# New approaches for military innovation in knowledge based economics: an inquiry into the new role of Defence in innovation processes

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**Abstract**

This article elaborates on the specificities of the Defence in innovation processes in the context of knowledge based economics. It suggests that understanding the role of Defence in innovation requires taking into account its status of final user of very specific technological projects. Defence may hold two statuses*:* *owner* and/or *lead user*. These contribute to understand its role as regards the various levels of its active intervention. This article explains in which cases the Defence might be assimilated to an *owner* and to a *lead user* in France and in the United States. It makes precise the implications of these roles in order to appraise the Defence's involvement in the innovation networks. This article underlines the importance of the variety of competences required or the Defence user (as a *lead user* and/or an *owner*).

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## Introduction

National Defence organizations - the Defence here after – act as the actor of specific public policies and as the final user of weapons systems. Understanding this twofold contribution to technological innovation has always been complex. Defense's implication varies with the countries, depending on local economic situation and on socio technological networks. In the context of knowledge based economics, the real contribution of Defence to new technological developments is growing blur. This contribution proposes to consider the specific status of Defence as user of technologies in order to appraise its contribution to innovation processes. The article suggests that understanding the role of Defence in innovation requires taking into account its position as innovative user in some very specific technological projects.

Knowledge based economics refers to the existence of distributed and specialized knowledge base[1]. Users of technology represent strategic actors in the innovation processes[2]. The heterogeneity of technological uses implies an accurate attention on the emergence of active users, who are not only the ones who exploit and possibly divert initial technological uses. They are also committed to the definition of technological solutions. National Defence organizations represent a very particular user of technology. Its contribution to the innovation processes may be assessed as active or passive user, according to Lettl and al.'s description making[3]. The Defence could intervene in the articulation of problems about existing products, in the elaboration of technical and military requirements and also in the evaluation of new technologies. Its role can develop up to an activity of co-conception of technological solutions. In these cases, the Defence could be considered as an active user in the innovation processes. It generates new ideas and contributes to the development and the validation of technological solutions.

The article aims at understanding how national Defence organizations –the Defence – contribute as active users to the innovation process in the context of knowledge based economies. There is no single approach about user centric innovation. This article borrows from two different bodies of scientific literature. It elaborates on investigations about the conception of complex program systems: the article shows that Defence endorses in many cases the position of an owner. Defence participates to the design of complex systems and endorses sometimes specific responsibilities at the level of the integration of technologies. The second reference goes to the status of lead user: as an inventor of technologies and of functionalities, Defence influences others users on the market.

The article shows that these approaches represent major characters of the Defence's contribution to innovation. Consequences deal with coordination arrangements. They focus on the division of labor and knowledge between Defence and firms in charge of the conception of weapons systems. This article investigates also the modalities of diffusion and control of knowledge assets in innovation networks. Consequences will also be appraised at the level of technological and organizational capabilities which are mobilized by national Defence organizations.

The article is divided into four parts. The first one contrasts the contribution of Defence as a specific user of technologies according to the reference frameworks. The second part outlines the method used to analyze the French and American cases. The third part presents the results of interviews realized between 2000 and 2007. It outlines the specificities of the implication of French and American Defence organizations in the innovation processes. It presents their contributions when they endorse the status of owner and of lead user. The next section explains the implication of these statuses as regards the division of knowledge and of labor. It elaborates on the organizational and technological capabilities required for Defence organizations in each framework. The article shows the consequences of these perspectives on the management of technological military programs. The article concludes about the modalities relevant for potential integration of the two forms of Defence contribution.

## Understanding the role of the Defence national organization as an active user in innovation processes

### Defence as the owner of complex products systems

The first approach of Defence contribution in technological innovation pictures the specificities of the conception of weapon systems. National Defence organizations represent the final user of complex products systems (CoPS)[4]. These programs are elaborated on the basis of a large array of technological and organizational competences. They integrate systems whose diversity and variety remains tremendously important. For example, the US Air force fighter aircraft F-16 Fighting Falcon integrates 3,900 different components and subcomponents[5].

Weapons programs are intensive knowledge projects facing a lot of financial and technological risks. Weapon systems have to be continually adapted to the variety of military missions and to the dynamic of technological change[6]. The management of these projects remain specific because of their hierarchic and modular organization. Brusoni et al. have explained that there is little correlation between the division of labor and the division of knowledge in this sort of framework[7]. Competences are embedded in complex relationships[8]. Various processes of in-sourcing, out-sourcing and joint sourcing are developed between the main actors involved in complex programs. Processes are the results of product architecture as defined by Ulrich[9]. This definition perfectly matches the integration of military CoPS in order to provide operational functionalities on the battlefield: "*product architecture is the scheme by which the function of a product is allocated to physical components*".

The integration function remains central in the armament sector[10]. Military CoPs refer to the specific role plaid by the Defence as user and by companies as system integrators. Defence interacts with the firm in charge of the integration in order to manage the dynamic interactions between components and subsystems. They create together the product architecture matching the requested operational specifications. The role of the Defence in CoPS is generally associated to the status of the [maître d'ouvrage][11], or *owner* of CoPS. It has two main characteristics. First, it represents the main user. Second, it is also an operator of its developments. The Defence acquisition agencies and R&D departments control and intervene on technological design and specifications in order to guarantee the appropriateness between military needs and industrial projects. The Defence as an owner is then assimilated to an active user in innovation processes. Military engineers and scientists co-specify the architecture of technological programs with the firm system integrator.

During the Cold War, the dependence of large firms to Defence procurement has been significant. The Defence commitment in the conception of technological design of complex system was very important[12]. Since the years 1970-1980, the new economic and socio-technical context has progressively changed the management of military CoPs. The explosion of ITs and the variety of commercial and societal applications for technologies and scientific results opened the way for the emergence of new industrial sectors and markets. Technological knowledge is often produced without any link to Defence R&D projects. This evolution occurs with the decrease of Defence budgets[1] and with the definition of new

[1] In France, between 1995 and 2000, the military public R&D investment reduced by more than 30 %. In 2000, military R&D investment represents less than 25 % of the whole national R&D budget while it reached 50 percent in 1990. This diminution implies a re-definition of the technological public strategy and a new motivation for European cooperations. In the United States, the Defense R&D budget remains stable. This is the reason why the Pentagon remains one of the main important public actors. It sustains the scientific and technological development even if federal actors such as Health Department emerge with tremendously increasing R&D budgets. Still in 2000, the Pentagon represents more than 50 per cent of the federal R&D budget.

priorites for public expenses at the end of the Cold War. Defence market power has then reduced[2].

