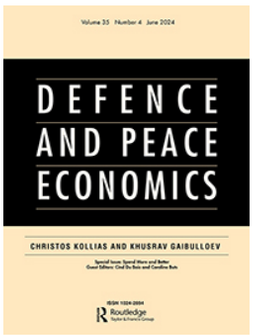

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Defence and Peace Economics

ISSN: 1024-2694 (Print) 1476-8267 (Online) Journal homepage: www.tandfonline.com/journals/gdpe20

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To cite this article: Renaud Bellais (2024) Market Structures, Competition and Innovation: Grounds for an Alternative Defence Industrial Policy, Defence and Peace Economics, 35:4, 448-463, DOI: 10.1080/10242694.2023.2182869

To link to this article: https://doi.org/10.1080/10242694.2023.2182869

DEFENCE AND PEACE ECONOMICS
2024, VOL. 35, NO. 4, 448–463
https://doi.org/10.1080/10242694.2023.2182869

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Market Structures, Competition and Innovation: Grounds for an Alternative Defence Industrial Policy

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ABSTRACT

Since the 1980s, most reforms in major arms-producing countries focus on keeping costs under control by either promoting competition between suppliers or by reducing information asymmetry through audits and controls. Indeed, cost escalation represents a challenge but, in fact, these reforms try to adjust the functioning of defence market rather than questioning the institutional features of this latter. The success of defence acquisition structures also explains their limits. The current organisation of defence market was perfectly adapted to the geostrategic context of Cold War and a technological momentum that favours symmetrical arms race between the United States and the Soviet Union. Even if these structures still help deliver advanced capabilities, they can be considered as not sufficient to cover all the operational needs of armed forces. The conception of capabilities needs to go beyond a long-term planning while industrial approaches open the way to more agile development and manufacturing. An alternative defence industrial policy is necessary to complement the existing one. More modular architectures for complex systems provide the opportunity to increase the reactiveness of capability deliveries and to foster both innovation and competition.

ARTICLE HISTORY
Received 20 December 2022
Accepted 17 February 2023

KEYWORDS
Armament; R&D; technology; procurement; industry

JEL CLASSIFICATION
H56; H57; O32

Introduction

The Russian invasion of Ukraine in 2022 has induced Western countries to announce important increases of military spending, with a focus mainly on reequipping armed forces. However, such flow of additional spending could be as much a curse as an opportunity if these resources are not wisely used. Prior to the war in Ukraine, European arms-producing countries were facing budgetary stalemates, which were primarily linked to the cost escalation of major programmes. Therefore, it is important that additional resources do not result in hiding existing acquisition issues. On the contrary, this turning point creates an opportunity to reshuffle acquisition policy in order to overcome recent challenges as well as to deliver the best value for money.

Improving the management of defence programmes has been a quest for major arms-producing countries for decades. If we can go back as far as the 1960s in the United States when Robert McNamara was Secretary of Defense, such efforts have become more and more urgent from the 1980s. The increasingly visible cost escalation was then amplified by important budget cuts following the collapse of the Soviet Union. This upward trend can also appear problematic with regard to export markets, since non-producing countries also face budget constraints and cannot afford more and more expensive capabilities. If capabilities become less and less exportable, this evolution could

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jeopardise the sustainability of the defence industrial base in most arms-producing countries that require exports to balance limited domestic orders.

Three decades of reforms have helped mitigate this trend without fully stopping cost acceleration of next-generation capabilities, as reports from national accountability offices (GAO, NAO, Cour des Comptes, etc.) underline. Procurement agencies have achieved significant improvements in the selection of suppliers, the use of competition, the design of contracts and the supervision of contract implementation but without questioning the adequacy of existing acquisition process with regard to the needs of armed forces.

It appears that most efforts have concentrated on keeping costs under control without changing the structures of defence market as they had emerged during the Cold War. Even though these reforms have delivered some significant results (Gray 2009), it is possible to question such focus on reforming rather than transforming defence market to deliver the expected outcomes. Indeed, the current relations between supply and demand still reflect the constraints of the second half of the 20th century. However, many military, technological and industrial dimensions have changed, which opens the way for another approach to defence industrial policy in order to not only spend wisely when budgets rise but also more effectively fit armed forces' needs.

This paper aims to discuss the grounds for a defence industrial policy adapted to the current stakes of international security. It focuses on major arms-producing countries that aim to achieve an ambitious strategic autonomy,[1] since related features are clearly perceptible for these markets and can also be found in small producing countries to some extent. The first part underlines the features of a defence market, organised in the context of the Cold War, that limit the ability to open up this market for newcomers and *de facto* favour incumbent suppliers. Part two explores changes that should lead to a revision of defence industrial policy in order to attract new suppliers and deliver more innovation and agility in order to deal with less predictable and quickly evolving threats.

Market Structures, State Planning and Competition

Since the 1980s, most reforms in arms-producing countries focus on keeping costs under control by either promoting competition between suppliers or by reducing information asymmetry through audits and controls. Indeed, cost escalation represents a challenge (Kirkpatrick 2004, 2008), but, in fact, these reforms try to adjust the functioning of defence market rather than questioning the institutional features of this latter. Such reforms have succeeded to a certain extent, but cost escalation remains an issue while defence market does not appear as attractive as expected due to heavy resulting regulation and barriers to entry vis-à-vis potential newcomers. This limited success leads to question whether reforms should modify the institutional setup of defence market rather than adjust its functioning.

A Market Organised Through State Planning and Regulation

Our analysis focuses on large arms-producing countries that aim to achieve an extensive security of supply and advanced strategic autonomy. Small arms-producing countries can be confronted with similar challenges, but their defence industrial base usually produces less complex systems and a more limited range of capabilities, which reduces the specificities of their domestic market. Therefore, the functioning of these armament markets can be closer to standard civilian markets in terms of competition. In order to reveal the specificities of this market, this article looks mainly at the market for major defence capabilities in the largest arms-producing countries.

