and simulation also can play a significant role in reducing costs, as well as in improving the manufacturing processes and in reducing the environmental damage.

3 - Strengthening the industrial base

In order to enhance synergy between military and commercial sectors, an effort should be made to use the same technology and industrial base, both for military systems and for commercial goods. It is therefore crucial to develop dual-use technologies and processes as well as implementing an acquisition reform dual-use oriented. Besides, the DoD can still play a significant role in boosting industries based on new technologies (like it has done for the microelectronics industry in the '60s) or in those sectors of military interest. Sharing the industrial base would allow the DoD to get the best out of commercial technologies and market management, while strengthening the process of technology transfer.

4 - Promoting basic research

Basic research is obviously essential to any technological development and should, therefore, be strongly supported by the DoD through the funding of high quality research. Recipients of DoD funding should be chosen on merit across Federal labs, universities and industrial firms. Basic research entails high levels of risk and private investors may be reluctant to spend money where the outcome is not foreseeable on the short-medium term. It is then one of the duties of the DoD to support long term basic research and to promote the education of young scientists and engineers.

5 - Assuring quality

In order to cope with reduced defence budgets the DoD has undertaken the downsizing and restructuring of its Research Development Test & Evaluation infrastructure. This means that the remaining centres and laboratories will have to meet high quality standards, specialising in those sectors considered as priorities by the military. As a consequence of such restructuring the DoD will also have to enhance collaboration with research organisations in the private sector. Monitoring and collaborating in international scientific programmes will be an additional way of assuring quality to the US S&T programme.

The key issue of the new DoD S&T policy, however, does not consist only in enhancing collaboration with commercial firms but also in promoting the development of technologies which can be used both for military and civilian purposes, matching cost-effectiveness and quality standards. This is way the DoD has given high priority to its dual-use strategy.

The Dual Use Policy of the Department of Defense

Two documents published in February 1995, *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology* by the DoD and *Second to None: Preserving America's Military Advantage Through Dual Use Technology* by the White House Office for Science and Technology Policy, offered a clear analysis of why and how the DoD's scientific and technology policy was going to change: "the dual use technology strategy represents a new way of doing business. DoD seeks to break down the barriers between commercial and defence industries and to institute compatible development and acquisition process internally. An integrated, national industrial capability that achieves 'world-class' benchmarks for cost, quality and cycle time, will allow the DoD to exploit the rapid rate of product development and the market-driven efficiencies of commercial industry to meet military needs"[18].

The new strategy was aimed at achieving a faster development of weapon systems as well as at speeding up the introduction of technological improvements in military equipment. A second benefit should be the reduced cost for using commercial components and technologies in weapons systems. Finally, it should "permit the DoD to maintain its ability to respond rapidly to national security contingencies. Close integration with the private sector is imperative if the nation is to be equipped to gear up its industrial capabilities quickly to meet the military demands of a crisis"[19].

The starting point was to modify the acquisition policy of the DoD and to change the strategy management of three sectors (also called "pillars of the dual-use technology policy", see the figure below):

1) R&D investment on dual-use technologies;

2) integration of military and commercial productions;

3) insertion of commercial capabilities into military systems.

Considering the acquisition reform as the basement and the investment strategies as the pillars of the DoD dual-use strategy "temple", the roof of such a temple should consist of a cultural change within the DoD's Departments and Agencies. This should enable the DoD to follow an acquisition policy based on "performance and affordability" and on the "state-of-the-art technology and manufacturing".

Figure 1

1) First pillar: dual-use technology investment

In seeking benefits from the collaboration with the commercial industry it is obvious for the DoD to place high priority in ensuring that the "commercial technology base remains at the leading edge in areas critical to the US military"[20]. As a consequence, the DoD will invest in those technologies that appear to have dual-use characteristics and match military requirements, and that would not be developed by private investments alone[21].

Investments in dual-use S&T have represented almost 25% of the all S&T programme in 1995. An important share of it went to project directed by the ARPA like those on information technology, materials technology, electronics and advanced simulation and modelling. These and other projects are clearly directed toward the development of technologies than can be used both for military or commercial goods (see box).

DoD Dual-Use R&D Focus Areas in 1995 ("First Pillar")

- Electronic Manufacturing
- Flat Panel Display
- Microelectromechanical Systems
- Advanced Composites for Aircraft
- Integrated High Performance Turbine Engine Technology
- Rotorcraft Technology
- High Density Data Storage Systems
- Wireless Communication

2) Second pillar: integrated production

Otherwise known as "dual produce", the integrated production is aimed at carrying out in commercial facilities technology development and production that can be purchased by the DoD at market costs. The DoD was seeking to reach this goal following two approaches:

a) fostering commercial industries to use and produce defence-sponsored technologies;

b) developing new manufacturing technologies that can satisfy the requirements of both the military and the private partners.

In the first case the benefits for the DoD would have resulted from the cost-savings entailed by mass production, economies of scale and economies of scope. Furthermore, such technologies would be made available for commercial production regardless of DoD procurement needs. This strategy has been successful in several cases, like the GPS systems, the Microwave Monolithic Integrated Circuits (MIMIC) or the Multi Chip Modules (MCM).

Most of such projects have been developed within the Technology Reinvestment Project (TRP), an ARPA programme aimed at establishing joint ventures between defence and commercial firms which have to cover a 50% share of the project budgets. Since the establishment of TRP in 1993, there have been three biddings with a total allocation of $686 million. The TRP seemed to be a real break-through in the traditional S&T policy and private firms showed to appreciate the programme: "The TRP was the centerpiece of the dual-use effort, and during its first two years, 1993 and 1994, the program was heavily subscribed to by prime defense contractors and numerous small - to medium - sized firms. In spite of this interest, the program was criticized by congressional defense advocates as not defense-oriented enough"[22].

In 1995 and 1996 the TRP funds have been reduced by the Congress on the claim that the programme was not sufficiently effective for defence purposes and in 1997 no new competition has been announced. The Dual Use Application Program has taken over part of formerly TRP tasks, although with a significantly reduced budget ($185 million in FY 1997) and in a more defence-oriented way.

The second approach emphasises instead the development and deployment of new manufacturing technologies with the aim of producing small quantities of military and commercial products at competitive prices.

3) Third pillar: insertion and promotion

The goal of this policy is to "insert the best commercial materials, products, components, processes, practices and technologies into military systems wherever possible"[23]. Nevertheless, the DoD recognises that the adoption of commercial products for military systems entails risks and costs for defence contractors. One way to avoid incurring in further costs of insertion is to design military systems, from the very beginning, considering the adoption of dual-use components. This being a completely new field for the DoD, most of the preliminary work will need to focus on three main areas:

- planning the insertion of commercial capabilities will require a constant effort in programmes management. In particular, the planning phase should emphasise the cost trade-offs implied in the insertion of a particular dual-use component;
- providing programme offices with the technical knowledge needed to identify and assess insertion opportunities. This means to collect and verify data on new technologies and products available on the market;
- co-ordinating the efforts made by the Armed forces and the commercial partners in assessing the suitability of dual-use components at general level rather than within each specific project.

The implementation of the dual-use strategy

At the beginning of the 1990s, the US economy was performing worst than the economies of other Western countries. In order to favour an economic recovery, the federal budget deficit had to be reduced drastically also reducing military spending, but it was also necessary to improve the technological competitiveness of US firms in international markets. The dual-use strategy was, therefore, conceived to be something more than just a reform in the DoD acquisition system, entailing significant consequences for the whole US defence industrial system, as well as for the US economy.

While strongly supporting the dual-use strategy, the Clinton administration was not able to gather enough political support for its programme which has been much criticised in the Congress during the mid 1990s: “In the 1990s, the political consensus in Washington and in Wall Street was that the nation needed to reduce its deficit rather than reinvest savings in the domestic economy. By the mid ‘90s, the conventional wisdom in Washington and Wall Street was that defense had made its contribution to deficit reduction and further cuts might be damaging to national security”[24].

The dual-use strategy proved to be difficult to implement since the approach was new, both for government infrastructures and private firms which had both little experience in bridging military and commercial activities. The efficacy of some programmes, like the TRP, cannot be assessed so far because there has not been enough time to experiment the full range of effects that could have stemmed from them. Overall the funding for dual-use initiatives has been increasingly shrinking: the TRP started off with a budget of $472 million in 1993 which decreased constantly during the following years until the programme was shut down in 1996-97. Funding for other dual-use initiatives peaked in 1995 with $1,536 millions and was reduced afterwards, down to $1,030 millions in 1997.

