The Hague Centre for Strategic Studies




# Knowledge Investment Quote

# KNOWLEDGE INVESTMENT QUOTE

An Outside-In Survey for the Netherlands' Ministry of Defence

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June - 2009

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# Abbreviations

| | |
|---|---|
| **ADF** | Australian Defence Forces |
| **BRIC** | Brazil, Russian Federation, India, China |
| **CAMS** | Centrum voor Automatisering van Mission-critical Systems, The Netherlands |
| **CBRN** | Chemical Biological Radiological Nuclear |
| **CML** | Centrum voor Mens en Luchtvaart, The Netherlands |
| **COTS** | Commercial off the Shelf |
| **DC** | Defence Capability |
| **DEE** | Development, Engineering and Evaluation |
| **DERA** | Defence Evaluation and Research Agency, United Kingdom |
| **DIS** | Defence Industrial Strategy |
| **DLR** | Deutsches Zentrum für Luft- und Raumfahrt |
| **DND** | Canadian Department of National Defence |
| **DoD** | Department of Defense/Defence |
| **DRI** | Defence-Related Industry |
| **DSTL** | Defence Science and Technology Lab, United Kingdom |
| **DSTO** | Defence Science and Technology Organisation, Australia |
| **DT** | Defence Tasks |
| **DTC** | Defence Technology Centre |
| **DTIB** | Defence technological and industrial base |
| **EDA** | European Defence Agency |
| **EW** | Electronic Warfare |
| **FFI** | Forsvarets Forskningsinstitutt, Norway |
| **FFRDC** | Federally Funded R&D Center |
| **FhG** | Fraunhofer-Gesellschaft, Germany |
| **FGAN** | Forschungsgesellschaft für Angewandte Naturwissenschaften, Germany |
| **FOI** | Swedish Defence Research Agency |
| **GERD** | Gross Domestic Expenditure on R&D |
| **GBAORD** | Government Budget Appropriations or Outlays for R&D |
| **GDP** | Gross Domestic Product |
| **GOVERD** | Government-financed GERD |

| | |
|---|---|
| **GOTS** | Government off the Shelf |
| **ICMS** | Interagency Civil Military Cooperation |
| **ICT** | Information and Communication Technology |
| **ISL** | German Research Institute Saint-Louis |
| **HCSS** | The Hague Centre for Strategic Studies |
| **KA** | Knowledge Area |
| **KE** | Knowledge Element |
| **KIS** | Knowledge Infrastructure |
| **KIQ** | Knowledge Investment Quote |
| **MARIN** | Maritime Research Institute of the Netherlands |
| **MER** | Market Exchange Rates |
| **MSTI** | OECD Main Science and Technology Indicators |
| **MIA** | Maatschappelijke Innovatieagenda |
| **MoD** | Ministry of Defence |
| **MOTS** | Military off the Shelf |
| **NEC** | Network Enabled Capabilities |
| **NICTA** | Australia's ICT Research Centre of Excellence |
| **NLDA** | Netherland Defence Academy |
| **NLR** | National Aerospace Laboratory |
| **NRC** | National Research Council, Canada |
| **NOI** | Nederland Ondernemend Innovatieland |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PPP** | Purchasing Power Parity |
| **R&D** | Research and (Experimental) Development |
| **RFID** | Radio Frequency Identification |
| **RMC** | Royal Military College, Canada |
| **R&T** | Research and Technology |
| **RTA** | NATO Research and Technology Agency |
| **SIPRI** | Stockholm International Peace Research Institute |
| **S&T** | Science and Technology |
| **SKA** | Strategic Knowledge Agenda |
| **SME** | Small and Medium Enterprise |
| **TNO** | Organisation for Applied Scientific Research TNO, The Netherlands |
| **TRL** | Technology Readiness Levels |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **UIS** | UNESCO Institute for Statistics |
| **WMD** | Weapons of Mass Destruction |

# Executive Summary

The Netherlands Ministry of Defence initiated an interdepartmental Future Policy Survey in March 2008. The remit of the Survey was to formulate policy options, without constraints, for the future ambitions of the defence effort of the Netherlands, the approximate composition and equipment of the armed forces, and the associated level of defence expenditure. The policy horizon spans about two decades. The three policy questions addressed in this report are:

- What knowledge areas are of relevance to the Netherlands MoD Science & Technology (S&T) base?
- What should be the Netherlands defence knowledge investment (knowledge investment quote or KIQ) annual budget & percentage (quote) of the Netherlands defence budget?
- What external and internal knowledge infrastructure is suitable for sustaining or developing the required knowledge and technology areas?