Since the second half of the 20th century, armament market is organised through a direct, long-term partnership between the state (in its military and political dimensions) and defence industry for the development, production, purchase and maintenance of defence equipment in major arms-producing countries (Ikegami-Andersson 1992).

Armed forces have relied on advanced technology through an aggressive pursuit of R&D and the development of a permanent defence industrial base. Technological superiority is considered as a key element to achieve military effectiveness, and R&D plays a major role in accessing relevant advanced technologies. In order to achieve such target, armed forces have developed a strong, long-term partnership with defence companies, in particular the largest ones able to carry on complex projects and to deliver advanced technology. Such dynamics resulted in a co-evolution between armed forces and their main industrial partners, reducing progressively the openness of defence markets in largest arms-producing countries[2] – granted that domestic design and production constitute a *sine qua non* condition for selecting a supplier.

Since 1945, the military rivalry between East and West (and beyond) has generated a permanent technological and industrial competition, which does not allow any relaxation in the improvement of military equipment. No State can be sure of having, once and for all, military superiority over its adversaries. It is therefore necessary to develop ever more efficient equipment. To achieve this objective, companies and armed forces must be able to rely on long-term capability planning, the management of which is entrusted to an agency mastering all the expertise required over the entire spectrum of related activities (basic research, applied research, development, manufacturing, etc.).

In order to respond to both technological and industrial challenges, a particular mode of organisation was gradually put in place, described as an 'administered mode of production' in France (Hébert 1995) or as 'state capitalism' in the United States (Melman 1970, 1974). This permanent arms economy relies on private companies but through a planning process organised by the demand side in order to secure a security of supply that cannot be guaranteed through market mechanisms. National champions were chosen for each category of equipment in order to avoid wasting resources in fratricidal competition at domestic level, thus leading to the creation of an oligopolistic market. In addition, at least until the 1990s, the vast majority of armament contracts were negotiated over the counter with *ex ante* defined margin rates (thus derogating from the rules of public procurement), so that companies can concentrate their efforts on improving the operational performances of capabilities.

Dumez and Jeunemaître (2017) put into relief that defence acquisition can be analysed as a political subsystem. Such concept developed in political science can help understand the stability but also possible rapid changes. In this approach, two dimensions are critical: images and venues. '*Images are beliefs and values associated with a policy. Venue refers to the existing set of institutions that conduct the policy. Within a subsystem, images and venue can be stable for a long time, when the public institutions in charge of policy and the associated private actors are both considered legitimate, and when the image of the policy is positive*' (Dumez and Jeunemaître 2017, 103).

Understanding the level (or absence) of competition requires to take into consideration the role of systems architecture and the related power of system integrators both *ex ante* (in defining military specifications) and *ex post* (in channelling acquisition towards follow-on programmes). Stability can be explained if and only if we understand how the value chain is organised and managed. Indeed, as Depeyre and Dumez (2010, 125) note, '*architectures provide the contours and framework within which actors interact*.' This concept helps describe the relations among partners throughout the value chain in terms of a minimal set of rules governing coordination, interactions, and interdependence.

The needs resulting from a permanent effort of military preparation explain the reasons for which a joint organisation between the state and industry has emerged, largely derogating from the principles of market economy. Security of supply is a priority objective for armed forces in arms-producing countries, which leads the state to favour the selection of domestic suppliers, *de facto* reducing the possible level of competition, in particular in countries where strategic autonomy remains a major target. For these reasons, number of decisions which normally come under the strategic choices of a company are in fact taken by the state in this domain. For instance, choices of technology and investment are subject to the guidelines of the state.

Due to an oligopolistic market structure at the domestic level in major arms-producing countries (or even the existence of sectoral monopolies), companies have become able to influence the

choices of capabilities or the development of new ones based on their technological and industrial assets. In fact, the state has set up a hybrid market organisation that combines both planning and market incentives. A bias towards planning can secure vested interests. A bias towards pure competition could jeopardise the security of supply. Therefore, this peculiar market represents a challenge for regulators due to contradictory objectives.

In an increasingly oligopolistic market structure (few suppliers), even monopolistic (a single manufacturer per category of capability), companies have acquired bargaining power despite the fact that their client, the state, also is a monopsony. Companies have levers to negotiate favourable margins. Moreover, the asymmetry of information gives them an advantage over state overseeing their costs. This bargaining power was very strong during the Cold War, when armed forces must equip at short notice and mainly used cost-plus contracts[3] awarded to legacy suppliers. However, confronted with soaring programme costs, states have gradually introduced more competition in the awarding of contracts as well as more incentives included into contracts in order to keep costs under control from the 1980s onwards.

This hybrid form of organisation, between market and planning, results in special relations between the State and defence industry. These relations are reinforced through long-term partnerships, contrary to what happens in most civilian markets, because defence industry goes along with armed forces throughout the life cycle of equipment and between successive generations of equipment (Bellais 2021).

Self-Reinforcing Barriers to Entry in the Cold War Defence Market

Due to the institutional setup of defence market resulting from the Cold War (primacy granted to technology, security of supply through sheltered domestic markets, etc.), cost escalation appears as a consequence of these structures to a large extent. These latter favour some choices that nurture cost escalation by giving an overwhelming role of technical performances along technology trajectories and by limiting *de facto* competition.

Defence systems are complex and expansive products because of expected operational performances, which require specialised industrial actors and advanced technology. This is the reason why barriers to entry can be considered as very high in defence market. These barriers are financial (due to important investments and large sunk costs), technical and technological as well as based on reputation effects and linked to burdensome procurement rules (Bellais 1999). All these dimensions are legitimate with regard to defence stakes in terms of capability reliability, operational superiority and security of supply, in both short and long term, but they have strongly influenced the institutional setup of this market, particularly in major arms-producing countries.