The massive introduction of ICTs has conveyed new complexity to the management of weapons systems. Systems of systems (SoS) represent large technical systems which cover a collection of distinct but interrelated military systems, and totally depend on information and communication technologies[13]. Such programs accelerate the evolution of the division of labor and of knowledge between Defence owner and the firms working as systems integrators. SoS implies a superior level of integration for weapons systems[14]. Firms act as lead systems integrators (LSI). It means that they develop leaderships and core competences which extend their responsibilities to the conception of the interfaces connecting together the various systems, and to the elaboration of the evaluation tools associated to systems of systems[15]. The contribution of national Defence organizations to the conception of weapons systems has therefore progressively changed. Defence does not intervene at all step of the design of technological systems. The role of Defence as an *owner* is progressively compelled to concentrate its attention on the definition of the operational and financial goals, and of evaluation processes for complex programs.

### Defense as Lead user

In the context of knowledge based economics, Gibbons & al. consider that the main sources of new knowledge depend on the efficiency of problem solving[16]. The production of knowledge is generated by the context of application and by heteregeneous practices. Innovation requires a systematic process of reflexivity implying various forms of exchanges between the users, the university and the industry. The strategic role of users becomes obvious. The latter contribute directly to technological invention[17].

[2] The semiconductor sector constitutes a major illustration of this phenomenon. At the beginning of the 1970ies, the Pentagon accounted for 90 per cent of the demand on semiconductor markets. Thirty decades later, it only downsized 1 per cent.

Defence concretizes a specific applicative domain of technologies. If many technologies are concerned with dual use potentialities and are produced outside traditional military innovation networks, the specificity of uses and applications in Defence organizations require mastering specific skills. Competences and sense making processes result from individual and collective experiences in military units. During the 1980 and 2000, the introduction of ICTs implies the emergence of new technological behaviours in military organisations[18]. The introduction of new ICTs functionalities and applications in command and control and in tactical units reshapes the contribution of Defence to innovation[19]. The originality of Defence in innovation processes is limited to the knowledge assets which military users – warfighters - accumulate with the experience of operational missions. Military users appear more frequently as contributors to innovation processes. Technological development requires a deep understanding of the characteristics associated to practices and uses in military interventions which warfighters are best positioned to introduce directly. Technology is embedded in organizational processes and requires the development of new technological functionalities suited to the resolution of actual problems in concrete military contexts.

Von Hippel defines the status of *Lead user*. This concept characterises specific users which are totally committed to the definition of new technical products in collaboration with the industry[20]. Lead users experience early the emerging market needs, and benefit immediately from the solution they contribute to make up. Morrison and al. describe the lead user's leading edge status[21]. It pictures an attitude in an organization though which individuals commit to the elaboration of technological solutions to problems which are not met by the other ones. The emergence of lead users deals very often with markets in which the life cycle of technologies is short, and in which heterogeneous users co-exist[22]. One of the main characteristics differentiating *the lead user* from the other users deals with the capacity to bring technological solutions and practices onto markets. It influences the behavior of others users. Progressively it imposes informal standards, norms and organizations associated to the introduction of new technologies[23]. During the 1970-80es, the early exploitation of ICTs by the Defence organization already pictured lead user attitudes. It has lead to new technological applications which have radically changed the use and practice on military and on civil markets.

The *lead user* and the *owner* status coin out two different conceptions of the role of the Defence in innovation processes. Lead users are more present in the definition of new technological functionalities than with a direct implication in the conception of the technical architecture of weapons systems and the integration of technologies and subsystems. The Defence as an owner is associated to the co-specification, orientation and decision of product architectures for military complex systems, while Defence as a lead user interacts with the developers in order to influence the definition of new uses for technological artefacts. Defence as owner and as lead user behaves as an active user involved in innovation processes and it manifests competences at the organizational level consistent with the one's described by Lettl & al.[24]. The user's ability to mobilize in-house knowledge and to combine existing and available knowledge situates this analysis in the framework of dynamic capabilities analysis[25] or of combinative capabilities[26]. It deals with the capability to integrate, build and reconfigurate internal and external competences, to transform old capabilities into new ones in order to address rapidly changing environments and long-run projections into the operational future.

These competences build a kind of distributed organizational knowledge system[27]. The knowledge required for national Defence organization to be present in innovation processes localizes at various levels:

- warfighters who are working for military units for able to act as lead users, and

- Scientists and engineers employed by military R&D laboratories and procurement agencies work for the owner function.

## Data and method

This paper is based on specific cases describing the ways endorsed by French and American national Defence organizations to commit to innovation processes. I have allowed an interpretive case study methodology[28]. National comparisons contribute to a deeper understanding for the implication of Defence organizations in innovation processes. Appraising critical competences at different organizational levels becomes also possible.

National Defence organizations as clients and users of technology relate to an array of institutions. Military units, acquisition services, research, development and tests laboratories inside ministries of Defence are parts of this network. Other government agencies also belong to this network when they are in charge of specific R&D missions and expertise activities in the framework of acquisition processes, provided that they work directly to the DoD or French MoD."

National Defence organizations boundaries are different in France and in the USA. The Pentagon owns and runs the half of the 726 federal R&D laboratories, which then relate to the various services. Many structures are dedicated to the acquisition process and to the coordination between scientific and technological activities. Each service also develops and manages battle labs in close interaction with military units, in order to experiment technologies in military context. Experimentations occur also during actual military operations. The Pentagon also runs the 8 *Federally Funded Research and Development Centers* (*FFRDCs*), which provide R&D investigations and technical expertise related to the acquisition processes.

In France, R&D policy and weapons systems acquisition remain principally in the hands of the Délégation Générale pour l'Armement (DGA), in cooperation with the French Services[29].

