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Defense RDT&E and Knowledge Management: A New Enquiry into Public and Public–Private Coordination

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Since the end of the Cold War, the political, economic and social context has become more complex for policy-makers. Budget cuts have made the constraints more significant to civil and military innovation policy-making, especially in Europe. Policy-makers need a huge amount of varied knowledge and information in order to meet policy-making requirements and be able to make decisions. Many actors in the private and public sectors produce knowledge and information.[1] One of policy-makers' main goals is now to appropriate knowledge and information and to manage them inside the administration. Networks are very complex because of the interactive and collective aspects of the innovation process.[2] For this reason, the link between actors and knowledge is inherent to the networks. Networks and technological and scientific intermediaries are necessary for innovation policy-making in both the civil and military sectors.

It has become necessary for the state to have information at its disposal in order to evaluate the strength and the weaknesses of the national innovation system. This evaluation makes it possible to identify the problems that need to be solved and thus it remains one of the main actors in the innovation process. No government can master information and knowledge about technologies, competition and demands.[3] It has no kind of monopoly in the process of innovation policy-making. That is why the scientific community uses the term "governance" to illustrate the role of cooperation between those public and private actors who generate and produce information and knowledge for civil and military innovation policies.

Regarding the specific policies motivated for defense and security purposes, the state remains the principal user of technologies. The need for precise military specifications and the basics of security applied to the reliability of the supply chain are the principal features of military innovation policy. That is why a continuous interaction between the

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state-user, the scientist and the industrial stakeholder always takes place during the earlier stages of the equipment process. The reform in defense-related policies (and the downsizing of budgets), the streamlining of the industrial sector as well as new Research, Development, Test and Evaluation (RDT&E) dynamics inherited from commercial markets have modified the ways to produce and manage relevant knowledge. The interaction between the traditional actors in charge of weapons equipment and the new actors in the civil innovation process prevailing in science and technology knowledge is one of the conditions necessary to maintaining national defense in the dynamics of the innovation process. This is why the management of the knowledge and information process has become more complex for military innovation policy-making.

This article focuses on the core management of knowledge and information in the military innovation process. The first section examines one of the main goals, explaining how the reforms in military innovation policies relate to the improvement of interactions between the state-user (as the customer), scientists and industries. The second section focuses on the role of the management of knowledge and information in order to improve the co-ordination between civil and military innovative paths. These phenomena form the two sides of the new patterns of defense RDT&E governance.

KNOWLEDGE COORDINATION IN MILITARY INNOVATION PROCESSES

The weapons equipment process implies various modes of interaction between the administration, the scientists and the industrial stakeholders. The triptych is essential at every stage of equipment development. Coordinating the knowledge and information of which the public and private actors are the holders and masters is a *sine qua non* to complete complex technology programs. The relationship between the three actors in the triptych has evolved during the 1990s. The aim of the reforms has been related to the improvement of the management of knowledge for weapons and equipment.

Intermingling of knowledge and information within the triptych

Information is defined as a flow of messages and data. Knowledge is anchored in individual beliefs and commitment: it permits one to understand phenomena. Creating and broadcasting knowledge imply organizational learning. Their effectiveness and productivity are not immediate. It is necessary to renew skills and develop professional training programs to maintain effectiveness and productivity. The needs of specific competences force the administration and industries to define new priorities for recruitment. Information processing depends on individual knowledge.[4] Networks that process knowledge and information are different: they require many actors who have heterogeneous practical skills. Individual mobility is necessary to improve broadcasting and creating knowledge inside the network. Networks represent therefore one of the principal ways to reduce technological and financial risks, to foster new opportunities and improve coordination.[5] Mobilizing competencies in the networks makes possible the strategies coping with the unexpected and the management of uncertainty. The

interaction between the state-user, scientists and industries is one of the main sources of innovation.

The military technological demonstrators represent one good way to confront points of views, knowledge and goals within the triptych. Each agent gathers some information and knowledge relevant to his activities. The nature of information and knowledge they manage and bring into the project depends on their role and responsibilities within the system of weapons production. Information and knowledge are partly specific and partly common to the public and private actors. It becomes highly complex to identify the limits of the actors' expertise in the crossover process. Production of information and knowledge by the triptych follows such an intertwined and embedded process among its actors that the very notion of knowledge or information transfer loses its relevance.

Knowledge and responsibilities within the triptych

The state is the single user of weapons equipment. Its goal is to make the best technological and financial choice. It searches information and knowledge, enabling it to act as a "smart buyer". Its agents have to understand the impact of each innovation on potential weapons equipment. The state has to be able to assess technological risks and costs of development in order to fulfill the unavoidable long-term (30 years) planning (cf. major weapons operational life-cycles). The concept of the "smart buyer" refers to the capabilities of the state-user to determine the relevant option among many open to it. A study about military innovation during the 1920s and 1930s[6] clearly shows that the structures' rigidity and the capabilities of agents to appropriate innovations play an important role in the choice of new major equipments in the evolution of the military strategy.