Based on these questions the following conclusions were drawn:

- A strong S&T base is necessary to mitigate uncertainty.
- The S&T base is not purely national anymore. Enhanced international collaboration would help to sustain an appropriate S&T knowledge base.
- In the short term the S&T base in the Netherlands is adequate, but the Ministry of Defence is still too much focused on a small number of traditional suppliers. This also calls for more flexibility in the R&D budgets.
- Integral security (internal and external security together) has become increasingly important. Mutual investments in R&D with other security-related ministries are useful and will enhance synergies.

- A change of the Netherlands defence S&T business model is the most important subject to look into. The security and defence S&T base of the Netherlands *needs to engage the total knowledge base*, including (non-traditional defence) industry, institutes and universities.
- At the senior levels, collaboration helps to confirm national priorities and future directions. A higher representation of the S&T community within the Netherlands Ministry of Defence is therefore highly important. This will then reflect the position of S&T in the defense value chain.
- Balancing of investments is necessary: where to invest in the short term and where in the longer term. Both in operational as well as in supporting activities.
- The Armed Forces Profiles themselves are not sufficient to define the defence-relevant S&T base.
- The most fundamental question and the hardest thing to do will be the formulation and the delivery of the programme. The direct relation with the military customer is very important. This could be arranged through client groups supported by roadmaps.
- There is a need for in-house Operational Research and Analysis support, as well as for people who understand system concepts.
- The current knowledge area Taxonomy needs some adjustments, reflecting the future needs and technology developments in combination with the ambitions of the Netherlands Ministry of Defence.
- A clear and internationally agreed definition for research, development, science and technology is useful, especially for international collaboration and benchmarking purposes.

# Introduction

The Netherlands Ministry of Defence initiated an interdepartmental Future Policy Survey in March 2008. The remit of the Survey was to formulate policy options, without constraints, for the future ambitions of the defence effort of the Netherlands, the approximate composition and equipment of the armed forces, and the associated level of defence expenditure. The policy horizon comprises about two decades.

An important aspect of the Survey is the development of so-called Netherlands Armed Forces Profiles. An Armed Forces Profile is a typical description of generic capabilities of the armed forces as a function of their ambitions.

One of the important policy studies of the Survey is a review of the composition of the knowledge investment portfolio and the size of the designated funds, related to possible Armed Forces Profiles for the future Netherlands defence forces.

## Basic research question

The basis for the study of the composition of the knowledge investment portfolio and the volume of the designated funds is the following strategic research question:

"What knowledge and technology areas are of importance for the fulfilment of the future needs of the armed forces and what knowledge infrastructure (within and outside the defence organisation) is required to achieve this? What is the approximate required size of the knowledge investment budget to meet the defence ambitions (related to Armed Forces Profiles)?"

Australia, Canada, Germany, Norway and the United Kingdom were asked to help answer these questions and to serve as a benchmark.

The strategic research question includes some underpinning questions that are either (partly) answered by the HCSS or with support from the HCSS. In this report, the following questions are addressed:

- What knowledge areas are of relevance to the Netherlands MoD Science & Technology (S&T) base?
    - What are the current differences in defence knowledge area clustering between the Netherlands and the focus countries?
    - Is a new clustering useful?
    - The use of Armed Forces Profiles is seen as a basis for determining future R&D requirements. How can the Armed Forces Profiles be used for that purpose?
- What should be the Netherlands defence knowledge investment (knowledge investment quote or KIQ) annual budget & percentage (quote) of the Netherlands defence budget?
    - What are the factors influencing the defence KIQ?
        - Which factors can be influenced by the MoD?
        - Which factors cannot be influenced by the MoD?
    - What are the national KIQs (R&D investment as a percentage of the Gross Domestic Product) of the focus countries Australia, Canada, Germany, Norway, and the United Kingdom?
    - What are the defence KIQs of the focus countries Australia, Canada, Germany, Norway, and the United Kingdom?
    - What are the KIQs of relevant/comparable industries?
    - What criteria for prioritisation of sourcing are used (how is the relevance (impact) identified? E.g. military need, ambition level, national industry)?
- What external and internal knowledge infrastructure is suitable for sustaining or developing the required knowledge and technology areas?
    - What governance models are used by the focus countries Australia, Canada, Germany, Norway, and the United Kingdom?
    - Which strategic criteria form the basis for these models?