This function is more centralized in France than in the USA. Inside the French Ministry of Defence (Fr MoD), the DGA hosts the technological and managerial expertise and remains the main interface with the external environment. The DGA gathers structures in charge of the management of weapons systems and the ones in charge of the realization of tests and essays (eg. the Centre d'essais en vol, CEV) in the framework of acquisition processes… Expertise is highly concentrated, yet the French services develop their own military tests and essays facilities. The French Air force has installed for instance the Centre d'expériences aériennes militaries (CEAM) where aircraft are tested, and technical problems related to military systems are resolved. In specific cases, operational military units are active in experimentations. It is the case of with the French Air Force Special Forces. Others structures contribute to the innovation processes. The ministry of Defence recently launched the Laboratoire Technico-operationnel (LTO) in order to develop new concepts and to experiment technologies in military contexts. The DGA and the Services run the LTO together. Two national public research centers are also directly committed to military R&D and to acquisition management: Office nationale d'Etudes et de Recherche Aérospatiale, called ONERA, which is in charge of applied research in civil and military aeronautic domains and the Direction des applications militaries (DAM) of the Agency of Nuclear Energy (CEA) which is in charge of the research and development of nuclear military systems.

I have reviewed the literature on these issues and on these cases. A total of 52 semi-structured interviews occurred between 2000 and 2007, each lasting between one-and-a-half and three hours. Theses interviewed focused on the nature of the contribution of national Defence organizations to innovation processes, on their competences and on interactions public organizations and private companies about the elaboration of technological knowledge. The interviews focused on programs of major importance for National Defence organizations such as: the Mirage 2000 and the F16 air fighter programs; the SCOAA and FCS systems of systems or specific ICTs projects like FPAN. 15 interviews occurred with executives working in the US DoD (Services, R&D laboratory, battle labs) and 22 o with executives inside the French MoD (DGA, Services, LTO). Other interviews were realized in government agencies working for the Defence in France (4) and in the USA (3). 8 interviews were realized with French and American firms specialized in the conception of weapons systems, and focused about the evolution of relationships between Defence national organizations and the firms. The author's participation to policy meetings and expert groups held in France and in the USA between 2000 and 2007 was also an asset for this research. The following table summarizes these Defence organizations, where interviews have been run.

| **National Defence organizations involved in acquisition processes** | **Executives interviewed inside structures of the ministry of Defence** | | | **Executives interviewed inside structures directly working for the ministry of Defence** |
|---|---|---|---|---|
| | Acquisition structures | R&D labs tests and essays facilities | Military units and experimentations structures | |
| **France** | DGA | CEV, CEAM | LTO, military units | CEA, ONERA |
| **USA** | Inside each service | Military labs and R&DT structures | Battle Labs and military units | FFRDCs |

## Case studies

The cases are structured as follows. First, the section explains the position of American and French National Defence organizations as the owner of military complex systems. It presents then their respective position as a lead user committed to the development of ICTs.

### The owner inside system integration networks in the USA

During the cold war, DoD Services have been very active in the conception of technological systems[30]. The division of knowledge and labor inside the integration system networks depended on the distribution of competences between military services and firms integrators.

For instance, the US Army endorsed the main part of the integration function for programs such as attack helicopter Apache and the main battle tank Abrams. The program acquisition structures and military R&D labs conceived in house 50 percent of the new strategic components knowledge[3] for these programs. US Army's labs and private firms were in charge of the other 30 percents[31]. The US Army was key to the resolution of conflicts and to the distribution of tasks inside the integration system network. It maintained the global picture for the integration of physical components and for the definition of operational functionalities.

Other cases exemplify that. The US Army was less active. In the missile sector, US Army R&D labs mastered fewer capabilities than the industry. Hey were not able to develop strategic components and to define new product architecture on their own. For example, private firms conceived autonomously75 percent of the technologies and subsystems for the Stinger and Javelin programs. The industry co-conceived with the US Army labs 25 percents of subsystems. In the cases of missile programs, the US Army acted as contractual authority in charge of arbitrating the tradeoffs among cost, size, weight and integration decision. Decision making about the physical integration of systems was mastered by the industry and not by the US Army.

With the growth of technological complexity and with the emergence of systems of systems, the division of knowledge and of labor between military services and industry has changed. If DoD Services try to preserve a capacity to understand the integration processes for complex systems, and even sometimes go as far as proposing alternative architectures[32], the part of outsourced R&D projects increases.

**Parts of R&D projects in-sourced by US military laboratories**

| | 1990 | 2000 |
|---|---|---|
| **US Army** | 46% | 35% |
| **US Air Force** | 36% | 29% |

[3] Strategic components represent new technologies and subsystems which impact the technological and military superiority or imply a major change in the conception of product architecture.

| | | |
|---|---|---|
| **US Navy** | 56% | 50% |

*US Department in house RDT&E FY 2000*

This evolution reveals different options endorsed by DoD Services. The US Navy develops initiatives in order to preserve its capacity to orient the system integration process. Systems of systems capabilities remain onshore. These capabilities are considered by the US Navy as strategic competences required to orientate technological programs. This position represents an explicit choice. It is largely criticized by firms which consider that it is now impossible for the US Navy to cope with the complexity of systems of systems. If the US Army and the US Air force maintain a capacity to orientate technological systems in specific areas, they lose parts of this capacity at the level of the architectural knowledge for large technological systems. Their R&D laboratories do not master the integration capacity for system of systems. The Future Combat System (FCS) financed by the US Army features one of the most emblematic instances for this evolution. It articulates seventeen weapon systems and platforms and is intended to suit to a large variety of contexts, missions and international cooperation modalities. The US Army does not intervene anymore in the conception of its technological design. It has lost the control over the evaluation of the FCS components in both areas of technological performances and of costs. The US Army only preserves the capacity to evaluate links between technological performances and operational functionalities in military context. Even if the US Army acquisition structures remain the final contractual authority inside the integration system network, Boeing and SAIC[4] endorse the role of "Lead system integrator. Criteria and goals dealing with budgets and military needs have to be defined very early by the US Army at the level of contractual specifications. US Army R&D laboratories focus their implication on the conception of specific critical component knowledge. They preserve their own control for the property right on these critical military

[4] SAIC is a company specialized in hard and software for military applications.

technologies but they have lost the capacity to coordinate networks activities, and to understand the whole technological conception of systems.

**Where does knowledge reside in American Defence organizations in the owner paradigm?**

The main function of military R&D laboratories has always dealt with the preservation of the US Defense technological superiority[33]. The capacity of in-sourcing conception of critical (component and architectural) knowledge has been considered as essential for DoD Services. This strategy aims to preserving the Pentagon decision making process independent from the private sector. That is the reason why military laboratories keep on recruiting system engineers and specialists in various strategic technological and scientific areas (eg. mathematicians and life science scientists, computer engineers…). These competencies are compulsory for the DoD be able to absorb knowledge produced by networks, and to develop co-conception activities with the industry.

