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Project Report

Defence Research & Development: Lessons from NATO Allies

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Abbreviations

AUV – Autonomous Underwater Vehicle
C2 – Command and Control
CBRN – Chemical, Biological, Radiological and Nuclear
CD&E – Concept Development and Experimentation
CHOD – Chief of Defence
COTS/MOTS – Commercial Off-the-Shelf/Military Off-the-Shelf
DALO – Defence Acquisition and Logistics Organisation (Denmark)
DERA – Defence Evaluation and Research Agency (UK)
DSTL – Defence Science and Technology Laboratories (UK)
EBO – Effects-Based Operations
EDA – European Defence Agency
EDF – Estonian Defence Forces
ESDP – European Security and Defence Policy
EU – European Union
FFI – Forsvarets Forskningsinstitutt (Norwegian Defence Research Establishment)
FSi – Forsvars- og Sikkerhetsindustriens Forening (Norwegian Defence and Security Industries Association)
GDREs – Government Defence Research Establishments
HCSS – The Hague Centre for Strategic Studies
ICT – Information and Communication Technology
IEDs – Improvised Explosive Devices
KAs – Knowledge Areas
KEs – Knowledge Elements
MOD – Ministry of Defence
MOI – Ministry of Interior
NATO – North Atlantic Treaty Organisation
NCW – Network-Centric Warfare
NDLO – Norwegian Defence Logistics Organisation
NEC – Network Enabled Capabilities
R&D – Research and Development
R&T – Research and Technology
RTO – Research and Technology Organisation
S&T – Science and Technology
SMEs – Small and Medium Enterprises
TNO – Netherlands Organisation for Applied Scientific Research
UORs – Urgent Operational Requirements
WMD – Weapons of Mass Destruction

Executive Summary

In conjunction with general trends, the report explores the approaches of three small NATO allies – Denmark, Norway and the Netherlands − to defence R&D and draws lessons for developing this field in Estonia. It attempts to answer why and what defence R&D activities these nations pursue and how these activities are organised. Firstly, the report examines the rationale for conducting defence R&D in knowledge-oriented defence organisations. It is found that the strategic utility of defence R&D derives from its contribution to mitigating the risks and uncertainty in national security and defence strategies, to improving military capabilities and to supporting 'intelligent customer' behaviour of the armed forces. In addition, R&D plays an increasingly important role in delivering interagency solutions in the age of asymmetric threats and in promoting greater integration into NATO and the EU, while supporting innovation in national defence industries. However, such multifaceted uses of defence R&D are often hampered by poor appreciation of opportunities and possibilities opened by it and by the short-termism and the excessive 'buy off-the-shelf' attitude in various quarters of defence organisations. The existence of a knowledge-oriented organisational culture and the focus on continuous innovation within defence systems are identified as critical factors for successful integration of defence R&D into national security and defence policies.

Secondly, the report analyses the factors that shape the defence R&D agenda of a country, such as its security policy, defence posture, technological ambitions, dominant scientific and military paradigms, existing knowledge base and available resources. It is revealed that the focus countries of the study seek to combine a broad scope of research (in order to support technological foresight and awareness) with niche specialisation in several areas (in order to concentrate resources and achieve excellence), which is necessary for *quid pro quo* knowledge sharing within the Alliance. A defence R&D agenda emerges through a highly structured and iterative process of determining the knowledge needs and gaps of a country and of finding ways to address them. The need to focus on applied research is emphasised, together with the relevance and quality of its results and the early involvement of the defence industry, which makes it possible to ensure commercial success of R&D projects. The study also reveals that some funding is necessary not only for demand-driven projects, but for 'free play' with ideas in the R&D community to encourage work on high-risk and high-impact innovative ideas that may transform certain security and defence capabilities dramatically.

The framework of defence R&D governance is also examined, following such principles as the openness and fusion of military and civil, public and commercial, national and international knowledge networks, the mobility of people and competitiveness in knowledge markets. It is found that some degree of centralisation in defence R&D management is common in all the focus countries, as it facilitates knowledge brokering between different knowledge producers and users, creates a reliable environment for transactions and ensures better accountability. However, organisational arrangements may vary from full ownership and control by the MOD (with defence R&D being part of a larger specialised agency or forming a separate dedicated agency within the defence organisation) to public ownership (with the MOD being only one stakeholder and customer among many). The report discusses potential advantages and disadvantages of these models. On the basis of its findings and analysis, the report makes a number of recommendations on how to stimulate and link demand and supply of R&D products, how to refine national defence R&D agendas and how to improve the framework of defence R&D governance.

Introduction

The increasing pace of scientific and technological development represents a great challenge to military organisations aspiring to stay at the cutting edge of technology. Large governmental defence research and development establishments (GDREs) and military laboratories, created in many countries decades ago with the purpose of helping to maintain technological superiority of their armed forces, used to play a leading role in producing radical technological innovations, which were subsequently adopted by the civil sector. This is no longer the case: the civil and commercial sectors have become much more vibrant and productive sources of knowledge and innovation, turning the military into a client who relies ever more strongly on commercial producers of new technologies.

As a result, fundamental questions are being asked about the future of GDREs and the defence research and development (R&D) domain in general. These questions are even more pertinent to small countries with small national knowledge base or with little defence R&D tradition. Policymakers in such countries are confronted with certain dilemmas and choices which, although of seemingly marginal importance today, may have very serious and disproportionately large strategic repercussions in the future. Three major problems can be summarised as follows:

- Should countries conduct any defence R&D activities at all? Why? What should be their role in national defence policies and management?
- What should be the nature and scope of a country's defence R&D function? How many and what kind of defence R&D activities should be pursued?
- How should defence R&D functions be governed, taking into account the general trends in innovation management and in defence R&D in particular?

This research report aims to explore the choices and approaches taken by some small NATO allies in order to draw relevant lessons and recommendations for Estonia. The report's focus countries are Denmark, Norway and the Netherlands, which share many fundamental philosophical views regarding the above questions although sometimes diverge in their practical approaches. The choice of the focus countries was determined by several factors, such as the relatively small size of these countries and their armed forces (even though in this respect all suitable countries would still be larger than Estonia in terms of GDP, defence budget or military force); the strong emphasis on knowledge society and innovation; the transatlantic orientation of their defence policies (membership in NATO), although they have varying relationships with the ESDP[1]; and the progress being made in transforming military capabilities.

In pursuing its aim, the report had to consider a broad variety of terms in connection with the study's area of interest. The terms most often used in literature and official documents are 'science and technology (S&T),' 'research and technology (R&T)' and 'research and development (R&D),' which all are different in scope, but when taken together, cover the entire innovation process – from basic research (invention) to training and education.[2] The report also views R&D as closely related to the pursuit of new knowledge because it "involves something done and understood for the first time" (Ince, 2009). Therefore, the paper often refers to the terms used in knowledge management such as 'knowledge creation' and 'knowledge sharing' when discussing the purposes and uses of defence R&D.

The report employs the R&D concept as central to its theme, thereby mostly focusing on the management of basic and applied research as well as experimental development activities, but it nonetheless adopts the stance that any reasonable approach to the use of R&D has to take into account the entire iterative process of innovation that occurs in and around military organisations. If defence R&D is not embedded in a broader framework of defence and national innovation, it is bound to produce little effects and continuously upset the expectations of policymakers and military practitioners. The study often uses the terms 'defence innovation' and 'defence R&D' interchangeably, thus underscoring their close relationship.

This study is exploratory rather than comparative in its nature: it seeks to identify and discuss the underlying conceptual issues, practical problems and their solutions, some of which affect all focus countries and some of which are different in each focus country. It neither follows a strict comparative methodology nor presents a great deal of quantitative data to compare the focus countries. It is concerned primarily with the arguments, logic and concepts behind various choices in defence R&D policies and strategies.

The report draws on relevant literature about the general trends in defence R&D in conjunction with the insights derived from a series of in-depth interviews with the representatives of the ministries of defence, defence research establishments, defence industries, think-tanks and the armed forces of the focus countries (in total 15

[1] Denmark has sought an opt-out from the ESDP and therefore it does not participate in the activities of the European Defence Agency (EDA); Norway, without being a member of the EU, is involved in the ESDP and the EDA by special arrangement; the Netherlands participates fully in the ESDP and the EDA.
[2] See the analysis of terms and their scope in Rademaker et al (2009: 7–8).

interviewees who represent both civil and military sectors and whose thoughts are treated following the non-attribution principle). The report is divided into four chapters. The first three chapters address the questions formulated above. Lessons for Estonia are presented in the fourth one. The report ends with conclusions and recommendations to defence policymakers in Estonia on how to refine further the Estonian national defence R&D policy and strategy.

1. The rationale for defence R&D

The questions why defence R&D is important and what role it plays in military organisations are fundamental. Given that much of what the armed forces need can be procured on the market, without having to bear the costs and risks of development and without losing precious time, these are legitimate questions, with which to challenge the governmental defence R&D function. This chapter analyses whether governments should continue investing in defence R&D, using the approaches taken in the three focus countries to illustrate the points made.

1.1 General purposes of defence R&D

Generally, R&D is associated with one of the constituent dimensions of a national defence strategy − technology. Given that “poor performance on any dimension has the potential to wreck the entire strategic enterprise” (Gray, 2002: 124), the role of science has to be thought through very carefully. The strengthening of the technological pillar of strategy and the acquiring or maintaining of technological superiority over existing or potential adversaries have often proven to be impossible without an extensive set of R&D programmes.

However, there is also a strong tendency to treat R&D, just as innovation in general, not only as a tool for supporting technological state-of-the-art growth of the armed forces. Innovation may encompass changes in non-technological aspects such as processes, methodologies, models or concepts as well (Conway & Steward, 2009). These changes often stem from the need to acquire knowledge by means of thorough and methodical research, followed by the development of new or improved policies. The improvement or transformation of those aspects of defence not related to technology, such as military organisation and administration or military operations, often has to rely on R&D in so-called ‘soft,’ non-technological areas.

When it comes to the technological pillar of strategies, sustained across-the-board investments in defence R&D have been either a privilege of some very resourceful nations (e.g. the United States) or an imperative to those countries that have pursued the highest possible degree of strategic sovereignty and have therefore developed a significant national defence industrial base over time (e.g. Sweden).[3] However, most non-technological defence R&D activities are well within the reach of small nations, which have limited resources but endless desire to seek new knowledge and to build flexible adaptive knowledge-based military organisations.