The first level contractor in military program needs to have specific abilities enabling it to act as an integrator of complex systems. It needs to master skills and knowledge required to coordinate the subcontractor's activities. Being a first level contractor makes it essential to have strong absorption and distribution capabilities. This is a prerequisite for these firms in order to remain a major player in the innovation networks.[7]

Academic research develops in order to further increase its understanding of phenomena and facts. Academic research works are time-consuming and results often materialize after much development and testing. Academic research activities are grounded in systematic skepticism, which is akin to introducing new strategic and technological options in the innovation process.

The limits of knowledge mastered by the actors inside the triptych

Access to the information and knowledge mastered by the actors within the triptych requires many technical and financial intermediaries.[8] Innovation is not considered as a linear process; it is analyzed as an interactive process. The important issue of locating the borders between individual and organizational knowledge then arises. Knowledge required for complex programs is not limited to the firm or the networks to which the firm is committed. Knowledge is disseminated between firms, academic research and users.[9] This phenomenon is not specific to defense-related issues. In knowledge-intensive sectors, the user remains a central actor in the innovation process because he

masters the skills and knowledge required to achieve complex products. The means that the innovation process depends on co-conception activities. The borders between knowledge involved in an industrial and academic research partnership are also very difficult to define. Theoretical knowledge might be used directly by the industry. This is the reason why research in various fields of academic research is directly financed and directed by the private sector.

One of the main consequences of this situation is the embedded character of knowledge within the triptych and has a distinctive fundamental character within the military innovation process. It might introduce increasing friction in the field of knowledge appropriation between the public and private actors. These confrontations might imply restrictions to knowledge and data transfers. The case of the French office dedicated to applied research to civil and military aeronautical areas, the *Office National d'Études et de Recherches Aérospatiales* (ONERA), remains one the best illustrations of this phenomenon. At the same time, ONERA develops research in collaboration with industry and it works as one of the French Ministry of Defense scientific agencies commissioned to evaluate the results of private research. In the United States, research conducted in the military laboratories is considered as an essential activity for the Pentagon to remain a "smart buyer"; it also represents a source of competition with private research.[10]

The management of information and knowledge becomes so complex that the expertise cannot be maintained except with extreme difficulty for the state-user as customer. First, maintaining expertise implies specific costs at the moment when defense budgets are constrained. Second, recruiting experts becomes more difficult for the state-user than before because of a twofold competition with the private sectors: for a given area, the number of experts available remains very low and the private sector can show off with higher pay. New solutions to develop weapons programs become therefore compulsory. There is a rising tendency to outsource specific activities and dedicated functions. This would only exacerbate the distribution of knowledge and information within the triptych in favor of the firms and industry. The problem of keeping alive "smart buyer" capabilities remains one that has to be solved within the entire acquisition framework.

Evolution of knowledge management within the triptych

The production of weapons equipment in France, the United Kingdom and the United States is characterized by two tendencies. First, in France and the UK, the interaction between the state-user, academic research and industry has become radically different from what it once was. Unlike in the US, in France and the UK knowledge networks dedicated to the production of weapons equipment have been disbanded. Second, the increasing role of the industry and of academic research in policy-making processes in the area of innovation progressively implies new partnerships between the public and private actors. Such an evolution seems to be effective for the technology prospective in the US and in the UK.

Stability and instability of the knowledge and information networks

Depending on the country, the interactions within the triptych have been more or less stable during the 1990s. In Europe, the knowledge networks in which the Ministries of Defense were considered central actors had to cope with a reorganization of the actors. New forms of coordination were introduced. At the same time, in the US, the interaction between the state, as customer, academic research and industry remained predominantly stable.

Among the features of the weapons production system in the United States are the mobility of the agents within the triptych and the involvement of universities in the military RDT&E process. American universities run more than half of fundamental research financed by the Pentagon. The mobility of these agents between the public and private sectors is very important. The Pentagon's agency, the Defense Advanced Research Projects Agency (DARPA), which is in charge of financing radical innovation, best illustrates this phenomenon. It is staffed by 240 people, who come from the universities, military laboratories and the corporate world. These people are responsible for managing RDT&E projects and delegating them to other organizations and structures. They remain in the agency for between three and five years. After this period, they return to their previous office, which has been secured for them in the meantime. The main projects financed by DARPA are concerned with applied research and the construction of technological demonstrators; 75 per cent of DARPA's budget is dedicated to the industry.

The French system of weapons production is characterized by the drastic restructuring measures that were introduced where relationships between the state-user (as customer), the academic research community and industry have been broken up and restructured several times. This approach has not been favorable for mastering knowledge. The responsibility for scientific and technical initiatives on behalf of the French Ministry of Defense is divided between the French Armed Forces and the *Délégation Générale pour l'Armement* (DGA). In comparison with the other states, these two bodies together are in charge of representing the state-user in respect of industrial and academic research. The DGA is one of the main features of the French defense technological system.