Looking at the above image of the "dual-use strategy temple", it can be observed that, first of all, the roof has fallen: cultural resistance (and the reaction of those economic interests jeopardised by the dual-use strategy) have undermined the effectiveness of the second and, partially, of the first pillar. The third pillar, focusing on the insertion process of commercial technologies in military systems, is more likely to hold out in the near future. On the other hand, the DoD seemingly has not changed its set of priorities, but the context in which the "new" S&T policy is currently implemented has substantially modified compared to that foreseeable only a few years ago. A certain degree of scepticism about the usefulness of dual-use is coming back: there is less emphasis on the benefits of using dual-use goods and on the "dual produce" process of integration between military and commercial sectors.

Chapter 5: Dual-use technology policies in Europe: three country-studies

France

In France, the defence industry and the military research institutions play a key role in defining the national security policy, as well as the industrial and technology policy. Government, Armed forces, defence industry and research institutions cooperate within a national arms production system which has been described by Chesnais and Serfati (1992) as a "mésosystème de l'armement".

At the core of such "system" we can find a public body with no equal - in terms of number of tasks - in other Western countries: the DGA (Délégation Générale des Armaments). Basically, the DGA is an intermediary between the Armed forces (and their operational needs) and the French defence technological and industrial base. A large number of expertises have been concentrated in the DGA with the aim of assuring the best "connection" between the military and the industry in terms of ability to identify the best equipment for the operational needs of the Armed forces and to set up industrial projects. A further task is to perform in-house research, to enhance its development and design capacity and its ability to manage large armaments programs. The DGA is also in charge of the public-owned defence industrial firms and has to define the guidelines of their activities.

Summing up, the DGA has direct responsibility over each phase in the process of developing and producing military equipment. Thus, we can consider the DGA the main actor in defining the military research and industrial policy in France, as well as the body who can more efficiently pursue a dual-use strategy.

The separation between military and civilian R&D: a problem of definition?

The almost monopolistic control of the DGA on military research in France has led to remarkable separation between military and civilian R&D activities. According to OECD 1995 data (see chapter 3), after a constant decline in the previous years, 30.3% of total government R&D expenses - corresponding to $3.5 billion - was still devoted to military projects. About half of this amount of money went to fund research performed in the laboratories of large defence firms (under the control of DGA), and the remaining half went to the DGA research centres and to the CEA (Commissariat à l'énergie atomique) which is responsible for all research activities in the nuclear field.

Such a concentration of responsibility in one single body, the DGA, has also led to create a specific nomenclature for French R&D activities which differs from the one used at the international level by the OECD and referred to as the Frascati Manual series. The French Ministry of Defence (MoD) defines three levels of funding for R&D activities:

- RDE Research, studies and prototyping (Etudes, recherches et prototypes),
- DBRDM Gross expenditures for military R&D (Dépenses brutes de Recherche-développement militaire),
- CRED Expenses for the Conseil de recherches et études de defence.

The RDE expenses include funding for conventional and nuclear R&D, prototyping activities and activities of ONERA (Office national d'études et de recherches aérospatiales), the main aerospace research centre in France. The DBRDM include RDE spending plus some MoD funds devoted to its research and experimental centres. Finally, the expenses of CRED do not include the so called "études amont". The concept of "études amont" is not comparable with the OECD concept of "basic research". The "études amont" obviously include basic research - i.e. activities preliminary to industrial production - but also other activities which can be labelled as "applied research" and "exploratory development". For this reason the "études amont" are broken down in two categories: the first includes the recherche fondamentale (more close to basic research) and other research activities targeting the needs of the Armed forces, the second includes mainly prototyping activities for the development of weapons systems or their components.

These problems of definition make it extremely difficult to compare French military research data to those of other countries. First of all, because there are significant discrepancies between data gathered by the French MoD and those gathered by the Ministry of Research and Space. For instance, the comparison between the data on gross defence research expenses (DBRDM) provided to the OECD by the MoD and the data on military research provided by the Ministry of Research and Space, shows that the MoD data is systematically higher (even deducting VAT[25]) than OECD data defined according to the Frascati Manual. This means that the DBRDM also include activities not considered by the OECD as "research".

What is relevant here is that the French MoD (or better, the DGA) does not even make any effort to adopt definitions that could be more easily compared with OECD's definitions, as well as with other civilian or dual research data.

Dual-use in France

In France, the "dual-use paradox" described in chapter 2 can be observed quite clearly. The most authoritative documents on the French research and technology policy have recognised the need to exploit the dual-use potential of the domestically developed technologies while stressing that the French technological and industrial base is traditionally dual.

On the other hand, government officials and defence analysts unanimously argue that France does not need a specific effort for promoting a closer integration between military and commercial sectors. The reason for this is that France has already a technology base dual "enough" and that it would be useless to define a MoD dual-use strategy. Also within the DGA, some experts admit that the French military industry could benefit from a higher degree of duality but it is perceived as a problem of the military companies, not a problem of the DGA.

Such an approach makes it very difficult to identify dual objectives in a context in which a basic assumption is that the MoD and the DGA do not have any specific role to play in promoting the development of an increasing technological competitiveness in the French industry. Besides, also in France the constant reduction in military spending makes it more difficult for the military to widen their traditional tasks.

Notwithstanding, also the French MoD is slowly moving towards paying a greater attention to dual-use issues. The following paragraphs will describe the main activities related to dual-use carried out in France in the last years.

The defence technology and industrial policy. The report of the Commissariat Général du Plan

In November 1993, the Commissariat Général du Plan (CGP), a planning body of the MoD, published a report, entitled *L'avenir des industries liées à la defence*, which suggested some strategic guidelines for the government’s defence S&T policy. The report of the CGP can be considered a synthesis of the prevailing ideas developed at that time within the French military industry and, in particularly, within the DGA.

The report recognised the need for a strong national military industry and defined some measures in order to restructure the defence industry taking into account the changing international environment. The CGP suggested three main objectives: to proceed with the concentration of the defence industry, to find new potential markets for French arms production (also through European collaborations), and to increase R&D activities in a perspective of "pursuing" US technological levels. However, the report also gave relevance to the process of political and economic integration of Europe which could lead to reconsider the need for single countries, like France, to be self-sufficient in the production of their own military equipment. The strengthening of French military industry had to be pursued, according to the CGP, both by opening new markets for French military equipment, and by defining an European strategy which should address several matters - from security and defence policy, to development, production and procurement of military equipment - enabling Europe to contain the "excess of commercial power" of the US[26].

An appendix of the CGP report was devoted to describe the French military technology policy. Such appendix was written by Victor Marçais, former director of DRET (Direction des Recherches, Etudes et Technique), a technical branch of the DGA. In this appendix the role of dual-use technologies is pointed out, but the concept of "dual technologies" is used in a very particular way, with reference to the process of defining what technologies are "critical" by the military point of view and how civilian and military technological strategies can be "integrated".

As to the definition of military critical technologies, a technology can be labelled as "critical", according to the CGP report if:

- it can be potentially used for civilian or military purposes (*dualité*);
- the country can accept a certain degree of dependence from foreign contractors;
- it is not "sensible" in terms of proliferation of weapons of mass destruction.

The dualité criteria leads the CGP to identify five classes of technologies:

- totally military technologies, lack of duality (nuclear technologies, electronic warfare, stealth-*furtivité*, etc.);
- technologies moderately dual (missile propellants, lasers, etc.);
- technologies partially dual (optics and optronics, electromagnetic, acoustics, etc.);
- technologies largely dual (aircraft engines, super-computers, etc.);
- technologies totally dual (see box below).

Critical technologies with the highest degree of duality (CGP, 1993)

- Computing tools for complex systems integration
- Modelling and simulation for complex systems integration
- Artificial intelligence and neural networks
- Industrial systems of production (including robotics)
- Materials treatment and shaping
- Ergonomic and neuroscience
- Methods and technologies for improving the safety of military equipment and weapons systems
- Analysis of the environmental impact of production and use of military equipment and weapons systems

Paradoxically, it is not the *dualité* the most important criterion for the CGP to define if a technology is critical, but rather the degree of dependence and the risks of proliferation. Considering 24 technological areas selected by the CGP, 8 of them are ranked as having the "highest" degree of priority. Out of the 21 sub-classes linked to these eight "very critical" technologies, only 2 subclasses (new materials and complex systems integration) are "totally dual". Twelve out of 24 are technologies which entail a proliferation risk, while France needs to be totally independent for other six technologies.

In a wider perspective, choosing these eight technological areas as critical for France, the CGP has shown its interest in supporting the traditional fields of activity of the French military technology policy: nuclear weapons, aeronautics and electronics. This point of view is obviously backed by both the Armed forces and the defence industry. Such an orientation can be confirmed looking at the seven industrial sectors which are linked to the 24 technological areas mentioned above: strategic missiles and nuclear warheads, tactical missiles and unmanned aerial vehicles, aircraft, space, military electronics, shipbuilding and land vehicles. In each areas, at least a large French producer can offer some products to the domestic (and foreign) Armed forces. The main conclusions of this process of identification of critical technologies for France are essentially the following:

- R&D investments should be focused on critical technologies, and should raise non MoD funds for research on dual-use technologies;
- the highest priority should be given to technologies for which France must be totally independent from abroad;
- the European collaborations in the remaining technological areas should be further boosted;
- technological forecasting has to be constantly updated.