During the 1990es, the Pentagon's internal transformations have modified its strategy as regard the absorptive capacity. R&D laboratories are less and less providers of technologies. They progressively concentrate their activities on tests and evaluations for technologies procured in the industry and in universities. The number of engineers and scientists in the military R&D labs has reduced by 10% to 20% during the decade[34]. If 30 000 engineers, scientists and technicians are still working in 2000 for military laboratories, the lack of specialists in strategic component knowledge tends to increase. Specifics labs (eg. optic lasers in US Navy Labs) have lost 50 percent of their personals. In general, DoD Services confront many difficulties in the recruitment associated to new technological domains. Services develop two alternative strategies. Either they choose to abandon specific technological field, or they transform their R&D laboratories in order to the "Government owned and Government operated" (GOGO) status. The GOGO status suit allows for an easier recruitment of specialists and for the valorization of scientists and engineers trajectories similar to the industry human resources management because the organizations are not bound to federal regulations anymore (for instance about wages).

In each service, R&D labs have somehow lost the capacity of coordinating and translating technological functionalities into operational contexts. This is the result of the reduction of knowledge exchanges and of scientists' and engineers' mobility between R&D labs, acquisition structures and military units. Relationships are more and more formal. The creation of a common language about concepts and military systems integration become more difficult.

### The owner inside system integration networks in France

The implication of French National Defence organizations in innovation processes has been important until the beginning of the 1980es. Aeronautic programs like the Mirage 2000 illustrate this point. The French Air force Staff defined the main military functions for this program. CEAM and DGA then translated these requirements into technical specifications. DGA made the final decision related to the economy of the program. DGA and CEAM intervened at all steps of the programs conception in order to arbitrate technological and financial change. They also introduced evaluation and control rules. The capacity of co-designing the technological architecture of weapons systems is not as much important in France as in the USA. For the Mirage 2000 program, CEAM and DGA aimed at orientating technological choices[5], but rarely intervened actively in the conception processes. The single exception deals with the necessity of in-sourcing specific conception features inside DGA sites, in the cases where firms are reluctant to develop them. For example, DGA had to recruit quickly in order to develop simulation tools because French firms had refused to engage R&D in this domain. DGA cooperated on the program with CEAM. When the air simulation project

[5] In privileging technological domains and in protecting industrial competences in order to secure supply chains.

has become mature and markets perspective concrete, DGA transferred for an industrialisation by specialized firms.

With the end of the 1980es, responsibilities for system integration increased inside the industry[35]. Firms progressively endorsed all responsibilities: financial, organizational aspects and the evaluation of cost and performance for the interrelations between technological changes and operational functions. The reforms of weapon systems acquisition in the 1990ies confirmed this trend. It impacted also the role of the French National Defence organizations in the conception of programs. DGA and CEAM have progressively lost their capacity to orient technological development inside integration networks. Priorities are now managed with outsourcing and market relationships[36]. DGA and CEAM define needs and requirements very early in the process. They make explicit the priorities in the contracts. They are less and less implicated in the technological dialogue between firms integrators and subcontractors. DGA and Services progressively hold aloof and do not commit to the management of technological complexity anymore. For instance, the French Air Force launched in 1997 SCCOA[6] program in order to modernize communication and information systems for C2 Air operations. SCOAA represents an actual instance of systems of systems. EADS and Thales cooperate for this program under a consortium, and act as lead system integrator. They endorse also all control and evaluation tasks. They develop specific simulation tools in order to evaluate the effectiveness of the program, in relation with various military scenarios proposed by the military. DGA and CEAM precisely define these aspects early in the contractual arrangement but do not arbitrate technological choices during the conception of SCOAA.

**Where does knowledge reside in French Defence organizations in the owner paradigm?**

[6] Système de Communication et de Commandement des Opérations Aériennes.

DGA has never maintained in-house R&D laboratories. It has only developed centres which focused on tests and essays in order to evaluate solutions conceived by the industry. In contrast with the Pentagon, the DGA expertise function has never been associated to a strong practice of technology and science. Only 10 % to 15 % of Defence R&D was dedicated to onshore tests and essays. DGA financed projects with in-house capabilities in order to serve specific domains. DGA's capabilities have always grounded in armaments engineers graduated from "Ecole Polytechnique, who all share the same technical culture and mental representations. They develop relational competences inside the networks in charge of integration systems, yet they hardly practice technology inside DGA itself. Technical competences are developed through the mobility of armament engineers between Defence and firms integrators. The (already mentioned) Mirage 2000 Air simulation project provides an instance of DGA's ability to in-sourcing and outsourcing technological projects (mainly on subsystems). After some years dedicated to the initial R&D for the project, DGA transferred the demonstrator under restrictive conditions. DGA's engineers who had worked on the project were repositioned inside the MoD.

Since the beginning of the 1990es, the DGA has lost its capacity of in-sourcing technological conception because of the consequences of sharp budget reduction. The DGA 1996 reform has introduced news relationships between National Defence organization and firms. The mobility of armaments engineers inside the industry is now led by restrictive conditions. 65 % of the activities of DGA's tests and essays centres are now dedicated to the appraisal of the documents associated to industrial proposals which do not imply actual tests anymore; 35 % deal with the redaction of technological specifications for calls for tender[37]. It is the case with the SCOAA project. Only 5 % of DGA total work share is dedicated to proper test and essays. Outsourcing tends to be generalized. In this context, preserving the diversity of internal technical capabilities becomes impossible. The armament engineer profile becomes progressively one of a generalist, in charge of managerial and contractual duties. DGA capacity to detect and assimilate new knowledge decreases considerably. It loses progressively its capacity of interacting on technological problems associated to the architectural design of weapons systems.

Military test and essays facilities like CEAM, ground their competences in field experiences and technological education (for instance engineer diploma) of military personals. Since the 1990es, CEAM and alike centres progressively lost the capacity to orientate the technological development of CoPs. Military tests facilities do not intervene anymore in all steps of the conception of systems as they used to do until the 1980ies, and now focus on some specific steps of the conception process. For instance, CEAM is mobilized:

- early in the contractual plan, when the Air force staff requires a support for the definition of military functions and specifications, and for testing the final product in order to elaborate the tactical doctrine documents.
- When firm integrators require operational and battlefield-related expertise, in order to evaluate specific features of weapons conception.