Because of the recurrent restructuring programs inside the French MoD, its relations with the industrial and the academic research have been unstable ever since the early 1990s. They did not happen on each occasion in the same way or with the same degree of destabilizing impact at all stages of the weapons development process. The DGA is responsible for weapons equipment contracting and for the RDT&E budget. During the Cold War, it had developed specific relations with both industry and the *Centre National de la Recherche Scientifique* (CNRS). It financed many RDT&E activities partially dedicated to the private sector but also to public research agencies. The DGA was considered as a partner intermediating with the scientific communities.[11] In 1996, the reform of the DGA was launched. Relations between it and the CNRS and other public research agencies were severed. After this reform, the DGA no longer took part in the development of national thematic innovation networks the *Réseaux de Recherche et d'Innovation Technologique* (RRIT), that were supported and financed by the civil ministries.

The French Army runs expertise centers for tests and evaluation. The centers' responsibilities deal with the validation of new weapons. Each center is characterized by a specific organization. For example, the *Centre d'Expérimentations Aériennes Militaires* (CEAM) provides advice to the Air Force general staff at every stage of weapons development, from the definition of military needs to the validation of demonstrators and acceptance of the first mass production model. It is in charge of working out the first-use doctrine and related documents for the initial training on all new military equipment. The CEAM keeps in touch with the first tier prime contractor and with all the major sub-contractors. The Agency also maintains a close relationship with the DGA for contract-based solutions and for the validation of program components and equipment. However, the CEAM is not involved in RDT&E projects managed by the DGA. There are very few contacts between the CEAM and other public research centers.

One of the main challenges for the French military innovation process is the need to establish new interactions between the state-user, industry and academic research. Today, policy-makers launch specific initiatives that are intended to promote more collaboration between public and private actors: for example, research seminars are organized between the DGA and the CNRS; and the number of grants for doctoral study co-financed by the DGA and CNRS has grown. These initiatives alone, however, have proved insufficient to improve knowledge management within the triptych.

In the UK, the Ministry of Defence (MoD) has completely altered the management of knowledge. The Defence Evaluation and Research Agency (DERA) used to be the MoD's agency responsible for research, development, technology and evaluation (RDT&E) during the 1990s. This agency was involved at every stage of weapons program development (RDT&E and weapons evaluation). It was the main actor in the execution of defense industrial policy. Ninety per cent of the MoD's budget dedicated to RDT&E and the whole of the Civil Aircraft Research and Technology Demonstration (CARAD) program were managed through DERA. In the middle of the 1990s, DERA launched new management structures in order to increase knowledge and information transfers among and between the Agency's several specialist establishments. However, knowledge management came under criticism for a number of reasons. First, coordination between DERA and the Armed Forces proved to be inadequate for the development of British weapons and equipment. Second, the transfer of information and knowledge between DERA and industry was too limited.[12]

These two points reflected the main characteristics of the military innovation system in the UK: they were also considered to be the major weakness in the UK's military RDT&E policy. To improve knowledge management, the policy-makers decided to privatize DERA, splitting it into Qinetiq and the Defence Science and Technology Laboratories (DSTL). Seventy-five percent of this Agency now forms Qinetiq, which performs all the military tests. The new agency of the MoD, DSTL, covers the remaining 25 per cent of DERA's former activities. It is in charge of applied research and plays a major role for the state-user to behave as a "smart buyer".[13] The expertise of DSTL is considered by the MoD as a guarantee for the future. The privatization of the DERA has been criticized by both the British Parliament and the Pentagon. The British Parliament underlines the risk for the MoD in losing independent scientific and

technological expertise. The Pentagon shows clearly the risk for the UK in losing its ownership of strategic scientific research and technology conducted in cooperation with the US.[14]

The commitment of academic research and industry in the military RDT&E process is relatively limited, for the moment. This is the reason why the British MoD has tried to initiate new forms of coordination between the public and private actors: so-called "towers of excellence" were created at the end of the 1990s to develop new public/private partnerships.[15] The MoD's goal was clearly defined: to co-finance RDT&E in order to prepare for the future and to maintain the United Kingdom at the forefront of knowledge and skills related to strategic technological and industrial activity. The MoD identified 71 critical technological areas disseminated inside 24 centers of excellence: each network has to define public–private agreements to develop the RDT&E projects. The first partnerships dealt with radars and acoustic sensors.

This example shows how new forms of coordination have emerged inside the triptych in the US, the UK and France. At the same time, new varieties of partnerships are emerging in Europe, based on various institutional contexts. For example, six European countries[16] have joined forces to specify rules for the European defense market. They negotiate inside what is now known as a Letter of Intention (LoI). Many exchanges of information have been organized between the state-users and industry. New European forms of cooperation have resulted from these initiatives and add to wider national public–private interactions. These developments, however, increase the instability of military innovation networks within Europe.