Once the role of R&D in creating and maintaining cutting-edge knowledge and technology for the armed forces is recognised, the critical question arises whether defence organisations should treat themselves as active knowledge creators or only as consumers of ready-to-use products, procured on the market and already reflecting the outcomes of R&D undertaken by suppliers. In short, should governments invest in R&D rather than just obtain knowledge and technologies from a plethora of suppliers?

Contemporary trends, such as the dominance of civil and commercial sectors in producing innovations and the globalisation of industrial supply chains and innovation networks, make military knowledge and technology more widely and easily accessible to both states and non-state actors. As a result, even big nations often think that the acquisition of commercial or military off-the-shelf (COTS/MOTS) technology offers a better way for satisfying their technological needs in the field of defence, for cutting costs and for reducing the time needed to build military capabilities, especially in connection with urgent operational requirements (UORs).[4]

Most of NATO allies have thus become more and more reliant and dependent on the commercial sector's willingness to invest in R&D in order to develop novel military applications and "on the capacity of the defence innovation system to spin-in technologies as a means of capturing the benefits" of commercial innovation (James, 2006: 232). However, such reliance, if mismanaged and not supported by appropriate in-house competences, may equally turn governments and the armed forces into 'dumb' customers, incapable of properly appreciating what is available on the market, what is being purchased or how to use technology or knowledge sourced from outside.

In addition, at least in alliances like NATO, which are built on trust and mutual support, it makes little sense to pursue national defence R&D programmes that are designed solely for national purposes. Mutual security dependence of the allies enables and indeed calls for extensive knowledge sharing and fusion across national boundaries with the help of such knowledge brokers as the NATO Research and Technology Organisation (RTO). The Alliance's common capabilities projects also require R&D efforts by all allies rather than

[3] 'Strategic sovereignty' is defined as "the ability of national government to exercise sovereign discretion in deciding how to use the military assets at its disposal in responding to a national security challenge" (Wylie et al, 2006: 260).
[4] See, for instance, Neal & Taylor (2001) on changes in the U.S. defence industrial base and R&D dynamics.

nationally focused undertakings. National defence R&D activities in various nations are thus increasingly shaped by the needs of the entire Alliance (and the EU, if a nation is participating in the activities of the EDA), although "national interest remains a potent constraint on cooperation where research and technical information is seen as having important military or industrial advantage" (James, 2006: 235).

It must also be noted that the boundaries between defence and broader security have become blurred in the defence R&D paradigm. In essence, the meaning of the concept of comprehensive security, with military and non-military aspects interwoven, is that knowledge and technological needs of various agencies (the police, intelligence services and the military) and security functions (anti-terrorism, protection of critical infrastructure, etc.) overlap to a certain degree. Since the 9/11 attacks in particular, the defence R&D focus has been shifting from big weapons systems to intelligence, detection, data analysis, protection and similar issues (Trajtenberg, 2006). Therefore, it makes more sense to draw investments to certain R&D projects and programmes from diverse sources, instead of relying just on defence funding. The benefits of the interagency approach are decreased, however, by the fact that the armed forces still retain a unique function and, as a result, a set of distinct knowledge requirements.

Finally, the fast pace and the diffused nature of scientific and technological developments also have an impact on the perceived role of defence R&D. Defence planners are confronted with much greater uncertainty in their defence planning cycles, stemming from faster technological, organisational, social and economic changes and the fluid character of the security environment.[5] As it is increasingly difficult to anticipate the future needs of the armed forces in connection with knowledge and technology and to address these needs properly, it is impossible to eliminate the risk that some disruptive developments and events will radically transform warfare or the demands placed on the armed forces in managing national security. Failure to consider such risks and to hedge against them may render the armed forces or even the entire security apparatus of a nation ineffective at a critical moment and may thus have catastrophic consequences for national security.

Together with other factors, these broad trends – the dominance of civil and commercial sectors in producing innovations; the pursuit of multinational and interagency solutions; and increased uncertainty in many strategic aspects – have given rise to several inter-related reasons for conducting defence R&D. These reasons are the following:

[5] Fukuyama (2007) analyses the nature of uncertainty, strategic surprises and the difficulties connected with their management from many different angles.

- To assist policymakers in managing uncertainty and hedging strategic risks (security and technology analysis and foresight);
- To address the unique needs of the armed forces (to support capability development, maintenance and use in operations);
- To help the armed forces to fulfil the role of a 'smart buyer'/'intelligent customer' (to support defence acquisition and spin-in processes);
- To promote integration into the Alliance (*quid pro quo* knowledge sharing and participation in common capabilities projects);
- To deliver new knowledge and technological solutions for interagency uses (to support comprehensive security).

In addition, the strengthening of a national defence industrial base is still considered to be an important reason for investing in defence R&D, especially if the development of the defence industry is part of a national state-driven economic development strategy or if the strategic sovereignty argument plays an important role in the security policy of a country. The latter is less of an issue for the nations that belong to a collective defence alliance and treat their security and defence as highly dependent on allied support and assistance.

However, it must be noted that the importance of the above reason is decreasing as far as governmental defence R&D programmes are concerned partly because the effect of such spending as a springboard for the defence industry or general economic development is often being questioned (James, 2004). Furthermore, state-centric and state-driven approaches are being supplemented by flexible public-private partnerships and private investments in R&D.

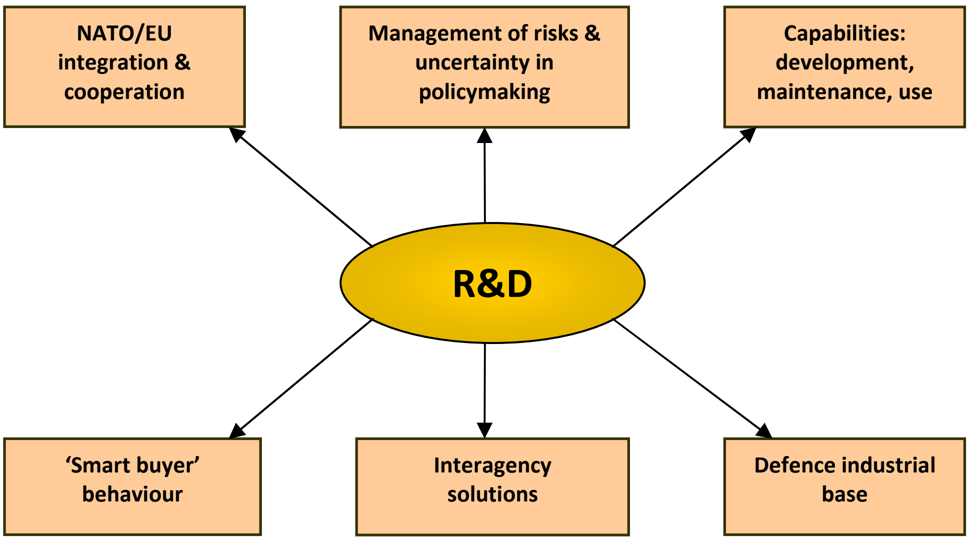

Figure 1. The role of R&D in security and defence.

1.2 The role of defence R&D in the focus countries

Among the three focus countries, **Denmark** is the only one that has the image that it does not invest significant effort and resources in defence R&D. Such a perception was prevalent both inside the country – among members of the Danish armed forces – and outside it – among the R&D community of the Alliance. It was suggested that the lack of a serious defence R&D ambition in Denmark is commensurate with the small size of the Danish armed forces and its defence industry (which concentrates mostly on the production of components and sub-systems). It is also understood that the importance of investing in R&D is further diminished by the policy of relying on COTS/MOTS technologies.

A superficial examination would suggest that Denmark has made a conscious choice to maintain only a symbolic defence R&D programme. However, the conclusion that Denmark 'does not do defence R&D' is quite unfair: Denmark makes efforts to maintain this function, although these are not as visible as they might be. Denmark's defence R&D programme, even though it might be modest compared to the other two focus countries, reflects most of the fundamental reasons for performing defence R&D listed above.

A strong emphasis is placed on the requirements of the military: R&D project proposals usually relate to the military needs that have been identified during operations or through a long-term planning process. In addition, researchers employed by the defence organisation contribute to enhancing the competence of the Danish armed forces as a 'smart buyer' by providing advice on procurement projects and by offering guidance on additional development work by technology suppliers, if necessary. Security and technology analysis and corresponding foresight activities are also carried out in Denmark to support defence planning.

By far the most powerful reason for Denmark to engage in defence R&D is, however, the imperative to contribute to knowledge creation within NATO as a prerequisite for winning the trust and respect of the allies, which would enable Denmark to gain access to ideas and solutions conceived and developed by them. Consequently, about a half of Denmark's defence R&D programme is dedicated to ensuring *quid pro quo* sharing of knowledge and technologies. (The R&D community in Denmark regrets that due to Denmark's opt-out from the ESDP, it also misses out on the opportunities now available for such sharing and collaboration through the EDA.)

Even with access to available knowledge within the Alliance's networks, it is admitted that improvements are necessary in the ability of the Danish armed forces to absorb knowledge that is available to them by virtue of Denmark's participation in NATO's research and technology programmes and projects. This illustrates the problem of knowledge diffusion or 'absorptive' capacity (see Chapter 3) in defence organisations. In this respect, there is a growing appreciation of the need to enhance skills of the armed forces in managing knowledge and technology as an integral part of strategy and operations, with special emphasis on the improvement of training and education in this area.

In contrast to the modest ambitions and the low-key profile of defence R&D in Denmark, **Norway** maintains a rather elaborate set of defence R&D programmes. Its well-established defence research tradition is associated with its defence and defence-related industry, which is relatively large for such a small country. [6] This industry has strong historical roots and has gradually built excellence in several areas of military technology. It therefore comes as no surprise that the support to the defence industrial base as a rationale for defence R&D is most pronounced in Norway (out of the three focus countries). Collaboration between the research community and the defence industry is considered to be very successful both in terms of satisfying the needs of the Norwegian armed forces and of maintaining the international competitiveness of the Norwegian defence industry. The involvement of the defence industry in defence R&D projects at an early stage is considered to be necessary in order to induce their economic realism and to ensure the commercial viability of their output.

At the same time, other strategic reasons for conducting defence R&D activities are also strongly represented in Norway's approach to the role of R&D in defence policy. Competence in technology analysis and foresight, built on R&D activities, serves as a critically important source of advice for defence policymakers and planners in decision-making processes with regard to future capabilities and management of potential security and technology risks. The technology policy framework for the armed forces is usually developed by the MOD in close cooperation with the defence R&D organisation.