At the beginning of the 2000ies, independent expertise and reports issued by the French Parliament criticized the loss of DGA and military test structures' capacity to evaluating and specifying industrial projects. In 2003, developing the French MoD's technological capabilities has become a priority of the French armament policy again[38]. However, the acquisition of technological competences remains low. Successive reforms which have occurred since 1996-1997 destroyed progressively the DGA organizational competences. Budget constraints limit the possibility for the recruitment of technical skills in order to reinforce DGA's absorptive capacity.

That is the reason why initiatives from 2003 awards focus on the definition of new modalities suited to the mobilization of external technological expertise. This represents another approach to absorptive capacity. DGA tries to animate technological networks on military-related issues by financing experts groups and seminars. Research centers commissioned by the DGA are mobilized for new missions and activities. New conventions grant ONERA and the Direction des applications militaires (DAM) of CEA, which a budget for new technological missions. Then deal with the investigation of new domains, and with the animation of academic and industrial networks. For example, ONERA is required to work about the conception of mini-UAVs. However, this process introduces new issues with the definition of competence complementarities between DGA and these research centers. More specifically, ONERA and CEA centers hardly develop any capacity to anticipating on the specificity of military needs, and to translating basic science projects into actual technology demonstrators. They miss a competence and a global picture. Outsourcing processes modify the boundaries between public and private organizations and, at the same time, tend to reduce the potential for innovation.

### National Defence organizations as Lead users

This paradigm emerges for national Defence organizations in the USA, and to a lesser extent in France. Implications occur rather at the level of ICT modules than at level of CoPS.

#### *New role of war fighters in innovation networks in the USA*

In the USA, the FPAN project (at the end of the 1980es) and the NCW doctrine (in the early 1990es) are two instances of new direct implications of the war fighters in innovation processes.

In the middle of the 1980es, two young pilots of the US Air Force took the initiative to develop software technologies in order to improve the mission planning system associated to the F16 aircraft. This project called FPLAN ("flight planner") was initiated because the usual software system based on a commercial version (called CAMP[7]) was not reliable. CAMP had

[7] Computer Aided Mission Planning System.

been financed and driven by the Air force acquisition service into formal contracts with Apple and IBM. The pilots developed the FPAN project with the Linux community and invented various applications associated to geopositionned maps[39]. In contrast with the CAMP project, FPAN developers made the human interface a priority. In a first phase, pilots used FPAN project without formal authorization. The military hierarchy became aware of the performance of the new system only during Gulf war II (1991) because the Air force needed a simple, rapid and efficient system in order to plan air military operations. CAMP received very negative user feedback. It was difficult to use and was partly rooted in mistakes in actual mission planning. This is the reason why, during the conflict, the hierarchy started to promote the generalization of FPAN. This software improved the conduct of the war.

In the 1993, FPAN was made the official mission planner for the F16 aircraft. The pilots who had initiated this software were positioned in the team in charge of the development and procurement of the F16 program evaluation. They worked with engineers of the Georgia Tech Research Institute (GTRI), a non profit research institute at university of Georgia. This collaboration was necessary to improve F16 mapping software on personal computers. In particular, they improved the graphic display and its computation. The engineers at GTRI wrote the code in collaboration with the combat pilots, who were committed to the conceptual design process.

US Air Force initiatives introduce progressively a different way of developing military software inside the conception of complex systems, involving operational users during technical development phases. A succession of feedbacks between military users and engineers occurred in order to test and to improve the functionalities of software. At the beginning, the military acquisition service was reluctant to integrating FPAN and successive improvements produced by the interaction of military users and GTRI engineers. The difficulties were numerous and affected the modalities to controlling and managing the technological and financial consequences of theses feedbacks. This impacted both the architecture of military programs and the correlation between programs related to NCW concepts[8]. Procurement services have attempted to stabilize new managerial practices in order to evaluate and implement software solutions at different steps of the conception and development of complex systems. This process is still going on.

Anticipating on the war fighters' needs, the US services face requirements which they then generalize and diffuse with cooperation and exports. The Pentagon might be considered as a *lead user* on military and on civilian markets at the same time: The FPAN software case exemplifies perfectly this point. During the 1990, it was supported by a large community of users in order to improve missions planning applications. The F16 program has been procured by twenty five foreign countries, which automatically receive the Falcon view software for mission planning. This software is also integrated into other American software dedicated to public (civil) agencies: for example the National Geospatial Intelligence Agency and the US Forest Service. The diffusion of knowledge pervades civil and military markets[40], and Microsoft™ integrates today the new application program interface initially produced for the F16 program inside its own GPS-related software for smart phones. In the first phase, Air Force pilots working on FPAN development also cooperated with Microsoft. Once the transfer performed, innovation was then led by civilian focuses.

Progressively, the US NCW doctrine and diverse military software applications have been diffused among NATO partners States; new practices have pervaded into the organizations. The American NCW concept influences largely all NATO partners. The strategic role of the US Services in multinational military interventions explains how new technologies diffuse rapidly among other nations. Furthermore, the Pentagon has created a specific forum called the "Command and Control Research Program" (CCRP), which is intended to increase

[8] The US services have elaborated the Network Centric Warfare (NCW) doctrine which promotes the massive introduction of ICTs in order to take advantage of the information superiority in the conduct of the war.

international exchanges on military experiences and concepts in this area. Scientists, industry and military executives coming from all allied nations contribute actively to the CCRP. Conferences and workshops deal with the diffusion associated to the practices, doctrines and principles associated to new technological uses.

**Where does knowledge reside in American Defence organizations in the lead user paradigm?**

The implication of military users in innovation processes is based on new innovative behaviors. Depending on the problem to be solved, military expert-users refer to their own capacity to innovate. Numerous instances inside the US Services may be described. This section provides two extreme cases. First, the development of new technological solutions has very little reference to existing products. In the 1980es, the development of FPAN software illustrates this point. These technological projects have related to high innovative capabilities at the level of the experts. FPAN proposed new functionalities (such as georeferenced maps) which had never been developed before. It contributed to radically modify the planning and preparation of Air operations. Second, the contribution of military users is limited to the improvement of technological functionalities already present in existing products. In the last decade, the development of new alert systems for missiles and of other modalities for the detection of enemy forces have been initiated by officers in the US Air force with the definition of new common operational picture tradeoffs, with an evaluation of information warfare firewalls guards and global broadcasting options[41]. In reality, this second instance does not modify the existing system in a radical way. It just simplifies and improves military uses and practices.