Policy networks in areas of military innovation: toward new principles of public–private partnerships

The state-user has to identify the strategic RDT&E areas required to prepare for the future and to maintain the basics of security when the reliability of the supplier chain is taken into consideration. The state-user needs to retain the skills critical to make technological choices and to understand the economic and scientific trends of the markets. The role of the state-user in information and knowledge networks depends on its own expertise. In the United States, the military laboratories master a variety of skills and their research deals with many scientific and technological areas. In the UK, new interactions between academic research and DSTL have been launched. The DSTL's scientists participate closely in the initiation of knowledge and information networks, and are considered to be experts in specific technological areas. Consistent with what happens in the US, British policy-makers seek after the coordination public–public and public–private from the scientific communities' exchanges of knowledge and information.

Inside the triptych, the role of the private sector has radically changed. Thanks to its international organization, the industry is clearly aware of the technologies and markets' evolutions.[17] This is one reason why the traditional borders between the public and private sectors have become blurred in the RDT&E process and weapons acquisition programs.[18] The governance of RDT&E activities implies more interactions between public and private experts on the one hand and with the policy-makers on the other in order to make sense out of knowledge and information. This explains why the

policy-makers' interest in scientific and technological prospects is growing in the US and the UK. The scientific and technological future is based on partnerships between public and private actors and represents a tool for policy-makers to define new priorities in innovation policies and to improve the coordination in public action.[19]

In future, all RDT&E activities will be multidisciplinary and imply a range of different expertise and additional knowledge. Furthermore, such activities have to be developed outside the hierarchy because it is based on free and collective exchanges.[20] The goals are to create common knowledge and to modify the perception of reality inside policy networks in order to modify the organizations' strategies.[21] The creation of public and private networks constitutes the preliminary stage for the fulfilment of scientific and technological futures. Research, Development, Technology and Engineering (RDT&E) as it is being pursued in by the UK case, represents one of the best illustrations of the rise of public and private partnerships in forming a common vision of the future.

In the UK, in the 1990s, the long-range planning exercise (the "Foresight" project) represents one of the most important tools for policy-makers to define the public RDT&E priorities. The steering committee was composed of representatives from six ministries (in particular Defence, Industry, and Education), two people who came from industry, one journalist, four representatives from the community at large, and three academics specializing in the social sciences. This committee set up 16 thematic groups among which Aerospatiale and Defence formed an important specific theme.

Several inputs expressed by the experts involved in the Foresight project have been adopted by the MoD. The experts suggested:

- increase partnerships between DERA, industry and the laboratories; and
- boost scientific training in the strategic areas for the future of the defense system.

A second "Foresight" exercise was launched in 1999. The thematic group concerned with defense and aeronautic RDT&E comprised 62 public and private experts, of whom 45 per cent came from the industry or from Qinetiq, 11 per cent came from academic research, 7 per cent experts working for the DTI, 24 per cent from the MoD and 13 per cent were private management consultants. The improvement of knowledge management in the defense R&T process represented the main objective of the second "Foresight" exercise. Cooperation between the industry and academic research for defense RDT&E was advocated through the practice of dialogue inside the "Foresight" exercise.

In France, during the 1990s, the Ministry of Defense also conducted similar exercises. Before 1997, each Armed Service developed its own projections of the future. After 1997, the French Armed Services and all the defense agencies started to work together on a plan designed to put into effect the *Plan Prospectif à 30 Ans de Recherche de Défense de la France* (*PP30*). The first of *PP30*'s achievements was to bring together a pool of 150 people from industry and public research institutes. Their brief was to elaborate on the French MoD's vision of the future and to define the main economic, political and technological challenges linked to it. For a second exercise, the French MoD brought in 400 people. The academic research and the industry were only indi-

rectly involved in the *PP30*'s activities through questionnaires. Today, *PP30* represents one of the means intended to improve the internal coherence of the French MoD's policy of defense RDT&E. Unlike the "Foresight" exercise in the UK, it does not increase the knowledge management inside the triptych, merely a degree of consistency between the various Armed Services.

The improvement of information and knowledge management is one of the major goals of defense RDT&E policy-makers. If, during the 1990s, the National Defense RDT&E reforms differed sharply between different countries, all have since taken into account the evolution of the boundaries between knowledge and information within the triptych. In the US and the UK, this evolution implies news forms of military RDT&E governance. The increasingly important role of prospective plans and policies is the best illustration of this phenomenon. In France, reform has shaped reorientations within the triptych, but public and private interactions have to be recreated. Not a single country, however, has yet been able to find a solution to identify clearly the nature of the skills that have to be maintained inside the administration in order for governments to remain a "smart buyer".

KNOWLEDGE AT THE CENTER OF THE CIVIL AND MILITARY COORDINATION PROCESSES

In the 1990s, military innovation policy implied new forms of interactions between the innovation networks structured, on one hand, by commercial markets and, on the other, by the defense markets. These civil and military interactions have become unavoidable because of need for a common base of knowledge. This evolution radically reshaped military RDT&E policy at every stage of public action from an early stage dedicated to issues such as future planning and funding, intellectual property rights and standardization.