As is clear from the above, defence R&D is employed in crafting Norwegian defence policy and it is quite well integrated into long-term defence planning. Although the interagency cooperation aspect did not come up in the course of the research, its existence can be deduced from the facts that about 10% of defence R&D spending comes from non-military sources and that terrorism is one of the central themes in defence R&D. International cooperation, both bilateral (especially with the UK, the Netherlands, the US, and, to some extent, Sweden and Finland) and multilateral

[6] The Norwegian Defence and Security Industries Association (FSi) has around 150 members (85% of them are SMEs). Four or five companies among them are systems integrators and main contractors.

(through the NATO RTO and the EDA), was very strongly emphasised as a means to expand Norway's defence knowledge base and as a reason for maintaining the excellence of its defence R&D.

The relevance and responsiveness to the requirements of the armed forces were perhaps the most strenuously highlighted aspects of sustaining Norway's efforts in the area of defence R&D. Indeed, national defence authorities usually refuse to support R&D projects that do not reflect military requirements, which have been identified on the basis of operational commands or have been defined by defence planners or managers of military capabilities. R&D is seen as playing a great role in ensuring that the Norwegian armed forces behave as a 'smart buyer,' able to obtain good value for money, while investing in technologies that will be of relevance in the future.

The role of the defence R&D community is equally important in addressing both the pressing challenges of the armed forces, which have been identified during ongoing operations or routine exercises, and in creating novel solutions and integrating them into the development of military capabilities. For this purpose, the defence R&D community in Norway interacts with Concept Development and Experimentation (CD&E) activities of the Norwegian armed forces. As CD&E is an iterative process with multiple inputs and feedback loops, it allows the defence R&D community to link its ideas about new technologies or technological improvements with the military's ideas about doctrinal or organisational changes and to test them as an integral part of the overall military innovation system.

Similarly, defence R&D has a high profile in **the Netherlands**, where it stems partly from a general ambition of state authorities to foster innovation in public and private sectors. This is achieved by making R&D an integral part of Dutch defence policy and planning and by using defence R&D results to foster growth in new innovative industries (by means of spin-offs) and to strengthen the competitiveness of the existing defence industry. The ability to cross-fertilise and inter-change outcomes of R&D investments between public and private sectors and between military and civil domains as a means to promote general innovation in the society lies at the heart of the Dutch approach to the defence R&D function.

At the policy and planning level, the interagency aspect is perhaps most emphasised in the Netherlands: the Future Policy Survey – a strategic planning tool, used by the Dutch government in the security sector – involves several ministries (the Ministries of Defence, Interior, Justice, Development Cooperation and Finance) and R&D is a distinct part of it. There is also common knowledge base being developed between the MOD and MOI to cover the areas of joint responsibility and interest, such as counterterrorism and CBRN defence. So, in the case of the Netherlands, it is in a way more appropriate to speak about 'security and defence R&D' rather than just 'defence R&D.'

On the other hand, the shaping of the desired future profile of the armed forces and the fulfilment of military requirements still remain central to security and defence R&D efforts. The defence posture review and concomitant changes in capability requirements usually trigger the analysis of knowledge requirements of defence organisations and lead to the redefinition of defence R&D investment priorities. Thus the development of military capabilities plays a substantial role in the Dutch approach to the rationale for defence R&D.

The usability of R&D results is one of the key criteria for judging success of the national defence R&D programme. In this regard, the role of R&D in building knowledge necessary for the mitigation of technological risks in a long-term defence policy is strongly emphasised. The ability to anticipate technological developments and their implications also enables the R&D community to provide independent advice to decision-makers in defence procurement processes, which reflects the role of R&D in helping the armed forces to be an 'intelligent customer.'

The linking of the R&D function with the operational concerns and problems of the armed forces is seen as an important element of maintaining the relevance of R&D for the Dutch military. Operational analysis and the participation of researchers in CD&E activities of the armed forces are instrumental in achieving this goal. However, it is reckoned that the intensity of both operational analysis and CD&E is too low in the Netherlands, compared to such countries as the UK or Canada. In this connection, the need for improvements has been identified, but this requires joint efforts by the armed forces and the R&D community.

The Dutch approach to security and defence R&D explicitly acknowledges that most of the relevant knowledge is created outside the military domain, so the military needs to possess a strong spin-in capacity or a capacity to adapt and apply that knowledge for military needs. However, some of the desired knowledge may be very specific and unavailable in the civil sector for use in the defence sector, and therefore has to be created separately by commissioning dedicated projects.

International cooperation is a powerful driver of defence R&D in the Netherlands. Dutch involvement in the EDA and the NATO RTO as well as its bilateral cooperation programmes with Norway, Canada, the UK, the US, Germany and other countries reflect the understanding that a purely national knowledge base is insufficient to advance innovation in the defence sector. The international dimension of Dutch defence R&D activities follow the same *quid pro quo* logic that was observed in the cases of Denmark and Norway: the Netherlands seeks to carve out a niche for itself in the Alliance, where its excellence would serve as a basis for knowledge and technology sharing and integration with the allies.

1.3 Challenges related to the fulfilment of defence R&D roles

In all three focus countries, certain difficulties are encountered by the defence R&D community when it comes to making a compelling case for using science and technology effectively and strategically for defence purposes.

The first major stumbling block is that defence policymakers and military practitioners are less and less able to understand science, the value of rigorous research and the opportunities that R&D investments create. The reason for this is that the background of most defence decision-makers and users is rooted in social sciences and humanities. As a result, they are poorly equipped for appreciating the contribution that research in, for instance, so-called ‘hard’ technical sciences could make to a defence strategy. To make matters worse, this is happening at a time when technology is getting more and more complex. Consequently, the R&D community observes a steady erosion of the capacity of the armed forces to define requirements for R&D and to use its results in order to create and manage capabilities in an intelligent way. Effective communication between the supply (R&D) and demand (military) sides has become a highly important issue.

Another perceived obstacle is the short-termism of the military: preoccupied with tactical and operational problems encountered in the ongoing operations, the armed forces seek ready-made solutions and quick fixes to address their UORs. Assuming that it may take years to bring R&D projects to fruition, they see little sense in turning to the R&D community for ideas and solutions.[7] Combined with their general lack of appreciation for the ‘added value’ created by defence R&D, this reinforces further the ‘buy off-the-shelf’ attitude in the armed forces and confines R&D to an advisory role in the procurement process.

However, according to many interviewees, this attitude ignores the reality that not all UORs can be satisfied by going to the market for ready-made solutions: such solutions are often simply absent. But it is often the case that the R&D community already

[7] To underline the long-term nature of R&D investments, findings of one British study are particularly relevant: this study confirmed that the quality of military equipment correlates strongly with the government’s R&D investments made around 10−25 years earlier (see Middleton et al, 2006). Although the impact of R&D on the quality of military equipment may appear to be of lesser importance to small nations, which produce little military ‘hardware’ themselves, it may be suggested that a similar correlation exists between long-term R&D investments and other aspects of defence (e.g. strategic personnel policy, military training, defence management, etc.).

possesses the necessary knowledge on how to address capability gaps, obviated by involvement in operations (provided, of course, that long-term research activities were undertaken to accumulate the knowledge). If collaboration between research, industry and military works well, novel solutions can be delivered to theatres of operations rather quickly.[8] The downside of this is that such solutions may come with a higher level of technological risks, which the risk-averse military may often find difficult to accept.

Last, but not least, the perceived utility of defence R&D for defence policymakers and the military might be affected by shortcomings on the supply side. In all three focus countries, it is acknowledged that even though scientists often have sufficient knowledge and expertise in those areas that are of interest to the armed forces, they sometimes do not have adequate understanding of military organisations, their functioning and requirements in order to be able to put their knowledge to practical use. In addition, their communication language often is too technical, making it difficult for users to decipher and grasp the relevance of existing knowledge. Effective communication and the involvement of knowledge brokers are seen as most important tools in addressing this challenge.

Summary of key points

- The convergence of various trends in innovation and defence management fosters a 'buy off-the-shelf' attitude in defence organisations and puts pressure on the defence R&D function in each country to better define its role and contribution.
- In advanced knowledge societies, the pursuit of new knowledge for security and defence purposes goes hand in hand with investments in both technological and non-technological R&D (processes, concepts, methods).
- Defence R&D rationale for small nations is multipronged: it enables small nations to manage future strategic risks sensibly, to improve military capabilities, to contribute to knowledge creation within NATO (and the EU, if it is in line with the national defence policy), to develop interagency solutions in a comprehensive security framework, to conduct 'smarter' procurement activities and to support the defence industrial base, if it exists.
- The acknowledgment of diverse defence R&D roles and strategic utility by defence organisations is contingent upon their general understanding of the 'added value' created by scientific research, their knowledge-oriented culture and their ability to look beyond short-term operational pressures.
- The relevance, usability and quality of delivered defence R&D solutions serve as the best arguments for appreciating the role and contribution of R&D. However, the armed forces need to develop mechanisms to integrate R&D into their CD&E programmes and a capacity to utilise R&D results effectively.

[8] Outside the focus countries, the UK MOD, concerned about how quickly UORs can be satisfied by industry sectors, is pondering the possibility of simplifying these requirements and of relying more on COTS/MOTS procurement – small NATO allies, such as the focus countries of this study, often see this as the only viable option. Nonetheless, British defence officials warn that too much simplification may result in equipping the armed forces for yesterday's wars and in diluting the R&D effort, thus undermining innovation and the possibility for novel applications making their way into ongoing operations (see Wagstaff-Smith, 2009).

2. Defence R&D themes

This chapter addresses the scope and themes of defence R&D, chosen as part of their R&D strategies by the focus countries. It starts with a general overview of the factors that determine strategic choices in R&D and then examines how these factors shape defence R&D agendas in the focus countries.

2.1 Factors that shape defence R&D agendas

Very few nations within NATO can afford to pursue a multidirectional in-depth defence R&D agenda and to maintain a large in-house research capability. Even the most resourceful allies often have to review their priorities and calibrate their R&D programmes accordingly. On the other hand, the reasons for pursuing defence R&D are quite compelling. In this connection, proper consideration should be given to the questions of what should be the national level of ambition in this area and what is necessary to ensure that R&D activities fulfil the expectations, elaborated in the previous chapter. In doing so, countries usually take into account the following set of factors (see Figure 2).