The implication of military users in innovation processes implies also new structures to support the innovative initiative inside services. The Pentagon encourages the emergence of user communities and develops battle labs in order to simulate operations, realize experimentations and validate new technological solutions, organizational processes and practices.

The FPAN project illustrates again the emergence and institutionalisation of user communities. At the beginning, exchanges between military users and R&D engineers remained informal. Interactions progressively expanded to US Navy officers. The institutionalisation of exchanges takes place progressively with the emergence of communities of military users. For instance, US Air force pilots have initiated the creation of the AFMSS community which encourages the development of new software for air planning in joint military operations. This community is opened to different specialities of pilots (transport aircraft, helicopter, jetfighter...) working for all military services (Air force, Army, Navy...).

The role of military users has been progressively institutionalized inside formal structures – called battle labs - dedicated to the experimentation of technologies in military actual contexts. Each DoD Service creates battle labs specialized in military missions (for example close air support), in specific military functions (command and control), in specific technologies (for example nanotechnologies). 12 battles labs have been created at the joint level. The US Air force runs 12 battle labs on its own, the US Army 15 and the US Navy 16.

Battle labs support the exploration of new ideas and foster new innovation paths. Battle labs generalize the practice of simulation, experimentation and of war games. Synthetic and virtual representations of the battlefield are created in connecting separate tactical perspectives simulated from multiple locations. Battle labs define performances criteria and the feedback processes with the structures in charge of military training, or of the definition of tactical doctrine. Essays and errors are capitalized in order to improve technological uses and organizational processes. For example, the US Army develops an experimental platform for testing specific combinations of system uses in real time. Military exercises mobilize frequently more than nine hundred soldiers in order to validate tactical configurations and uses for new technologies.

Battle labs are composed by military and industry officers; specialized engineers come often from DoD R&D laboratories. Inventive military users develop rarely alone new technological solutions, because they often depend from external support for technological and industrial expertise. Industry executives participate too. New forms of Defence and industry collaboration emerge with direct and frequent face to face interactions between military users and the industry. For instance, developers are invited to participate to military experimentations. They are considered as observant and directly embedded in command and control teams. These collaborations impact the development of new innovations and the diffusion of new technological solutions and standards on market. The whole process has become easier.

### *New role of National Defence organizations in innovation networks in France*

In France, the implication of military users in innovation also emerges but their contribution is less recognized than it is in the USA. However, during the 1990 and 2000es, innovation processes oriented by military users tend to increase. Progressively, French military users seek to adapt the US technologies to their own case problem. Technological functionalities are consistent with the American ones but they are adapted to the specificities of the French military doctrine and to the subsequent action processes. French armed services try to initiate specific adaptations of the NCW doctrine. Military users propose incremental technological evolutions. For example, in the French Air force, Special Forces paratroopers propose an evolution of current software and new functionalities in order to combine Air fighter and land warriors. Technological solutions were tested in Afghanistan in 2003 and 2004. These locally develop innovation in order to address accurately the specific organizational context which global *lead users* cannot grasp. They represent local *lead users,* as suggested by Von Hippel[42].

The implementation of the technological evolution in the management process of complex systems is not easy. User initiatives imply new technological functionalities which are quite different from the software functionalities defined inside the conception of the weapons systems. The emergence of innovation military users requires new organizational features in order to articulate their initiatives with the constraints of DGA and lead contractors to manage the performances and cost of complex systems. The SCOAA program illustrates this point. The initiatives of Air force paratroopers imply functionalities and software which totally differ from the initial conception of SCOAA financed by the DGA and defined by the Lead systems integrators.

**Where does knowledge reside in French Defence organization as lead user?**

If the innovation processes supported par military users is less developed in France than in USA, French military users combine a cumulative military experience with their innovative behavior. For instance, commandos demonstrate a large military experience in all areas, related to the mentioned adaptation of the US new NCW Doctrine. They are deeply committed to their missions and they are invested in the possibility to improve operational performances by the introduction of new technology. They commit themselves in learning as much as possible about technology. They participate in scientific colloquia and read various technological documentations to understand the specificities of relevant ICTs. They exploit knowledge produced by users and innovation communities outside Defence organization.

The role of military users in innovation processes is less institutionalized than in the USA. Inside the French Ministry of Defence, military users communities do not officially exist, even though formal structures of experimentations are progressively introduced. The ministry of Defence launched in 2006 specific experimentation structures called "laboratoires technico-operationel” (LTO) consisting in new military experimentation platforms dedicated to command and control tests and essays at the level of tactical missions. The goal is to systematize the commitment of military users to the definition of new technological solutions. The LTO exemplifies new platforms of collaboration between the DGA, the Services, and the industry. It focuses on an active presence of the military in the innovation processes. These laboratories are too recent to be evaluated in their real activities. 20 months after they were installed, it seems to be very difficult to appraise their contribution to innovation processes. The cultural shock which they have brought with them remains anyhow obvious. Difficulties deal with the capacity of Defence organization to combine bottom-up processes based on users innovation processes with the top down management of technology and innovation.

## Discussion: Lead user and owner: two converse perspective about the contribution of national Defence organizations to the innovation process

*Owner* and Lead user represent two different types of users in innovation networks. Innovative behavior varies with the nature of technologies and of required competences, and with the dynamics of networks. They imply three different perspectives for the involvement of the National Defence organizations in innovation processes. The cases illustrate that Defence does not innovate independently from firms. Differences relate to the mechanisms of coordination between Defence and firms (1), to the division of labour and knowledge in networks (2), and to the organizational and technological capabilities required for national Defence organizations (3) in these frameworks.

### Coordination and governance

The first difference between *lead user* and *owner* focuses on mechanisms of coordination. The *owner* status supposes a hierarchic and modular organization suited to managing the interdependence between component knowledge assets. The Defence as an *owner* represents a strategic actor positioned on top of a pyramidal network structured by systems integrator[43]. Defence endorses various responsibilities in the networks run by the industry. It contributes to clarify modalities for the division of tasks and governance rules for each weapon program. The cases inquired highlight that National Defence organizations had the possibility to endorse the responsibility for the conception of architectures on their own: First, by proposing alternatives for the solutions developed by the industry when the latter was not be able to match exactly the technological and military specifications. Second, by internalizing the conception for architectures or for strategic subsystems in order to preserve the administration control over the network.

