STRATEGIC VALUE OF NATO's INVESTMENT ON SCIENCE, TECHNOLOGY & INNOVATION (STI): MANAGEMENT OF INFORMATION AND KNOWLEDGE AS INTANGIBLE ASSETS

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This paper discusses the defence Science, Technology & Innovation (STI) investment within NATO. As a complex process it involves multiple stakeholders with common interest in development of knowledge through R&D activities, connecting current and future military capabilities. The objective is to generate and provide evidence-based scientific advice to decision-makers and deliver advanced solutions to national and NATO challenges. This process can generate valuable intangible assets for the Alliance in form of information and knowledge-based capital. The challenge for NATO is to manage and exploit the advantages of collective defence STI on behalf of its 29 members. The article approaches defence STI policies in comparison with power of politics and national as well as industrial interests. The attempt to quantify scientific knowledge as added value with significant return on investment unfolds the dynamics and vulnerabilities within NATO's corporate culture. Although complexity is the main argument and pre-assumption, multidisciplinary aspects (political, economic, social, technological, and legal) are carefully examined and explored, providing a comprehensive approach of its strategic value to the Alliance.

Key words: *Defence investment, NATO Science & Technology, Information & Knowledge Management, Intangible Assets, Defence Industry, Return on Investment, Added value, Emerging Military Technology*

1. INTRODUCTION

Almost 60 years ago the lunch of Sputnik 1 by the Soviets, caught the west and mainly the US by surprise in the technology race of a bipolar world.

In light of the intense competition on defence technology (i.e. use of nuclear power, atomic energy, intercontinental ballistic missiles, nuclear submarines, air & naval superiority, Command & Control, etc.), there was a profound incentive and emerging necessity for S&T1 close cooperation within NATO. In the late 50s the Alliance[2] successfully investigated the option of broadening its security policy with non-military tools such as scientific collaboration (among others like political, economic and cultural cooperation). Until the end of the 80's, NATO was on high alert not only operationally but also in terms of science & technology. As the rivets in the Iron Curtain were beginning to pop, the years that followed can be described as years of unconscious sedimentation of this alert state. Fukuyama's "end of history" and the evident victory of economic liberalism, had an impact in the minds of decision makers with regards to investment in military technology and related R&D, and its role to the post-cold-war era. On the other hand, economic globalization and new global market rules had a great effect on industry worldwide that shaped the way international business was about to be conducted, equally affecting the defence industry that started to be more active in a quasi "borderless" market. This new environment was mostly seen as a business challenge or business opportunity. Furthermore, as today the digital revolution is changing the fundamentals of society as we know it, emerging technologies such as artificial intelligence, robotics, internet of things, biotechnology and quantum

[1] Science & Technology

[2] Clarification to the reader regarding the meaning of the word Alliance in comparison with NATO. The role of NATO is mostly to help Nations get their act together collectively and achieve their common goals. So, by "NATO" we mean the 30th entity, the NATO staff in the HQ, the Commands and Agencies, that collectively serve the Nations (29 Allies). And therefore "Alliance" as a notion include the Nations and NATO altogether.

computation (just to name a few), are providing not only unconventional opportunities (in the pursuit of conquering outer space for instance), but also unconventional threats (such as cyber-attacks) that create great challenges to the capabilities of any military power. NATO's Science Technology & Innovation (STI) is directly related to its ability to adapt to the constantly changing global environment, in relation to broader aspects such as military and geostrategic interests, emerging technology development, local and world politics, legal challenges, global economic situation, and socio-cultural metamorphosis.

2. THE CHALLENGES

As the technology race after the lunch of Sputnik1 by USSR intensified the following was stated by Dr von Karman in 1950 (Wattendorf:1969, p.24), which could have been as well mentioned today by NATO STI community.

> *I came to the conclusion that the mobilization of science for research useful for defense, is yet in a very rudimentary stage in most countries. It appears that the mobilization of scientific effort in Continental Europe can be effective only if the countries work in close collaboration with one another.*

Since then, a series of efforts have been made by the members of the Alliance to bring together the greatest minds of the scientific and engineering community to leverage their resources for the benefit of their common goal of scientific & technological superiority in the defence sector against its adversaries.

During the last two decades, military technology has become more accessible to the public due to its interdependence with the technological advances in the civilian domain. NATO (through CNAD[3]) has tried to coordinate efforts and initiatives of collaboration between military and industry in order to explore innovative solutions that will maximize returns in the form of military advantage and technological edge. This bottom-up approach will help nations introduce new innovative ideas to NATO. STO[4] tech-trends, technology watch-cards, emerging technology assessment tools and on-line crowd-sourcing forums (such as the ACT[5] Innovation Hub), are some of the today's means of harnessing innovation activities within NATO. These tools highlight potentially disruptive development in S&T for the Alliance and ensure the convergence of common efforts to the most important areas of research (STO Tech Trends Report 2017). Furthermore, as China developed capabilities approaching parity to US (and by implication NATO), collaboration of the STI stakeholders became a crucial necessity for the Alliance.

