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CIVIL-MILITARY TECHNOLOGICAL INTEGRATION IN EUROPE

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"*Integrate : .1. To make into a whole by bringing all parts together; unify.*

2.a. To join with something else; unite. b. To make part of a larger unit".

American Heritage Dictionary

INTRODUCTION

This discussion paper draws on WP2 contributions from CREDIT-METDAC members and on the J. Molas-Gallart's, and A.James and P. Gummett's WP1 Discussion papers. It also tries to put civil-military technological integration in the context of important recent developments in the study of the innovation and technical change.

Since the beginning of the 1990s, sweeping changes in the geopolitical setting, along with financial constraints put on public, including defence budgets, and changing relations between technologies of defence and civil origin are the main factors stimulating civil-military technological integration. Still, to go beyond rhetorics on these issues requires us to explore what are the real and practical steps made in this direction as well as the very obstacles hindering the implementation of civil-military technological integration.

WHAT DOES CIVIL-MILITARY TECHNOLOGICAL INTEGRATION MEAN?

As suggested by the above definition, integration, in a broad sense, means that various components are united into a whole. Integration should be seen as a process, not as a static situation. As regards technology, it could mean that the frontiers between military and civilian are increasingly blurring. Note that this process, if it were to work, would go far beyond what is usually meant by "dual-use technologies" (DUT) . The latter suggests that, as some technologies are dual-use, others remain specific, with most commercial and military activities remaining separated. Civil-military technological integration, by contrast, places the technological innovation process, and the alleged convergence between civil and military technologies in a institutional and organisational context, an hypothesis that fits with major findings of those developing an evolutionary approach in the study of technological change. Integration means that products and systems, based on complementary, close or similar technologies, are designed, developed and produced in the same organisational frame (a 'whole' or a 'unit' in the definition).

Here, industry constitutes the analytical level where issues relating to the integration of both activities (civilian and military) are addressed. If and when completed, the process of civil-military technological integration would mark the emergence of quite a new situation, at odds with the one which prevailed in the five post-war decades, and actually would mark the extinction of what was once called "the military-industrial complex" by President Eisenhower in his farewell speech to the US nation[1].

Put in another way, achieving civil-military technological integration would mean that not only technologies used to design, develop and manufacture products and systems have become quasi similar, but also the dissolution of the defence organisational set up.

In this paper, we identify three forces shaping the new relations between civilian and military activities, hence their degree of possible integration. They are Technology, Globalization, and System integration.

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[1]Delivered to the Nation by television and radio on Jan.17, 1954.

TECHNOLOGICAL TRAJECTORIES

For centuries, technology has played a core role in defence issues, however new relations between technology and defence production have emerged during WWII. During the five post-WWII decades, technological development has not only been the main propellant for maintaining military superiority, it also has contributed to the shaping of systems of innovation in major industrialised countries (see contributions from Chesnais on France, Mowery, Rosenberg on the US, and Walker in the UK, in Nelson editor, 1993 and also various contributions to the Cornell University Workshop, 1998) .

As regards the situation of the defence industry in the post-cold war era, technological trajectories offer a rather conflicting picture. On the one hand, the promotion of dual-use technologies by MoDs and industry, which is mentioned in several contributions to WP2, could pave the way for easing integration between defence activities and those using some similar technologies. At least in principle, defence procurement reforms and MoDs' reorganisation under way are aimed at encouraging closer integration. On the other hand, what could hamper the process is that: first, an increased use of commercial technologies is perceived as a threat to military superiority, because of their availability to potential enemy states ; second, it could mean that the reliability and affordability of weapon systems become more dependant upon commercial companies' strategies, a move which could worry military services.

DUAL USE AND 'CRITICAL' TECHNOLOGIES…

Several contributions to WP2 address dual-use technologies (DUT) issues. They mention lists of technologies with civilian and military applications, circulating from M(D)OD's agencies. Those initiatives come mostly from the side of defence interests, a noticeable exception being the European Commission's Framework Programme for Research and Technological Development, with estimates by the Commission that one-third of the Framework Programme's share is DUT-oriented. However, few data are available on the quantitative importance of funds earmarked to DUT[2] [Galas-Molart, WP1 Discussion paper].