The security environment and security policy. For nations with considerable security and defence agendas outside the Alliance's framework (e.g. the UK or France), the strategic sovereignty principle is an important determinant of their R&D activities and the strategies of their defence industries, which are closely connected. Their defence R&D agendas are rather ambitious. However, for smaller allies, who rely heavily on the Alliance for security, interoperability with other allies, the building of transatlantic complementarities in knowledge and the fulfilment of the expectations of the Alliance are of much greater importance (Versailles & Merindol, 2006). These factors are more dominant in their defence R&D themes than aspirations for strategic sovereignty.

Defence posture. Knowledge needs are heavily influenced by what a nation wishes to use its armed forces for. The provision of support to the armed forces that concentrate on preparing for interagency expeditionary operations far from national territory dictates quite different R&D requirements than those that would apply, if they were focused on homeland defence. Readiness to engage in operations across the entire spectrum calls for a different R&D agenda than a focus on just one particular type of operations.[9] The effect of this factor is moderated by the NATO transformation agenda, which defines a unified framework for thinking about the future of defence. Nonetheless, national differences in defence posture and concomitant requirements

[9] See Rademaker et al (2009) for an analysis of 'armed forces profiles' and their impact on knowledge requirements.

concerning capabilities will persist and will continue to influence their choices in connection with defence R&D strategies.

Technological posture and ambitions. Technology foresight activities as a means to mitigate various risks, the provision of support to 'smart buyer' behaviour in defence procurement and assistance in competent and cost-effective management of military technology through its life-cycle impose certain requirements on defence R&D agendas. The definition of such an agenda in precise terms might represent a challenge: "[…] not a single country […] has been able to find a solution to identify clearly the nature of the skills that have to be maintained inside the administration in order for governments to remain a 'smart buyer' […]" (Merindol, 2005: 167). However, there is a general view that if a nation accepts the need for technology foresight or a 'smart buyer' posture, it must have at least some knowledge in many areas of science and technology by maintaining an S&T awareness programme.

The degree to which a particular nation wishes its armed forces to be at the cutting edge of military technology also shapes the scope and nature of its defence R&D efforts. On a scale of military innovation diffusion, some position themselves among innovators, some among 'early adopters' or the 'early majority', while some may find themselves among the 'late majority' or 'laggards' due to a lack of ambition or resources (or both). This stance determines, for instance, how much investment (if any) is directed towards high-risk and high-uncertainty development of pioneering technologies or radical concepts, for which a conservative military or a risk-conscious industry sector may have little penchant.

Dominant paradigms and paradigm shifts. New concepts regarding the use of military force often precede bursts of technological and doctrinal innovation. Similarly, scientific progress produces new technologies and their innovative applications in defence. Network Centric Warfare (NCW), cyber defence and automated warfare are all good examples of how paradigm shifts in science and in military affairs or fusion of several previously distinct technological areas create new themes for defence R&D, in which many nations are eager to acquire competence and capabilities. There is some 'peer pressure' in the Alliance to stay tuned to these developments and subscribe to the established paradigm. (Sceptics might argue that this often turns into a blind zeal to adopt new conceptual or technological fashions, which fade all too soon.[10]) National defence R&D agendas of small allies has to reflect broader trends in scientific and

[10] See, for instance, Vego (2006) for an excellent criticism of one of the conceptual fads – Effects-Based Operations (EBO).

military affairs, partially because not doing so would mean losing relevance and credibility in the Alliance's research collaboration and knowledge sharing networks.

Existing knowledge base. Although forward-looking organisations often systematically expanded their knowledge bases, the existing knowledge base – of a country in general and of its defence organisation in particular – is a significant factor in deciding on what defence R&D should focus. Each country has its own traditional or recently acquired strengths in civilian research, commercial and military expertise.[11] These strengths serve as a basis for defining the niches, in which defence R&D excellence is pursued, nurtured and shared with the allies.

Resources. The shortage of both financial and human resources is a key constraining factor for smaller allied nations. The observation that "defence R&D has obvious opportunity costs through the use of scarce scientific personnel and assets that could be used on civilian research" (Hartley, 2006: 169) is most relevant to them. On the other hand, the ability to combine civil and military innovation as well as private and public resources helps to alleviate this problem. As a general guiding principle, NATO nations are encouraged to spend at least 2% of their defence budgets on R&D. Even if this figure is achieved, the shrinking of defence budgets means that the nominal sums that are made available might only permit a very modest national defence R&D programme or that the allies have to join their resources to implement common R&D projects. At the same time, the size of a talent pool that science in general and defence R&D in particular could tap into might constitute an even greater constraint than budgets.

As the last point before proceeding with the defence R&D strategies of the focus countries, it should be noted that the determining of R&D agendas is not an entirely top-down process, which flows in one direction only. Figure 2 demonstrates that the outcomes of R&D programmes may have an impact on the factors that shaped the agenda in the first place. For instance, security and technology foresight may lead to insights, which prompt modifications in defence posture or even security policy. Radical innovations in one area can produce massive shifts in dominant military paradigms, thus unsettling the entire strategic R&D framework. There can also be a bottom-up flow of ideas from the R&D community, as to what new knowledge areas could be developed and exploited for defence purposes. All efforts to define defence R&D agendas therefore constitute an iterative process with multiple feedback loops.

[11] See Versailles & Merindol (2006) for an analysis of transatlantic complementarities in technology.

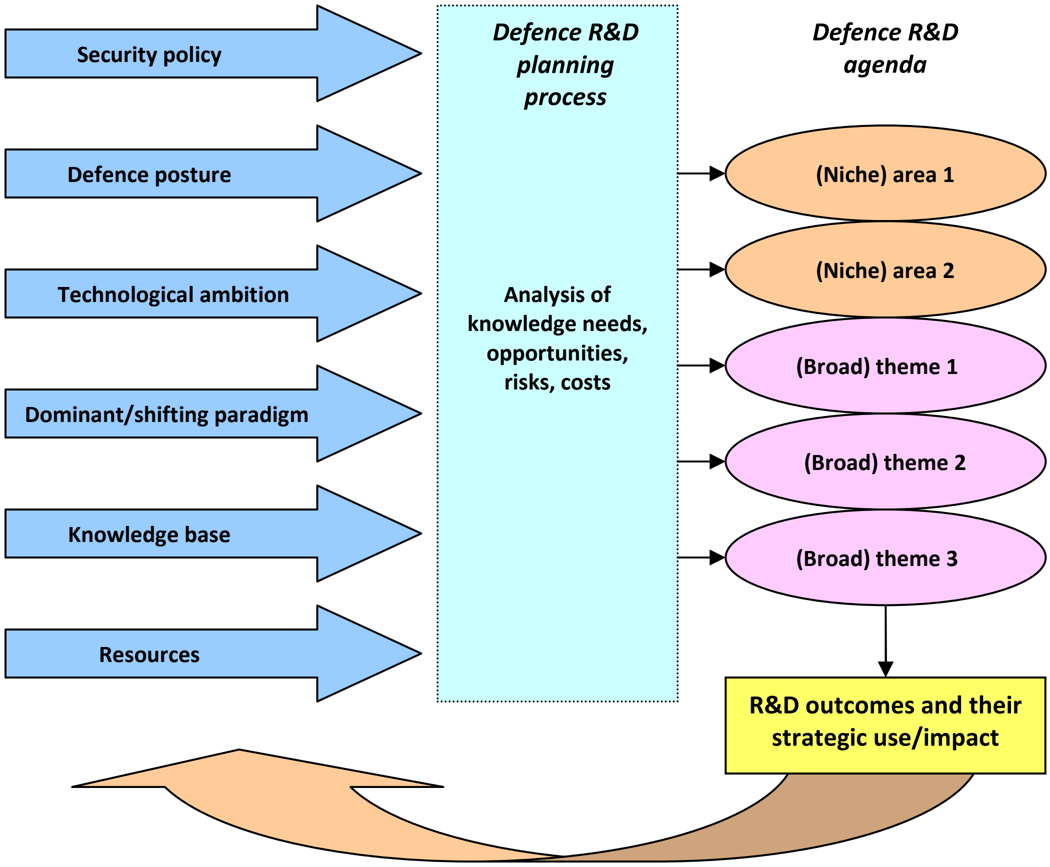

Figure 2. The factors that shape defence R&D agendas.

2.2 Defence R&D strategies in the focus countries

There is no formal defence R&D strategy in **Denmark,** although its R&D plan on the whole contains a few strategy-like points. It follows the principle of developing deep and specialised knowledge in several niche areas. As a rule, its defence R&D investments focus on applied research with the implicit understanding that basic research should be conducted outside the defence organisation, while defence R&D should primarily concentrate on the development of knowledge and applications of relevance and utility to the military.

As was mentioned earlier, the country relies heavily on its partners in the Alliance to address its knowledge needs – a practice which reflects its overall security policy. R&D specialisation in several fields contributes to NATO and enables bilateral *quid pro quo* exchanges, with the UK and the US as priority partners. Defence researchers and engineers also turn to the civil sector (universities, commercial companies) to fill knowledge gaps.

When it comes to specialisation, Denmark's geographical position (vast maritime areas, presence in the Arctic region) and related military missions have led to research and industrial excellence in radar technology, radar signals and signal processing. These represent the country's traditional R&D areas and technological strengths. However, the shift in its defence posture, whereby Denmark became heavily involved in international operations, meant that, for instance, force protection (including electronic warfare and a counter-IED capability) also became a significant component of its defence R&D agenda.

Danish defence R&D portfolio also includes various elements of C2 technology, which is partly related to Network Enabled Capabilities (NEC) and battlefield information management systems. In broad terms, this reflects the desire to be in tune with the technological and conceptual paradigm, which has come to dominate capability development in NATO. At the same time, very specific concerns about how to maintain coalition and inter-service interoperability during operations also play an important role in focusing on these issues in R&D. The fact that Denmark has had a project-based organisation for NEC since 2004 (which is being dismantled now) and is quite successful in NEC-related technology diffusion in the armed forces demonstrates that its level of technological ambition is relatively high. This serves, in addition to satisfying operational needs and reflecting NATO-wide trends, as an additional motivator for Denmark to focus on C2 technologies (including NEC) in its defence R&D.