The relations between civilian and military technologies in the CGP report

The target of the CGP's report is clearly to guarantee an important role for France at international level and to acquire, in the military field, the technological and industrial skills of the United States: "les négociations en cours ou à venir au GATT ont une très grande importance pour l'avenir des industries liées à la defence qui ont ou auront, puor la plupart, des activités civiles de pointe, activités qui font l'objet d'une concurrence acharnée notamment entre la France et les Etats-Unis.

L'objectif des Etats-Unis est clairement de reprendre le leadership technologique et commercial dans des secteurs tels que l'aéronautique et l'espace où la France et l'Europe leur ont pris des parts de marché, et les matériaux et l'électronique où le Japon a pris la tête."[27].

The relationship between the United States and the European Union is moving toward a reduction of public support to industrial activity, even in the military field. This could weaken the European industry, the French one in particular, considering the different dimension of the military and civil domestic market in many sectors as the airspace or electronics. The necessity to modify even the technological policies in such competitive context is obvious and the public European interventions have to be similar to the US ones: "il semble bien que l'Europe et la France devront accepter le modèle américain. La seule issue pour nos industries de pointe sera d'augmenter le soutien civil et militaire à la recherche et au développement technologique ..."[28].

The report underlines the need for the MoD to be involved in the broader process of enhancement of the national innovation system, by increasing integration between civil and military R&D: "Compte tenu de la compétition économique actuelle et future, le ministère de la Défense ne devrait-il pas s'impliquer davantage dans la politique technologique nationale? En ce qui concerne les ministères civils dans leur ensemble, la fixation de choix et d'objectifs technico-économiques stratégiques pour l'industrie et l'économie nationale permettrait une meilleure coordination et une plus grande efficacité."[29].

According to the CGP's report, much of the new policy will depend on a reorganisation of the current defence industrial complex, composed by:

"- la defence: Délégation générale pour l'armement (DGA) et états-majors,

- les instituts et laboratoires de recherche,

- les industriels, eux-mêmes organisés entre architectes/systémiers, sous-sistémiers et équipementiers.

Ces organismes constituent un 'réseau' dans lequel il faut organiser une concertation permettant la synthèse nécessaire, recalée périodiquement, de manière à aboutir à la mise en place de 'plans d'actions technologiques' optimisés par rapport aux besoins estimés."[30].

The French model can be described, therefore, as a "network" with the capability to reorient the national research toward targets which take account of the French strategic exigency, but with particular attention to the potential developments of dual-use technologies.

The DGA and the dual-use technologies

In October 1991, the *Armement*, the official review of DGA, had already published a monographic number on dual-use technologies. In such publication, the concept of dual-use is clearly defined by the DGA: above all, it does not envisage the integration of the military R&D for the achievement of civil technological and economic targets: " ... ce qui justifie la recherche militaire, c'est avant tout de contribuer à la defence, et non de contribuer au développement économique de la nation."[31].

In France, there is a widespread claim that the structural duality of the military R&D entails spin-off benefits. For example, the aeronautics military sector has constantly transferred technologies and know-how to the civil sector. Overall it has contributed, with the research developed by ONERA, to the capability of managing military programmes. Almost all aeronautic experts have been trained within the military sector. On the other hand, according to the DGA: "le phénomene inverse de 'retombées militaires d'un effort civil de R et D commence à apparaitre" and seems to foster technological evolution through the transfer of research results: between different phases of the same research; between allied countries; and between civil and military sectors.

However, here, the DGA does not consider duality as an external objective, but rather as an intrinsic potentiality: "... Cette dualité de beaucoup de nos recherches s'inscrit d'ailleurs dans nos structures. ... D'une façon plus générale, on peut dire qu'en France la manière dont s'effectuent nos recherches vise à tirer la meilleure partie de la dualité."[32].

Thus, a continue exchange of knowledge between military and civil sectors is realised with the collaboration of the DGA with industrial firms, research institutions, Research's Minister or CNRS, university or single experts. According to such interpretation, this represents a perfect case of duality. However, further complications could rise in consideration of:

1. the regulations and the culture that can create difficulties in the integration of commercial components in military systems;
2. the adoption of dual technologies entails cost-savings only at the end of the construction phase;
3. the different period of amortisation of a military product compared to a civil one.

The implementation of dual-use is mainly understood as the possibility to increase the spin-on effect transferring know-how from the civil sector to the military one. The DGA considers this as a "chance" that should be exploited, increasing the capability to identify such spin-on opportunities. Such a process should be completely exogenous from the military research activity managed by the DGA[33].

The 1994 Defence White Paper

The latest official document on French defence's industrial and technological policy is the *Livre Blanc sur la Defence*, published in 1994. The *Livre Blanc* gives details on what should be France's procurement policy and industrial strategy for the military sector. The main topics tackled in the *Livre Blanc* are:

1. the need for an independent industrial base for military armaments;
2. the orientation toward international co-operation without loosing the capability of developing autonomously the necessary equipment;
3. the collaboration with other countries in non-strategic sectors;
4. the dual-use capabilities entangled in both civil and military goods;
5. the recognition that in some sectors the civil innovative process is faster than military progress.

Technological "hierarchy" is seen as the cornerstone of the French military technology policy. At the top, there are those technologies - basically related to nuclear weapons - where the French want to maintain a full independence in order to enhance the deterrent effect of the force de frappe. This means that an expensive research body, characterised by high levels of secrecy and by a significant separation from civil research structures will have to be maintained. On the other hand, the presence of the Commissariat à l'Energie Atomique (CEA) has not significantly influenced in the last years the French military S&T policy.

At a lower level of the technological "hierarchy" there is the non-nuclear strategic sector: technologies of information, for the communication's protection, search and use of information, stealth technologies, electronic war, systemic technologies. In this sector, France wants to hold a competitive position even with respect to its own political and economic partners. First of all, the United States which are considered the main concurrent of France in the military technological field and on the international market of armaments.

Finally, there are the non-strategic technologies. In this field, French policy is aimed at upgrading its capabilities also by collaborating with other countries, especially Europeans. Within this last sector electronics and new materials are particularly relevant.

In such context, the duality is once again considered within the spin-off concept: "l'ampleur de l'effort consacré à la recherche et au développement se justifie par l'utilité militaire des buts poursuivis. On ne peut cependant sous-estimer l'importance pour la Nation des retombées directes ou indirectes de technologies de pointe qui contribuent au développement d'activités dans le secteur civil."[34].

Besides, there is the recognition that in some sectors "la defence n'est plus le moteur de l'innovation.". In telecommunications, information sector, electronic components and new materials, even the defence can find an interest in opening itself to the international market, although avoiding the integration process between military and commercial activity.

The restructuring of the DGA

In 1996, the French MoD has defined a project aimed at restructuring the DGA. This project, which will be implemented in 1997, is linked to the new *Loi de programmation militaire* approved in the French Parliament in 1996 which has abolished the conscription designing a professional Army, reduced in size and technologically more advanced. While expenditure for military personnel will probably decline, military investments are expected to be constant in the near future. Nevertheless, the pressure for a reduction in the overall military spending will have as a result an attempt to cut, if not the investments in R&D and equipment, the bureaucratic costs of the DGA. Thus, the project for a "nouvelle DGA" is mainly focusing on cost savings: in 2002 the costs of DGA will have to be reduced by 30%. The future DGA will be leaner with fewer offices, laboratories, equipment and employees. Its main activity will be military equipment development and acquisition: the management of industrial companies, the co-ordination of industrial R&D and several international activities are going to became only secondary tasks. In this perspective, the DGA will increasingly operate as a commercial company managing complex military programmes35. An approach based on five criteria - cost, impact, performance, probability of success and time - will lead DGA procurement choices, giving priority to the operational needs of the French Armed forces and leaving out its role of preserving the military industrial base.

In this process of transition towards an organisational model at least partially shaped on commercial companies, will the DGA promote the integration between military and commercial sectors?

The answer is probably no. The DGA is currently changing its organisation rather than changing its culture. This is because the pivoting role of DGA in the military industrial sector is not going to change also if it has to become less expensive and more efficient. In this context, a dual-use strategy is not proposable, at least until the concept of promoting "dual" production in the military industry and a commercial model of organisation in the DGA will not been completed pursuing "dual-use" as a primary objective of the French military technology policy.

United Kingdom

The British dual-use policy

During the 80's the British military sector, in particular the armaments production, has experienced a bold policy of privatisation - pursued by Conservative cabinets - as well as the introduction of commercial methods and standards in the management of weapons systems programmes.