The rationale for using more commercial "off-the-shelf" technologies (COTS) is now well known. First, costs of developing indigenous military technologies have so escalated that they rendered unaffordable for most countries the cost effective design, development and manufacture of new generations of weapon systems [James, Gummett, Discussion paper, WP1] . At the same time, the rate of technological change has speeded up in some commercial sectors (e.g. electronics and information technology) making some military components which have been integrated in weapon systems, after a long process of development, falling well behind advanced commercial technologies in terms of performance.

When issues related to military-civil integration in the defence industry are addressed, it is important not to ignore the complex of companies, large and small, that constitute the industry's supply chain. An outstanding fact is that large prime contractors of defence equipment tend to be defence-specialised with rather limited integration between the military and civil sides of their business. On the contrary, the small and medium companies surveyed in a recent study reported that they did not operate separate defence and non-defence divisions and few had geographically separate defence and non-defence operations [James, WP2, James et al., 1998] .

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[2] It was reported by professional magazines that funds for DUT at the Air Force Research Laboratory's budget (AFRL) would account for 25% of the total R&D budget. In France, a budgetary item was posted for the funding of 'dual-use' activities, but was finally dropped because the real content of activities had little to do with budget lines.

[On Dual-use technologies issues, also see contributions in Gummett, Stein, 1997] .

...ENCOURAGED BY DEFENCE PROCUREMENT REFORMS AND MODS' REORGANISATION

The move towards using more civilian technology-based components has been encouraged by reforms in defence procurement [Molas-Gallart, WP2] . Both anecdotal evidence and more in-depth studies have highlighted how some defence requirements and specifications were costly for the taxpayer and sometimes useless for military needs. Now, in the three main weapon producing countries, the US, France and the UK, M(D)oDs have passed from the stage of reviewing the procurement process to that of reforming it.

Defence procurement reforms are a part of a more dramatic reorganisation process of MoDs agencies and departments. MoDs'procurement agencies are usually considered as a major player in the defence industry field, with multiple roles including regulation, weapon programme management, customer, producer of goods or of R&D [Serfati, 1998] . Those multiple functions are performed by various institutions, departments, directorates, etc. For a decade or so, procurement reforms have often been associated with MoDs' organisational restructuring. They were often pieces of neoliberal governmental policies which thrived from the eighties on in most industrialised countries.

Here, we are concerned with how much the transforming of MoDs' missions and the creation of new institutions have modified, or could modify in the future, existing networks related to military technology. In the US, after the Clinton administration entered in service, several initiatives were taken, including the TRP, and the transformation of DARPA into ARPA [Reppy, WP2] . In the UK, policymakers seem to be have very active in both procurement reforms and the promoting of DUT [Gummett, WP2] with the creation of the Defence Evaluation and Research Agency (DERA) in 1991 and the Defence Diversification Agency (DDA) in November 1998. DERA was set up to supply scientific and technical services to MoD, partly through its own labs and tests facilities, partly by placing contracts with universities and industry. In France, which was tardy to adapt DGA to the new context, since 1997 a dramatic reorganisation of labs and test facilities has been under way [Serfati, WP2] , with basically the same objective as set for DERA in 1991 .

In general, the process of MoDs restructuring is based on separating the various functions, transforming departments and/or directorates in agencies, in order to give them more autonomy vis-à-vis the MoD. The creation of the Defence Procurement Agency (DPA) replacing the Procurement executive, decided in the UK early 1999, again portends what could be the future in other European countries. It is no more unrealistic to think that, in a few years, some 'regalian' missions could be accomplished by privatised agencies (see the discussion on DERA's privatisation[3]) . However, such a perspective is highly challenged, not least by industrialists, worried about the strong competition which would result from such move. It is also rejected by military and MoD, as stated by a top RAF official[4].

OBSTACLES TO FURTHER CIVIL-MILITARY TECHNOLOGICAL INTEGRATION

[3]"British MoD Mulls Privatisation of Agency, *Defence News*, December 8-14, 1999

[4] Air Vice-Marshal PJ O'Reilly : "*With strong industrial endorsement, it was concluded that.. it would be inappropriate for the MoD to relinquish control and management of the major part of defence acquisition*" [1998]

Dual-use technology is only a limited element of Civil-Military technological integration. Integration would mean that most of defence systems be based on "secularised" technologies, while the defence industry's frontiers would be blurring.