Information and knowledge management in weapons development: from closed to open networks

A common base of knowledge for civil and military needs

The innovation process deals with the manufacture of new products, the introduction of new production methods, the exploitation of new materials, and the emergence of new markets. In the military production process, innovation manifests specific characteristics. Ministries of Defense finance RDT&E activities in order to develop the technologies that do not exist on commercial markets. Both civil and military innovation processes are determined by their final use. The main features of the military innovation processes deal with three main points: the level of performances; the codification process of knowledge; and the economic development of technological results. These three characteristics gradually pervade the whole area of technology committed to the military innovation process. Information and space technologies are good illustrations of this phenomenon. Today, no matter which technological sector is under consideration, the main feature of military innovation relates to the complexity of the actions taken by the system integrator because the development of any new weapon systems is based on the overlapping of complex technological sub-systems.

Many technologies and innovations are classed as "dual". This term refers to a variety of civil and military uses, though technology and innovation are not strictly "dual" in essence. "Duality" results from a combination of organizational and economic decisions, which are the source of possible knowledge sharing between civil and military production. The "dual" label could change over time; it depends on the evolution of market demands and on the institutions developing new technologies. Many components and generic technologies are used in both civil and military products. The needs of commercial and military semi-conductors and telecommunications remain, for instance, essentially similar. This is the reason why some analysts believe that the number of critical technologies common to the commercial and military markets is expanding,[22] even though the process of system integration in the military sector retains specific features.[23]

Military RDT&E activities remain essentially concerned with fundamental and applied research. These activities do not mobilize *a priori* specific military skills and knowledge. The "know-how" is just directed towards specific military needs. RDT&E activities only become specific when they get integrated into commercial or military development processes. Yet, if the knowledge remains partially common, compartmentalization often arises because of the existence of organizational market constraints. In all technological production, individual relations are structured by the dynamic of the knowledge-creation process. In defense-related industrial production, knowledge networks are characterized by the central role of the prime contractor, which behaves at the same time as the integrator of the complex sub-systems. Here, two main characteristics have to be taken into account. First, the partners' networks are more restricted in the defense arena than in the commercial market.[24] Second, the continuous interaction between the state, as the number one customer, industry and academic research from the RDT&E process makes the nature of the network unique.[25]

The existence of a common base for civil and military knowledge implies the need for increased coordination between military and civil sides of the public acquisition. This coordination, as such, often qualifies as "dual policies", even though it relates specifically to RDT&E management.

Getting access to the knowledge networks structured by civil and commercial areas

During the 1990s, economic, political and technological stakes radically changed. In this period of transition, innovation networks became very unstable. Innovation networks depend on the creation of both explicit and tacit knowledge, which leads to the development of innovation networks. The specific nature of defense innovation relates to commercial needs: in contrast, the production of knowledge shifts towards civil markets. In this case, the stakes for the state, as defense customer, are to get access to the scientific and technological activities developed inside the commercial innovation networks and to understand them.

Access to knowledge and information implies costs, even if Ministries of Defense do not themselves initiate the RDT&E process. The state, as customer, has to pay in order to benefit from the RDT&E activities financed by the private sector. When the scientific and technological results have been integrated inside industrial production, the appropriation process for the development of weapons implies the existence of a

contract. At the end of the process, in order to meet military requirements, industry has to establish specific production sites. These sites are not very profitable as a direct consequence of the low level of military series production. In that case, the state invariably also has to finance these production sites and bear the costs of specific product-related capital items.

Increasing the coordination between civil and military public activities requires solutions to be found that conciliate actors pursuing different goals and strategies.[26] How can agents mastering heterogeneous knowledge and pursuing different priorities coordinate their activities? How can they adopt compatible behavior? The capacities of actors to profit from information and knowledge depend on individual skills, professionalism and experience. The usefulness of information and knowledge depends on the context. During the reforms launched in the 1990s, the Ministries of Defense in France and the UK could have had their access to knowledge limited by obstructive behavior from defense contractors who either did not have the cognitive capacity or awareness how to understand the reforms' goals or did not find it to their advantage to want to see the reforms succeed. Time constraints also could have limited access to knowledge and information. Further, MoD executives have always relied on collective organizations and on their specific assignments. The inflexible segmentation of the market also limited the transfer of knowledge and information and, as such, the defense market represents one of the best illustrations of the restriction of knowledge transfer and the protection of intellectual property rights in technology-intensive activities.

"Dual" policies imply a new organization in order to improve knowledge and information transfer. Policy-makers have to make things easier for all the parties involved in the process. For the state, access to knowledge and information requires a wide area of expertise at the top level in order to understand the political, technological and economic stakes related to specific scientific and technological strategic sectors. The state, as customer, builds up such expertise as is necessary to incorporate into the defense system innovations financed by the civil commercial sector. Civil and military policy-makers have to increase the exchange of information and points of view in order to operate the process. The ultimate goal is to modify public and private actors' behavior in order to improve the management of RDT&E in various areas such as project financing, new rules for intellectual property rights, standardization, etc.