At national level, governments develop innovation strategies for commitment to invest in new technologies. Among the most recent examples is the US 3rd Offset Strategy and the UK "Defence Innovation Initiative" which have the potential to bring high value deliverables to national defence and in effect, to NATO capabilities.

We can presume that costs and benefits of an investment, are the most important factors for the decision making on NATO STI investment. Accordingly, sharing and pooling of resources can potentially achieve significant economies of scale. The catalyst, is the increasing complexity of networks of state and non-state actors that impose asymmetric threats, in combination with the accelerating change in the strategic environment. Complexity, in sense of increasing uncertainty over time, makes decision-making uncertain in the long-term. Smart decision making on targeted STI defence investment is vital for the generation of new knowledge in technology, and the responsive confrontation of such complexity. There are however several drawbacks to consider, such as high development costs (in relation to size and share of the niche market), various regulatory hurdles (based on national restrictions), and technology ethics on responsible innovation that have an

[3] Conference of National Armaments Directors
[4] Science & Technology Organization (NATO)
[5] Allied Command Transformation

impact on social acceptance of disruptive technology, despite the economic benefits.

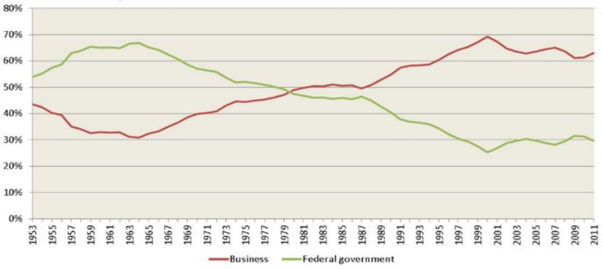
Although one of the major objectives for the Alliance is to increase the transparency and accountability of various investment programs (including those related to STI), the positive results are not yet fully visible, due to factors such as complexity in terms of corporate culture, shortage of resources, and changing mindsets and attitudes due to challenges of disruptive change. These are only some of the causes that can lead to transformation failure.

According to the OECD[6] (2016), prior to 1970 nearly 70% of all business R&D (in the largest OECD countries) was directly funded by government. Today this figure is close to 10% (the US example of Figure 1 is a classic one). The change of this model fits the needs and requirements of its time in light of the privatization of most of the defence industrial sector of the western world during the last decades. As a result, nations today enjoy the benefits of lower costs and economies of scale due to this competitive environment.

Non-tangible forms of capital, such as knowledge-based capital (KBC), are increasingly the largest form of business investment. Assessing their role for economic growth and value creation for firms, requires effective measurement of such assets. We can refer for example, to R&D, intellectual property assets (such as patents, trademarks and designs), software and databases, or brand equity, firm-specific human capital (including training) and organizational know-how.

Defence research and innovation today is correlated more with the technology developed in private sector and the latter is the one driving the development of cutting edge technology that the military is applying on new concepts for defence purposes. This strong relationship between defence and private sector creates a scientific interdependency between military advanced technology and the civil oriented R&D.

Figure 1. Source of funds in USA, % Share of Public and Private Sector, 1953-2011.



Source: A. Hunter & R. Crotty, "Keeping the Technological Edge", Center for Strategic & International Studies (CSIS), September 2015

The free exchange of ideas is the academic way, (and experts believe it's the best way) of accelerating the progress of IT and Artificial Intelligence. Since the industrial revolution, we have experienced the first stage of globalization based on reduced trade costs. The innovations however remained mainly within the most developed or industrial countries (G7) ending up in a "great divergence" (1820-1990) due to the still high communication costs (Baldwin:2016). Around 1990 these costs started falling which led to people and businesses from different countries connecting and paving the way to the new globalization. At the same time, the collapse of the iron curtain that released the pressure of defence expenditure from NATO countries is not the only causal event. The ICT revolution creates an incredible information and knowledge spillover effect, among countries regardless to their economic power, connecting high-tech with low-wage nations through new pipelines of knowledge flows. It is by no coincidence, that during the same period national defence STI shifted even more (not for all member states equally) towards the private sector and industry and away from government-controlled research institutes.

Contrary to NATOs confidentiality in sensitive military requirements involving disruptive technology, in some cases industry have started to loosen up their secrecy by publishing journal articles and engaging academics on far-reaching research activities. Regarding artificial intelligence (AI) for

[6] Organisation for Economic Co-operation and Development

example, many companies such as Google and Apple are deciding to release and share research data in order to further foster the deep learning and AI within the global scientific community. This technology applies to many defence oriented technologies (drones, navigation & targeting systems, robotics and software development) proving the vital role of industry engagement in STI decision making today.

Yet, secrecy of inventions is not something new for NATO and there is a related agreement signed back in 1960 ensuring the mutual safeguarding of defence related inventions for which applications for patents have been made. This type of limitation and prohibition imposed to NATO countries may have caused some difficulties in the collaboration between member states. The secrecy measures of this agreement are today still valid and they are the means of safeguarding patent rights related to classified military inventions.