Obstacles to further integration are multiple. First, it should be never be kept out of mind that, for those in charge of security and defence, acquiring or maintaining military superiority is the main objective, to which technological development should be subordinated. The US 1997 National Defence Panel underscored the significance of "*the technological revolution that is transforming advanced industry-based economies into information-based economics and that promises to effect a revolution in military affairs..[a discontinuous change usually associated with technology but also representing social or economic changes that fundamentally alter the face of the battle*" [5]. This intertwined combination of technological change and military superiority objectives makes top DoD officials concerned that the action taken by the military to take advantage of new technologies is insufficient[6], while too much money is devoted to pursuing cold war weapon programmes.

Since the sourcing of this technological revolution is recognised to be found in the commercial side, the military has increased the use of components and equipment bought from the market. Space technologies, the military role of which has dramatically risen[7], is a good case in point. In Europe, Pentagon estimates are that, in a decade, as much as 70% of defence communications could go through commercial satellites[8] [Business Week, June 15, 1998] . Such reliance on commercial technologies could paradoxically mean upscale intrusive controls on commercial activities from the DoD and State Department. A congressional panel recommended in September 1997 that US satellite trade polices return to the US Department of State because the Commerce Department is not vigilant enough in guarding against the transfer of sensitive technology to other nations[9]. Finally, the Department of State licensing regime was voted in 1999 under the Storm Thurmond National Defence Authorization Act for 1999, imposing restrictions on the export of communication satellites. The four biggest NATO allies strongly criticised this decision, claiming their companies would be badly hurt in commercial markets[10]. This fears were not unfounded, since the Act as passed states : "*It is the sense of Congress that... the United States should pursue policies that protect and enhance the United States space launch industry* "[11].

The US Congress decision is not isolated, rather it is part of more general concerns[12] that developing and using dual-use technologies available from commercial markets, *de facto* increases opportunities for any potential enemy to capture those technologies, and even to conduct "cyberspace attacks" and reinforce hacker arsenals[13]. An outcome could be that, as the trend to integrating cost-off-the shelf-technologies, or slightly adapted commercial technologies, in defence systems is growing, stringent regulations voted for security and

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[5] Transforming Defence : National Security in the 21Th Century, Washington, DC : Report of the National Defence Panel, December 1997, page 5.

[6]'Gansler Maps Future Priorities, Cites Quick Pace of Technological Advancements, Emerging Threats' , *Defence News*, April, 19, 1999

[7] USAF estimates it will spend more than $230 billion in new military spacecraft and $22 billion in launches over the next 10 years, *Defence News*, April 19, 1998

[8] This number is sometimes presented as a dramatic change in the procurement management, as it amounted to 60% in 1998.

[9] *Defence News*, September, 21-27, 1998

[10]Allies Rap U.S. Export Rules, *Defence News*, April, 26, 1999

[11] Quoted in "US technology Export Rules Draw European Fire, *Defence News*, March, 22, 1999

[12] "Commercial Technology Use Splits Experts ; Do Risks Posed by Market Availability Outweights Benefits to U.S. Military" , *Defence News*, June, 1-7, 1998

[13]*Defence News*, March, 15, 1999

defence concerns could reinforce the control of the military on commercial sectors. Just to give an example, GPS constellation is operated by the US Force but widely used by civilians, and the military would be given the possibility to jam civilian signals, if they are to prevent enemies to get military signals. As increased controls are being discussed in the space industry[14], US companies are worried that this could undermine their effort to fully address the booming commercial segment of the industry. Such a worry is somewhat similar to those of electronic companies contracting with the DoD in the fifties and in the sixties[15], when they were eager not to be placed in the situation of being cut from commercial markets because of contracts struck with the DoD [deGrasse, 1984] .

In sum, in technological fields and industrial sectors where technological integration is increasing, in the same time military regulation is enhanced, with the risk of erecting a "wall of separation", however different this may be from the one existing in the defence industry during the cold war era [Markusen, Yudken, 1992] .

Then, concerns have been expressed by some in the defence industry and MoDS' agencies that drawing too heavily on commercial technologies could endanger the availability of advanced civilian components for defence systems, this for various reasons including : the fact that these components are becoming obsolete at a fast rate, or the risk that the companies delivering such components might decide to stop manufacture because production runs are too small. Claims that depending too much on commercial technologies could jeopardise the long-term affordability of defence programs can also be found in France [Serfati, WP2] .