First, defence systems rely on advanced production capacities. Armed forces need systems with very low default rate and high performances, which place defence industry among high-tech sectors. These constraints impose tough production criteria that usually differ from civilian industry. Kovacic and Smallwood (1994, 97-98) propose a taxonomy of six generic activities that define the scope and quality of a company's competencies and provide a determinant advantage for incumbent companies: system integration (perhaps the most important activity); the design and production of individual components and subsystems; testing and evaluation; training and technical support; maintenance and repair; modification and refurbishment.

Second, these competencies are required because armed forces look for advanced, complex systems. They go along with a priority granted to technological performances. Two dimensions can be criticized about the way defence programs are defined: armed forces focus on incremental innovations (while being technologically ambitious) along given technology trajectories and existing capability architectures that appear more and more costly. Both armed forces and the industry tend to favour technology-intensive solutions, which is not always the best way of fulfilling operational needs. Such focus on advanced technology favours incumbent companies that already master both these technology and competencies to deliver technology-based innovations for complex systems.

Third, security of supply constitutes a top priority in major arms-producing countries. The relative stability in arms production results from armed forces' wish to maintain production lines that are considered as crucial for national security. Since they are responsible for national security, armed services must have an industrial and technological base at their disposal domestically to respond to an emergency. As a result, some production units represent a strategic resource and must be preserved, even when there is a low level of domestic demand. '*The Defense Department would find it risky and even reckless*,' notes Kurth (1993, 308), '*to allow a large production line to wither and die for lack of a large production contract*.' This is the reason why armed forces have sometimes launched new productions when a major programme ended to avoid closing a unique and essential industrial capacity, even though such systems do neither provide path-breaking innovations nor fill a crucial lack of equipment.

This 'follow-on principle' (Kurth 1972) has two main consequences: a relative stability of the main arms-producing firms, and a technological continuity – resulting from both firms' lobbying and armed forces' conservatism. This explains why the military-industrial organisation '*has endured for several decades, in some cases dating back to the Second World War, despite the ebbs and flows, the booms and busts in defense spending*' (Kurth 1993, 307). Such a system constitutes a truly high barrier against technological disruptions and the introduction of new, alternative defence systems, etc. as long as the tension between available weapon systems and operational needs is not too strong.

Such a bias induces a tacit agreement with defence firms that promote the renewal of existing systems – relying on assets, technology and know-how they master. This strategy can be useful to maintain the defence industrial and technological base, but it has strong negative effects on both market incentives and innovation,[4] especially in an age of uncertainty and geopolitical evolution. Indeed, the follow-on principle favours existing systems against new ones, which do not have the same backing from legacy companies, armed forces and decision-makers for economic, operational and political reasons respectively. It then represents another barrier to entry, since incumbent companies benefit from a real competitive advantage (Kovacic and Smallwood 1994) and the quietness of monopolistic power.[5]

Fourth, specificities of defence procurement also explain why competition was pretty limited in defence industry: transaction costs are important and can represent sunk costs as a company does not have guarantees to win contracts except when it is an incumbent. There are few companies that possess the ability to satisfy these requirements. This is the reason why reputation can constitute a barrier to entry (Bellais 1999).

Looking for new suppliers can be very expansive, and there is no guarantee that they will be able to deliver defence systems on time, on cost and on performances. As armed forces need to receive expected systems in due time and as soldiers' lives are at stake, it does not worth switching from existing suppliers to newcomers – except if the former fail and if alternative solutions of the latter clearly outperform existing ones. Selecting a supplier by relying on reputation can significantly reduce transaction costs and minimise risks but also significantly lower competition and the ability to have alternative solutions emerging.

Due to the existence of such a political subsystem, Dumez and Jeunemaître (2017) underline the possibility for companies to leverage on an influence rent that Ahuja and Yayavaram define as '*the extra profits earned by an economic actor because the rules of the game of business are designed or changed to suit an economic actor or a group of economic actors*.' Influence rent can be easily linked to a company's reputation, particularly in defence market where interactions between the supply and demand appear quite intense throughout the acquisition cycle.

Fifth, incumbent defence companies and particularly integrators can secure their positioning in this market because they master the rules and processes of defence acquisition, which are complex and induce high *ex ante* costs. They have developed specific know-how to comply with the rules of public procurement and to reduce transaction costs. They also understand in depth customers' needs and requirements, and they usually participate to the establishment and evolution of doctrines. All these elements reduce the ability of newcomers to break into the defence market.

All these barriers to entry have become higher and higher since the 1950s in major arms-producing countries, because requirements of performances increased through time, with consequences on production costs, and the size of defence market has reduced *ceteris paribus*. There are a smaller number of new programmes, and, if the total value of defence seems stable, increasing unit costs (Kirkpatrick 2008) result in a smaller number of players on the supply side. Importing an off-the-shelf solution could limit this issue, even though exporting countries do not escape from these trends but can propose alternative solutions, sometimes less capable but significantly cheaper like Turkey, Israel or South Korea.

The Central Role of System Integrators and Lock-In Effects

As defence systems became more complex and advanced, defence companies have developed a technological and industrial expertise. This latter has become more and more essential to manage large programmes, at least for major defence capabilities, a trend also identified for civilian complex systems (Hobday, Davies, and Prencipe 2005). Thus, it was not surprising that large arms-producing countries asked major companies in the late 1990s to become 'Lead System Integrator' (LSI), that is, taking charge of some project-related missions historically implemented by the Ministry of Defence.

Before empowering large companies with organisational tasks, acquisition services used to define the requirements of defence systems, then organised competition among potential suppliers at subsystem and component levels, and supervised the development and production thanks to in-house competencies. The Ministry of Defence also had direct contact with Tier-2 or Tier-3 industrial partners, so that it could prevent integrators from leveraging on asymmetrical information to promote specific technical choices as well as inputs or to increase their margins. With the LSI approach, based most of the time on a system of systems, the state asks an industrial leader to carry out most of the design and supervision tasks previously realised inside the Ministry of Defence.