# Readers guide

The analysis underpinning the answers to the above questions is structured in three chapters. Chapter 1 introduces the research questions, provides an overview of defence-relevant future technology and compares the knowledge portfolios of the focus countries. Chapter 2 provides an analysis of factors that potentially influence the knowledge investment budget of any MoD. It also compares the military expenditure and defence knowledge investment quotes of the focus countries. Chapter 3 covers the defence knowledge infrastructure. It analyses possible governance models and compares the knowledge infrastructures of the focus countries. The issue of international collaboration is also addressed in this chapter. In addition to the subconclusions at the end of each of the three chapters, a separate section with general conclusions and recommendations is provided.

The analysis is supported by a range of information and data from various sources. A large part of this information and data has been used directly in the chapters. The remainder serves as background material that may be found in Appendix A-H.

# Method

The study focused on a number of aspects of the Netherlands Defence Knowledge Infrastructure and Defence Knowledge Investment Quote. It consisted of desk research, a survey of the literature, a questionnaire, an international workshop and Delphi analysis. The format of the questionnaire, which was sent out to the focus countries in preparation of the international workshop, can be found in Appendix A Questionnaire Format.

# Definitions and comparability of data

Because of definitional issues, comparing data on knowledge management and investment may be difficult. Science and Technology (S&T), Research and Technology (R&T) and Research and (Experimental) Development (R&D) are three different categorisations that are widely applied for bringing knowledge-related investments and activities under a common header. Even when two organisations make use of the same term, this does not imply that this refers to the same definition. See Appendix H Description of Terms for more information on the definitions.

These definitional differences make it difficult to compare data on knowledge investment. For reasons of consistency, the HCSS has tried to use OECD data as much as possible. However, since the OECD dataset is limited to OECD member states and a small sample of focus countries falls outside the OECD, wherever necessary these data have been supplemented with data from the UNESCO Institute for Statistics Science and Technology database. Although UNESCO uses the same definition of R&D as the OECD, some minor differences exist between the two databases. Charts relating to R&D expenditure displayed in this report therefore serve as indicators of trends rather than precise representations of actual spending.

Furthermore, in specific cases it is difficult to compare data even when they come from the same source. An example is the difference between government-financed Gross Expenditure on Research and Development (GERD) and Government Budget Appropriations or Outlays for Research and Development (GBAORD) (see also Appendix H Description of Terms for a description). Although both indicators are measures of government expenditure on R&D, the differences between government-financed GERD and GBAORD may lead to confusion. A prime example is the percentage of R&D money spent by the Australian government on defence R&D. In Appendix G Defence knowledge infrastructures focus countries, it is stated that in 2002/03 18.8% of GOVERD (government-financed GERD) went into the Defence Science and Technology Organisation (DSTO). Figure 6 Defence R&D budget as a percentage of total GBAORD, low end, however, indicates that in the same year, only 6.68% of GBAORD was devoted to defence-related R&D. This gap seems to be too large to be explained by the difference between GERD and GBAORD alone. It is unclear, however, what caused it.

Cross-country comparison of defence-related R&D or S&T data also has its limitations. Definitions of defence-related R&D/R&T/S&T vary and defence budgets do not always explicitly specify knowledge investment. Since even senior officials are sometimes confused about the level and composition of their own MoD's knowledge investment figure, these data do not always provide a clear insight.

Comparability of data is further limited as a result of differences in currency conversion methods. In order to compare international data, local currencies are usually converted to constant dollars. The methodology, however, differs. The OECD, for example, uses the purchasing power parity (PPP) methods, while SIPRI applies the market exchange rates (MER) methodology. On its website, SIPRI notes that differences in methodology

can lead to vast differences in outcome.[1] Differences in outcome also emerge when different base years are used for calculating constant dollars.

A final note concerns the use of data on military expenditure from the SIPRI database. Military expenditure according to the SIPRI definition (see below) should not be confused with defence budgets. Thus, although Figure 3 Military expenditure in mln US$, focus countries, 1988-2007. shows a clear declining trend for German military expenditure between 1996 and 2007, this does not automatically mean that the German defence budget decreased as well. In fact, information provided by the German MoD shows a marginal increase of the budget in the same period. The overall trend, however, is comparable.