The aim of the British government was to maintain a high level of competitiveness of the British military industry in designing and producing advanced weapons while reducing the British Armed forces procurement spending. This industrial policy, aimed at getting from the military industry "value for money", has led the British military companies to be largely independent in defining their own priorities in R&D from the guidelines suggested by the government.

On the other hand, the MoD has constantly been among the main sources for R&D spending in the UK: the ratio between military research spending and total public spending in R&D (40,8% in 1995) has not significantly changed in the last years. Such a high level of investment in military R&D is also a heritage of the Cold War period, when the British science and technology policy was strongly influenced by the need of developing national skills in some strategic areas, like nuclear weapons production and long range force projection.

The British military innovation system is based on a separation of roles among military firms and public laboratories. About 40% of military R&D spending goes to public research laboratories. In 1991, several military research laboratories were put together within the Defence Research Agency (DRA), a MoD's agency. The following four laboratories, which are the largest British military research centres not involved in nuclear research, are currently managed by the DRA:

- RAE Royal Aerospace Establishment;
- ARE Admiralty Research Establishment;
- RARDE Royal Armament Research and Development Establishment;
- RSRE Royal Signals and Radar Establishment.

The main military research centres not controlled by the DRA are: AWE (Atomic Weapons Establishment), which performs research activities on nuclear weapons, and CBDE (Chemical and Biological Defence Establishment), focusing on chemical and biological weapons. The DRA has progressively widened its activities acquiring in 1995 the Institute of Aviation Medicine (IAM) and the Army Personnel Research Establishment (APRE). Currently, the DRA is carrying out activities in eight areas (see box below), employing about 6,000 people with a budget of £ 600 million.

DRA research areas

- Aircraft Systems Sector

Expertise and facilities to enable the generation and assessment of affordable technical solutions across all the key technology areas upon which both military and civil aircraft depend for their effectiveness.

- Centre for Human Sciences

Provides advice and consultancy on all aspects of human factors and personnel related issues.

- Command & Information Systems

Research and development focused on tactical, operational and strategic communication and information systems.

- Electronics Sector

Holds the technology base for much of the componentry and sub-systems critical to military systems.

- Land Systems Sector

Research-based technical advice to the MOD to assist procurement decisions for the Services.

- Sea Systems Sector

Focus for MOD research and development relating to above and underwater platforms and weapon systems.

- Structural Materials Centre

As a dual-use technology centre, the SMC staff and facilities are available to both defence and civil customers for materials research and technical services.

- Weapons Systems Sector

Strategic and applied research and project support to meet customer requirements for advice over the full life cycle of weapon systems and the technologies for guided weapons and novel systems.

In 1993 the DRA was given the legal status of trading fund. This move has to be considered as included in the larger process of privatisation and restructuring of research activities, including the military ones. Since then, the DRA and its laboratories do not receive research grants anymore and have to raise funding for its own research activities also applying for research contracts to the MoD. The DRA competes, for research contracts by the MoD or other ministries, side by side with public and private research laboratories, as well as British and foreign firms. The increasing introduction of commercial procedures for the assignment of military R&D contracts led in five years, from 1991 to 1996, to a 20% reduction in military R&D spending without any drawback in the scientific and technological output.

In 1995, the DRA became a branch of another MoD agency, the Defence Evaluation and Research Agency (DERA). The main purpose of DERA is the dissemination of its approach to research management in other public and military laboratories, including: the CBDE (chemical and biological weapons), the Defence Testing and Evaluation Organisation (DTEO) and the Centre for Defence Analysis (CDA). DERA is currently the largest military research organisation in Western Europe, not including nuclear research. Although DERA is mainly a military agency, it has also a large research capacity in commercial areas: the high quality of its research is proved by being in compliance with the highest commercial quality standards (ISO 9000 e NAMAS).

The industrial contribution to military research

A large share of military research spending in the United Kingdom (about 55% of the total) is devoted to research performed by industrial firms. The British military industry is able to produce every kind of armaments with the exception of ballistic missiles, strategic bombers and aircraft-carriers. As reminded above, the British industry has been progressively privatised in the ‘70s and ‘80s except for the nuclear weapons production. At the beginning of the 90s, the military industry employed about 400,000 workers, which is to say about 10% of the total industrial workforce. In the same period the military industry output accounted for a share from 10 to 20% of total industrial output in the UK. Of course, the R&D activity developed in industrial firms is mainly linked to applied research and products development. On the other hand, the MoD has a very limited influence on companies' strategic choices: its prevailing interest is to set competitive criteria for entrusting research contracts.

Notwithstanding the MoD policy, which is obviously aimed at maintaining a significant military industrial base also if acting in a competitive context, a relationship between civilian and military activity, whether in research, or production can be observed. Already in 1992, a parliamentary office - the Parliamentary Office of science and technology (POST) - carried out a research on dual-use and conversion activities in the UK and pointed out several experiences of diversification and conversion in the British military industry.

An objective for the UK technology policy: to establish a LINK between public research and industry

In 1986, the British government established a pioneer initiative, called LINK, in order to boost research co-operation among universities, private firms, and public institutions. Until 1997, 1,150 companies (300 of which are small and medium firms) have co-operated with about 170 science-based institutions (83 of which universities) in 83 programmes which have had very good results according to a survey carried out among the participants. This survey has pointed out that promoting partnerships involving universities and industrial firms for pre-competitive research is particularly effective offering to small and medium firms a chance to develop and introduce technologically advanced products and processes.

Since 1993, the LINK initiative is managed by a governmental office, the Office of Science and Technology (OST), while 13 Government sponsors, including the Ministry of Defence, are actively supporting it. The OST is mainly playing a role of co-ordination, orienting the LINK programmes towards those objectives defined by the 1993 UK White Paper on research policy: *Realising our potential: A strategy for science, engineering and technology*. One of the key issues raised by the White Paper was the need of fostering the collaboration between government, industry and research institutions. The most important activities in this field include: the restructuring of the Research Councils (six of which have re-focused their activity in order to offer a larger support to industry needs); a redistribution of tasks among several government departments dealing with technology policy; and the establishment of an ambitious project of technological forecasting (Technology Foresight).

LINK is a relevant part of this effort aimed at exploiting the UK scientific and technological potential. Within the LINK programmes, the government sponsors (including several Departments and Ministries) can fund projects aimed at improving the UK competitiveness in sectors in which the British industry is comparatively weaker than its competitors. In the research field, the Research Councils can support high level basic research matching it - through the LINK initiatives - with the industry needs.

Also in the military field, the LINK initiative can play an important role promoting partnerships between industrial firms and military laboratories. In fact, while LINK can be hardly oriented to develop military technologies, the MoD and the DRA are supporting it in order to make easier transferring technologies in a dual-use perspective.. Particular attention has been paid to the definition of a collaboration between the MoD and the Department for Trade and Industry (DTI) for promoting dual-use research through the DRA 's Dual-use Technology Centres.

The role of defence and aerospace in the Technology Foresight

Within the Technology Foresight - the above mentioned national technological forecasting effort which started in 1995 - a special attention has been paid to the aerospace and defence sectors because of their contribution to the advancement of the national technological base and to the British trade balance.

Considering the existing competencies and the future needs in these two sectors, the Technology Foresight Programme focused on seven key sub-areas, which are:

- Systems Integration
- Process Technologies
- Materials and Structures
- Simulation, Modelling and Synthetic Environments
- Aerodynamics (including Emissions and Noise)
- Sensor Systems, Data Fusion and Data Processing
- High-integrity, Real-time Software

The main findings of Technology Foresight have been published in a report defining also some measures to be rapidly implemented, as well as some long-term objectives. For instance, the report suggested to establish two programmes of applied research, involving both military and aerospace firms and universities, for developing dual-use and civilian aerospace technologies. The financial support to two dual-use initiatives - the CARAD (Civil Aircraft Research and Demonstration) project and the TDP (Technology Demonstrator Programmes) - by the DTI and the MoD was also suggested. The general guidelines for an industrial and technology policy in the defence and aerospace sectors - as outlined by the Technology Foresight report - are listed in the box below.

Relevant policy issues which must be addressed for fully exploiting the UK technological potential in the defence and aerospace sectors (*Technology Foresight, 1995*):

- The Challenge to Companies. Companies must develop and implement plans to increase industry R&D investment significantly against long term technology goals.
- National Strategies for Defence and Aerospace Technologies. Industry, Government and Academia should establish strategy frameworks for Defence and Aerospace technologies.
- MOD Procurement Policy. Government and industry should review MOD procurement policies to place more emphasis on UK industry competitiveness and wealth creation.
- Market Distortions. Government, with Industry support, should establish effective means to monitor and correct market distortions.
- International Defence Collaboration. Government must accelerate where appropriate the establishment of common defence requirements and acquisition in Europe.
- Financing. Industry and Government, in partnership, should work to reverse the current declining UK spend on research and demonstration.
- Air Traffic Control. The UK should seek to work within Europe to define standards for an advanced air traffic control system and participate in supporting demonstrator activity.
- Space. Consideration should be given to adjusting the balance between national and European funding and reforming European and UK space institutions.
- Skills. Undergraduate training in multi- and inter-disciplinary subjects supporting the Panel's key technical priorities should be developed.