Since for NATO the intelligence of military technology is also a geostrategic issue, this open window of knowledge sharing by the industry, gives the opportunity to the STI community of the Alliance and its decision makers to have a more complete picture of the future technology and to be able to define with more precision the future requirements of its forces (WIRED:2016). The new reality of knowledge offshoring through new global value chains in combination with the new world trade policies and international agreements (WTO[7] and multilateral free trade agreements) have created an environment where international competition does not only apply to the final product but also to the jobs in the manufacturing stage. In that sense specialized skills don't guarantee future jobs.

3. DYNAMIC POLICIES IN A DYNAMIC ENVIRONMENT

3.1. The Shift of Dynamics

It becomes evident that as the nature of the market becomes more dynamic, it is affecting all business sectors, including defence industry. Changes are more sudden, individual, more unpredictable and in many cases more uncontrollable, resulting in cooperation agreements between manufacturers of different countries and mergers & acquisitions. As a consequence, defence industry, research institutes and the academic world are more internationally connected.

The recent policy trend in R&D and innovation tax incentives and the impact of such tax relief on the cost of R&D is worth mentioning. According to a STI Outlook (OSCE/World Bank Group: 2016), governments are increasing the tax incentives, either income-based or expenditure-based, in form of income tax (corporate or to individuals), social security contributions, VAT, preferential import tax rates, land & property tax etc. Hence, industry can be more flexible in identifying the ideal mixture of policies for the maximization of value added and ROI on STI investment. However, not all NATO countries apply the same tax incentive policy, and NATO (as a tax-exempted organization) is still called upon to fill those gaps and provide STI solutions within a collaborative framework.

In the NATO context, close collaboration with industry is crucial in order to be able to define its requirements and avoid the risk of a-priori development of the capabilities in isolation. The former Assistant Secretary General (ASG) for Defence Investment in NATO (Patrick Auroy) had identified some problems in this process. First, militaries embrace new innovative break-through ideas too fast, without any real assessment of the effectiveness to the required capability, while industry realizes that such investment is not only impractical but also economically inefficient. A second problem identified, was the paradox of a company assisting NATO in technically framing the right kind of tender and then finding itself excluded from bidding on it, on the grounds of its advance knowledge. (IHS Jane's, Vol. 53:2016). Providing more opportunities to industry for experimentation of new concepts and technology, would allow NATO, from a risk- averse, to become a risk-management organization; a paradigm-shift that can also change the status quo of **NATO-**

[7] World Trade Organization

industry cooperation (NATO-Industry Forum:2015). The potential strategic autonomy of EU on defence as collective action in conjunction with possible impacts of Brexit and the focus of the US on burden sharing among allies, creates an even more dynamic environment.

3.2. Trade implications

In the information age of the 21st Century, the use of data is as important as energy security and has the potential to be a powerful force for global growth, sustainability, democratization and societal progress. Big Data is more than technological hype; it has the potential to significantly transform military functions such as intelligence, command & control and logistics, enabling effective and faster military decision making. Accumulated scientific and technological data, is converted to **structured information** and potentially to a **new form of value** as "knowledge", through exploitable intellectual property (patents, licenses, copyrights, designs).

There are significant global interdependences of trade in value added, with regards to the relationship between exports and final demand, which is translated into jobs. As free trade agreements also make defence related business more flexible in an open market, member nations with strong defence industries (such as USA, Germany, UK, France) benefit from exports to other allied countries, which reflect their employment dependences. In effect, a big percentage of military technology related jobs in one country is sustained by foreign demand for its final defence related products. This can impact the decision making on defence STI investment and can influence political decisions at NATO level.

Large enterprises within EU are affected by export controls more often than Small-Medium enterprises (SME) because larger companies often cooperate with research institutes & academia outside the EU, and that intra-company transfer of dual-use technologies is also subject to dual-use export controls, (SIPRI Report: 2015). Regarding research (basic and applied science), where the basic product is knowledge in form of data and processed information, the limited (or non-existent) communication barriers have now given the green light to free flow of scientific information between NATO members. In Europe, apart from the Intellectual Property Rights (IPR), there are limited export related regulatory barriers which are arranged via respective non-disclosure agreements. In the US, IP and export control regulations and laws are still very strict with the use of International Traffic in Arms Regulations (ITAR) of the Department of State, and Technical Assistance Agreements (TAAs). At development and prototyping stage, export licensing for STI products becomes more relevant. The importance of establishing an EU–US trusted community of companies for transfer of defence related products has been pointed out in various NATO studies (TADIC SG-180: 2014).

Until a few decades ago, defence technology was more distinctive compared to the technology for civil use and thus such technology had more unique or **niche customer base**. Today this technology is related more to a commercial equivalent (mainly IT, AI and robotics related). The effects of knowledge spillovers of public research have high priority to allies (through patenting and publication IP), but also to the adversaries through reverse engineering or imitation. Protection of IP rights and industrial interests are becoming crucial factors for any decision-making process on defence STI investment. China for instance, is suspected of having stolen approximately $1 trillion USD of intellectual property via cyber-attacks. (The Mackenzie Institute: 2017). There is no doubt that industrial intelligence driven by political intentions, has played a major role in the history of defence industry.