The US provides an interesting insight into these characteristics: it has brought together various experiences that have adapted to the evolution of RDT&E management, one that is specifically related to defense tasks. It has also included the coordination of civil and military innovative processes. A Rand Corporation study[27] has shown the variety and degree of cooperation between the US Army's Laboratories and private industry involved in the commercial domestic market. It identifies four types of public and private partnerships relevant to the development of defense RDT&E projects. These types of partnership are, in turn, characterized by specific rules on: intellectual property rights; different contractual terms with regard to time and specifications; and various proportions for public and private investment. Each of these partnerships implies various roles for the US Army Laboratories in the innovation processes.

In the first case defined by the Rand Corporation, the US defense-related laboratories (i.e. the US Army laboratories) play a leading Research, Development, Test and Evaluation role. They define the goals, the specifications and, finally, evaluate the RDT&E results. The contractual stipulations are the basis of the guarantee for control of technical performance, of the delivery schedule, and the budget. In this case, the DoD's Laboratories finance the whole RDT&E project dedicated to meet a specific military requirement.

In the second type of partnership, that which is dedicated to public and private partnerships, the US Laboratories endorse the *initiative*. They initiate RDT&E projects and specify the level of technological performance in the same way that the US Army Laboratories play in their capacity as the *leader*. They finance the major part of the RDT&E projects and the contract allows the US Army to control the activities related to the whole project. However, the US Army aims to encourage industry to finance part of the RDT&E project on its own. Potential commercial markets will, therefore, have been taken into account, because the US Army allows industry more room to define the specifications of the RDT&E project and also its schedule.

In the third type of partnership, the US Army Laboratories are described as an *active participant*. Here the US Army registers its interest in an RDT&E project, explains some it its requirements, and identifies and defines the specifications it considers indispensable for future weapons systems. Here, the US Army allows commercial firms more autonomy and takes into account the distinctive features of the commercial markets, including, *inter alia*, the basic constraints to the project. Public and private cofinancing is encouraged, but the level of the US Army financial participation would depend on how much the firm's RDT&E project took into account military and commercial needs. The transfer of intellectual property rights to the private sector is encouraged, but if research shows up as having strategic significance, the US Army Laboratories preserved the right to restrict the diffusion of the technologies during the execution of the project.

In the fourth, and last, type of public–private partnership, the US Army Laboratories play a qualified role as *minor participant*. In this case, the RDT&E project meets what are essentially commercial needs. If the US Army is interested in the results of a project, it registers its needs and tries to meet some common specifications in collaboration with the industrial partners concerned: for which reason, the US Army Laboratories require to be informed about the results of the RDT&E project. This partnership is based, essentially, on informal relationships, conducted through such things as seminars, working groups, etc. The US Army does not control the level of technological performance or the use of the RDT&E project's budget. If its presence in such a project becomes proactive, it does not take the form of a financial participation, but in terms of bringing into the project some expertise and advice in dedicated technological and scientific areas.

The US Army Laboratories extensively use the first type of public–private partnership. The RDT&E projects remain structured primarily to meet military needs. When the US Army Laboratories are engaged as either a *minor* or a *major participant*, both the public and private partners committed to the project often use CRADA contracts. Sometimes, specific Federal programs, such as the Small Business Innovation Research

(SBIR) program supported by the Small Business Administration (SBA), are also used. The transfer of intellectual property rights to the private sector is often encouraged in the third and fourth types of public–private partnership, whereas it is restricted in the first and second types. At both extremes, two cases of public and private relationships coexist: either the US Army Laboratories finance and control RDT&E projects dedicated to specific defense needs or they develop a firm scientific and technological partnership dedicated to fostering their expertise and skills. Generally speaking, they allocate very little money to a RDT&E project that is driven primarily by the commercial needs.

This example demonstrates how a "dual" policy modifies RDT&E management. In reality, a "dual" policy covers a wide variety of solutions in the different countries. The nature and variety of the MoD's scientific and technological expertise is the main explanation of this situation in the UK.[28] The variety of public actions dealing with prospective projects involving Small and Middle-sized Enterprises' (SMEs) support are also very good illustrations of the phenomenon.

In the USA, the Pentagon is a major actor in Federal government's support for SMEs. The DoD distributes more than half of the SBIR and Science and Technology Transfer's (STTC) budgets. These programs represent one of the DoD's mechanisms with which to support new strategic and technological industries, such as ICT and biotechnology. Inside the SBIR and the STTC, military laboratories represent the Pentagon and develop various partnerships with innovative SMEs and provide firms with technical expertise. The DoD allocates US$500 million dollars per annum to around 1,000 SMEs for these projects.

In the United Kingdom, a Defence Diversification Agency (DDA) was set up in 1990. Its main objective was to facilitate meetings between the British defense RDT&E community and innovative actors of the civil and commercial world. Its budget amounts to only £1 million. This agency comprises 24 people, seven from the MoD (three from DSTL and four from the central administration of the MoD) and 17 from QinetiQ. DDA's employees are managers who have to mobilize the skills and infrastructures of the RDT&E centers related to DSTL and Qinetiq in order to promote and facilitate the commercial applications of technologies financed by the MoD. The DDA facilitates the transfer of intellectual property rights related to defense innovation towards SMEs. It also participates in regional innovation networks, is engaged with business links that are cooperative networks dedicated to SMEs, and provides many technology advisers.