A key question for the Technology Foresight programme has been how to make the British industry - including the defence and aerospace industry - able to preserve a high level of competitiveness on international markets. The Technology Foresight report suggested to increase public and private R&D funding but also to improve the application of the results of R&D activities.

Also the Mod can play an important role in this context promoting dual-use research and some activities have been actually defined. In 1995, the MoD published a list of dual technologies which was considering for funding (see the next box). Besides, the MoD has joined the LINK initiative as sponsor and has established the Pathfinder programme and the *Dual Use Technology Centres.*

Dual-use technology areas identified by the UK MoD (1995)

1. Electronic and Photonic Materials and Circuits
2. Software Engineering
3. High Performance Computing
4. Machine Intelligence and Robots
5. Simulation and Modelling
6. Radar and Passive Imaging
7. Signal and Image Processing
8. Signature Control
9. Weapon Systems
10. Computational Fluid Dynamics
11. High Energy Density Materials
12. Composite Structural Materials
13. Biotechnologies
14. Flexible Manufacturing
15. Nuclear Weapons Technology

The Dual Use Technology Centres

The *Dual Use Technology Centres* (DUTC) have been established by the MoD for commercially exploiting the research performed by military laboratories. Many research activities carried out in military laboratories can produce results with potential civilian applications. Thus, the MoD is interested in collaborating with commercial firms from a very preliminary stage of some research projects in order to identify, as soon as possible, commercial applications for newly developed technologies. Such collaboration will take place in the DUTC.

The MoD is going to establish several DUTC (the first ones are listed below) which will have different tasks and different structures. In some cases, they will be based in a single place (for instance, the *super computing* centre will based at Farnborough or the centre for marine technology at Haslar); in other cases the centre will become a *network* linking laboratories and firms working together on a common research project.

Dual-use Technology Centres

- Structural Materials Centre
- Super Computing Centre
- Software Engineering Centre
- Centre for Marine Technology (Haslar)
- Electronics Dual Use Technology Centre (Malvern)

The Pathfinder Programme

In November 1992, the DRA set up a programme, called Pathfinder, aimed at defining the potential contributions of British industrial firms to military research projects. The MoD appropriates yearly £ 500 million for funding, through the DERA, research activities of military interest carried out in civilian firms. Periodically, the MoD convenes a meeting with the top management of the largest British firms in order to inform them on how the military research priorities are evolving. The information provided by the MoD enable the industrial firms to define their research programmes matching their needs with the technological needs of the MoD. Such a partnership between the MoD and the national industry can offer a large potential for developing dual-use technologies because the firms which apply for a research grant are not sure that their projects will be funded (the projects are evaluated by the DERA on a competitive basis) and are probably interested in pursuing research results which can be commercially exploited.

All British firms which perform research can apply to the MoD for research funding under the Pathfinder programme. Each year about 500 research projects are submitted to MoD and about one fourth of them is funded . The average cost of a Pathfinder project is about £ 200,000, 70% of which is provided by the MoD.

The MoD dual-use strategy: "the best technology, but affordable"

This description of the dual-use initiatives which are taking place in the UK suggests that the British government had defined a quite clear "dual-use strategy". The British government has understood, in the last years, that the economic and technological development of the UK had to be supported also by using the resources poured in the military research system. The high level of the military research in the UK could offer a relevant contribution to enhance the competitiveness of the British industry if the "separation" between military and commercial activities will be reduced.

On the other hand, the British MoD is fully aware that the UK Armed forces will become soon unable to afford the best technology if it will be too expensive. Thus, the MoD "dual-use strategy" is mainly aimed at evaluating to what extent the commercial industry can provide the Armed forces with the equipment and the technologies they need. The guidelines of this strategy - not very different from those of the US DoD - are the following:

- funding military research while leading private firms to invest in dual-use technologies critical for the MoD;
- producing military items in commercial firms;
- applying commercial technologies in military production.

Germany

In a research report on *Defense Conversion. Redirecting R&D*, published in 1993 by the Office of Technology Assessment (OTA) of the US Congress, an appendix was devoted to describe objectives and functioning of the main German institutes of industrial research. What made the German innovation system so interesting for American researchers (and policymakers) was the ability of those institutes to carry out military, or even dual-use R&D, within civilian research laboratories. In fact, the German attitude in this field is totally different from the traditional US approach, not keen on giving responsibility on dual-use activities to military laboratories. The German model looks to the Americans like a "perfect" dual-use research system in which military and commercial needs can be jointly managed.

Military R&D activities in Germany

Military oriented R&D activities in Germany are divided between:

- research and technology (R&T), covering the period from research to the decision on a concrete project, and
- the actual development, which includes the definition and testing of a specific weapon project.

The objective of military R&T is to obtain assessments by experts - independent if possible - of the security situation and of the innovation processes, and to improve the performance standards of military processes, technologies and systems[36]. Actually, in Germany only a few military research activities are carried out in military laboratories. The Armed Forces are responsible for only a small part of total military R&D and are mainly involved in testing activities.

MoD laboratories in Germany

- Forschungsanstalt der Bundeswehr für Wasserschall und Geophisik (FWG)
- Wehrwissensaftl. Institut für Schutztechnologie/ABC Schutz (WiS)
- Wehrwissentschaftl. Institut für Material-Untersuchungen (WiM)
- Bundesinstitut für Chemisch-technologie Untersuchungen (BICT)

Neither basic research, nor the design of new weapons are under the responsibility of the military laboratories. Also because several large German research institution - as well as some universities co-ordinated by the German Research Foundation (DFG) - are involved in military research as well.

Research institutions involved in military research in Germany			
National Research Centres (16 institutions including DFLR)	Fraunhofer Society	Max Planck Society	Federal Institutions performing research (56 institutions): the four MoD laboratories and FGAN are under the responsibility of the MoD.

A relevant example of military-oriented R&D centre is the FGAN (Forschunggesellschaft für Angewandte Naturwissenschaften - Research Establishment for Applied Science) which is not a MoD laboratory even though it works 100% for the military. The FGAN was founded in 1975 as Establishment for Astrophysical Research and since 1995 its activity has been oriented towards the military applications of electronics and optics. It currently runs six research institutes and conducts research in the following areas: sensors, electronics, cybernetics, information technology and human factors research. FGAN is mainly oriented to perform applied research aimed at:

- improving the performances of present and future reconnaissance methods and systems;
- improving and develop modern guidance and control systems;
- increasing the efficiency of command and control processes.

If the FGAN is an example of civilian research centre totally working for the MoD, the DFLR (Deutsche Forschungsanstalt für Luft- und Raumfahrt - German Aerospace Research Establishment) is an example of real "dual-use" research laboratory. The DLFR carries out research mainly in three areas: aviation, space flight and energy technology. DLFR has seven research centres, five departments and 25 institutes; DLFR institutes activities are focused on developing new technologies, performing scientific investigations and testing materials and equipment - often in co-operation with industrial firms and universities, both national and international. These institutes have large-scale test facilities, such as wind tunnels and research aircraft, control centres and satellite receiving stations. DLFR provides German industry with scientific and technological know-how in its field of activity which is devoted to military needs only for a small share of its overall activity (nearly 10%). So, while DLFR is one of the largest receptors of research funding from the German MoD, its activity is largely oriented to commercial needs, showing a real dual-use attitude.

A very special case of dual-use research institute is offered by the Fraunhofer Society (Fraunhofer Gesellschaft). The Fraunhofer Society is the leading organisation in the field of applied research in Germany. It includes 47 institutes working on several research fields, the most important of which are: Materials and Components, Production Technologies, Information and Communication, Microelectronics and Microsystems, Sensor Systems and Testing Technologies, Process Engineering, Energy/Environment/Health, Technical and Economic Studies.

The Fraunhofer Society has about 8,500 employees and its research centres are spread all over

Germany, offering to the industry a constant support in developing new products and processes. The scientific and technical advice from the Fraunhofer institutes is particularly important for small and medium firms which can take advantage of the extensive Fraunhofer research capacity and facilities when their own capacity are not sufficient to develop technological innovations needed to remain competitive. However, the Fraunhofer Society has to be considered also a dual-use research institution since four Fraunhofer institutes are totally dependent on MoD research contracts. The Fraunhofer "military" institutes are:

- EMI - High Speed Dynamics "Ernst-Mach-Institut",
- ICT - Chemical Technology,
- INT - Technological Trend Analysis,
- IAF - Applied Solid State Physics.