But can industrial espionage be as effective as R&D? According to a research paper by E. Meyersson and A. Glitz, East Germany had "*enjoyed significant economic returns from its state-run industrial espionage operation.*" (C. Nickisch, Harvard Business Review: 2016*).* It is not only just the espionage, rather the whole scientific and technical knowledge transfer (with reverse engineering), as well as the recruitment of the best scientists in a post-war period, such as the best German brains were recruited by the US at the end of WWII.

Major political changes such as government administration changes of key stakeholder countries or political instability due to upcoming elections in an environment already troubled by global immigration and financial turbulence, inevitably affect the decision making in NATO, influencing as well the political position of all member countries. To paraphrase the words of Metternich, “**when USA sneezes, NATO catches a cold**”.

Extending the challenges to the domain of education, NATO may find difficult~~ies~~ to attract highly skilled, educated and experienced scientists as the competition in the global market provide attractive options that have driven the vast mobility of scientists and skilled engineers during the last decades. Organizations, research institutions, multinational enterprises or even SMEs manage to attract the best experts in the market by offering very competitive salaries, career advancements, and research opportunities to work with prestigious peers in excellent research facilities, providing autonomy and increased freedom to carry out research and experimentation. NATO collaboration programs, special facilities as well as national research centers are offering analogous (but maybe not as competitive) incentives depending on their R&D priorities in an effort to use skills of highly educated people to leverage innovation and R&D.

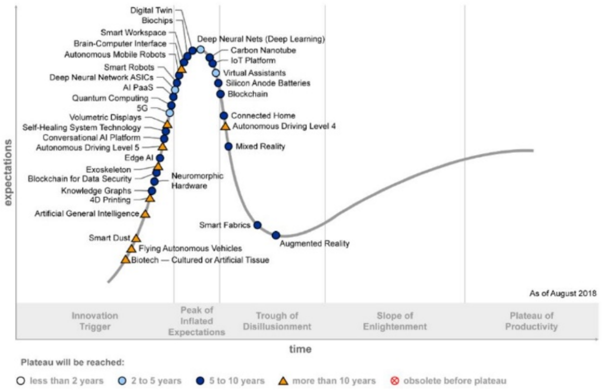
Experimentation can lead to valuable results, regardless of the outcome (positive or negative). It is therefore of great importance for scientific results to be reproducible and available to the scientific community despite their outcome. It has been noticed by the academic community (especially in medicine and biology) that negative results are not published, resulting in misleading scientific evidence. In the case of emerging dual-use technology, it is important for all scientific results to be available, especially if the technology requires accuracy and detailed specification that affect the precision of a new weapon or command & control system.

Scientists in either public sector or industry are interested in promoting their work through successful scientific publications. The phenomenon of publication bias has been quite common and, to an extent, understandable as we live in a competitive market where private enterprises intend to maximize the outcome of their efforts. But by not publishing or making available negative results, we are disrupting the evidence-based science. If this also happens in industry and military R&D programs, then this may end up disrupting the potential disruption of a technology with unknown consequences. Similar concept applies to S&T patents as people today invent more per R&D euro or dollar. Hence, patents are not an afterthought of creating a new product anymore but are at the beginning of the R&D effort.

3.3. Time Vs Expectations

The speed of transfer of scientific knowledge in addition to the speed of communication and transportation~~,~~ has made ~~it~~ possible for adversaries to obtain technology that disrupts the current security status quo on a local and global scale.

Figure 2. Gartner Hype Cycle for Emerging Technologies, 2018

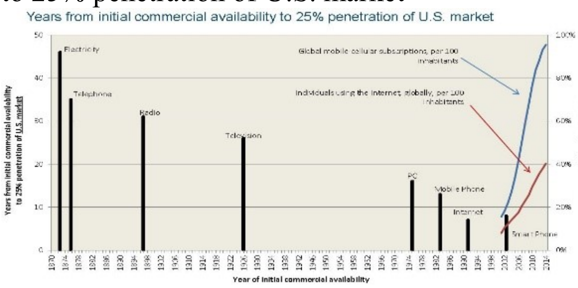


Source: Gartner © 2018, Inc

Most emerging technologies (according to Gartner) follow a pattern from their initial innovation trigger until their final mainstream adoption, through a “hype cycle” that uses time and expectations as the two main parameters. It is worth mentioning that in comparison to the 2016 and 2017 Hype Cycles, emerging technologies such as drones, AI, machine learning and block chain move fast on the hype cycle path, proving the dynamic relationship between time and expectations.

This trend presents promising technologies with potential high degree of competitive advantage, and not surprisingly it is in correlation with NATOs' tech trends of the last years. And if we think of the digital revolution and fall of communication barriers of the last decade, one may conclude that civil and military technology has developed into a **converged path** that makes it difficult to distinguish their dynamics as defence industry in private sector is today~~s~~ driving force.