Finally, it is worth noting that obstacles to the implementation of dual-use policy in the UK and in the US, emanated less from M(D)oD agencies than from defence companies (in the UK) and from political resistance[16] (in the US) . As already mentioned, the main resentment against the new DERA policy, based on a more commercial attitude (contracting out to industry) came more from defence than from commercial companies, the former expressing fears that DERA could become a real competitor, as the latter generally responded positively to DERA's initiatives regarding technology transfer [Gummett, WP2]. In the US, DARPA's director was fired in April 1990 for placing a DARPA contract with a non-defence firm [Reppy, WP2] .

GLOBALISATION

While the economic process of globalisation of civilian industries and financial markets was taking place during the eighties, the defence industries remained entrenched and sheltered within their national frontiers. Only from the nineties on, with consolidation in the US industry taking place, did discussion and comments on how much the defence industry has become "global" begin to surface. Noticeable is that the expression applied more to companies' strategies - labelled as "global"- than to arms production proper. Actually, globalisation of the arms production through trade, openness of the frontiers to foreign competitors, sourcing of technologies needed to design new generations of weapon systems is at its very beginning. The understanding of the globalisation process as firm-centred, however correct it is, remains partial, since it ignores the decisive role of states and governments.

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[14] "Officials See U.S. Military Role As Commercial Space Protector, Defence News, November 30-December 6, 199

[15] *Defence News*, September, 14, 1998

[16] But to what extent did the political resistance to dual-use policy from Republicans reflect vested interest and "porkbarelling" ?

Compelling evidence that these latter have played a decisive role in the promoting of financial globalisation, in particular in the UK with the Thatcher government, can be found [Helleiner, 1994] . An approach to globalisation which neglects the role of governments is all the more debatable in the defence industry. The following sections will address globalisation from both governments' and companies' perspectives.

TRANSATLANTIC INTEGRATION, RATHER THAN GLOBALIZATION

If the role of national governments remains critical, then that of the US is predominant, with over 35% of world defence expenditures, over 60% of NATO equipment expenditures, and two-thirds of the world Military R&D expenditures [all of these data come from the 1999 SIPRI yearbook] . When seen together with the large edge gained by US Prime contractors over their European competitors, the size of the DoD budget provides a kind of "asymmetric" situation, which becomes even more visible with the US tapping of foreign science and technology for military purposes [Hagelin, WP2, Hagelin, 1997] . In that sense, it could be more accurate, to speak of a US-led process of internationalisation of the defence industry, rather of globalisation. This process will undoubtedly be enhanced by the unchallenged US technological military edge, as well as by the NATO's new Strategic concept leading towards further harmonisation through Rationalisation, Standardisation, Interoperability (RSI). As evidenced in the war against Serbia, when we move from rhetorics to 'real time' implementation, crisis management is in the hands of the US, a simple fact already visible during the Gulf war. The reason could be that as "*in the absence of war, these differences* [in the requirement process in Britain, France and Germany] become entrenched...*generally, direct test in combat conditions is a greater catalyst for change*" [Hayward, 1998].

Interrelation between the US technological edge and its military role was stated by one expert as follows : '*For the United States, there is a strong belief the core challenge is to build forces for high-intensity warfare around new technologies. The US definition of the Revolution of military affairs (RMA) focuses upon the development of a global force appropriate for a wide variety of missions. Interdependence with allies forces is defined in terms of how Allies can plug into an overall architecture*" [17] . Further analysis on what can be expected in the coming decades as regards US-Europe relations can be found in a pre-war against Yugoloslavia WEU document[18] [1998] .

Now, the strengthening of the European-US collaboration process in the defence industry may render all the more acute the need for European nations to find out if and how their S&T results have been used by the DOD in the last decades [Hagelin, WP2] .