Besides niche specialisation, there is a broad technological awareness programme, which supports understanding of future disruptive technologies and capabilities and provides input to 'smart buying' activities. In the course of the interviews, however, some criticism was voiced about this function, claiming that it has been eroded and that R&D has been excessively subordinated to procurement projects at the expense of providing advice to defence policymaking on future risks and threats (this criticism has been refuted by R&D managers). It is also quite limited in terms of dedicated human resources but, as was noted earlier, it is anyway difficult to judge the extent of knowledge and skills needed to ensure that technology foresight delivers on its promises.

The human resources of the defence R&D function within the defence organisation comprise around 30 scientists and engineers, who represent such areas of expertise as ICT, electronics, electromagnetics, electro-optics, sensors, etc. (This number does not include researchers working for the private sector or conducting research for such defence contractors as Terma.) Only one laboratory is owned by the defence organisation, with the rest of the needed capacity being available through agreements with universities and technical institutes. In terms of budget, the defence organisation provides for a half of the seed fund (18 mil DKK or ca 2.4 mil EUR) for the development of prototypes and experimental technologies, with another half supplied by the private sector.

As befits a country with a high profile in defence research, **Norway** has a clearly articulated defence R&D strategy, which is partly set out in the regularly revised and updated defence White Papers. The latest White Paper (No. 38, 2006-2007) laid down eight technological areas of priority, in which R&D efforts are necessary to build and maintain national competences and to support the development of military capabilities (see Table 1) (FFI, 2009). This list captures the traditional strengths of Norway's research activities and industry, due to which it has established its niche within the Alliance (ammunition, missile technology, maritime technology), its strategic position (dominance of maritime space, winter conditions, etc.), general military trends (NCW, automated warfare), the technological ambitions of the Norwegian defence organisation and its desire to develop state-of-the-art capabilities.

During the interviews, however, it was emphasised that in order to maintain the knowledge base and competences, which might be in demand in the future, scientists working for the MOD and the armed forces do not confine themselves to these eight technological areas. For the same reason of competence-building, their work is also not limited to applied research: basic research is also conducted within the defence R&D realm, even though R&D managers find it challenging to balance its long-term objectives with the more immediate focus on applied research. In addition, so-called 'soft' research topics – defence analysis, security policy studies, analytical methodologies, scenario development – are also integrated into the defence R&D function.

Partly as a reflection of the defined technological areas, but also due to the need to address other important roles discussed in the first chapter, the defence R&D agenda currently revolves around five main themes: transformation and CD&E (scenarios and structure analyses, concept and system development, modelling and simulation, etc.); terrorism and security in society (protection of society, protection against WMD, etc.); the introduction of network-based defence (information infrastructure, information operations, sensors, effectors, etc.); military operations (combat techniques, platforms, soldier equipment systems, safety and protection, logistics, AUVs, navigation, etc.); defence and security in the Arctic (surveillance and mapping, cold weather operations, etc.) (FFI, 2009).

As warranted by its relatively ambitious agenda, Norway's defence R&D function has been allocated the appropriate resources: 685 personnel (388 scientists, 79 research technicians, 10 research fellows). This number does not include the R&D personnel in the private sector or in civil research establishments, who are involved in defence projects. (The interviewees stressed in particular that the quality and the motivation of human resources were pivotal to the success of defence R&D.) The government's total defence R&D budget in 2008 was 664 mil NOK (ca 78 mil EUR or about 2.1% of the defence budget), a quarter of which was made up of a block grant, which was not intended to cover the costs of any specific projects, but dedicated to basic research, technology monitoring and foresight (FFI, 2009).

Regardless of such sizeable capacity and substantial resources, it is generally recognised that Norway's defence R&D function needs to cooperate with national and foreign non-defence governmental laboratories, universities and defence industries in order to achieve the desired effect. (The defence industry, for instance, provides some funding for basic research in materials science). In addition, international collaboration, as was pointed out in the first chapter, forms a significant dimension in Norway's defence R&D strategy. As a result, Norway's defence R&D function is part of a much wider innovation network, which it uses as a 'force multiplier' for its investments and efforts.

A similar approach, which combines a broad knowledge base with niche areas of specialisation, has been adopted in **the Netherlands**. Through a highly structured process of reviewing problems that need R&D solutions, its defence R&D strategy defines 4-year 'programme contours' and a number of so-called 'Knowledge Areas' (KAs) – areas where new knowledge was necessary and where resources were going to be focused on. (The taxonomy of KAs is helpful in assessing progress, seeing problems, linking R&D activities with research outside defence, etc.). KAs are often specified in greater detail by sub-dividing them into Knowledge Elements (KEs).

The current Dutch defence R&D agenda consists of eleven KAs (Rademaker et al, 2009) (see Table 1). This list, similarly to Norway's technological areas, also attempts to combine various factors that were discussed in the beginning of this chapter and to translate them into clear directions for R&D investments. Interestingly, in addition to such factors as the need for new knowledge, the existing knowledge base and the future profiles of the armed forces, the Dutch defence R&D function specifically takes into account national and international markets for R&D products that exist outside the Netherlands government as a customer. This reflects two strands of thinking: firstly, that the sources of income of a national defence R&D supplier should be diversified; secondly and conversely, that the Dutch MOD must have freedom to choose knowledge providers other than its main defence R&D agency.

In contributing to international collaboration networks and satisfying market demand, the Dutch defence R&D community relies on specific niches where it has achieved excellence: radar and sensor technology, human factors (behaviour under stress, etc.), systems integration as well as technologies and methods for modelling, simulation and experimentation. Research in human factors as a niche area should be underlined at this point because it seems to be a subject of growing interest in many NATO countries and in the NATO RTO (Walker, 2009).

The main focus of the Dutch defence R&D agenda is on applied research, although some funding is allowed to be channelled into cooperation with universities (e.g. the sponsoring of defence-related PhD projects, which could also be used as a recruitment tool), thus bridging out to the realm of basic research. Projects, which span the whole spectrum from basic research to the highest technology readiness level, are only conducted in exceptional cases (normally, the defence industry gets involved and takes over the development part quite early).

In terms of research capabilities and resources, the Netherlands have four large national laboratories (CBRN, technology analysis, radars and sensors, aerospace technology research) outside the armed forces and two smaller in-house facilities (army and navy ICT laboratories). The main defence R&D agency has more than 1,000 employees. Its funding comes from diverse sources, with the Dutch government and its departments (the Ministries of Defence, Interior, Justice, etc.) acting as a large contributor that provides 50 mil EUR in subsidies (which are currently being transformed into programme funding) and further 30 mil EUR for contracts secured through competitive bids. Another 50 mil EUR is drawn from other customers such as foreign governments, industry, the EDA, etc.

Although financial resources are normally tailored to customer needs (based on a ‘demand pull’), there is an understanding that there must also be some free funding available to play with new ideas, perhaps even without any success or immediate outcome. The ‘right to be wrong’ is seen as an element, without which it would be impossible to develop completely new applications or disruptive technologies (for which customers cannot articulate their demand because they cannot imagine them, although they would highly benefit from them). Therefore, about 15% of government funding supports ideas from the defence R&D side, without being related to any specific ‘customer requirement’.

Table 1. Defence R&D agendas of the focus countries.

Denmark	Norway	Netherlands
--Radar technology --Signals and signal processing technology --Force protection technology --C2: NEC, battlefield information management	8 Technology Areas: --ICT --Systems integration & architecture --Missile technology, autonomous weapon & sensor systems --Underwater technology & sensors --Simulation technology --Weapons and missile propulsion technology, ammunition & explosives --Materials technology --Maritime technology	11 Knowledge Areas: --Sensors (Knowledge Elements: radar sensors, electro-optical sensors, sonar and acoustical sensors, etc.) -- General situational awareness (KEs: sensor and data fusion, classification and identification, etc.) -- Operational decision-making (KEs: decision-making in teams, air space management, etc.) -- Communication (KEs: communications systems and networks, etc.) -- Platforms (KEs: construction and materials, propulsion and energy supply, etc.) -- Weapons and munitions (KEs: kinetic, explosive, directed energy, non-lethal, etc.) -- Protection (KEs: armour and reinforcement, deception, defensive electronic warfare, etc.) -- CBRN detection and protection -- Logistics and life cycle management -- Policy and planning (KEs: strategic analysis, planning cycle support, etc.) -- Personnel readiness (KEs: selection, education, training, etc.)

Summary of key points

- A country's national defence R&D agenda is shaped by its security policy (including commitments to collective defence alliances), defence posture, technological ambitions, dominant S&T and military paradigms, existing knowledge base and resources.
- To reflect different rationales for defence R&D in national agendas, small nations often follow the principle of combining a broad knowledge base with several areas of deep knowledge (niches of excellence).
- Applied research dominates defence R&D agendas, with some basic research being conducted mostly for the purpose of maintaining necessary scientific competences or of bridging out to civilian research.
- Although user requirements dominate the process of determining the scope and directions of R&D, some funding is provided for 'free play' with new ideas or for projects initiated by the R&D community.

3. Defence R&D governance

Having examined the ‘why’ and ‘what’ aspects, the third fundamental question is ‘how’: how do small NATO allies, given their defence R&D purposes and agendas, organise and manage this area? This chapter looks into their approach to defence R&D governance: who are the main players in this area, how they interact and what are the advantages and disadvantages of each model.

3.1 General models and principles of defence R&D governance

A general review of the literature reveals that defence R&D governance in small countries exhibits certain traits, which reinforce each other:

- *Openness.* Although protection of national secrets and intellectual property are still important considerations,[12] the contemporary defence R&D governance architecture is increasingly configured as an open innovation network with multiple connections with and inputs from various knowledge institutions and stakeholders. This includes integration with national innovation systems and international collaborative networks to enable knowledge sharing and cooperative learning.
- *Communication frameworks.* It is vitally important to create an effective framework, in which communication between users (ministries, the armed forces), industry and the research community can take place. This concerns especially the establishment of clear requirements for R&D and the identification of opportunities. In this regard, it is also important that the defence R&D community has direct access to senior policymakers, thus being able to make its input into defence policy and planning at the highest level of decision-making.
- *Knowledge brokering.* Most countries have established an institutional hub for knowledge creation and brokering, which makes it possible to translate military language into scientific and engineering language and *vice versa*: “[…] technological and scientific intermediaries are necessary for innovative policy-making in both the civil and military sectors […]” (Merindol, 2005: 159). It is where diverse ideas and people are brought together from different fields or networks and connected with user requirements, where project or programme management is undertaken and where the locus of responsibility for defence R&D outcomes lies.

[12] See Bellais & Guichard (2006) on the difficulties of transferring knowledge between government-owned and private research organisations related to the protection of information and intellectual property.