Figure 3. Years from initial commercial availability to 25% penetration of U.S. market



Source: A. Hunter & R. Crotty, "Keeping the Technological Edge", Center for Strategic & International Studies (CSIS), September 2015.

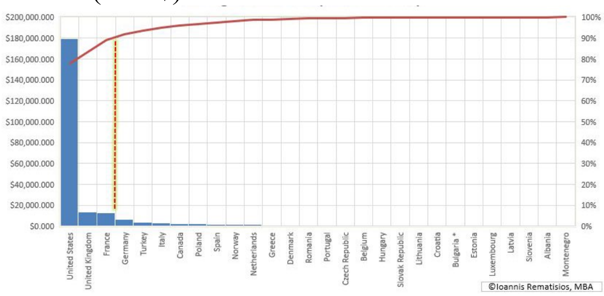
Whether it is a multinational enterprise or a local SME or a start-up, STI results can come by surprise and totally unexpected by the traditional strategic view. From the above trend we may suggest that penetration of the market by new inventions and technologies becomes dramatically faster. In addition, if we consider the fast acceleration of phenomena due to the **low communication costs and the knowledge spill-over effect** among industries, states and non-state actors, the task to accommodate and coordinate STI activities (let alone the decision making on the respective investment) within NATO, is even more challenging and requires a vision of micro and macro horizons simultaneously as part of a change in culture.

4. MEASURING THE UN-MEASURABLE

The intention of STI activity is not to yield immediate tangible profits and since it carries considerable risk, its measurement becomes rather problematic as it contradicts the basic concept of investment and its decision making within an organization. NATO has the ability to transfer those risks to external stakeholders, such as defence industry and the private sector, but at the same time this process might become problematic as well if it is not deployed with adequate operational analysis and effective defence planning process at strategic level.

At the Warsaw summit (July 2016) nations confirmed their agreement from previous summit to reinvest in defence at least 2% of their gross GDP, including guideline of spending 20% of the defence budget on new equipment and R&D. Despite national efforts, there is still much work to be done in order to have a more balanced sharing of the costs and responsibilities. In the Pareto chart below, referring to the average of the last seven years, in absolute number (million USD), three nations (USA, UK & France) cover the 90% of the total expenditure on equipment & R&D.

Figure 4. Pareto Chart - Defence Expenditure on Equipment (including R&D) – Average 2010-2017e[8] (in M$)



How does the "politics of 2%" affect defence R&D? According to Carnegie (2015) it has been the subject of many critics as it measures input instead of output. It is believed that 2% says very little about a country's military capabilities and level of readiness, deployability, and sustainability. Both politically and militarily speaking~~, it~~ cannot assure the willingness of the country to deploy forces and take risks.

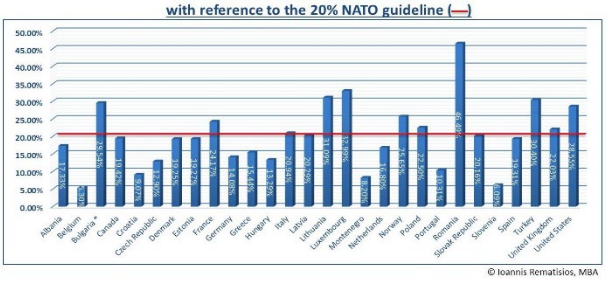
And the question remains non-ephemeral: Do the member states spend their resources wisely? Jan Techau (Carnegie:2015, online) goes one step further. The 2% "says nothing about the investment or research and development ratios in the budgets, which are

[8] Figures for 2017 are estimates

usually counted among the most valuable indicators of whether a country is serious about its defense effort", doubting its ability to quantify the share of risk. The most noteworthy political risk, related to the 2% (and related R&D expenditure target), is that any failure to meet the target will potentially have detrimental impact on the credibility of the Alliance.

According to a European Commission Press Release (30 Nov 2016), the US spent on defence (in 2015) more than twice as much as the total of EU countries who (for the same year), actually decreased their spending by ~12%.

Figure 5. Percentage (%) of total defence expenditure (2017e) on equipment (including R&D)

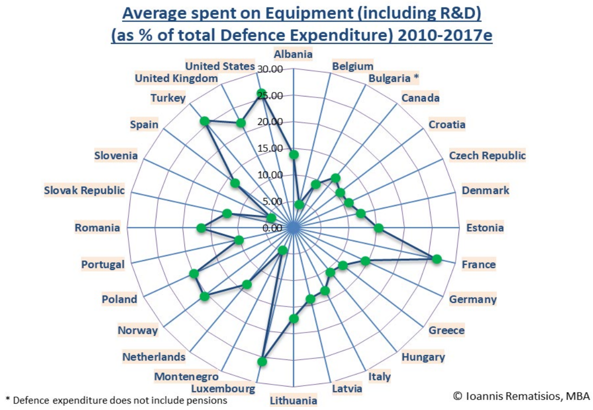


Source: Data extracted and processed by the author, from the official NATO website (http://www.nato.int/cps/en/natohq/news_145409.htm) (e=estimated)

The above chart[9] provides official available data of the year 2017 estimations of defence expenditure on equipment and defence R&D with reference to the 20% NATO guideline. There is a diverse distribution among member nations. For instance, we notice figures as low as 5-6% for Belgium and Slovenia and above 30% for Lithuania, Luxemburg and Turkey, while Romania is considered an outlier with great volatility (comparing to data of previous years). National priorities and strategies can explain most of the fluctuations. For a more complete picture we can examine the averages of the last 7 years in the radar chart of figure 6. The figures in percentages are lower showing that in general, member nations are now increasing their respective budgets, but the diversity of the percentages and volatility on an annual basis is still evident.