This trend in favour of LSIs appears quite common in the largest arms-producing countries, at least inside NATO. In the United States, the LSI approach even led to a specific contractual framework. The first legally defined LSI contract was awarded for the anti-ballistic missile programme to Boeing in 1998 (Dumez and Jeunemaître 2017, 108). Additional contracts were signed in the following years. In 2002, the Boeing/SAIC team was selected for US Army's FCS (Future Combat Systems) programme. The Lockheed Martin/Northrop Grumman team played a leading role for US Coast Guards' Deepwater programme.

The emergence of explicit LSIs reflects a structural evolution of the demand side. Public institutions have lost, at least partially, their ability to conceive systems and to supervise their technological and industrial development. This is a consequence of both more complex systems and more advanced technology as well as successive reforms of procurement institutions with a significant decrease of competencies in system engineering and technology to focus on procurement policy to keep costs under control (Bellais and Droff, 2016). Today, many states lack adequate technical and engineering skills to design and supervise complex programmes. Therefore, they tend to move towards mega-prime contracts relying on the expertise of large companies.

Depeyre and Dumez (2007, 8) remark that, for the Deepwater programme, the absence of an LSI would require the DOD to set up 14 project management offices. This could have represented a challenge since the DOD reduced its acquisition staffing by 50 percent from 1994 to 2005. Thus, an LSI approach can also reduce transaction costs on the demand side, granted that a company is able to provide a more effective project management.

If systems of systems introduce complexity, this capability-building approach builds in fact on architectures in the continuity of existing capabilities. The disruption from past programmes results from the rising networking of systems, adding transversal dimensions between a system's components and subsystems. However, the innovation content for each of these systems can be analysed as part of sustained technological trajectories too, most of the time, in order to secure the sustainability of system architecture. This assessment is supported by the lack of newcomers entering in

defence market. Two decades after the emergence of the LSI concept, companies competing as system integrators remain the traditional defence players (Dombrowski and Gholz 2006).

The LSI experiment in the United States ended with the cancellation of both FCS and Deepwater programmes. Due to the failure of such approach, Congress eventually prohibited awarding LSI contracts from 2010. Gholz (2004, 18) clearly states that "*trying to buy 'systems' of systems' all at once is a bridge too far, needlessly increasing complexity, reducing oversight, and overloading bureaucratic management capabilities*." Even though the term of LSI was abandoned in the United States, the emergence of such concept in the late 1990s corresponded to a more and more pregnant reality in the structuring of defence industry. If the concept was banned, underlying dynamics remain strong, and they contribute to reinforce the dominant position of incumbent companies.

For instance, the future combat air systems that are likely to replace combat aircraft of 4th and 5th generations but are not limited to the next-generation combat aircraft. France and Germany signed an agreement in April 2018 to develop such 'SCAF', and the United Kingdom announced the launched of its Tempest programme in partnership with Italy and Sweden in July the same year (enlarged to Japan in December 2022[6]). In both cases, projects do consist not only of the next-generation platform but a comprehensive system composed of manned and unmanned platforms as well as effectors (missiles and remote carriers), sensors and information and communication systems.

Even though many stakeholders put into relief innovative dynamics regarding defence systems, most of innovations appear incremental rather than radical or disruptive in a systemic perspective. Indeed a new-generation platform delivers more capable features, without any doubt, but the platform and related technologies take place in a continuum with preceding platforms. There are technology paths that are co-evolving around dominant designs, which tend to become more and more mutually reinforcing since the 1950s.

In other words, while component knowledge changes dramatically from a generation to the next one, these bricks take place inside a given product architecture, this latter acquiring a stronger and stronger stability. As Henderson and Clark (1990, 9) note: '*Incremental innovation introduces relatively minor changes to the existing product, exploits the potential of the established design, and often reinforces the dominance of established firms*.' Radical innovations can open up whole new markets or architectures, but they are quite rare in defence industry – with the notable exception of electronics in the late 1960s.

Paradoxically, incremental innovations in both component and architectural knowledge tend to reinforce the capabilities of system integrators and their industrial partners, because it refines and deepens pre-existing choices, favouring the domination of an already-selected design. Henderson and Clark (1990, 14) underline that '*one cannot understand the development of an organization's innovative capability or of its knowledge without understanding the way in which they are shaped by the organization's experience with an evolving technology*.'

The history of defence industry since the end of World War II is a perfect illustration of self-reinforcing dominant designs regarding major defence systems. In the early stages, in the 1940s and 1950s, before the emergence of a dominant design for each kind of major platform (tank, combat aircraft, frigate, etc.), defence companies used to compete and thus to propose alternative designs with many different, competing technologies or component knowledge. Once a specific design became broadly accepted, all producers have converged towards a shared pattern, which then defined a common basis for a given capability segment. Such dominant design signalled the general acceptance of a single architecture on both demand and supply sides. This trend is supported in the field of defence systems by the existence of a military doctrine and, increasingly, the requirement for interoperability nurtured by increasingly networked systems.

Due to such dynamics, in a given market segment, companies can less and less propose alternative configurations. There is a strong path dependency, even more so as new component knowledge acquires more value through the existing architectural knowledge and creates added value for this latter.

Keeping control over system integration constitutes a means for largest companies to prevent newcomers or their industrial partners throughout the value chain from challenging their control of the gates of defence market. We should indeed not mix technology disruption with improved technical performances. Technology disruption usually leads to a new architectural design, while technical performances tend to protect existing designs against the emergence of alternative ones. Core technologies appear much more stable than one could expect, but their potential can increase exponentially as demonstrated, for instance, by semiconductors or aerodynamics.

New Grounds for a Defence Industrial Policy

The success of defence acquisition structures also explains their limits. The current organisation of defence market was perfectly adapted to the geostrategic context of Cold War and a technological momentum that favours symmetrical arms race between the United States and the Soviet Union. Even if these structures still help deliver advanced capabilities, they can be considered as not sufficient to cover all the operational needs of armed forces.

In fact, changes on both demand and supply sides require an alternative defence industrial policy. The conception of capabilities needs to go beyond a long-term planning while industrial approaches open the way to more agile development and manufacturing. More modular architectures for complex systems provide the opportunity to increase the reactiveness of capability deliveries and to foster both innovation and competition.