That what is sometimes called globalisation of the defence industry is actually US-led, does not mean that no benefits can be drawn by European companies. British Aerospace is probably the most prepared among European companies, to benefit from this process. Following a strategy in order to become 'leaner' (in civilian activities) and 'meaner' (in defence activities), the UK Prime contractor has been able to set up a network of transatlantic

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[17] R.Laird, in Defence News, November 30-December 5, 1998. Quoted by 'The NATO Summit and its implications for Europe' , *Assembly of Western European Union*, 15 March 1999, Document 1637

[18] The WEU document refers to recent Rand studies assessing the respective role of the US and Europe in three board, likely contingencies and indicates whether responsibilities are likely to be borne mostly by the US, mostly by Europeans, or by a mix of both. Here is just an example of the burdensharing on the Maghreb as envisioned by the Rand studies : '*keeping sea lanes for Middle Eastern oil and Maghreb energy...would remain first and foremost tasks for the United State*s' (page 27) as '*mixed US-European responsibilities* [would concern] *implosion in Algeria* ' (page 28) .

collaboration agreements and to jump into sizeable defence programmes (e.g.JSF) . French Thomson-CSF, in a rather similar vein, that is by cutting off its military from commercial business, is stubbornly pursuing a strategy focused on international defence, including European and Asian markets. The French company hopes to be attractive enough to set up collaborations, including in capital, with American companies.

NEW PLAYERS : INSTITUTUTIONAL INVESTORS AND THE "MARKETS"

In the defence industry, institutional investors have increasingly become active. Their growing influence reflects what is usually coined as "market pressures". Throughout the eighties, pension and mutual funds have spread their control over the bulk of large companies (the "corporate governance") , setting new objectives ("shareholder value") and introducing new methods of management, e.g. "reengineering", all of them aimed at cutting down labour costs. Actually, they have been a driving force in the globalisation of financial markets, and through it, in the globalisation of most industries.

In the defence industry, the need for industrial consolidation coupled with institutional investors' pressures, marked a strong departure from the situation existing in the "old times" of the cold-war era. There is no doubt that until the end of the eighties, defence companies were profitable, however the decrease in defence procurements and the dropping of 'cost-plus' practices since the beginning of the 1990s have made competition harder.

The UK has been the first country to be confronted with those new players. Once reluctant to invest in bloated companies delivering facing declining procurement orders, financial institutions, through the more competition-oriented procurement reforms initiated by P. Levene and the privatisation of defence companies, have increased their role at the board of Prime contractors. In the US, notwithstanding the role played by the 'visible hand' of the Secretary and deputy of defence in the cooking of what is known as the 'last supper' [The Economist, 1997] , the consolidation process that lead to the creation of three giant companies (Lockheed Martin, Boeing and Raytheon) was prodded by Wall Street, with the objective of Prime contractors creating more "shareholder value" .

The increase clout exerted by institutional investors could accelerate the adoption of both commercial-based management and financial practices by the defence Prime contractors, and contribute to further civil-military technological integration. On the former, it is striking to read how the radical change in the way BAe is reconsidering its strategy, departing from a functional to a process-based organisation, with Integrated Product Development Teams (IPDT) involving customers, users and suppliers in the development and support of the aircraft [Clark, 1998] . IPDT, drawing upon organisational technologies such as concurrent engineering, project management, long known from and used by Japanese companies, substantiates the role of user-supplier interaction in the innovation process [Lundvall, 1992] . Implementing new methods of industrial management should be seen in relation to the increased role given to Prime contractors in the procurement process and the introduction of a life-cycle approach [Molas-Gallart, WP2] .

It is evident that 'shareholder value' is taking hold in the defence industry as in most other industries, and defence companies have to meet performance standards set by international capital markets [Vlachos, 1998]. As US defence companies are closing the gap with civilian ones as far as the role of financial markets is concerned, it does not mean that they are on the verge of losing their distinctive features. First, they will have a hard ride if they are not to be outperformed by the scores of Wall street, the buoyant mood of which was said to be marked

by "irrational exuberance" by Mr Greenspan, the Fed's Chairman[19] . Defence industry turnover is made mainly from the government, depending more on votes by the Congress than on market competencies[20]. Increasing the 'shareholder value' went through both downsizing and acquisitions, and the mergers & acqisitions binge that took place in the US defence industry (over $62 billion of asset value between 1993 and 1997) encouraged defence firms, especially the largest and most specialised among them, to concentrate on military core competence [Markusen, Serfati, 2000] . Consolidation is by no means a process which was stopped by the regulation authorities' veto put on the Lockheed Martin-Northrop Grumman merger. The process will continue unabated, while, as suggested above, lessons and outcomes drawn from the NATO strikes will probably give a boost to transatlantic marriages. Meanwhile, both domestic and transatlantic consolidation will reinforce the concentration of firms on their military core competencies, a fact also evidenced in Sweden, with the dropping of civilian interest by Saab [Hagelin, WP2] , in France with consolidation being driven by "defence-needs industrial logic" [Serfati, WP2] .