Interactions between the MoD and the SMEs are very different and less intensive in France than in either the United Kingdom or the United States. The interface is exclusively financial. The DGA is a part of the French MoD and is in charge of the SME support budget. SMEs do not benefit from defense technological advice. The results of France's MoD support for SMEs are limited.[29] The number of SMEs benefiting from this public source of support is small, and SMEs' ignorance of potential defense financial support partially explains the poor results. New public action has been proposed to improve defense support for SMEs and to increase the DGA's knowledge of strategic innovation. For the first time, a DGA/*Délégués Régionaux de l'Industrie, de la Recherche et de l'Environnement* (DRIRE)[30] partnership has been launched. In order to

give the DGA access to local industrial capabilities, a partnership between the DGA and the Agency, Anvar[31] and the investment bank *Confereration Générale des Petites and Moyennes Enterprises* (CGPME) has also been encouraged. These initiatives imply more civil and military coordination for public benefit. However, these initiatives do not rely on the Ministry of Defense's defense RDT&E centers such as the *Direction des Centres d'Essais* (DCE),[32] *Office National d'Etudes et de Recherches Aerospatiales* (ONERA) and the *Commissariat à l'Energie Atomique* (CEA).[33] Compared with the US and the UK, French individual technological and scientific skills have not been mobilized in the civil and military coordination process.

An analysis of prospective initiatives provides another illustration of the different national approaches dealing with the coordination of civil and military public research activities. In the UK, the national program "Foresight" has improved communications between various institutions who can share very different experiences. It represents a mechanism with which to define a common strategy for civil and military public action. It is complemented by the amassing and collation of data and information from a "technology watch" in order to evaluate the impact that civil technologies have on current and future weapon systems and to understand better major scientific and technological change.[34]

In France, the opposite situation prevails. Prospective French networks are not considered as a way to improve the effectiveness of a common civil–military research, development and technology strategy. Such a mechanism has never been thought of with which public and private experts can help define common civil and defense needs in the long run.

At the end of the 1990s, the French Minister of Finance, Economics and Industrial Affairs (MINEFI) launched an exercise named "*Technologies Clés 2005*". The goal was to provide the policy-makers with a global vision of critical technologies. The definition of technological criticality was based on four criteria: socio-economic needs (the potential growth of commercial markets in the next five years); environmental considerations; technological dynamics (the emergence and maturity of the technology); and last, but not least, defense and security imperatives. The steering committee was characterized by the absence of academics, an under-representation from industry, and an over-representation of people affiliated to the central administration and government Ministers. There was no one representing the Defense Minister on the steering committee, nor was anyone representing the Defense Ministry in the working subgroups. In fact, the interests of defense and security were not a priority in the MINEFI's forward-looking exercise. Out of the 119 critical technologies identified, only 29 (around 25 per cent) were considered as critical for defense and security and/or the aeronautical and/or space sectors. Surprisingly, no technology in the energy or life sciences sectors has been identified as critical for defense-related issues.

In the final analysis, the advantage of the *PP30* is that it will force the main French MoD departments, divisions and Services' agencies involved in RDT&E policy to work together. Nevertheless, this is clearly insufficient, considering the political and technological options retained by the Ministry of Defense: only a complementarity of RDT&E public action across Europe and a modification to the defense budget in the technological areas that are not financed by the civil administrations and/or the private sector will

improve matters. The *PP30*'s network should, therefore, be opened up to civil experts both in France and in Europe. *PP30* lacks a forum for advice and judgement among various experts about economic, political and technological tendencies.

KNOWLEDGE PRIVATIZATION AND THE APPROPRIATION OF INNOVATIONS: NEW PROBLEMS FOR THE MILITARY SECURITY OF THE SUPPLY CHAIN

The security of the supply chain constitutes an important requirement for the defense system. It implies an industrial policy with which to support industrial and technological development and to guarantee the permanence of strategic firms. Today, the lack of interaction between civil and defense RDT&E activities effectively prevents public intervention. More than this, knowledge privatization makes the control over national scientific and technological innovation more complex than ever before. It implies the need for initiatives for industrial policy. This tendency implies new perceptions for policy-makers about the control of national technology and of defense-related intellectual property rights and standardization. Such a trend would radically modify the role of the industry in the both the civil and military policy-making processes.

Knowledge privatization (in particular the activities related to fundamental research) initiated in the US forms an important development in the dynamics of industrial innovation. Firms can access and incorporate academic research results to access patents until they finally emerge with the final marketable product. In this event, firms obtain exclusive rights to the potential research results. This evolution primarily concerns ICT and biotechnology. Two major risks, however, emerge in this context: first, the production of generic research might both be limited and the quality of academic research decrease.[35] Second, public reaction might remain more limited than before.