## Observations and conclusions regarding the definitions

The jargon of the research and development world is diffuse. Different terms are often used to describe the same activity, and sometimes the same terms are used to describe different activities. Another observation is that the availability of data, especially regarding defence-related research investment, is limited. Hence, it is difficult to draw conclusions on the basis of the data provided by MoDs and the 'indirect sources' (e.g. OECD) used by the HCSS for the analysis.

In this report the HCSS analysed the definitions that are most universally used by our sources. The main elements of each commonly used definition was then compared with the other definitions. On the basis of this analysis, the following matrix was drawn. x cells represent elements that are covered by a definition.

On the basis of this delta analysis the HCSS estimated to what extent the use of different definitions influences the analysis and conclusions in this report, especially regarding Chapter 2. Defence knowledge investment quote.

In turned out that the general data on R&D investment are hardly affected by definitional issues. These data come from two sources, the OECD and UNESCO, both of which are clear and coherent about the definitions they work with. Nevertheless, minor differ-

1. On the SIPRI website, the military expenditure of the Russian Federation is mentioned as an illustrative example. Converted to PPP dollars, Russia's military expenditure was $ 82.8 million. This figure is 2.4 times as high as the same figure in MER dollars ($ 34.7 million) for the same year. See also: Stockholm International Peace Research Institute (SIPRI), "SIPRI military expenditure database." (accessed 11 February 2009).

ences exist between both databases. Since both organisations use the same definition of R&D, it is unclear what caused these differences.

Table 1 **Elements of Different Definitions**

| | Basic Research | Applied Research | (Experimental) Development | Technological Procedures and Methods | Education | Training | Services |
|---|---|---|---|---|---|---|---|
| **R&D** | x | x | x | | | | |
| **R&T** | x | x | x | x | | | |
| **S&T** | x | x | x | | x | x | x |

Data on defence-related knowledge investment are much harder to compare. Different states or different organisations within a state often work with different concepts (R&D, R&T and/or S&T). Moreover, these concepts are often ill-defined. Most documents published by MoDs or other defence organisations lack a clear definition, making it very difficult to comprehend which elements are covered and which are not.

In terms of management of R&D processes, this problem may not be of prime importance. Financially, however, this lack of a clear definition poses major problems, as it generates confusion about the level of investment and makes comparison very difficult. It would be very helpful if the MoD would consistently apply a shared and clearly stated definition of its knowledge development effort.

# Defence Knowledge and Technology Areas

Knowledge and technology are seen as important enablers for armed forces capabilities. They are also an important mitigation measure for defence planners dealing with 'deep uncertainty'.[2] The relations between capabilities, knowledge and technology, however, are not linear. The focus countries Australia, Canada, Germany, Norway, and the United Kingdom all use different methods to establish this link. Some of these countries do this explicitly, while others deal with this issue in a more implicit manner. Also, some countries base their considerations mostly on historical data and projections, while for others national industrial ambitions and/or economic objectives are also important. All focus countries take into consideration reasons of preparedness for short-term or long-term military requirements. As a rule of thumb, relevant knowledge build-up takes five to ten years and is primarily a people's business.

In this chapter defence- and security-relevant knowledge and technology areas are described and detailed. Second, the relevance for the MoD-NLD is described, starting from a combined approach of methodical analysis and expert opinion based on the expertise of the researchers, open source analysis and the results of the questionnaire.

## Knowledge areas

Knowledge and technology development relevant to defence and security takes place in both the commercial and government arenas where demand pull and technology push play a role. The knowledge portfolio needs to span the short-, medium- and long-

2. International workshop on Knowledge Investment Quote and Knowledge Infrastructure.

term time horizons. Typically, the near term is up to 5 years, the medium term 5 to 10 years and the long term 10 to 20 years. The far-horizon work is often done in collaboration with universities and can address technologies that are new and possibly of great interest to defence. Medium-term work is often undertaken in collaboration with the industry to promote technology transfer and commercialisation of the R&D. Near-term work can be done in industry or defence labs, depending on the location and availability of the needed facilities and skill sets.

In times of peace, investment can mainly be restricted to maintaining the knowledge base. When pressing operational needs are to be answered, extra investment is needed to assist in the solution of operational problems.