As a private institution, the Fraunhofer Society is only partially funded by the German public authorities. The German state is supporting Fraunhofer's investments in research facilities and equipment, but the research activities are financed by research contracts from public bodies (like the MoD), as well as universities, large firms or consortia of small firms. The Fraunhofer institutes are deeply involved in the economic activity of the regions in which they are based. They are connected with other public and private institutions through what we could define a "research network", which offers a very special chance to spread technologies and know-how among different actors. It also represents a very good environment for promoting "dual-use" activities - and especially the transfer of military technologies to commercial firms and vice-versa - considering the effort of diversification towards civilian fields which the Fraunhofer military-dependent institutes are currently pursuing.

More oriented towards basic research is the Max Planck Society (Max-Plank-Gesellschaft zur Förderung der Wissenschaften) a research institution whose foundation dates back to 1911, as Kaiser-Wilhelm-Gesellschaft, and has been promoting scientific research in Germany since then. The Max Planck Society has 69 institutes and several working groups and laboratories. Many of these laboratories are renowned for the high level of their scientific production, mainly in fundamental sciences, like physics, biology or mathematics. Also the Max Planck institutes sometimes gain research contracts from the MoD but they are not research centres strongly dependent on MoD funding.

The Research and Technology (R&T) Concepts of the Bundeswehr

In 1985 the German Federal MoD defined a "Research and Technology Programme" (RTP) in order to define a national strategy for enhancing the innovation process in the Bundeswehr. Within the RTP it was considered an interesting option for the military to use civilian developed technologies. Such an option was based on recommendations by a "Commission for the long-term planning of the Armed Forces", previously established.

Since 1985, the actual guidelines for providing the Bundeswehr with an adequate technological background, including both civilian and military developed technologies, has been collected in a document called "Research and Technology Concept". This document is produced yearly and its circulation is restricted to people involved in military R&D activities. The definition of the R&T Concept is an integrated part of the Bundeswehr planning process including, as already stressed, all pre-development activities in the MoD, i.e. not considering full scale development of military equipment.

Every year the results of the MoD technology policy are evaluated and the R&T Concept is updated through a process in which are involved both industry and research centres. The main principles of the R&T Concept are the following:

- The MoD does not fund basic research and technology with its own budget and is adopting civilian technologies for military needs wherever possible,
- All R&T activities are combined on an inter-service basis and co-ordinated in one single R&T Concept for the Bundeswehr,
- The armaments division[37] is responsible for co-ordinating all R&T activities, for the annual updating of the R&T Concept and for consulting both research institutes and industry, on the one hand, and planning staffs of the services, on the other[38].

The *1994 German Defence White Paper*[39] offers an additional information stating that the priorities of military research are defined according to the needs of the military services, as well as from inputs coming as a result of:

- civilian research activities funded by the Federal Government,
- activities of international co-operation,
- research activities carried out in the business sector.

As an example of the outcome of this process, the table below shows the priorities set by the German MoD in 1996.

Priorities of the German R&T Concept

1) To improve and adapt reconnaissance capabilities. Specific efforts are made in:
new sensors and sensor processing, radar for satellites, multi spectral sensors at automatic target recognition, long range unmanned aerial reconnaissance, aerial surveillance for navy applications.
2) Command control communications and intelligence systems are to be improved in:
command and control, interoperability of command information, battlefield IFF, tactical communication.
3) Mobility is to be improved by:
mine detection and clearance on the ground, new air transport facilities.
4) Protection against future weapons systems by:
reduction of detectability (stealth), effect of high power microwaves, warning of biological and chemical substances.
5) Extended air defence by: hypervelocity missiles, new concepts for extended air defence.
6) Next generation of armoured platforms for the Army:
active armour plating.

(Source: German Embassy in London (1996)).

What emerges from both the process of setting priorities and the results of such process in terms of technological areas is a strong emphasis on the contribution of civilian technologies to the enhancement of the ability of the Bundeswehr to fulfil its needs. The 1994 White Paper was already very clear on this point: "Costs can be further limited by making increasing use of civilian technologies in the armed forces. In some sectors of military equipment, the speed at which one generation follows another is influenced by ever greater and faster leaps of innovation in civilian technology. This is particularly true of command and control, communications and reconnaissance systems.

In the future, the armed forces will be making greater use of systems and components of civilian technology. Thus, the Bundeswehr will benefit from the innovatory power and the competition of the civilian markets."[40].

A "dual-use" innovation system

As it has been shown in the third chapter, the contribution of business funded R&D in Germany accounts for about two thirds of the total expenditure for R&D. This is a key factor in giving to the German manufacturing industry an impressive innovative capacity. Also the indicators of innovative output using patent data show that the German industry is a powerful engine of innovation. In this context, the role of the State in promoting R&D and innovation is - compared to country such as France or the United Kingdom - far less important than that of the industry. This is particularly true in the military field, where, as seen above, the share of public funded R&D has constantly been less than 10%.

Federal R&D expenditure on defence research and development, 1992-96.

Figures are in million DM at current prices.

1992	1993	1994	1995 (budget)	1996(gov. draft)
3,065	2,635	2,610	2,866	3,204

Source: BMBF (1996).

As a consequence, the MoD has shaped a technology policy mainly aimed at extracting from the civilian industry, which is technologically advanced and very competitive on many international markets, the best technologies available for the needs of the Armed forces. Within the framework of the military needs, as defined by the Armaments division of the MoD, most of the proposals for the development of new technologies, as well as of new weapons systems, come from private research centres or industrial firms where commercial and military research activities can be more easily performed in a context of cross fertilisation.

In such a context, and also considering that the German defence industry virtually disappeared after the World War II, the German industry came to be competitive and able to define autonomous strategies only during the second half of the '70s when a strong public support was needed for developing high-tech areas , like aeronautics or military electronics. But the support given by the German government to the military industry in the last decades has not modified the orientation of the German industry towards a "dual-use" innovation system. Some cases of "segregation" of military production - like in the fighter aircraft or submarines production - are far from being general and are not relevant compared to the overall activity of the German industrial base which appears to be intrinsically dual and able to activate an effective technology transfer between civilian and military sectors.

The lack of research laboratories owned by the MoD, the presence of a number of small and medium firms as defence contractors and the large contribution of business R&D to total R&D, together with the solidity of the German industry and the political stability of Germany, have contributed to create and to maintain the "German model" of pursuing a dual-use research and production which has been so largely studied (and to a some extent admired) in the US.

A weakness of such a "German model" - often neglected by foreign observers - can be found in the links between government and industry. The strong financial and economic autonomy of the largest German industrial groups, coupled with the strong partnership existing between the largest companies and the local governments (at least in those *länder* more dependent on military production), make the industrial companies hardly influenceable by the central government. On the other hand, the main contractors - especially the Daimler Benz group, the main German arms producer - are often favourite in competitions for arms acquisition and can easily obtain arms export licences. In some cases the German industry seems able to influence the choices of the government, while other industrial groups in Western countries continue to be strongly dependent on government choices.

Chapter 6: Conclusions

The different meanings of conversion and dual-use

Among the main findings of this study it can be pointed out that national specificities in terms of dual-use policies are strongly dependent on existing differencies in the national civilian and military systems of innovation. It is quite obviuos to note that where national governments play a relevant role in defining the national industrial and technological policy - like in Europe - it is easier to find a direct support to dual-use activities than in the USA, where industrial policy is, to a some extent, a “forbidden word”.

Nevertheless, in terms of concepts definition and effectiveness of the implemented measures, the situation can change dramatically. Indeed, the European countries show to be less able in managing complex dual-use programmes than the US. The rationale for this, according to the sharp opinions of most of the European experts interviewed, is that the European countries simply do not need dual-use programmes because they already had dual-use innovation systems, while the US has to rapidly build a new one.

On the other hand, in the US defence planners and analysts have developed in the last years several original analyses, as well as experiences, on how to deal with dual-use technologies. Although these activities have given mixed results, the US have an experience in this field far more advanced than the European countries have (with the partial exception of the UK).

Already at the beginning of the ‘90s, each country defined its own approach to “dual-use” ranging from those not considering dual-use a relevant issue for the national technology policy, to those making it the key concept of their national military technology strategy.

For instance, in Germany, where a dual-use approach had *de facto* shaped the national technology base on which the MoD relies for its needs, the idea of implementing a military and industrial “conversion” has been more successful, especially looking at the big military infrastructures in the former East Germany.