Evolving Threats, Diversity and Resilience

The central question is to change the foundations of the architecture of defence market and not to try to reform it based on *status quo*. This is even more necessary given that the nature of adversaries has changed (Kilcullen 2020) and that the sources of innovation with military potential are largely outside the traditional arms market, as shown in particular by emerging technologies: artificial intelligence, data, autonomy, quantum-enabled technologies, biotechnology, hypersonic technologies, space, novel materials and manufacturing, and energy and propulsion.[7] However, the preservation of market structures from the Cold War makes it very difficult to adapt to operational needs while promoting situational rents for incumbent companies or the conservatism of armed forces.

The planning process was very effective during the Cold War for two main factors. First, core defence technologies were emerging. It was necessary to keep investing and preserve (or acquire) operational dominance over potential adversaries, due to a predictable obsolescence of existing capabilities. Second, since these adversaries shared the same technological referential and military objectives, it was quite easy to forecast where they would put their own efforts and thus structure capability development through a planning process. Even though this process remains relevant for major state adversaries and capabilities that have not reached full maturity, it appears less capable to deal with non-traditional threats, which are less predictable (Bellais and Le Blanc 2002).

Such threats like IED, missiles, loitering munitions or drones represent major challenges for deployed forces and evolve at a timescale incompatible with the cycles of traditional capability development. In fact, the planning process is very relevant when managing known and long-term threats, but it becomes less effective to dealing with adversaries leveraging on off-the-shelf civilian technology and inputs and developing unexpected capabilities (Sapolsky 2001). Deploying new capabilities or adapted ones requires a more agile industry, often involving companies coming from outside the defence industrial base.

Indeed, access to the arms market is very difficult for new players, in particular for the most complex systems, because their proposals are not already part of the capability planning process fixed predominantly by demand side. Certainly, major arms-producing countries have put in place alternative paths to attract atypical innovators and start-ups, but these are parallel systems that fail

to plug into capacity planning. Some do not hesitate to speak of 'innovation tourism' (Flagg and Corrigan 2021; Briant 2022).

Over the past decade, major arms-producing countries set up new agencies aim to look for non-traditional defence innovations, from Defense Innovation Unit (DIU) in the United States to Defence and Security Accelerator (DASA) in the United Kingdom and Agence d'Innovation de Défense (AID or Defence Innovation Agency) in France (Schnitzler 2020). In 2022, NATO even launched a technology incubator, DIANA, and the NATO Innovation Fund. These agencies have demonstrated that an alternative way for innovations in military capabilities was possible, but they appear not enough integrated into the capability planning process. Indeed, their main success concerns small capabilities, useful but not central to military equipment or procurement budget, or knowledge components that have not already disrupted complex systems.

The creation of DIU in the United States does not differ in this from AID in France or DASA in the United Kingdom. These institutions are valuable since they attempt to capture innovation capacities outside the defence industrial and technological base, but the very functioning of defence market places them immediately outside this market or, at best, at its periphery. This alternative way seems to operate outside or inside the core of acquisition process, which remains structured on the follow-on principle. This is a nice-to-have approach but far from a game changer to modify defence market in depth at least on specific segments.

However, the problem appears deeper because even incumbent players remain prisoners of conservative choices despite innovative solutions they can suggest. In fact, armed forces remain the ultimate decision-makers for this market, in which demand always creates supply ultimately (Bellais 1999) despite interactions with the industry regarding capability definition.

In both cases, the question is about an institutional change. During the Cold War, the planning system was conceived in order to avoid any misjudgement in capability decisions. As a result, the demand side has become very prescriptive. It does not only define an operational need but also conceives a precisely defined answer from the technical point of view that the supply side must transform into a technological and industrial solution. This approach limits opportunities for companies to innovate beyond technological deepening. It is therefore not surprising that such lock-in into technological trajectories creates barriers to entry and, consequently, opens the door to monopolistic behaviour from incumbent companies.

If the satisfaction of capability needs requires a basis for which planning is possible, defence market must be more open by establishing requests not on very specific descriptions of military capabilities, but on the definition of operational objectives to be achieved. In this field, the evolution of civil space sector is remarkable and can serve as an example, for instance when NASA opened up the launcher market to newcomers by relaxing its system specifications. This therefore presupposes not adjusting the functioning of defence market but modifying its mechanisms and structures. If this can appear as unachievable, we must keep in mind that current market architecture is, after all, quite recent from a historical perspective and corresponds to the constraints in the second half of the 20th century. An institutional reading is necessary to understand the possibilities of reform and their limits.

However, it would be illusory to think that it is possible to 'normalise' the arms market, because the latter is only partially the result of market forces (Bellais 1999). The institutional architecture put in place during the Cold War certainly pushed the logic of planning very (too) far, which corresponded to a particular moment in both geopolitics and technology (Bellais and Fiott 2017). The discipline imposed to the supply side through pure competition can prove ineffective, even devastating, when it results in drastically reducing the defence industrial and technological base of a country wishing to retain national sources of supply and ensure a certain level of strategic autonomy.

Procurement agencies face a trilemma between keeping cost under control, accessing innovative solutions and guaranteeing the security of supply. This trilemma could be solved by defining an appropriate defence industrial policy without giving too much priority to one of these three

dimensions. Defence market is less a market than a political construction primarily aimed at meeting state needs associated with a principle of prohibition and a derogatory status for actors on the supply side (Krause 1992). There is therefore a necessary arbitration between competitive pressures and the satisfaction of a certain strategic autonomy in arms-producing countries having such an ambition.

However, it is important not to adopt a simplistic approach of competition. It cannot be only a matter of price. Getting the best value for money can constitute an important objective, but this latter can be achieved through different approaches. Indeed, capabilities must correspond to what armed forces need to achieve their missions. Keeping costs under control for existing capabilities could not be the best solutions. Sometimes, proposing an unexpected solution to a capability need or a modification of an existing one could better fit operational needs. Therefore, competition could apply for an end-product, but, since this market is highly concentrated, it is unlikely that auction-like competition for public market could be compatible with the abovementioned trilemma.