Two, designing, developing and manufacturing weapon systems remains a highly specific business. That more responsibility is given to the Prime contractor in the obsolescence management makes the business riskier from the perspective of maintainability [Molas-Gallart, WP2] . Despite improvements, the lead times remain longer than in most other industries, a fact which has to be carefully managed at a time when the investors' time horizon is narrowing, and dividend incomes are demanded to be paid each term. All of this means that the defence business is marked by strong remaining specificity as far as industrial management is concerned.

A NOTE ON GLOBALIZATION THROUGH VERTICAL INTEGRATION

The major US defence and some European companies are becoming more internationalised. This process is going through a large set of collaborative agreements, control of capital of other companies, and exports, more than by 'delocalising" their production and realising 'greenfield investments" (i.e. the setting up of new facilities) in host countries. A globalisation related issue is on the nature of the consolidation taking place. In the early stages of the mega-mergers process, costs/benefits based analysis of vertical and horizontal consolidation were conducted. When the DoD and Department of Justice opposed to the Lockheed Martin-Northrop Grumman merger, some interpreted this decision as marking the end of the merger era. Still, the rationale for such a veto is unclear, with opposition to vertical integration (from airframe to electronic subsystems) being invoked by some, as other claimed that the merger would kill competition on the "horizontal" electronic warfare market [see analysis in James, 1998] . How market power gained through consolidation threatens "fair competition" is in general, one of the "black holes" of the neo-classical economic theory[21], as evidenced by the complex and challenged decisions regarding monopoly position issues taken by the European Commission (DG 4) . In the case of the defence industry, the situation is all the more difficult since competition has for decades narrowed down to a handful of contractors with 'arms'-

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[19]Since the Fed's Chairman declaration (one year ago or so) , the Dow Jones has risen by over 20%....

[20]The President Clinton's decision to increase the procurement budget by billion 110 dollars between 1999 and 2003 was hailed by the defence business, 'US Procurement Rise May Bolster Industry Earnings' , *Defence News*, July 20-26, 1998.

[21] The response made by business is not more compelling. The chairman of the US Electronic Industries Alliance, which lobbied against the Lockheed Martin-Northrop Grumman merger, asked if "*[y]ou think consolidation in the United States has gone as far as it can go*", replied "*There are limits to how big you can be....[T]here are advantages to being small and responsive. Adaptation is the key. As Darwin said, it's not the strongest or the smartest that survives, but the best adapted*" *Defence News*, February 15, 1999

length relations' between major players (including MoDs) being rare. How UK regulation authorities will react to the BAe-MEs merger is not yet clear, as fears have been expressed on the risks for competition if it were to be accepted [Heisbourg, 1999] . In France, consolidation resulted in a large set of monopoly positions, and in the remaining in competition fields such as satellites, a "secret" deal was struck between the two national champions, Matra Aerospatiale and Alcatel Thomson CSF [Serfati, WP2] .

DEFENCE SYSTEMS INTEGRATION

Among the dramatic changes in defence production, those regarding the role of "defence systems" is probably overwhelming. In France, some have spoken of "meta-systems", or in the UK of "systems of systems", both referring to the basic fact that weapons are more and more connected to each other and incorporated in a "chain of command" by senior military staff. Just to give a recent example, a $1.5 billion US DoD procurement is earmarked in the 1999 budget to integrate more than 40 air, space and missile defence command and control systems. The reason for it is that the Air Force hopes to consolidate the operations of several separate systems that provide commanders with information on the battlefield.