## Defence-relevant future knowledge and technology

The world is undergoing a global technology revolution,[3] which integrates developments in biotechnology, nanotechnology, materials technology and information technology at an accelerating pace. The technology of 2020 will continue to integrate developments from multiple scientific disciplines in a 'convergence' that will have profound effects on society. Examples of some of the (integrated) technology applications that may be feasible by 2020 include:

- Personalised medicine and therapies;
- Genetic modification of insects to control pests and disease vectors;
- Computational (or 'in-silico') drug discovery and testing;
- Targeted drug delivery through molecular recognition;
- Biomimetic and function-restoring implants;
- Rapid bioassays using bionanotechnologies;
- Embedded sensors and computational devices in commercial goods;
- Nanostructured materials with enhanced properties;
- Small and efficient portable power systems;
- Mass-producible organic electronics, including solar cells;
- Smart fabrics and textiles;
- Pervasive undetectable cameras and sophisticated sensor networks;
- Large, searchable databases containing detailed personal and medical data;

3. Based on Silberglitt et al., *The global technology revolution 2020, in-depth analyses*; and reviewed against Ministry of Defence, Government of the United Kingdom, *Defence Technology Strategy for the Demands of the 21st Century*, Joint U.S. Defense Science Board - U.K. Scientific Defence Advisory Council Task Force, *Defense Critical Technologies*; TNO Defence, Security and Safety, *Defence Technology Survey 2006*; Federal Ministry of Defence, Government of Germany, "2006 Annual Research and Technology Report, Defence Research for the German Armed Forces in the Process of Transformation"; Federal Ministry of Defence, Government of Germany, "2007 Annual Research and Technology Report, Defence Research for the German Armed Forces in the Process of Transformation."

- Radio frequency identification (RFID) tracking of commercial products and individuals;
- Widespread bundled information and communications technologies, including wireless internet connectivity;
- Quantum-based cryptographic systems for secure information transfer.

These examples are already making their appearance in defence and security applications. Although not proposed as an exhaustive set of developments, numerous related developments stem from the above shortlist.

Especially in the Netherlands, and based on studies on the Defence Industrial Strategy (DIS),[4] as well as on developments with regard to Nederland Ondernemend Innovatieland (NOI – The Netherlands as an Enterprising Innovation Country),[5] the Maatschappelijke Innovatieagenda Veiligheid (MIA – Social Innovation Agenda on Security)[6] and the interagency civil-military cooperation ambitions (Dutch: ICMS),[7] [8] a number of overlapping areas of interest are being identified where collaborative S&T investments would enhance synergies in both the defence and the security areas of responsibility. These documents especially suggest that the following four areas of interest show significant overlap between the defence and security fields:

- Information and Communication Technology (ICT);
- Network Enabled Capabilities (NEC);
- Physical protection;
- Simulation, education and training.

## Current clustered knowledge areas

Currently, the Netherlands Ministry of Defence has divided its R&D investment portfolio into eleven knowledge areas (KA). In order to provide additional detail, knowledge elements (KE) are also specified. See Appendix C Current and Suggested New Knowledge (Sub)areas of MoD-NLD for the detailed description.

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4. Ministry of Defence, Government of the Netherlands and Ministry of Economic Affairs, Government of the Netherlands, "Defensie Industrie Strategie, Eindrapportage."

5. Ministry of Economic Affairs, Government of the Netherlands, *Innovatieprogramma Veiligheid - analyse*.

6. Nederland Ondernemend Innovatieland, *Maatschappelijke Innovatie Agenda Veiligheid.*

7. Ministry of Defence, Government of the Netherlands and Ministry of the Interior and Kingdom Relations, Government of the Netherlands, *Rapportage Intensivering Civiel-Militaire Samenwerking*.

8. Ministry of Defence, Government of the Netherlands and Ministry of the Interior and Kingdom Relations, Government of the Netherlands, *Catalogus Civiel-Militaire Samenwerking*.

The clustering helps to structure R&D products and processes in a comprehensible manner. To date, the current clustering has been a useful instrument, but the ongoing developments, such as the technological developments mentioned above, may necessitate some re-examination.

Any attempt to adjust the current set of knowledge areas should take into account three important criteria. First, to develop a good policy for S&T management the different knowledge areas should be as coherent and disjunctive as possible. Second, the research volume of each cluster should be substantial. Third, the overall number of knowledge areas and elements should be manageable.