In a monopolistic market, we should consider that competition applies either based on expected effects without pre-defining the effector or, for complex systems, by opening the competition all over the value chain and not only for the end-production. This introduction of market pressures requires that the state limit its definition of the end-product and let potential suppliers of capabilities or intermediary products a sufficient margin of manoeuvre that helps them innovate with better capacities or lower costs.

Opening Up the Architecture of Defence Capabilities

Indeed, private companies are effective when they can image new solutions to solve existing needs. The emergence of New Space (e.g. SpaceX and Blue Origin for launchers, OneWeb and Starlink for space services) provides a clear demonstration that disruptive innovations are possible when the demand side defines what to do and not how to do it. Otherwise, solutions are likely to depend on existing trajectories, new capabilities being the improved version of the previous one.

For simple systems, it appears necessary to avoid that requests for proposal are over-prescriptive in order to open up defence market to newcomers, but this represents a limited share of this market as demonstrated by the good connection between DIU (and its equivalents) and special forces for instance. The true challenge consists in injecting more market pressures for system architecture as well as at the different levels of the value chain. Here, the use of modular architectures and open platforms could help increase the level of competition into the defence industrial base, notably since it creates an opportunity to attract newcomers and rise the competition with lower barriers to entry.

Initially conceived at IBM's computer division in the late 1950s,[8] the principle of modularity was put forward as a product design strategy aimed at defining a standardised set of interfaces among components of a complex system. When a system is 'modularised,' each element of its design can be developed and improved in an autonomous manner as long as it fits inside the system architecture. From an engineering perspective, such an approach aims at achieving three objectives (Baldwin and Clark 2004):

- to make complexity manageable;
- to enable parallel exploration and development of innovative components;
- to accommodate future uncertainty through agile evolutions.

In such an approach, companies do not design or produce a whole system. A modular architecture helps them focus solely on modules that are parts of the global system thanks to standards and predefined interfaces. Compatibility among modules is ensured by design rules that govern the architecture, interfaces and standardised tests and validation that guaranty both the performances of modules and system efficiency. Modularity helps mitigate risks as it provides flexibility within a stable frame.

Using a modular architecture favours a convergence between civilian and defence systems. Indeed, it is no longer necessary to design a component or subsystem specifically for a given product. When possible, an effective approach consists in identifying a civilian component or subsystem with sufficient performances (or which can be improved at acceptable cost) rather than to develop a dedicated military one. In doing so, military specifications can be reduced to unique features, and such evolution reduces the bargaining power of system integrators.

It is worth noting that this new approach results from operational needs. Modularity and open architectures are necessary to face threats that differ from the Cold War. Indeed, this period was characterised by highly dangerous, but predictable, threats due to strong symmetries in conceiving defence between East and West (Bellais and Le Blanc 2002). Today, armed forces must still possess such capabilities, but they must also prepare for lower-intensity conflicts as well as for less predictable threats than during the Cold War because of adversaries using asymmetric strategies, non-traditional innovations and non-conventional capabilities to compensate the lack of level playing field in traditional military capabilities.

Therefore, hybrid warfare, asymmetrical warfare and other means to overcome classical military power lead to look for more flexible military capabilities, able to adjust to unanticipated operational contexts. This is different from highly performant capabilities optimised to counter or dominate a clearly designated threat through advanced features defined *ex ante*, like Typhoon combat aircraft for dogfight or Leclerc main battle tank for tank battles. While such capabilities are very effective to dominate adversaries in a predetermined configuration, they can appear less useful to manage unexpected situations. Arms-producing countries have to continue to prepare for a peer-to-peer competition but to develop a complementary approach to cover alternative threats simultaneously.

Versatility has become a key feature to get the highest potential from defence systems, and this requirement changes the way these latter should be developed, produced and modified throughout their in-service deployment. Modularity can support the blossoming of architectural innovations, a point already underlined in a broader perspective by Henderson and Clark (1990) through their framework for defining innovation as described in Table 1. As such, it diminishes the pre-existing advantage of incumbent companies through a new level playing field.

Modularity enables to make components and subsystems evolved through an autonomous path without requiring major changes of the architecture. It is important to keep defence systems up to date, especially when they are supposed to stay in service for several years or even decades. The more components and subsystems evolve autonomously, the less system integrators can master the access to the customer or create dependency on follow-on solutions.

Modularity allows a greater division of labour, but it can also change the balance of power between the integrator and its industrial partners in the value chain. It allows create opportunities for newcomers to contest incumbent companies' role as system integrators.

The key challenge is to adjust defence industry to a fourth industrial revolution that is likely to induce radical changes over all dimensions of industrial activities (Brynjolfsson and McAfee 2014). In other words, defence industry must change to respond to both the expectations of armed forces and to the ways industry operates. The conception of systems can no longer be based on planned obsolescence resulting in decade-long developments; and the volumes of production have

Table 1. A framework for defining innovation.

		Core concepts	
		Reinforced	Overturned
Linkages between core concepts and components	Unchanged	Incremental innovation	Modular innovation
	Changed	Architectural innovation	Radical innovation

Source: Henderson and Clark (1990). 'Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms'. Administrative Science Quarterly, 35(1), 12.

decreased so much in defence industries that techniques of mass production appear less effective and very expensive.

The transformation of innovation expectations and the fundamentals of industry leads to a level playing field in which the fastest and the most adaptive company can secure potential markets: with the ability to enter a market without unbearable and sunk costs, defence markets are likely to become more contestable, at least for certain capabilities or subsystems. Nevertheless, it seems likely that such in-depth transformation of defence industry will be painful, especially for incumbent companies.

Even though the creation of a 'Defence Industry 4.0' appears to be essential, it is not granted that non-defence companies could be interested in serving the needs of armed forces. Therefore, it seems necessary that states set up industrial and technological policies that both support the transformation of defence companies and attract purely commercial ones in the field of defence capabilities.