- *The mobility of people.* An important feature is that people – scientists, engineers, analysts, military and civilian defence personnel, employees in the industrial sector – are constantly moving between the three domains (the government/the armed forces, R&D, industry) by means of temporary secondments and career assignments. This is because "individual mobility is necessary to improve broadcasting and creating knowledge inside the network" (Merindol, 2005: 160). As a result, better understanding of the imperatives that prevail in each domain is gained and better circulation of expertise is achieved.
- *Competition and partnerships.* Governments are increasingly opening up the area of defence R&D governance for competition due to a variety of reasons, including the need to "inject commercial logic" into the operations of GDREs in order to increase their efficiency and accountability (Molas-Gallart, 2001: 418). Responsiveness to market demand, the commercial potential of innovations (e.g. as spin-offs) and the conditions for the diversification of R&D funding have become significant considerations in re-designing defence R&D governance systems. In a similar vein, risk and cost sharing with stakeholders outside national defence system has emerged as an important element in defence R&D governance.

In addition, some analysts suggest that when designing the architecture of defence R&D governance in small countries, the necessary capacities should be taken into account. These capacities include a technological awareness capacity ("a means of effective technology searching to identify opportunities for R&D investments"), an absorptive capacity ("institutions, incentives and processes for effective technology learning"), a transactional capacity ("a trusted transactional environment to facilitate knowledge formation and exchanges") and a technology management capacity ("a business model capable of identifying and re-assigning risks at various stages of the product and process life cycle") (Wylie et al, 2006: 271).

Defence R&D governance can also be viewed from the perspective of ownership and focus. Under this approach, there are five general models. The defence R&D function may be: 1) MOD-owned and -oriented (in-house capabilities, fully controlled by the MOD); 2) publicly-owned and defence-oriented (public organisations, focused on defence research, but independent from the MOD and governed by means of public statutes); 3) publicly-owned and civilian-oriented (universities and institutes that are not related to the defence sector, but their research contributes to defence knowledge); 4) privately-owned and defence-oriented (private research establishments that focus solely on defence customers); 5) privately-owned and civilian-oriented (private institutes or R&D branches of companies) (Rademaker et al, 2009: 32-33).

It must be noted that in the grand scheme of defence R&D governance, the above five models may be mixed, depending on what knowledge the MOD seeks and for what purposes (Rademaker et al, 2009: 34-35). In some areas, the MOD might wish to retain full control and to maintain in-house expertise, thus running its own research establishments or branches (e.g. to build a technological awareness capacity).[13] In some areas, it might wish to garner more independent advice, thus relying on publicly-owned defence-oriented organisations. In some areas, it might see a pressing need to reach out to the civil sector, thus relying on and cooperating with publicly- or privately-owned civilian-oriented organisations.

The key here is that the MOD must have a clear understanding of what kind of knowledge it needs, who can best supply it, what in-house competences or capacities are necessary and why. The resulting governance framework could be located anywhere on the continuum between the highly-centralised state-owned model – with the MOD and the armed forces at the very centre of it, exercising full control over the defence R&D agenda – and the highly-decentralised system – with most of defence R&D in the hands of the public and private sectors, leaving the national armed forces the role of one customer among many.

3.2 Defence R&D governance in the focus countries

In accordance with its modest ambitions, **Denmark** does not have a dedicated defence R&D establishment anymore, but it retains an MOD-owned R&D capacity concentrated in the Danish Defence Acquisitions and Logistics Organisation (DALO), subordinated to the Chief of Defence (CHOD). The Applied Research Branch, where most of this capacity lies, is tasked with planning R&D activities, managing research projects, ensuring support to other defence branches, cooperating with the civil sector and participating in the activities of the NATO RTO.

The DALO is an agency that houses capabilities directors, who are charged with long-term capabilities development and who sit on the defence research board, so that the defence R&D function interacts closely with the planning and development of military capabilities and with defence acquisition projects. It also has channels of communication with operational commanders and thus stays in touch with their views and needs. In

[13] For example, although the UK privatised most of its defence research agency, DERA, now known as QinetiQ, part of its functions were retained under the MOD's ownership and control in the form of the newly created Defence Science and Technology Laboratories (DSTL).

general, there appears to be intensive, often quite informal communication flows in many directions, which helps the defence R&D function to be open to external inputs and to stay involved.

The formal chain of command to the CHOD runs through the DALO chief, thus separating scientific advice and analysis from security and defence policy assessments and reviews at the highest level by at least one organisational layer. With R&D being so closely associated with defence acquisition processes, the MOD and the Danish Defence Command may find it difficult to appreciate the role of defence R&D as a policy instrument and as an important source of strategic advice rather than merely an adjunct to procurement. On the other hand, the informal style of communication, unconstrained by official channels tied to a formal chain of command, which is characteristic of the organisational culture of the Danish defence system, facilitates knowledge diffusion across organisational boundaries.

The absence of a separate dedicated defence R&D establishment – which is logical, given the scope and ambitions of the Danish defence R&D function – receives some criticism from outside, namely from the two other focus countries. It appears that some of Denmark's international partners consider the abolishment of a separate agency to be a mistake and argue that in the long term, Denmark may come to regret this decision as it has diminished the strategic value and impact of R&D. At the same time, some outsiders do not view the Danish approach as too damaging and point out that even countries with much greater ambitions in defence R&D (e.g. Sweden) are, or have been, pondering the option of putting defence logistics and defence R&D organisationally under the same roof.

Norway has adopted the model of MOD-owned and -controlled defence R&D governance. Its Defence Research Establishment (FFI) is an agency within the Norwegian defence organisation, subordinated to the MOD. Its Director General has direct access to the top echelons of the MOD and the armed forces, thus ensuring that the analyses and advice of the defence R&D community play an important role in defence policy and planning. The FFI Charter stipulates explicitly that the provision of advice to the Minister and CHOD on potential implications of scientific and technological developments is part of the agency's mission (FFI, 2009).

Members of the MOD and members of the FFI Board form the Defence Research Policy Board – a principal body that decides on the strategy of Norway's defence R&D and issues guidelines to the FFI. The FFI Director General also works with the Defence Research Review Board to examine the progress and outcomes of research programmes and projects. The FFI follows assessment and reporting standards that are common to all Norwegian publicly-funded research institutes and universities.

The FFI works closely with the Norwegian Defence Logistics Organisation (NDLO) to support projects concerning defence capabilities. At one point, its merger with the NDLO was considered, which would have produced a similar governance structure as in Denmark. However, at the insistence of the armed forces, which were fully content with the support they got from the defence R&D community, it was eventually decided not to change the governance model. Some interviewees also regarded this decision as very important in retaining qualified human resources in defence R&D.

At the same time, there is some personnel mobility, which enables the FFI to tap into and to circulate tacit knowledge in a broader defence innovation community. Some staff members follow technology as it moves through various development stages and to other agencies or the private sector. Military personnel are occasionally seconded to the FFI, thus bringing their operational experiences into the FFI’s projects. The FFI’s staff have a possibility to work for universities, thus keeping in touch with the latest developments in fundamental research.

The communication flow in the triangle, formed by the armed forces, the R&D community and industry, is very much facilitated by regular workshops, seminars and conferences, which are organised by both the FFI and the Defence and Security Industries Association (FSi). For instance, the FSi organises at least one annual seminar for each technology area and one annual large conference covering all technology areas, where the representatives of industry, research and government institutions exchange views on requirements, opportunities and results. The FFI holds project workshops and publishes papers to keep stakeholders involved and informed.

Compared to other small allies, Norway has enough resources to maintain a separate MOD-owned and -controlled defence R&D agency. So far, it has seen the need to continue doing so. Although the Norwegian MOD and the armed forces remain its largest customers that provide substantial funding to it, the FFI is becoming open to free market forces, as it seeks to draw external funding from other governments and organisations. This indicates that the affordability of this model might be problematic in nations that allocate much fewer financial resources for defence than Norway.

In the case of **the Netherlands**, the defence R&D infrastructure is centred on the defence arm of the Netherlands Organisation for Applied Scientific Research (TNO), established by the Dutch government as a public research organisation with a mission to promote technology and innovation in Dutch society and economy. TNO’s mission is set out in a separate law; it operates under the auspices of the Ministry of Science. Its activities are organised along several interwoven thematic lines, with defence being only one of them. It has a separate dedicated branch to serve its customers in the defence and security sectors – TNO Defence, Security & Safety – which also participates within NATO RTO and EDA projects on behalf of the Netherlands.

The Dutch knowledge hub of defence R&D is thus close to civilian technological innovations, in which other parts of TNO are involved, and, *vice versa*, it also keeps technological innovations in the field of defence easily accessible for civilian use. Furthermore, as part of its mission, TNO is allowed to create spin-off companies, to establish partnerships with business enterprises and to participate in industry projects, thus inserting commercial considerations into its operations.[14] It positions itself as a knowledge broker in the overlapping networks of business, public, civil and military interests. However, it also strives to keep those interests at arms length and to maintain a strong reputation for independence, which is enshrined in its charter and built into its institutional character.

Independence, on the other hand, does not presume the lack of responsiveness to customer needs, including the MOD, the armed forces and other government security agencies. To the contrary, very robust mechanisms for common planning, consultation and collaboration are in place to ensure that TNO Defence, Security & Safety delivers what the government needs. Strategic matters are covered by the TNO Defence Research Board, which includes representatives of the MOD (a Deputy Secretary General), the armed forces (a two-star general) and the MOI.

In keeping the MOD involved and interested, it certainly helps that science and technology have a relatively high profile in defence policy: the Netherlands MOD has created the position of chief scientific advisor at the Directorate of General Policy Affairs. The planning and oversight of defence R&D projects, whether sourced from TNO or from other knowledge suppliers, are facilitated by the fact that the MOD also has a substantial administrative capacity in this area – a separate Defence R&D Directorate with 23 employees, who interact with R&D project managers at TNO (or other contracted suppliers) on a constant basis to examine and review the progress and outcomes of projects.

In addition, customer relations are strengthened by means of personnel mobility. For instance, some military personnel have taken up assignments with TNO, although a wish

[14] A good example is The Hague Centre for Strategic Studies (HCSS), which conducts what is often called 'soft research' (the security environment, security policy and governance, military affairs, conflict research, etc.): it is a private company, which was established to satisfy the demands of national and foreign customers in this field and is fully owned by TNO.

has been expressed to increase such involvement. Operational analysts at TNO Defence, Security & Safety are also taking tours of duty with the Dutch contingent in Afghanistan.