The *lead user* acts inside horizontal networks. It is suited to bottom up processes. Innovation emerges from the interaction between industrial developers and a community of military users engaged in technological practices and specific contexts. New technological functionalities require primarily volunteer collaborations based on information and knowledge exchanges. Defence (as *Lead user*) and firms are therefore committed to new forms of interaction. Collaboration emerges outside RDTE plans and before any contract negotiations, as testify both France and the USA. Interaction is grounded in information exchanges on the operational context, on tactics, and on technologies, which most often occur at the initiative of war fighters motivated by performance improvements. Interaction requires new trust relations between Defence and the industry.

Governance rules imply specific modalities related to the control and to the diffusion of knowledge assets inside innovation networks. The *owner* aims at modalities relevant for the management of strategic knowledge assets in order to maintain scientific and technological military competitive advantages. The main focus is about controlling strategic knowledge assets. It comes with in-sourcing strategies, with restrictive conditions for the exploitation of industrial knowledge and with property rights rules.

The *lead user* is one actor of the network who contributes to the diffusion of information and knowledge. It tends to disseminate freely innovation paths while others contribute to knowledge and resource building. The diffusion of information enhances the innovator's reputation and enforces solidarity inside the innovation network. *Lead users* do not develop specific intellectual property clauses because the user's invention is readily imitable. Defence, as a *lead user* has to remain ahead of competitors regards the improvement of technologies. The community becomes a locus for exchanging services and sharing knowledge[44]. Interdependences emerge automatically. Defence as a *lead user* aims at initiating and diffusing new technological solutions and practices among others users. It faces a main challenge: convincing about the relevance of technological solutions and exchanging about all knowledge assets. The Pentagon had launched initiatives encouraging the other national Defence organizations to reveal their practices and doctrine and facilitating the access to US military technologies and uses. For example, the Command Control Research Program (CCRP) is a Pentagon's forum set up for exchanging about practices, concepts and experimentations of Command and Control technologies among allies. It endorses the rules of open science. CCRP is organized like a scientific community: communications to workshop, referee processes, open discussion, exchanges and debates, publications in dedicated journals run along scientific norms. Military officers and experts are omnipresent. The CCRP network serves the diffusion of informal standards about command and control, technological and organizational designs proposed by the US Services[45].

**Division of labour and knowledge in innovation networks**

The second difference deals with consequences of the respective positions of *owner* and *lead user* as regard the division of knowledge. The ability of Defence to orientate technological developments in innovation networks exists in both cases, yet does not follow the same path. For the last two decades, National Defence organizations as *owner* have acted as an integrator of technologies, and in specific cases, as a provider of technologies. The evolution of the status of *owner* is an intended consequence of the new division of knowledge between Defence and the industry.

In the 1990es, national Defence organizations have faced an inextricable problem related to the preservation of capabilities to orientating and/or co-specifying the architecture of military programs. Outsourcing technological knowledge becomes a default option. Defence focuses now its intervention on operational aspects and it commits less to the definition of physical interfaces. In many cases, Defence understands the industry proposals, yet remains unable to introduce any alternative. It remains a contributor for the elaboration of communication and informational governance structures inside the network of integration systems and aims at managing costs and performances. It institutionalizes the formal dialogue with firms are implicated in co-design processes. When weapons programs become very complex, Defence outsources the whole technological knowledge and entirely depends on the industry. The Future combat systems in the USA or the SCOAA program in France illustrate this point on similar programs. In these cases, National Defence organizations only provide the information relevant for the innovation context. Defence remains indirectly present in the combination of industrial and technological assets. Defence influences the division of labor in the networks on the basis of the acquisition policy. It may influence the bidding and teaming strategy of firms through procurement processes. In this context, the combination of assets depends on the capacity of firms to valorize their own technical and relational competences, and their ability to manage the informal interactions prevailing for procurement on military markets.

As Brusoni and Takeishi have described[46], the consequences of outsourcing of knowledge are the loose of power to orientating technological development inside innovation networks. This is the reason why the US Navy has made the choice of preserving the capability of system of systems conception. This in-sourcing strategy for critical knowledge assets is the direct consequences of its will to preserve its power of orientate technological networks. The status of *owner* illustrates the case of a particular organization which needs to know more than it makes as described by Brusoni and al. And, Takeishi[47]. Its knowledge capabilities remain alike the ones preserved by systems integrators.

The status of *lead user* reveals new forms of contribution in innovation processes for national Defence organizations. The *lead user* spends its time in adjusting the technologies available and adapting to its needs. The contribution of military users is essential when technologies and/or uses of technologies imply knowledge and skills which are only mastered by warfighters. Von Hippel, and Brown and Duguid refer to the notion of sticky knowledge: it characterizes this kind of knowledge which is totally embedded in individual and collective practices[48]. This investigation about Defence organizations complements sticky knowledge with another property for the expert users. They represent rare and non substitutable competences (-ies) in innovation networks.

The relationships between Defence as *lead user* and the industry are based on transactions about learning costs. These ones can be quite high because the warfighters' knowledge remains tacit, embodied, and situated. Firms are dissuaded from acquiring so specific knowledge. In these cases, the division of knowledge and labour are based on the complementarities of knowledge assets between National Defence organizations and Firms. This process is made easier by the industry recruiting former war fighters, who do not possess actual field experiences, yet are able to share and interact with soldiers. The power of Defence in networks relates to the ability to identify and mobilize expert users inside programs, and not to master architectures.

**Technological and organizational capabilities of Defence organizations**

Technological capabilities are necessary to cope with technological complexity. Organizational capabilities refer to "*particular forms of organizational knowledge that* *account for an organization's ability to perform and extend its characteristic "output actions"*[49]. This section will explain the differences between owner and lead user from the perspective of National Defence organizations.

***Questioning the status of Defence as an owner***

Defence as an *owner* is supposed to master architectural knowledge domains requested for the management of the integration of technologies. Core integration capabilities relate to understanding and bringing together technologies, components, subsystems, software, skills, managers and technicians. Like systems integrators in the industry[50], the conjunction of organizational and technological competences allows for the management of in-sourcing, outsourcing and joint-sourcing decisions at the level of architectures, subsystems and components.

The Defence as an *owner* refers to multitechnological competences. The core integration capbilities require very often the acquisition of component knowledge at the level of strategic subsystems and technologies[51]. They are located in acquisition services and R&D and tests laboratories, which translate military needs into technological artifacts. The Defence as an *owner* combines two generic technological profiles.