For instance, William Lynn and Adm. James Stavridis noted in their foreword of FitzGerald and Sayle's *Creative Disruption*: 'Google's recent acquisition of Boston Dynamics, a DARPA-funded organization that develops some of the world's most innovative robots, served the Pentagon with an unsettling notice: the center of gravity in cutting edge, military applicable research is shifting abruptly away from the defense establishment to relatively new commercial firms with loads of cash to invest' (FitzGerald and Sayler 2014, 5).

One could wonder if these industrial and technological trends are likely to result in reducing significantly barriers to entry in defence industry. Indeed one could consider that such transformations are bound to improve the level playing field, in particular if economic leaders like the GAFAs or BATXs want to break into defence market. The 'New Space' provides a natural experiment on how powerful non-specialised companies, which have money, will and technological skills, can put a previously very stable space market upside down.

A New Balance Throughout the Value Chain of Defence Capabilities

Architectural innovations are likely to depreciated or even nullify the usefulness of incumbent companies' architectural knowledge. Henderson and Clark (1990, 13) use the term 'architectural innovation' to look at '*innovations that use many existing core design concepts in a new architecture and that therefore have a more significant impact on the relationships between components than on the technologies of the components themselves*'. Modularity provides opportunity to newcomers as system integrator to propose either a classical architecture with new component and subsystems, or alternative architectures that combine both old and new modules.

Major subsystem producers can, for instance, be tempted to upgrade their positioning in the value chain and become system integrator. This possibility is favoured by the changing repartition of added value inside a platform, notably because of the increasing share of electronics and digital contents over the decades. Today, the value of electronics and software has become predominant for combat aircraft, mission aircraft or most naval platforms, while aircraft manufacturers and naval shipyards remain the system integrator in their respective sectors.

This evolution can be illustrated with the US Navy's Littoral Combat Ship programme. In 2004, Lockheed Martin, General Dynamics and Raytheon submitted design proposals. It was decided to produce two types of vessels: the Lockheed Martin's *Freedom*-class design and the General Dynamics' *Independence*-class design (a trimaran initially developed by Austal).[9] It is quite surprising that none of competing system integrators was a naval shipyard. Indeed, this example illustrates the fact that fulfilling armed forces' needs does not necessarily require to stick to an existing platform or system. Focusing on functionalities rather than the incremental evolution of existing capabilities can nurture competition on both price and innovation.

Indeed, each competitor set up a team with partners able to produce ships or support such manufacturing. General Dynamics is associated with Austal U.S.A, the American subsidiary of Australian shipbuilder Austal. Lockheed Martin's team includes Gibbs & Cox, Marinette Marine and

Bollinger Shipyards to produce its *Freedom*-class littoral combat ships. However, the rising weight of subsystems in this kind of platforms changed the balance of power at the detriment of legacy system integrators.

The new balance of power inside the value chain illustrates what Brusoni and Prencipe (2001, 181) identified: '*Once a dominant design has emerged, it is encoded and thus becomes embedded in the organizational set-up, which is why architectural innovation represents such a subtle and dangerous challenge for incumbents*.' Indeed, system architecture relies on key, most of the time tacit, interfaces and knowledge (Henderson and Clark 1990) that protect incumbents from newcomers. Once decades-long system integrators have lost their predominance in designing architectures, the level of competition can increase quickly.

Nevertheless, it is important not to overestimate the reshuffle of the balance of power inside the value chain. Systems of systems rely on network capacities, for which system integrators play a critical role either as providers or as the guarantor of the systemic effectiveness. Depeyre and Dumez (2007, 5) note that '*developing disruptive technologies to be integrated in big systems that required being open, modular, and made of many subsystems is not obvious*.' The competition could evolve at a slower pace with regard to the architecture than for components and subsystems in a modular architecture of defence systems.

System integrators derive their authority because they control the means and ways to coordinate knowledge components and organisation of the whole value chain. '*Not only does learning about the architecture require conscious effort, it also may entail different kinds of organizations, people and skills*,' underline Brusoni and Prencipe (2001, 181). Other industrial stakeholders need them to ensure the overall consistency of the end-product and to coordinate all partners involved in the various stages of design and manufacturing towards a common goal.

As Henderson and Clark (1990, 17) note, '*Once an organization has recognized the nature of an architectural innovation, it faces a second major source of problems: the need to build and to apply new architectural knowledge effectively*.' In defence industry, we must add a prerequisite: no new capability can succeed until a suitable doctrine has been established. In fact, Toffler and Toffler (1993, 62) already remarked that '*changing any military's doctrine is like trying to stop a tank armor by throwing marshmallows at it*.' You need to reach a tipping point so that armed forces accept to leap from a legacy capability to an alternative one.

As Brusoni and Prencipe (2001) underlines, despite the adoption of modular product architectures, knowledge components and organizational coordination cannot be achieved by relying only on automatic mechanisms or standards. It is far from being a 'plug and play' configuration. System integrators still play a critical and essential role in order to achieve knowledge and architectural coordination, which requires the interactive management of stakeholders throughout the value chain. In fact, it appears not so easy to segregate component and architectural knowledge, and sometimes there are no clear boundaries.

Another dimension is at play in defence industry. Incumbent companies benefit from the reputation effect that we previously mentioned. We can even identify a hysteresis effect. Even though incumbent companies do no longer provide specific advantages for armed forces, their strong relations provide a premium to incumbent companies' proposals. Additionally, to some extent, these companies contribute to the definition of military doctrine, and they can influence through this process military requirements to preserve their vested interests. It is therefore important that the institutional setup of defence markets ensure the level playing field between competing proposals, which must be assessed on objective criteria with regard to armed forces' needs.