Although the Dutch model addresses many important considerations relating to defence R&D governance in small states and offers great flexibility, it also carries certain risks, which have to be managed very attentively by those in charge. Firstly, it has to be taken into account that many foreign GDREs instinctively distrust R&D agencies that are driven partly by commercial interests, i.e. not exclusively by public interests. For this reason, TNO is always very meticulous about putting forth its public credentials when dealing with foreign MOD-owned and -controlled R&D organisations. In addition, TNO never uses R&D project results that have been obtained through such international partnerships to create spin-off companies.

Secondly, there is always the risk of conflict between public and private interests within the system, which may undermine the credibility and reputation of the knowledge broker or the agency specialising in defence R&D. The organisational culture of TNO and its defence research branch is therefore built on the constant need to balance these interests, to adhere firmly to its public charter and to emphasise its independence and transparency.

Table 2. Advantages and potential disadvantages of defence R&D governance models in the focus countries.

	Model	Institutional arrangement	Advantages	Potential disadvantages
Denmark	MOD-owned defence-oriented	Part of a specialised defence agency with a different mission (DALO)	-Affordability: little administrative overhead -In-house agency: trust of the military and foreign GDREs -Close interaction with capabilities development	-Subordination to defence acquisition: low profile in advising the overall defence policy -Focus on defence customers: limited opportunities for an interagency approach
Norway	MOD-owned defence-oriented	Separate dedicated agency (FFI)	-High profile in defence policy advice and management of strategic risks -In-house agency: trust of the military and foreign GDREs -Distinct institutional culture and capacity	-Expensive for the defence organisation as the sole owner -The defence organisation is overly dependent on one single knowledge supplier
The Netherlands	Publicly-owned defence-oriented	Specialised arm of a national applied research organisation (TNO)	-High inter-connectedness with civilian research and commercial innovation sectors -Independence and high profile of scientific advice -Distinct institutional culture and capacity -Broad customer base and flexibility in customer-supplier relations	-Risk of conflict between commercial and public interests

Summary of key points

- A country's defence R&D governance architecture stems from its national R&D strategy and agenda, but it usually seeks to establish an open and effective communication framework and to facilitate competition, multiple partnerships, the mobility of people and knowledge brokering.
- When constructing a country's defence R&D governance framework, various desirable capacities in its defence organisation (technological awareness, absorptive, transactional, technology/knowledge management capacities) should be taken into account.
- Depending on its knowledge needs, availability and the desired degree of control over its defence R&D agenda, a country can develop different ownership models of R&D governance (from MOD-owned and -controlled to privately-owned and civilian-oriented R&D institutions).
- It is characteristic of the defence R&D management systems in the focus countries to have a defence-oriented R&D hub, albeit under different institutional affiliation or ownership arrangements, each with certain advantages and disadvantages.

4. Lessons for Estonia

Extrapolating from the experiences of the three small NATO allies, this chapter suggests lessons for Estonia in its defence R&D strategy and management. Some of these lessons are already being applied and might not supply any entirely new insights, but they would still serve as an additional tool for benchmarking Estonia's approach. In other instances, they might point to the issues, which need more thorough analysis and discussion, and to the need to review the policy.

4.1 The role and utility of defence R&D

The very first lesson, which emerges from the focus countries, is that defence policymakers and military practitioners need to appreciate the diverse roles that R&D may play in defence and the interagency environment. No single rationale, from among those discussed earlier, can serve as a sole basis for a viable long-term defence R&D policy and strategy. It is rather a balanced combination of these roles, which leads to a coherent and meaningful defence R&D programme and an effective governance architecture.

For instance, if a country focuses solely on the requirements derived from its long-term defence development plan, it may overlook the role of defence R&D in building its competence for technology foresight and thus become vulnerable to a sudden appearance of disruptive technologies or unexpected developments in the security environment. In a similar vein, a sole emphasis on supporting a 'smart buyer' attitude may lead to its low utility in informing defence policy about strategic risks or opportunities associated with developments in science and technology.

On the other hand, the maintaining of only a very broad conceptual role, e.g. a policy and planning advisory role, may undermine a country's ability to contribute to defence R&D within the Alliance and to derive benefits from participation in its knowledge networks. In addition, too much focus on serving interagency needs may reduce the utility of R&D in addressing many unique needs of the armed forces. The aim should be to find the right combination of purposes, carefully crafted as an integral part of the overall security and defence strategy of a nation, and a balance between ambitions and available resources.

A related lesson is that there is a need to overcome the issue of ignorance on the part of potential stakeholders and beneficiaries about defence R&D. Due to the underlying difficulties of understanding science and technology by policymakers and military users, it may be extremely difficult to establish a meaningful role for defence R&D in the organisational culture and strategy of the MOD and the armed forces. However, it is also obvious that if there is any ambition to develop the military as a state-of-the-art knowledge-based institution, such ignorance is quite detrimental and will eventually make the ambition unrealistic. It is difficult to imagine that, for instance, the Netherlands could have achieved its present advanced level of military capability without its efforts to build and use its knowledge base, much of which was achieved by investing in R&D.

Too little investment in and attention to defence R&D roles would be in disharmony with visions of high-tech military capabilities and technologically aware policymaking. For a small nation, however, too much ambition may prove equally damaging as it may lead to greater opportunity costs than is sustainable or desirable at the expense of the nation's investments in civilian research (which may eventually produce knowledge and applications useful in the defence sector) or in other areas of defence (e.g. training and education). Similarly, the level of ambition in the development of new technologies must be realistic. Experiences of the focus countries show that pursuing development activities at the level of systems is a very demanding undertaking for a small country with limited resources and a small knowledge base. Consolidation of efforts on the level of components or sub-systems brings better results when it comes to participation in the international defence market.

It is also clear from the experiences of the three focus countries that defence R&D and military organisations must meet midway between the 'ivory tower' of science and the 'buy off-the-shelf' attitude of the military. Defence R&D must be focused on producing what is relevant and usable in terms of knowledge and technology, while the military must actively seek new knowledge, be willing to experiment and take certain risks as part of constant learning, innovation and improvement. Innovation must be embedded into its organisational culture and be interconnected with defence R&D, using such tools as CD&E.

4.2 The direction of R&D

A key lesson for defining defence R&D agendas is that decision-makers should have a reasonably clear picture of current and future knowledge needs in security and defence and that they should understand how these knowledge needs can be satisfied through R&D programmes. Factors determining these needs were discussed at length earlier, so it will suffice to highlight that they represent a convergence of demand from multiple internal (defence policy and planning, capabilities development, defence procurement, armament and equipment management, operations, personnel management and doctrine development authorities) and external (police, intelligence and rescue services, etc.) stakeholders.

NATO and the EU seem to loom large over defence R&D agendas of small nations. Be it *quid pro quo* philosophy or a more general determination to achieve deep integration into multinational security alliances, with R&D being one of the instruments for doing so, membership in NATO (and the EU) has major implications for national defence R&D agendas. To put it plainly: arguments related to strategic sovereignty should play only a small role in determining the defence R&D agenda of a small allied nation, which is firmly embedded in a collective defence alliance.

In this regard, it is of crucial importance to identify the niches, where a country seeks to be recognised as a top-league player, characterised by excellence and state-of-the-art technology. Estonia is even smaller than the focus countries, so it would be reasonable to choose not more than two niche areas. Ideally, they would represent as much convergence of the factors discussed in Section 2.1 as possible. For instance, one of them could be the niche of software development, comprised of several knowledge elements (cyber defence, programming of autonomous platforms and systems, etc.), which would make Estonia highly visible in the Alliance and competitive in the R&D market.

When defining knowledge areas, the overarching principle is to find the right combination of breadth – in order to ensure a high degree of awareness and accumulation of knowledge necessary for managing risks or for responding to new strategic circumstances – and depth in the selected niche areas. It is also worth taking into account that together or in combination with 'hard' research, 'soft' research (e.g. in various fields in the social sciences, behavioural sciences, etc.) should be included in a defence R&D agenda, thus making it more multidisciplinary and reflecting a broader spectrum of needs. The emphasis of R&D investments should clearly be placed on applied research as opposed to basic research.

In defining and satisfying knowledge needs, another important lesson is that some of those needs are not consciously appreciated and clearly articulated by potential users. As the example of the three focus countries demonstrated, it is necessary to leave at least some space on a defence R&D agenda for the R&D community to engage in 'free play' with its ideas and to mount a 'supply push': this could result in novel projects, which could go well beyond the imagination of users, create extremely valuable new knowledge and open up unexpected new strategic opportunities. Some funding for basic research might be required in this regard, but this should make up only a very small fraction of total R&D investments.

Market demand and the willingness of the defence or defence-related industry to invest in R&D also seem to play a role in shaping defence R&D agendas. However, if defence R&D is largely driven by these considerations, national security and defence authorities may find it difficult to ascertain their interests and may become too dependent on commercial suppliers of knowledge, often overpaying for that knowledge. Knowledge areas, where the risks are too high or the payoffs too low for the defence industry, might also become neglected to the detriment of the public interest in security and defence.

4.3 Lessons for defence R&D governance

The last of the three sets of issues, which this report has looked at, is defence R&D governance systems or knowledge infrastructures. Indeed, their precise configuration depends on how a particular country answers to the questions of why it should conduct R&D in the defence sector and what its agenda should be. Only when a country has clarified the rationale for defence R&D and the scope of this function, it is possible to determine where the necessary knowledge and capacities lie, whether they should be developed in-house or sourced from outside and whether the governance system should be decentralised or centralised.

The first important principle stemming from the experiences of the focus countries is that a knowledge infrastructure should be as open and flexible as possible, with the additional imperative of affordability for Estonia in particular. It should serve as a conveyor belt of knowledge and innovation between civil and military, public and private sectors as well as national and international networks. It should provide an effective framework for articulating, communicating and understanding user requirements and for utilising R&D results.

It appears that in order to enable effective knowledge brokering, to balance it with knowledge creation and to enhance the visibility of R&D in a country's security and defence policy, some degree of centralisation of this function is required. The defence R&D network of a country should have a central hub (an agency, an institute, a department or a branch), which would interact with user, scientific and industrial communities. By means of such a hub, user requirements would be more effectively connected with R&D capabilities, scientific knowledge and commercialisation processes. Project management and accountability for project results would also become more transparent.