[9] For NATO data processed by the author, see table in Annex I.

Figure 6. Average spent on equipment (including R&D) as % of total defence expenditure (2010-2017e)



Source: NATO official data (https://www.nato.int/cps/en/natohq/news_145409.htm), processed by the author. (e=estimated).

4.1. Knowledge as added value for NATO

What can be considered as **added value** of defense STI expenditure for NATO?

Added value of multinational collaboration on STI in a NATO framework comes from a number of opportunities.

- **Pooling and sharing** to address challenges that are **over and above** those that could reasonably be handled using individual national resources.
- **Determining the niche market size and market share** in the industry, through NATO programs on specific technology affecting the development cost per unit and the supply & value chain.
- **Promoting standardization and interoperability** by delivering coherence in a trans-Atlantic perspective and **minimizing duplication of effort** and military capabilities. (~80% of defence procurement in EU states is run on national basis) (EC: 2016).
- **Leveraging existing multi-national public-funded research programs** in dual-use technology perspective, **bridging** North America and Europe.

Added value can be identified not only in innovative weapon technology but also in innovation applied in processes such as logistics. For example, the Integrated Munition

Health Management (IMHM), is a systematic process for enhancing the intelligent management of life-cycle of munitions that provide benefits to NATO countries in terms of cost, safety, performance, interoperability and availability of munitions. STO has successfully demonstrated the **technological maturity** that has been achieved in this field.

New scientific & technological **knowledge** is considered as added value for the fulfilment of strategic goals & objectives of the Alliance. Since knowledge is discrete, it requires large fixed costs. This means that the price of research & development (either for military purposes or not) is usually much higher than what consumers (or nations in the case of NATO) are willing to pay. It is therefore important for organizations from different sectors to be able to share and exchange ideas on a basis of common values.

If only 5% of innovative ideas in industry mature into **revenue-generating products**, and it could take four years until we see their impact, (Street: 2016); then NATO would gain great benefits from such activity. On the other hand, according to a RAND (2015) report for UK defence, research shows a time-delay of approximately 15 years between R&D investment, which impacts the quality of defence equipment.

Sensitive or classified information and knowledge is important for the competitive advantage of a firm. This **protected knowledge** is difficult to convert into added value and to measure its tangible results upon delivery. Valuation of returns on break-through innovative projects is better performed when accompanied with respective risk assessment and monitoring.

4.2. Intangible assets and Knowledge ROI

An important aspect of the notion of added value, is the de-risking through the exploitation of shared information and knowledge. Learning what the other allies do and how they do it, creates the basis of standardization of systems and equipment, and eventually interoperability of NATO forces in future operational environment.

CNAD, 52 years from its establishment (1966), has the mission to enable multinational cooperation on delivery of interoperable military capabilities, and to engage industry on defence planning and development in order to cultivate the solutions for the foreseeable future security challenges. Pooling of resources will consequently lead to **pooling of markets**. The engagement of industry (including startups) gives access to new technology in the private sector that could potentially become dual-use.

The **stock of scientific and technical knowledge** is increasing proportionally with the rise of the STI investment. As a result, this knowledge reduces future R&D costs and most importantly it increases the spillovers from current to future R&D activities (Coe, Helpman, et al.: 2008). In the NATO context this effect crosses national borders of member nations providing economic benefits through the defense industry.

Industry in return, can calculate its economic value added by using its capital change and the net operations profit after tax. Nevertheless, reliable data from NATO accounts is essential for any kind of calculation. The adoption of **IPSAS** 31 standard[10] by NATO reporting entities, has significantly helped the **transparency and accountability** of intangible assets. According to the standard, NATO reporting entities should capitalize integrated systems and include research, development and implementation (including both software and hardware elements).

Due to the specific nature and use of the item of intangible assets, shorter depreciation lives should be applied and useful life per asset category should be enclosed in the financial statements. Additionally, the reporting entity should capitalize other types of intangible assets including copyright, IP rights and software development. (NATO Accounting Framework: 2016). What is crucial is the implementation of the policies and standards.

In the US for example, the Best Buying Power (**BBP 3.0)** initiative is designed to improve the DoD's performance. R&D efforts are conducted by government labs, non-profit research institutions, and defense companies

[10] International Public-Sector Accounting Standards

(both large and small). Innovation also comes from the commercial sector and overseas. Successful utilization of these sources of innovation and technology, does not depend on the policy but on the professionalism of the people who implement it (US Under Secretary of Defense AT&L: 2015).