- The first one deals with system engineers who maintain capabilities of understanding the main problems related to architectural knowledge. The system engineer develops managerial and technical skills suited to the assimilation of technological complexity. He allows to partition systems into smaller manageable subsystems. He understands and predicts interactions which affect the overall design. He remains a generalist who develops a strong technological culture on weapons systems. He is also able to refer to histories, economic and cultural aspects relevant for the success of weapons programs.
- The second profile describes engineers and scientists specialized in component knowledge, which is considered as strategic for weapon systems conception. These

specialists have strong social relations with R&D networks in a specific technological or scientific area. They increase the value of their expertise domains at the expense of the global picture and of the other knowledge domains relevant for the considered weapon system. Architectural decisions at the level of the Defence *owner* require a balance between the perspectives endorsed by specialists and by generalists.

The Defence as an *owner* supposes strong organizational capabilities in order to distribute tasks inside and among networks, and coordinate all activities. It supposes a capacity to create consensus and converge towards meaningful solutions at a collective level. Organizational capabilities of the Defence *owner* contribute to create an environment suited to reduce the complexity inside weapons programs.

Technological and organizational capabilities of Defence as an *owner* differ in the USA and in France. Modalities for in-sourcing and outsourcing technological conception have been affected by the Defence's technological and organizational capabilities. In the USA, the Pentagon was inseparable from large multitechnological capabilities based on the practice of technology and of scientific activities in military R&D laboratories. Military Services have developed a capacity to manage in-sourced technological knowledge on the long run. In France, the Defence technological and organizational capabilities never aimed at recurring and long-lasting in-sourced R&D interventions in the conception of complex systems processes, and always focused on punctual projects.

In the context of knowledge based economics, the US and French National Defence organizations cope with the transformation of their capabilities. They are transitioning from large multitechnological and organizational capabilities to a restrictive set of technologies and managerial capacity. Despite the difference between the US and French cases, this evolution questions the persistence of the status of owner as such. It seems the inevitable consequence of new ways to divide labour and knowledge required for the conception of large technological project.

**Emergence and institutionalization of lead users**

The Defence as a *lead user* is associated to the capacity elaborating new uses of technology. This phenomenon implies the emergence of expert users who seek for novelty. Corresponding sticky knowledge is co-located predominantly in tactical units and in warfighter practices. Military expert users are characterized by innovative and independent attitudes. In France and in the USA, they develop all characteristics identified by Lettl, and Lettl and al.. Expert users develop a particular innovative behavior based on their technical know-how, focusing on the resolution of organizational problems related to their professional activities[52]. They are generally self-educated in technology areas. It remains difficult to assess what comes first: motivation for the resolution of problems or true openness to new technologies. They prove a tolerance against ambiguity and accept to test new instable technological solutions in real life. As underlined by Von Hippel, communication competencies remain critical[53].

The development of the *lead user* status implies two steps: first the emergence of first movers involved in innovative communities and then the institutionalization of their activities inside the organization. Several co-conception layers emerge: battle labs, virtual platforms for exchanging about field experience, informal projects with the industry, ect.

In the USA and in France, military expert users have progressively emerged during the 1980 and 1990. Initiatives all grew up out of hierarchical decisions and structures. When the military hierarchy becomes aware of the benefits of the new technological solutions for the conduct of military operations, it encourages the diffusion of technological systems and practices. Progressively, it also encourages the development of user communities[54] and of new forms of technological experimentation. The hierarchy launches therefore initiatives (such as battle labs) in order to generalize military implication in the definition of new technological solutions and to host experimentations.

This institutionalization of experts-users represents new forms of organizational capabilities. New forms of organizational arrangements and coordination modes emerge inside and outside Defence, and benefitting to Defence organizations. The institutionalization of experimentation structures (the US battle labs and the French LTO) requires the combination of military users, engineers and scientists very early in the acquisition processes. These new experimentation structures resemble the "*creative groups"* described by Von Hippel. "Creative groups" are developed by the *lead user* in order to imagine new experimentation and simulation for news technologies[55]. These allow the possibilities of users to reveal their practices and improve themselves. These new forms of collaboration and innovation management are considered as a revolution military innovation.

In France, and to a less extent in the United States, the generalization of military implication in innovation processes remains relatively low. The emergence of expert users has been complexifed by the constraint on human resources and careers. Lower mobility reduces the possibilities for the construction of required technical and operational expertise. The military is very often under pressure and does not have the time required for the experimentation of new technological functionalities. Such initiatives represent more a peripherical activity than a full time position in France.

## Conclusion and perspectives

The article has shown that an analysis based on the implication of the Defence as an active user of technological solutions gives the possibility to better understand its various contributions in the context of knowledge based economics.

In France and in the United States, gradual changes in the Defence commitment to innovation processes are perceptible. The Defence as an *owner* transforms progressively into a passive user associated to the definition of technological solutions. In the United States, the Defence maintains a higher capacity of co-conception of complex systems architectures than in France. In both cases, the technological complexity modifies considerably the division of labour inside system integration networks. Defence does not co-specify the systems at the same level anymore. More frequently, Defence has to outsource technological control and evaluation of industrial projects.

This articles shows that Defence may endorse new role. The status of *lead user* may be applied to Defence. It represents a new form of Defence's contribution which based on the valorisation and mobilization of sticky knowledge. This status is relevant to take into account the specific knowledge assets required for the development of new technological functionalities.

The status of *lead user* and *owner* are not mutually exclusive. However, in the context of knowledge based economics, In the USA and in France, the introduction of user centred approaches of innovation challenges the governance structures mainly inherited from owner model. It represents a source of tensions. New governance rules and structures have to be installed. Two perspectives could be tested in the future.

The first one focuses on the differentiation between bottom-up and top-down innovation processes. The institutionalization of the role of user communities and battle labs may be reorganized by acquisition services and organized as a solution dedicated to specific innovation domains. Both processes preserve their autonomy. The second perspective aims at integrating together the owner and lead user paradigms. This may be performed in order to complement RDTE processes. Programs specifications may both emerge through the bottom up and top down processes, which implies to find out rules for arbitrating potential conflicting issues. This coexistence will obviously require specific organizational levels populated with officers and experts who have a relevant perspective on the whole innovation system, and who know how to best mobilize and combine bottom up and top down processes.

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