Full ownership and complete control of this hub by the MOD might be detrimental to openness, flexibility and affordability, although from the perspective of the military community and international partners this would make the hub more trustworthy. The MOD might become too attached to a single provider and would have to carry the financial burden of sustaining it alone. It might also be problematic for a state agency to try to spin off innovations into the commercial sector or to participate in the competitive defence R&D market. On the other hand, a publicly-owned and defence-oriented hub of defence R&D, such as TNO Defence, Security & Safety, seems to offer quite good opportunities for reflecting and combining diverse imperatives and trends in this sector.

The establishment of a central hub for a country's defence R&D network outside its defence organisation, however, does not relieve the MOD and the armed forces of the necessity to integrate the R&D element with all the policies and activities, which could apply R&D as a source of advice or for finding ways for continuous improvement, adaptation and change. This would entail the creation of a proper communication and interaction framework between the defence R&D hub and various users in the defence organisation ('transactional capacity') and the implementation of effective knowledge diffusion mechanisms in the defence organisation ('absorptive capacity').

In order to address the above issues, it would be expedient to implement such measures as the creation of the position of a scientific advisor with access to the top echelons of the MOD and the armed forces, development of linkages between defence R&D and military training and education as well as 'lessons learned' systems, regular thematic workshops and conferences in priority knowledge and technology areas, etc.. The MOD should also maintain a certain administrative capacity to assist its decision-makers in crafting the R&D strategy and overseeing its implementation, which need not be as large as the R&D Directorate of the Dutch MOD, but nonetheless its existence would facilitate the management of the knowledge infrastructure and make it easier for the MOD to exercise its influence over it.

Summary of key points

- Defence R&D should serve multiple stakeholders both within the defence organisation and the broader security sector in Estonia, but its diverse roles should be properly appreciated by those stakeholders and well balanced with each other, so that Estonia's defence R&D strategy would not over-emphasise one single purpose of R&D investments.
- Given the resource constraints and the 'opportunity costs,' realistic ambitions and reasonable mutual expectations need to be established through dialogue between users and the R&D community.
- Estonia should carefully concentrate its R&D investments in a few niche areas, where it can achieve excellence within the Alliance, but at the same time it should allocate some resources for the development and maintaining of a broad knowledge base as a source of security and technology awareness and as a risk mitigation measure.
- Some degree of centralisation of the defence R&D function above its defence-oriented knowledge hub is necessary, but full ownership and control of this hub by the MOD might not be optimal for Estonia in terms of affordability, flexibility and openness.
- The defence R&D community needs to be represented at and to have direct access to the highest policymaking levels in order to integrate scientific advice into security and defence strategies, while users have to develop their administrative and absorptive capacity to benefit more from their interaction with knowledge suppliers.

Conclusions and recommendations

Contrary to the wide-spread notion that defence organisations of small nations do not and should not invest in defence R&D, the report found that this is an area, which serves a range of purposes. The experiences and attitudes of the three focus countries provide further proof to this point, as even the least ambitious of them finds it necessary to support development of its defence with R&D activities. Defence R&D can be as relevant and important to small countries as to large ones. To take an analogy from the economy, investments in R&D can be as vital to SMEs as to large corporations, perhaps even more so.

If deployed for strategic uses, defence R&D can assist defence organisations in being flexible, adaptive and forward-looking as well as in staying at the cutting edge of knowledge and technology within NATO. It would be a highly paradoxical situation if a state professed to follow a knowledge-based model of development and to encourage the private sector to invest in R&D, while its security and defence community exhibited the opposite attitude and behaviour. Although not without difficulties in establishing R&D as part of the institutional fabric of defence, this is well appreciated by the defence organisations of the focus countries.

The scarcity of human and financial resources is an important but not a decisive consideration in judging whether a small country should invest in defence R&D. It is rather a matter of having the right attitude towards new knowledge and innovation. Smallness only sets certain limits on how to target investments and on how to organise defence R&D. It dictates the need to be very structured in defining knowledge needs and uses, to focus major investments on several niches of excellence, while sprinkling some funds to diversify the knowledge base, and to seek very practical applications and solutions. This also makes it imperative that the walls, which compartmentalise knowledge networks into defence and broader security, military and civil, public and private sectors as well as into national and international domains, are removed as fully as possible.

It is obvious that many users, both within defence organisations and in the broader security sector, may have an interest and a stake in gaining new insights through research and in the development of its outcomes into new or improved technologies, processes, concepts or methodologies. There is no need to list those stakeholders again, but it is important to emphasise that everything starts with these stakeholders accepting R&D as an undertaking that adds substantial value to solving their current challenges and, more importantly, to preparing for the future, just as it is done in Norway, the Netherlands and Denmark.

Such considerations as the diversity of stakeholders and contributors to defence R&D efforts dictate the need for a single organisational hub, which forms the centrepiece of a defence R&D programme. It is also easier to concentrate resources and to use them more effectively and efficiently, if R&D activities are centralised to a certain degree and also highly visible. In this regard, placing R&D in some corner of yet another defence agency, no matter how important – as it is done in Denmark – or keeping it under the full control and ownership of the MOD as a separate entity – as it is done in Norway – might not be the optimal solution. The Dutch model of a publicly-owned and defence-oriented R&D agency seems to be a more viable option for Estonia, which combines the merits of openness, synergies between knowledge sectors, flexibility in choice for users, the overall visibility of defence R&D and the affordability of its governance framework for the MOD.

The following recommendations stem from the above inquiry into defence R&D in the three small NATO allies and into broader trends in this field.

- **Raise awareness.** Enhance science and technology education for future and current military leaders and civil servants in their professional development programmes in order to ensure that they understand the opportunities and risks in this area for national security and defence. Efforts should be made to develop their understanding of how R&D investments could help improve institutional decisions, policies, capabilities and organisational performance at various levels.
- **Manage expectations.** In connection with raising awareness, the defence organisation must develop an understanding that: 1) research is not always about technology – research into non-technological aspects of defence and the development of new concepts, methodologies or processes are equally important; 2) all R&D efforts do not have to lead to prototypes and new applications – some enhance the knowledge base, some support 'intelligent customer' behaviour or provide a better understanding of future risks; 3) many R&D programmes take years to produce results, so patience and a long-term horizon are crucial.
- **Stimulate demand.** Establish a requirement across the entire defence organisation (departments, headquarters, agencies etc.) to generate and communicate a continuous demand for new knowledge, which is necessary for resolving conceptual and practical short-, medium- or long-term challenges and

problems in various fields. Ascertain how the new supplied knowledge is utilised.

- **Stimulate supply.** Provide some seed funding for the scientific community to develop new ideas of potential interest to the defence sector. A system should be created, whereby the defence organisation is able to recognise and express its interest in ongoing or planned civilian research projects (e.g. through comparing them with knowledge and technology lists, which are of critical importance to the military and which are developed as part of security and technology foresight activities) and to contribute to them. Emphasis should be placed on applied research.
- **Link demand and supply.** Link defence R&D planning and results diffusion mechanisms with institutional planning (e.g. long-term defence planning) and implementation (e.g. capabilities projects), knowledge management and innovation processes (e.g. CD&E, operational 'lessons learned,' etc.) in the defence organisation. This should include, *inter alia*:
    - The creation of facilitating communities of practice, which bring together practitioners, scientists and industry representatives of a particular area;
    - Regular (e.g. annual) conferences and workshops for knowledge users and suppliers;
    - The provision of easy access to searchable databases of ongoing or completed R&D projects and their outcomes;
    - The mobility of people between user organisations/structural units, organisations conducting R&D and industry (temporary assignments, etc.).
- **Expand the stakeholder base.** Involve other security sector organisations (e.g. the MOI and its subordinate agencies, the Ministry of Justice) in determining common problems, concerns and knowledge demands, which require R&D solutions. Agreements should be reached on partnerships to advance new knowledge and technological solutions for comprehensive security.
- **Enable representation and access.** Consider the need for the position of a chief scientific advisor/chief scientific officer, which would be filled by a scholar of considerable stature and experience, with direct access to the most senior decision-making levels in the defence organisation and with a task to provide

advice on the use of scientific research and technology in security and defence policy.

- **Develop a systematic approach**. Structure knowledge demands into distinct areas, audit the domestic knowledge base and compare them in order to identify gaps and ways to address them. It should be decided which areas will be developed for the purpose of maintaining a broad knowledge base as a risk mitigation or awareness measure and which ones will be developed as niches of excellence for the purpose of contributing to NATO (or EU) knowledge networks. In addition, it should be determined which, if any, in-house scientific and technological competences are necessary and which competences can be sourced from the outside.
- **Provide and prioritise resources.** Seek to fulfil the NATO benchmark of spending 2% of the defence budget on R&D. Using a 'programme approach,' channel most of the government funding to the chosen niche areas of specialisation, while providing some funding for the development of a broad knowledge base. In each programme, provide a small portion of funding for 'free play' initiatives of the R&D community and for bridging out to basic research.
- **Nurture a defence R&D hub.** Identify an existing public multidisciplinary institute for applied research or projects agency (possibly under the Ministry of Education and Research), which is willing to develop security and defence themes together (and in conjunction) with its other themes. The agency should be developed as a knowledge broker, capable of translating security and defence requirements into scientific or technical language and *vice versa*. It should be linked with the business sector (e.g. by allowing the creation of spin-offs, by requiring the participation of a commercial enterprise as a precondition for project financing, etc.) and with potential customers outside Estonia.
- **Promote international collaboration.** When knowledge requirements and the national level of ambition have been determined and a defence R&D hub has been created, collaboration with international partners should be accepted as a strategic principle in defence R&D. The choice of bilateral and multilateral collaboration partners within NATO and the EU for *ad hoc* or strategic long-term partnerships should be made on the basis of knowledge needs, complementarities and political considerations (the level of priority in overall defence cooperation).

- **Exercise control and oversight.** Develop a rigorous system for measuring the performance of R&D projects and the quality of their outcomes and for gauging their compliance with user needs and requirements. The contracting authority (the MOD, the MOI, etc.) should support it with appropriate administrative capacity. The representatives of the MOD and the EDF should be included in the board of the agency, which acts as a defence R&D hub.
- **Remain flexible and pro-competition.** Adopt the principle that the MOD (together with other stakeholders) retains the option of soliciting projects from other Estonian or foreign knowledge providers than the national defence R&D hub in order to keep the national defence R&D agency under competitive pressure (to control costs and to encourage responsiveness to user demand).

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