The **returns** on NATO defence investment on STI could be separated into two types. The first concerns **tangible** benefits to the member nations that are mostly indirect via savings on internal R&D costs, or technology spillover effects and technology transfer across member nations (boosting national economies and employment rates) or via sharing and pooling of resources for common projects. The second is merely political and geostrategic, where the benefits are considered rather **intangible**, in form of achieving strategic goals and establishing/maintaining long-term peace in NATO's joint area of operations. Both types of benefits are equally important since the first provides the incentives for NATO nations in today's new world order to achieve the collective strategic goals of the second.

If the Alliance were to attempt to evaluate its intangible assets (technological innovation, or even copyrights and patents) the process would be quite challenging. Civil corporations would convert future benefits to a discounted amount by either capitalizing a single period of benefits or by discounting a future stream of benefits. Tools such as the weighted average cost of capital (WACC) or the internal rate of return (IRR) to the investor are income models that cannot have the same meaning for a non-profit intergovernmental organization. Companies also measure their return on their intangible assets such as technology R&D, by considering the average ROA and ROI indexes of the industry, the Net Present Value (NPV), or even the Pay-Back-Period.

NATO STI however, is not actually competing with industry, as its purpose is different. We can assume that member nations (as the principal stakeholders) should not expect any tangible profit although in today's global financial environment they do set some minimum tangible loses. For the European side of the Alliance, such measurements are more complicated than the other side of the Atlantic. According to the European Commission, each euro invested in defence generates a return of 1,6 particularly in skilled employment, R&D and exports (2016). This is a generic statement that represents measurements of average figures. If for instance, major international companies such as Lockheed, BAE Systems, Thales, Raytheon, General Dynamics, Leonardo, (just to name a few), are succeeding in gaining major NATO defence contracts, this could be converted indirectly into **returns on investment** for the respective nations through their national defence industry (contribution to tax returns, unemployment rates, etc.). This argument would apply mainly to the nations that have significant and competitive defence industry. Defence offsets on the other hand, can be a contractual burden for the exporter with disadvantages on employment, co-production and technology transfer issues. For "smaller" member nations, national contribution to NATO STI programs does not reflect any relatively significant tangible returns. In their case, the actual benefits come from **access to scientific knowledge**, newly developed technology, and **transfer of the know-how** as shareholders of the stock of this knowledge. R&D returns apply indirectly over time as that technology increases collective defence capabilities, potentially applied in an "Article 5" case scenario, (commitment of mutual protection and solidarity within the Alliance).

With regards to rate of returns on public research, according to most studies, the overall value that is generated, is 3 to 8 times the initial investment over the entire life-cycle of the investment. Public sector research has a positive effect on productivity, and according to a study on major OECD countries for the period 1980-1998 (Dominique Guellec and Bruno van Pottelsberghe de la Potterie: 2001), the long-term elasticity of government and university research on productivity is ~17%. In the same study, the effect of universities is higher because government scientific laboratories usually have non-economic objectives such as supporting defence (Georghiou:2015).

After the product development and prototyping phase, defense production seems notorious for its general inefficiency and high costs which have inevitable consequences on productivity (Draca, 2012). If it is so common at national level, we can imagine the complexity at NATO level. This phenomenon partly explains the behavior of member nations and their skepticism on committing and allocating funds in common STI investment.

5. CONCLUSIONS

Trying to forecast the cost curve of a new technology in the defence sector is partly a derivative of science, partly a kind of art charisma of the individual, and partly a coincidence of events with a fortunate interpretation of external factors. The Alliance has a great challenge to capture all three aspects. The STI related expenditure although it is of high long-term strategic value for NATO, highly depends on national decisions and priorities. This expenditure, therefore can have a big dose of volatility and uncertainty based on multi-disciplinary factors in the framework of a dynamic political, economic, social and technological environment.

Returns on STI is not a matter of profit or managing earnings as it might be the case for industry and private sector. The actual capitalization of defence STI within NATO is the confirmation of the added value to the Alliance and its sustainable military capabilities that ensures military deterrence. ROI on scientific research is the accumulated knowledge that is created among the scientific community. Information & knowledge management plays a critical role at this stage. As a result, scientists and engineers get closer to something innovative, to a breakthrough technology that might be disruptive for the military environment, or perhaps closer to the "next big thing". Effectively this knowledge becomes a precious intangible asset for NATO, in form of intellectual capital, and capitalization of the intangible returns can only be achieved in the "market" of the future battlefield (land, air, sea & cyber). The challenge is to maintain this type of asset that derives from **corporate culture**. The shift of the creative part of STI investment towards industry, creates a risk of losing its knowledge capital, or what Arthur (*2009, p.160*) is calling ***"shared unspoken culture of common experience"***.

Today, large global military powers are in a new armaments race that goes hand-in-hand with a military technology race affected by rapid developments on private or public sector, which contradicts the skepticism of many member nations, especially those suffering from global economic turbulence. This contradiction represents a contrast of economies of scale versus societies of scope. Because this complex and paradoxical situation requires policy makers and national decision makers to ensure **maximum value for money** for their tax-payers, it is for the benefit of the Alliance to seek synergies and productive collaboration on common STI programs.