In the United Kingdom, the privatization of DERA clearly modified the organization of UK defense RDT&E.[36] The MoD now lacks the competence to support innovative SMEs. The reason lies in a loss of skills in favor of Qinetiq. DDA's managers have, therefore, to engage in their research and development activities in collaboration with engineers and scientists at DSTL and Qinetiq. In reality, Qinetiq is not responsible for public industrial support and has shown itself reluctant to facilitate SMEs' diversification activities. For example, the patent transfer strategy is radically contradictory: on the one hand, the DDA looks to facilitate patents transfer in order to optimize the exploitation of RDT&E results financed by the MoD; while on the other, Qinetiq wants to increase the profitability of the transfer of non-strategic patents and guarantee the maximum protection of its strategic patents. In the future, the DDA's mission will become more and more difficult because today all defense RDT&E patents currently remain the property of Qinetiq.

The context of knowledge privatization implies three types of major change in the policy-making process. First, the necessary security of the supply chain implies that MoD assists a firm's capacity for appropriating knowledge in situations where the major innovations have not been developed on national territory. The Pentagon considers that this point constitutes one of the major challenges for maintaining the

US's civil and military technological superiority. In an interview he gave in 2000, Bruce Don, Director of the RAND Corporation, explained that the acquisition of a firm's capacity was one of the most important challenges to American security.[37] Another difficulty concerned the confidentiality of strategic firms that were taken over, or acquired by, foreign interests. US policy-makers need to check the control of the capital of firms working in the area of critical technologies financed by Federal agencies. This, however, is not managed in a very satisfactory way,[38] since they forbid American firms to sell patents related to the results of research financed by Federal agencies except for a five-year period following the initial investment.

This public intervention cannot be considered efficient because the evolution of the strategy of the firms and the instability of industrial activities in strategic defense-related areas make it difficult to exercise effective public control. First, the opportunities for foreign companies to acquire American firms related to defense programs are ostensibly very restricted. When such financial initiatives are allowed by the Federal administration, the firm's employees have to remain American and it is strictly forbidden to communicate any strategic information relating to US weapons to any foreign government or company.

Second, military RDT&E policy is based on a "top-down" approach. This means that political and public decisions are generated by the agent's behavior. The state used to be considered a "discriminating monopsony", or single purchaser. Today, this situation has clearly changed. The state has lost its advantageous position in the knowledge and information networks. Very often, defense has become a technology-user similar to any other organization or institution inside the network. In such a context, the defense policies of intellectual property rights and standardization will have to be modified. These public interventions are now totally embedded inside national and international public activities that do not differentiate defense from all other activities

Third, industry plays an increasingly essential role in the civil and military policy-making process. In particular, the negotiating power of the multi-national industrial corporations has increased substantially. This development represents one of the more distinctive characteristics of Europe's institutional framework. For instance, multi-national corporations play a central role in the evolution of the European Union Commission's declining involvement with European innovation activities and with the development of the European market.[39] Nowadays, this situation also characterizes defense RDT&E activities. Launched in 2001 and 2002, the initiatives such as the Advisory Council for Aeronautical Research in Europe (ACARE) and Strategic Technologies for the Army of the 21st Century (STAR 21) are concerned with the air traffic, civil aeronautical, and defense and security sectors; they list the main principles intended to maintain within Europe a technological excellence in these areas. ACARE and STAR 21 were proposed by multi-national firms to the European Commission, directly. Such a situation makes it obvious that the state remains more dependent on industry to orientate RDT&E policy. The Western European Union exercise European Science and Technology Strategy (SCITEC) is another example of this phenomenon: launched in 1995 by the West European Armaments Group (WEAG), the definition of the critical technologies (the "dual" and specifically military one) was realized on the basis of industrial initiatives.

The specific role of industry in the European innovation policy-making process could be explained by the complexity of European public institutions. The coherence of national and European public activities represents one of the main challenges to RDT&E and innovation policy. The coherence of the public intervention related to the civil and military RDT&E activities happens to be more complex and difficult than when dealing with purely civilian activities. The reason lies in the co-existence of two different institutional contexts: civil RDT&E policy depends on the first pillar of the European Union, whereas the foundations of defense RDT&E policy only refer to the second pillar. The practices and knowledge codification are very different on both sides.

Only the multi-nationals have really mastered the working methods in both fields. For instance, Thales is one of the prime contractors on military programs and at the same time behaves as one of a major project's coordinators related to the ICT and material sectors in the European RDT&E program, the *Programme-Cadre de Recherche et Developpement* (PCRD).[40] The experiences accumulated by the multi-national firms in coordinating RDT&E activities are more important than those of public institutions. Firms have learned from their various experiences of European management of RDT&E projects. No doubt the role of industry in the European policy-making processes will increase in future years. In such a context, new questions emerge. What, for example, will be the nature of the public–private relationship in the civil and military RDT&E policy-making processes? What is the nature of public and private interests involved in these processes?

After the Cold War, a new economic and political context radically reshaped the terms of defense RDT&E policy. A new problem emerged at every stage of the innovation process. Defense Research and Development policy has become more and more complex and implies new forms of public–private coordination and public–private partnerships. Various national contexts have shown that there are different options available to policy-makers. The success of any reform depends on their capacity to improve knowledge management in the development of ever more complex defense technological systems.

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