Indeed, conversion has been intended in Europe mainly as a complete restructuring of the military industrial base with few concerns for conversion of military R&D. This can explain the very small number of laboratories which in Europe are working for military-unique purposes. On the other hand, the concept of “conversion” in the US is less “fundamentalist” than in Europe and has been instead referred to military laboratories, as well as military bases and installations[41]. As already pointed out in chapter 4, a relevant support to conversion raised in the US at the beginning of the ‘90s, together with serious concerns about the reduction of the competitiveness of the US manufacturing industries on the world markets. It seemed then wise to jointly meet national security and economic security needs, mainly by promoting mutual technology transfer between the military technological and industrial base and the commercial industry. The US experience has to be considered a special case mainly because of the huge amount of technological know-how developed - but only partially used - in military laboratories and available, at least in principle, for civilian uses. The "conversion" from military to civilian uses of technologies as well as of infrastructures, personnel skills or land has been long considered a needed step for supporting that economic recovery which has actually taken place in the mid '90s. This is the main reason because the demand for a "conversion policy" was so pressing in the political debate (especially in the 1992 Presidential campaign) and has became since then one of the main disputed issues between Democrats and Republicans.

In Europe, the concept of conversion has been mainly referred to the "military industry conversion". It means that, far from aiming at using an existing stock of technical knowledge - developed by the military - for civilian purposes, like in the US, the "conversion policy" has been perceived as a policy aiming at dismantling - after the end of the Cold War - an uneffective and oversized military industrial base. Two opposite opinions emerged in Europe about the need for a "conversion policy". On the one hand, conversion was perceived as not necessary because of both the small size of the military in most European countries and the need for an adequate level of military capacity at national level. On the other hand, conversion was considered as necessary in order both to face the economic crises that were affecting some European regions formerly producing large quantities of arms and to set new national priorities in science and technology policy for keeping the pace with the US and Japan.

Besides, while in the US a "conversion policy" appeared as the only acceptable way the government could promote industrial and technological development shelving the traditional hands-off attitude of the US government towards industry; in Europe industrialists feared that a "conversion policy" could give to the government an additional instrument of control over the national industry.

As a consequence of such different evolutions, almost any public intervention aimed at linking the military and the civilian sectors has been labelled in the US as "conversion policy", while in Europe the "conversion policy" has been increasingly associated with the "regional conversion policy" largely supported in the last years by both several national governments and the European Union.

Also the meanings of "dual-use" differ in the US and in Europe. The concept of dual-use has been largely perceived as being more manageable by the industry. While "conversion" has been seen as linked to state interventionism, the implementation of a "dual-use" strategy appeared to be a satisfactory way to exploit the commercial potential of military technology, preserving the existing industrial base which could have been at least partially jeopardized by a more intrusive conversion policy. But while in the US the dual-use policy has been intended as a component - aimed at promoting linkages between military and civilian fields - of a wider conversion policy (as it was conceived in the US), in Europe it has been considered an alternative to a more radical conversion policy.

Bearing in mind the theoretical framework discussed in chapter 2, it can be assumed that the US scientific and political debate on “dual-use”, being more “open” than the European one to discuss and compare different approaches about how to deal with “dual-use” and related concepts, has also been more fruitful, developing very innovative concepts including that of “civil-military integration”. On the other hand, in the European NATO countries which have been considered in this study, it is still quite common to discuss about “dual-use policies” assuming that the separation between the military industry and the civilian one can not be overcome.

Objectives of the dual-use technology policies

Comparing the objectives of the dual-use policies in the four countries, it is possible to find a larger convergence than in the theoretical field.

First, it has to be stressed that the Ministries of Defence have kept, in all of these countries, a firm grip on any national technology policy which could affect the ability to fulfill the technological needs of the Armed forces.

Thus, in France the DGA, which is refocusing its activity on the management of arms programmes, is strengthening its control on basic research performed in public and industrial laboratories. In Germany, although in a different institutional context, the Direction for research and technology of the MoD Armaments Division has a coordination role over all R&D and technological activities both within government departments and civilian scientific agencies and industrial laboratories. In the UK, the DRA has maintained its control on most military research activities performed by public laboratories. Finally, in the US the DDR&E has refocused in 1996 its technological activity on purely military goals as a results of concerns in the Congress about the ability of the current military technology base to fulfill the needs of the US Armed forces.

Such an influence of the military on R&D activities it is not new: the promotion of dual-use tecnologies, in the four countries, has always been a secondary goal for the government, with a partial exception in the US with reference to a few programmes aimed at technological dissemination, like the Technology Reinvestment Project.

In France and Germany, where specific dual-use programmes have not been established at all, it is only possible to note that an evolution is taking place pushing the military planners to seriously consider the potential contribution of commercial technology for improving the efficiency of the Armed forces. Nevertheless, in France, the government and the military have never changed their minds in considering the pursuit of economic development to have nothing to do with military or dual-use technology policies. In this perspective, the dual-use has not been considered an “autonomous” objective but a useful methodology to be applied in the military systems management.

Besides, in the US and the UK most of the dual-use programmes established in the last years have been more oriented to strengthen the military technological base than to establish a dual environment for developing technologies and know-how both for military and civilian uses. Finally, in all of the considered countries, the need for saving resources to invest in the military sector has been put forward as the best reason for moving towards dual-use.

Results of the dual-use technology policies in four NATO countries

Considering that in the four countries under scrutiny it has not been possible to identify a technological policy specifically aimed at promoting a dual-use environment and, least of all, at defining a strategy for integrating civil and military activities, it is hard to assess the activities carried out in this field.

Nonetheless, a wide discussion has been open on the need for the military systems to be more "integrated" with the civilian sectors. Several experiences, although often unsatisfactory, have shown the limits as well as the potentialities of dual-use programs and policies. The US experience has paved the way to the establishment of programmes promoting both "conversion" of military technologies towards dual-use and "insertion" of commercial technologies in military equipment (see table below).

Examples of US dual-use technology programs and their prevalent objectives	
Transfer of knowledge from military to civilian fields	Transfer of knowledge from civilian to military fields
- CRADAs - Technology transfer programmes	- Dual-Use Application Programme - Programmes aimed at technology insertion

Some activities which have extensively used a dual-use approach have been developed both in the US (TRP) and in the UK (DUTCs), but a comprehensive assessment remains difficult mainly for three reasons:

- most of the dual-use programmes and activities described above have not lasted for a sufficently long time;
- dual-use policies in Western countries are strongly dependent on changes both in government and in Parliament;
- apart from the US in the 1992-94 period, no country attempted to define a coherent dual-use or civil-military integration strategy.

With the relevant exception of the CRADAs in the US, a pioneering and successful attempt to establish links between military laboratories and civilian firms which dates back to 1986, and the similarly successful British LINK programme, established in 1986 as well, all dual-use related programmes considered in this study have a quite short story.

The US DoD Small Business Innovation Research programme, first established in 1982, became a large programme only in 1992 and some results are expected to be assessable around the year 2000. The Technology Reinvestment Project, established in 1993 as “a key component” of the President Clinton “conversion” plan, has been abolished in 1997 without having had the chance to exploit its potential. Also other several DoD programs aimed at developing dual-use technologies date back to 1994 or after and it is really hard to trace any significant result.

In the UK, the first DUTC has been established in 1994 and the Pathfinder programme began only two years before. Considering that technological programmes are designed to produce positive results after at least a decade, it is not possible to assess them.

The experience shows, (also in this case the US have offered extensive evidence), that dual-use issues are still considered a political sensitive matter in Western countries. This is why some political parties may strongly support “conversion” policies, while other parties may boldly oppose them. The dramatic restructuring of President Clinton conversion strategy which has taken place in 1996 under the pressure of the Republican majority in the Congress, confirms that dual-use policies can still be perceived as having an ideological background. This can obviously boost them or, more frequently, make them very difficult to manage. Considering the US experience, it is not trivial to wonder what consequences the recent changes of government in the UK and France can have on their technology policy: the dual-use orientation of the British programmes may, for instance, be discussed or, on the other hand, the new French government may manage the DGA restructuring asking for more dual-use activity.

The most serious problem in assessing what the US, the UK, France and Germany are doing in the field of dual-use technology is the lack, in these countries, of any comprehensive “strategy” pursuing an integration towards civilian and military sectors. It has been largely argued in this study that specific “dual-use” programmes or policies have to be considered only as very preliminary bridges between military and civilian fields. The most authoritative experts on dual-use technologies have offered extensive evidence that a significant reduction in military spending not matching the ability of the military to fulfill its tasks can only be achieved through the reduction of the “separation” which currently exists between military and civilian activities. To promote dual-use technologies is a relevant step in shortening the distance between such activities but it is not enough. Without defining and implementing in a "civil-military integration" strategy influencing how military personnel is recruited and trained, how military equipment is developed and purchased or how military industrial and technology policies are defined, even strongly supported dual-use technology activities can produce very poor results.