Despite major changes in industry at large, this explains why we can still see a strong stability of defence companies. As Brusoni and Prencipe (2001, 201-202) state, '*modularization does not derive from, nor bring about, knowledge modularization*.' The integrator still masters specific knowledge and organisational skills that secure both the end-product and the management of the related value chain. Even modular architecture does not mean that modules can fit perfectly in a smooth way without the integrator's expertise. In other words, '*the knowledge boundaries of the firm*

fundamentally differ from the boundaries of the firm as defined by make-or-buy decisions. In a nutshell, systems integrators "know more than they do"' (Brusoni and Prencipe 2001, 202).

Even though system integrators are likely to remain the backbone of major complex defence systems, their positioning within the value chain should not lead to reduce or stifle the dialogue between end-customers and key industrial partners. One of the major challenges consists in finding the right balance between the preservation of the core of defence industrial base, which is essential to manage capability architectures and the sustainability of arms manufacturing, and the openness of defence industry for newcomers proposing innovative solutions in terms of cost or performances. This requires more agility in both budget flexibility (beyond planned investment) and ability to integrate new components and subsystems during the development phase and even once a programme has started series production.

Conclusion

Defence industry has been experiencing a surprising stability for decades despite many geostrategic, budgetary, industrial and technological changes, especially after the end of Cold War. This situation results from high barriers to entry and the ways users-producers relationships are organised. Nevertheless, such stability can be jeopardised not only by budgetary constraints but also by long-term transformations on manufacturing far beyond the realm of defence industry as well as innovations in technology and capabilities coming from outside the defence industrial base.

If modularity or the fourth industrial revolution can become 'game changers,' their impacts on the level of competition remain limited for the time being. One could also consider that challenging today's system integrators would create more risks than possible benefits as they play a critical role as the guardians of systems integrity and effectiveness.

Nevertheless, this should not prevent other industrial stakeholders from increasing their interactions with end-users. Such possibility can result from a strong concept of LSI or any equivalent in the relation between the state and the system integrator. This trend can reduce transaction costs for the state and reinforcing the balance of power at the benefit of system integrator.

However, it would be detrimental to armed forces in the long term, since it is likely to reduce both competitive pressures and innovation in technology, concept and manufacturing. As Eric von Hippel clearly demonstrates over decades of research, interactions between users and producers are important to innovate. This is particularly the case when related products rely on a large share of 'sticky information' (von Hippel 1994). In such case, only strong user-producer interactions can help understand means and ways to conceive, design, produce and maintain defence systems.

Indeed, such an approach is already implemented in some arms-producing countries like the United States and France, but most of the time as an exception rather than a rule today; or it mainly concerns small capabilities, e.g. in order to equip special forces (Frances and Larrieu 2023). This approach remains peripheral to the development process of defence capabilities. Israel provides the only example of systematic use of strong user-producer interactions (Dougherty 2020; Ortal 2022), notably through the spiral development, a design approach that remains under-developed in other countries (Gray 2009).

The acquisition process and related market setup inherited from the Cold War have been able to deliver the highest benefits from technology advancements for armed forces. Even though this institutional setup remains very useful, it has favoured a lock-in of this market that limits innovation to reduce cost and provide new features. The focus on cost escalation and price control has diverted the attention from modifying the institutional organisation of defence market, which appears less relevant today. A reshuffle of market setup appears therefore a key dimension in order to improve the performances of defence market.

Notes

1. Indeed, competitive pressure is easier to implement for less ambitious country, even with a limited defence industry, since they can open their call for proposals for foreign competitors. Then, they have to accept that the selected capability might not be produce domestically and comes with restrictions and limited control over related knowledge, therefore limiting their strategic autonomy.
2. Countries with limited or no defence industrial base have indeed a more open market, since they do not expect to develop all their capabilities or they would prefer to acquire some of them off the shelf, sometimes through a competitive tender between international suppliers. Such competition does not mean that importing countries can access a large variety of solutions, since major exporting countries follow the same development process. Competition can take place on price, performances and political criteria but, most of the time, between quite similar capabilities based on domestic requirements of the exporting country and not specifically designed for export markets due to the high costs of R&D, which prevents companies from developing innovative solutions solely for export customers.
3. Cost-plus contracts provide for the reimbursement of all costs authorised for a programme implementation. The provider receives fees calculated for example in the form of a percentage, defined *ex ante*, of the initial estimate of costs for a project. Most risks are therefore borne by the state.

   Alternatively, the state can choose firm fixed-price contracts, where price is negotiated *ex ante* and cannot be modified *ex post* if the supplier faces higher costs than expected. Indeed, there also exist different categories of risk-sharing formula between cost-plus and firm fixed-price contracts.
4. If states lessen the objective of strategic autonomy to some capabilities only, they can avoid such bias by introducing competition from foreign suppliers as many countries do even if they expect to keep a domestic defence industrial base.
5. John Hicks once observed that 'the best of all monopoly profits is a quiet life.'
6. https://www.baesystems.com/en/article/uk-japan-italy-global-combat-air-programme-delivering-next-phase-of-combat-air-fighter-jet-development (9 December 2022).
7. NATO, Emerging and disruptive technologies, last updated on 17 October 2022, https://www.nato.int/cps/en/natohq/topics_184303.htm, (retrieved on 17 October 2022).
8. 'The Standard Modular System (SMS) is a system of standard transistorized circuit boards and mounting racks developed by IBM in the late 1950s, originally for the IBM 7030 Stretch.' According to Wikipedia (https://en.wikipedia.org/wiki/IBM_Standard_Modular_System).
9. For a comprehensive analysis of the LCS programme, see for instance Naval Technology, 'Littoral Combat Ship (LCS)', 13 January 2020, https://www.naval-technology.com/projects/littoral/.

Acknowledgments

The author is grateful to anonymous reviewers, who provided very relevant comments that helped significantly improve this article. This research also benefitted from useful exchanges at the 13th Annual Defence and Security Economics Workshop (Ottawa, 2018), the 25th International Conference on Economics and Security (Perugia, 2022) and Workshop on Democracies and Civil-Military Relations (Aix-en-Provence, 2022).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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