The dramatic importance taken by defence systems integration has two sources. The first is related to technologies and not military-specific. The economics of technical change has for a long time stressed on the fact that technological innovation is more and more dependant on "technologies fusion", which allows firms to create new industries (mecatronics, optoelectronics) [Kodama, 1991] . Also, the aerospace industry provides an interesting case, and sometimes is labelled as a "technologies-integrating industry" [Giget, 1991]. Henderson and Clark's findings are that commercial achievement for firms relies on their ability to design a new "product architecture" , i.e. recombining the way components (in a broad sense) are integrated et tied up with each other in a new coherent assemblage [1990, page 11]. Finally, in the computer industry, it has been argued that the new approach adopted in the US, with the growing importance taken by "process integrators" , "project managers" could be one major factor for the revival of some firms (IBM, Intel) and the creating of some highly competitive start-ups [Iansanti, West, 1997] .

A second source of the growing importance of defence systems integration is defence needs centred. Military superiority is increasingly based on complex systems, the US C^4I program (Command, Control, Communications, Computers and Intelligence) being a case in point. It is not sufficient to design and produce cutting-edge weapons: they have to be placed in a posture making them efficient from an operational perspective[22], which includes organisational capabilities, readiness, logistics, etc.

Firm competencies needed for system integration are at the crossroad of technology proper and organisation, raising questions about the tacitness versus codification of knowledge debate. According to students of technical change, organisational learning is a "spiral movement" where tacit knowledge is transformed into codified knowledge, followed by a movement back where new kinds of tacit knowledge are developed in close interaction with the new kinds of codified knowledge [Freeman, Soete, 1997] . In the case of defence system integration, where design and development are generally unique, a large body of knowledge is

[22] See, for example, a presentation by a top manager at GIAT-industries (a tank producer) : Because "*there is a overwhelming tendency towards functional integration of weapon systems in their environment use..the authot suggests that the concept of core business product line be extended to the following domains : the armed forces' logistics support system, the integrated-module approach for forces...*" [Spindler, 1998] .

tacit, because the military superiority of such systems comes from their technical complexity, which can be solved only by a 'test and trials' process, as well as from the fact that their technologies will not be broken through by potential enemies. Thus, far from promoting technological convergence, the high complexity degree of the new generation of defence systems could maintain, maybe increase separation between military and civilian activities. This is not in contradiction with the fact that components and subsystems are increasingly delivered from the commercial sector [Molas, Walker, 1992] resulting in the fact that subs-systems and second-tier suppliers are in many respects characterised by high levels of civil-military integration [James, WP2] .

SUMMARY AND KEY QUESTIONS FOR THE STUDY OF CIVIL-MILITARY TECHNOLOGICAL INTEGRATION

In this discussion paper, it has been argued that technological Civil-military technological integration in Europe faces obstacles coming from various sources. Reliance on commercial technologies has been increasing for years; however, this process is opposed by forces which slow down and even could reverse it. Given that the basic objective of using technology is ensuring military superiority, preventing potential enemies from getting access to it remains essential. What changed in recent years is the sourcing of some radical innovations, in particular in information technologies, which can increasingly be found in the commercial sector, not the need to design and develop highly specific technology based defence systems, if military superiority is to be maintained. This is made it clear by DoD officials and experts[23], and Military R&D expenditures are heavily invested in defence systems integration. An outcome is that Prime contractors, confronted with the duty of designing ever more complex defence systems are concentrating, through domestic and international consolidation, on military core competence. Finally, the size of the US market as well as the huge superiority of the US defence companies is a compelling reason for European defence companies to look for transatlantic collaboration. Such a strategy could jeopardise both *industrial* integration in Europe (by falling short of consolidating European companies) and *technological* integration between military and commercial activities (because of European companies' defence-oriented strategies) .

Key questions for a research agenda could include :

- To what extent is the complexity of defence systems leading the process of European and transatlantic consolidation?

- Can the reform of defence procurement lead to further integration in the European defence industry or conversely, enhance the grip of the US industry on the internationalisation process ?

- How do Prime contractors succeed in reconciling financial market short-term pressures with their long-term commitment to the design and development of weapon systems (an adapted version of 'shareholder vs. stakeholder value')?

- What is the extent and consequences of European and US tapping of foreign S&T for military purposes?

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[23]H. Mark, Director of Defence research and engineering, DoD :"*Our collective security is best maintained by knowing more than our potential know, and then by applying that knowledge to the creation of weapons that will make it impossible for these enemies to prevail* [1999] .

- Dual-use technology policies in Europe: what contributions come from the Commission and other European-level institutions and what consequences on the shaping on the European defence industry can be expected?