Nevertheless, as today's scientific development reflects more dual-use technological achievements, STI investment contributes also to social returns, in form of growth, productivity, consumption rates and employment rates, due to technology spillover and knowledge transfer. On the contrary, in a disruptive global environment, use of advanced technology by non-state actors has increased exponentially, leading to loss of **government monopolies** over military technology. Finally, exploitable information and knowledge in form of intangible assets, creates a new environment that disrupts the conventional processes in STI defence investment.

The mission to provide secure environment to NATO allies is not a business strategy or a political agenda and is not compared with any political cost nor with any lost opportunity cost. The members of an enlarged Alliance are once again called upon to proactively work together on defence STI and ensure maximization of efforts on scientific research and innovation for defense purposes. Today, in a socio-economically unstable world of rapid-pace technological change (driven by consumer demand), a robust management of intangible assets is required by NATO to defend its members from another technological surprise.

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The authors take full responsibility for the contents and scientific correctness of the paper.

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Annex I

Table 1.

Distribution of defence expenditure on Equipment (including Defence R&D) 2017e

NATO Member	% of total Def_Exp 2017e	Amount (million $) of_Exp on Equipment (Actual) 2017e	20% of Def_Exp (Expected) 2017e	Δ amount 2017e Actual Vs Expected	Δ in % (2017e) reference to the Expected Guideline
Albania	17.33%	$26.3358	$30.3935	-4.057618125	-13.35%
Belgium	5.30%	$228.0764	$860.6525	-632.5761133	-73.50%
Bulgaria *	29.54%	$242.4913	$164.1945	78.29676757	47.69%
Canada	19.42%	$3,946.1046	$4,062.9567	-116.8520846	-2.88%
Croatia	9.07%	$192.1346	$130.2465	61.88812081	47.52%
Czech Republic	12.90%	$273.1877	$423.7042	-150.5164939	-35.52%
Denmark	19.25%	$705.9716	$733.4756	-27.50399174	-3.75%
Estonia	19.27%	$99.9645	$103.7330	-3.768439642	-3.63%
France	24.17%	$10,714.2718	$8,866.5678	1847.703973	20.84%
Germany	14.08%	$6,035.7010	$8,575.0247	-2539.32371	-29.61%
Greece	15.44%	$705.9791	$914.4754	-208.4963221	-22.80%
Hungary	13.29%	$180.1037	$270.9921	-90.88846308	-33.54%
Italy	20.94%	$4,722.6496	$4,511.5646	211.0849498	4.68%
Latvia	20.29%	$98.7341	$97.3164	1.417711875	1.46%
Lithuania	31.09%	$244.1701	$157.0947	87.07533378	55.43%
Luxembourg	32.99%	$91.5845	$55.5223	36.06227172	64.95%
Montenegro	8.20%	$5.8916	$14.3635	-8.471971701	-58.98%
Netherlands	16.80%	$1,583.8644	$1,885.2699	-301.4055012	-15.99%
Norway	25.65%	$1,618.5389	$1,261.8318	356.7071455	28.27%
Poland	22.50%	$2,249.4081	$1,999.4574	249.9507172	12.50%
Portugal	10.31%	$280.9388	$545.2092	-264.2704195	-48.47%
Romania	46.49%	$1,786.9952	$768.7486	1018.246647	132.46%
Slovak Republic	20.16%	$219.6478	$217.9560	1.691760902	0.78%
Slovenia	6.09%	$28.1400	$92.3596	-64.21953795	-69.53%
Spain	19.31%	$2,250.4874	$2,330.9054	-80.41803489	-3.45%
Turkey	30.40%	$3,743.6749	$2,463.0508	1280.624044	51.99%
United Kingdom	22.03%	$12,087.6564	$10,972.5985	1115.057863	10.16%
United States	28.55%	$195,087.0790	$136,682.8000	58404.279	42.73%

* Defence expenditure does not include pensions.

- Amounts are in current prices and exchange rates (NATO Press Release, PR/CP(2017)111, 29 Jun 2017, https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2017_06/20170629_170629-pr2017-111-en.pdf)
- NATO uses US dollars (USD) as the common currency denominator. Exchange rate applied to each Ally is the average annual rate published by the International Monetary Fund (IMF) and estimates from the OECD for the current year.
- Conventional sign: e = estimated

Note to readers (as per source report):
Iceland has no armed forces. For nations of the Euro zone, and Montenegro, monetary values in national currency are expressed in Euros for all years. Estonia adopted Euros from 2011, Latvia from 2014, and Lithuania from 2015.
To avoid any ambiguity, the fiscal year has been designated by the year which includes the highest number of months: e.g. 2016 represents the fiscal year 2016/2017 for Canada and United Kingdom and the fiscal year 2015/2016 for the United States. Because of rounding, the total figures may differ from the sum of their components.

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