Appendix:

Activities carried out in the period June 1995 - June 1997

During the period of my NATO fellowship on "Military technologies and commercial applications: Public policies in NATO countries", I have focused my research activity on the definition of a theoretical approach to the problem of the relation between military and civilian technologies and on the study of the US approach to dual-use related issues. During last year I have carried out a bibliographical research in Rome, especially using the library of the Archivio Disarmo Research Centre. During the same period, I collaborated with the Military Centre for Strategic Studies of the Italian Ministry of Defence with respect to a report on "Competitiveness of the defence industry and the dual-use problem".

Additionally, I attended several meetings with international experts in the field of dual-use technologies. Most of these meetings are related to the participation, as a speaker, to a NATO Seminar, and to a visit in the US. In July 1995, I joined a NATO ASI Seminar on "Defense Conversion Strategies" which was held in Scotland. There I had the chance to contact several international experts on dual-use technology policies and to discuss extensively with them. The experts I met in Scotland included: Prof. Philip Gummett, PREST University of Manchester, UK; Professor Tarja Cronberg, Technological University of Denmark; Dr. Lance Davis, Director Science and Technologies, DoD, USA; Prof. Keith Hartley, CDE University of York, UK; Dr. Peter Lock, University of Hamburg, Germany; Dr. Adrian Mears, Defence Research Agency, UK; Dr. Jordi Molas-Gallart, SPRU University of Sussex, UK; Prof. Roland de Penanros, Université de Brest, France; Dr. Kathleen Robertson, ARPA, DoD, USA.

In April 1996 I arranged, with the collaboration of the United States Information Agency, a visit in the United States aimed at meeting several government officials and experts in order to discuss issues on military and dual-use technology policies. During my visit in the United States I met the following experts: Dr. David Isenberg, Center for Defense Information, Washington DC; Dr. Dan Gouré, Center for Strategic and International Studies, Washington DC; Dr. Richard Van Atta, Defense, Research and Engineering, DoD, Washington DC; Dr. Guy Hammer, BMDO, DoD, Washington DC; Dr. Steven Wax, ARPA, DoD, Washington DC; Dr. Gary Pagliano, Congressional Research Service, Washington DC; Prof. John Zysman, Berkeley Roundtable on International Economics, Berkeley CA; Dr. Michael Oden, Rutgers University, New Brunswick NJ; Dr. Clark Abt, Director of Massachusetts Defense Technology Conversion Center, Cambridge MA; Dr. Steven Miller, CSIA Harvard University, Cambridge MA; Prof. Richard Samuels, Massachusetts Institute of Technology, Cambridge MA; Prof. Harvey Sapolsky, DACS Massachusetts Institute of Technology, Cambridge MA; Mr. Brandon Stauber, Los Angeles Regional Technology Alliance, Los Angeles CA; Dr. Ian Lesser, RAND Corporation, S.Monica CA.

In the second year of the fellowship period I have visited Germany and France. With the assistance of the French Embassy in Rome, I met in October 1996 some French experts and government officials in Paris. During my stay in Paris I have met: Prof. Paul-Ivan De Saint Germain, Director of CREST (Centre de Recherches et d'études sur les stratégies et les technologies) at the Ècole Polytechnique; the Armaments' Engineer (IGA) Daniel Pichoud, Head of the Office for dual technologies at DRI-DGA; Professor Claude Weisbuch, Scientific Director of DRET-DGA; Mr. Georges Seguin, Head of the Office for NATO at DRET-DGA; and the Chief Armaments' Engineer Paul-René Sanseau, Head of the Office for International Affairs at DGA.

In March 1997, I have been introduced by the German Embassy in Rome to the Federal Ministry of Defence in Bonn. During my visit in Bonn I have met some researchers of the Bonn International Center for Conversion, an independent research centre carrying out research on conversion related issues. There I attended several meetings especially thanks to the collaboration of

Dr. Michael Brzoska, Head of Research at BICC. At the Federal Ministry of Defence, I met Dr.Manfred Roy, head of the Office IV/2 and the engineer Hans Paetzold.

Last but not least. I would like to stress that the academic contacts I have in the four countries considered in this study have been able to provide me with accurate information about which are the issues currently under debate in their respective countries, and who are the people involved in defining dual-use technology policies.

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Notes

1 The “military technical revolution” is a concept proposed by the Center for Strategic and International Studies. See Mazarr et alii, 1993.
2. An introduction to the issues related to the globalisation of technology is offered by: Ostry and Nelson, 1995 and Archibugi and Michie, 1997.
3. DoD, 1992, pp.30-31.
4. See Alic J. et alii (1992).
5. Alic J. et alii, 1992, p.4.
6. Jet aircraft, computers, semiconductors, and microwave ovens are often mentioned as examples of such "spin-off effect".
7. The Bonn International Center for Conversion argues in its "1996 Conversion Survey": "Conversion is an contested concept. Some would rather not use the world at all, while others claim that conversion is impossible to achieve in practice. Some judge conversion to have failed, while others argue that conversion is unnecessary. At least some of these disputes result from differencies in interpretation of the concept of conversion" (BICC, 1996, p.16).
8. Some aspects of the "crowding-out effect" in the military field are discussed in Sandler and Hartley, 1995.
9. The concept of the military production as "hierarchical system" has been developed by Molas and Walker (see Molas and Walker, 1992).
10.. The most extensive analysis of the evolution of the Japanese defence industry can be found in Samuels, 1994.
11. Data for Germany for 1990 refer only to Western Germany.
12. The source of data on military R&D spending is the OECD. According to OECD methodology, defence R&D includes all government expenditures for military R&D including military nuclear and space R&D but excluding civilian R&D financed by ministries of defence (e.g. meteorology).
13.. Such opinions have became prevalent in the US economic community at the beginning of the '90s. See: D'Andrea Tyson, 1992, and Sandholtz *et alii*, 1992.
14.. See: Bischak, 1997, p.3.
15.. See: Clinton and Gore, 1993, p.7.
16. Department of Defense, 1996, pp.2-3.
17. *Ibidem*, p.11.
18. *Ibidem*, p.3.
19. *Ibidem*, p.4.
20. *Ibidem*, p.7.
21. *Ibidem*, p.7.
22. Bishak *et alii*, 1996, p.4.
23. Department of Defense, 1995, p.23.
24. Bischak, 1997, p.28.
25. VAT: Value Added Tax.
26. CGP, 1993, pp.59-63.
27. *Ibidem*, p.157.
28. *Ibidem*, p.157.
29. Ibidem, p.159.
30. Ibidem, p.148.
31. De Saint Germain, 1991, p.6.
32. *Ibidem*, p.8.
33 In 1992 a study carried out by the US Office of Technology Assessment, *Lessons in Restructuring*

defence industry. The French Experience, offered an interesting description of French dual-use activities:"...the DGA supports development of dual-use technologies with promising military applications. Unlike Germany, where research on dual-use technologies is funded by civil ministries, dual-use research in France is the primary responsibility of DRET. The directorate of co-ordinates its funding efforts with the civil ministries to ensure an efficient division of labour and to leverage its investment. For example, while the Ministry of Industry supports research on civil electronics, DRET provides targeted funds for work on products with specific military applications, such as electronic warfare systems and infrared seekers.
Another important factor is that the French Government imposes no legal, regulatory or accounting barriers to combining civil and military activities in the same facilities (other than security restrictions and military specifications)." (OTA, 1992,p.25).
34. Ministere de la Defence, 1994, p.118.
35. From the DGA report to the Mod released on September 9, 1996: "... Elles posent ensuite le principe de rapprocher le mode de gestion des activités de production exercées par la DGA au plus prés de la pratique des enterprises industrielles".
36.. BMBF,1996, p.165.
37..The Armament division is the branch of the Federal Ministry of Defence dealing with planning, research, development and control of the acquisition process of military equipment.
38. This description of the principles of the R&T Concept comes from: German Embassy in London, (1996).
39. Federal Ministry of Defence, (1994).
40. *Ibidem*, p.40.
41. According to Gansler (1995), p.40: " ... the transformation of individual firms and plants to either dual-use or commercial operations is similarly essential. This transformation has received much attention and government funding under the heading of "defense conversion," yet its definition has been left, perhaps intentionally, extremely vague. In fact, the term has become so all-encompassing that it has included:
-community economic adjustement to defense cutbacks and downsizing;
- industrial defense plant conversion/diversification to civil sector work;
Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.Error! Main Document Only.- retraining of laid-off defense workers;
- training in modern manufacturing technology to redundant defense firms -usually at the lower-tier supplier level;
- transferring defense technology to nondefense businesses;
- transformation of the isolated defense industry into an integrated civil/military industrial base; and
- shifting defense R&D investments to focus on dual-use product and process technologies.
This list spans an extremely wide spectrum, suggesting that all the recent attention to defense conversion has not produced a consensus on what should be done.".