Appendix C Current and Suggested New Knowledge (Sub)areas of MoD-NLD contains a suggestion for a restructured set of knowledge areas and knowledge elements.

## Clustered knowledge areas of focus countries

The international questionnaire also raised the issue of the knowledge clustering used by the participating countries for their S&T management. Appendix E Current Knowledge Area Clustering Focus Countries provides an overview of the clustering in knowledge areas and – where specified – in knowledge elements of the focus countries.

Generally, the knowledge clusters are derived from different characteristics:

- Capabilities
- Tasks
- Systems of Systems
- Systems
- Knowledge or technologies

Since all focus countries base their clustering on a combination of some of the characteristics mentioned above, the intercountry comparison of knowledge clusters is difficult. Nevertheless, an attempt has been made to compare the knowledge clusters of the focus countries with the knowledge areas of the Netherlands in a single figure (see Table 2):

Table 2 **Commonalities & differences in knowledge clustering.**

| |  |  |  |  |  |
|---|---|---|---|---|---|
| **Sensors** | x | x | x | x | x |
| **Generating Situational Awareness** | x | x | x | x | x |
| **Operational decision making** | x | | | | |
| **Communication** | x | x | | | x |
| **Platforms** | x | | x | | |
| **Weapons & munitions** | | x | x | | |
| **Protection** | | x | x | | |
| **CBRN detection and protection** | x | x | x | x | x |
| **Logistics and LCM** | | | | | |
| **Policy and planning** | | | x | x | |
| **Personnel readiness** | x | x | | | x |
| | | Networks<br>Complex systems<br>System Autonomy<br>Environment | Cross cutting Tech | Combat systems, Disrupt. Tech, Info Ops, Terrorism<br>Cold Weather Ops. | Materials structures<br>Energetics<br>Space systems |

On the surface, it seems that there exists a large degree of variance between the knowledge clusters applied by the focus countries. Table 2 Commonalities & differences in knowledge clustering seems to confirm this view and appears to indicate that the focus countries show great variance in the focus of their research. An analysis at the *knowledge element* level, however, indicates that the differences are much smaller. Thus, even though the focus countries use different types of clusters, the scope of the research is quite comparable. The international workshop[9] corroborated this statement, concluding that differences appear in the depth of the knowledge base in an area rather than in the scope. These differences stem from differences in national or industrial ambitions and from history.

During the workshop another commonality was found. All participants stated with regret that their knowledge bases were especially focused on hardware-related technologies and less on operational and strategic analysis and human factors-related issues.

9. *International workshop on Knowledge Investment Quote and Knowledge Infrastructure*.

## The Netherlands Strategic Knowledge Agenda vs. new knowledge and technology

The international questionnaire also asked the focus countries to provide an overview of the *new* areas of interest they focus on. In the overview below, these new areas are plotted against the themes and issues of the NLD Strategic Knowledge Agenda.[10] The SKA was used as a reference, because it is the temporarily most actual policy-relevant MoD document for this analysis. For this reason it was used as a reference to see whether the choices made in the SKA comply with the new technology areas as foreseen by the focus countries.

The left column of Table 3 The Strategic Knowledge Agenda vs. new technology areas of focus countries lists the various themes and areas, including a description. These themes and areas are then compared with the new technology areas of the focus countries in the column on the right.

10. Ministry of Defence, Government of the Netherlands, *Strategische Kennis Agenda van het ministerie van Defensie*.

Table 3 **The Strategic Knowledge Agenda vs. new technology areas of focus countries**

| Strategic Knowledge Agenda (demand) Knowledge Themes | New Technology Areas |
|---|---|
| **Deployment and sustainability**<br>This knowledge theme covers a wide range of research aimed at enhancing the deployment and sustainability of the military forces. Topics include logistics, alternative energy supply, human behaviour, weather conditions, and climate change. | Effects of climate change on military capabilities |
| | Novel power source |
| | Wideband mobile wireless networking |
| **Network information and infrastructure**<br>Adequate operational information and communication systems that function under any weather conditions and are well-protected from enemy countermeasures are crucial in military operations. Communication networks and information systems form the core of this knowledge theme. | Microsatellites |
| | New sensing (hyperspectral, terahertz) |
| **C2 and intelligence**<br>Information is of vital importance to any military effort. On a strategic level, intelligence is key. On a tactical level, it is essential to have an overview of what takes place in a complex irregular area of operation. This ranges from target detection and identification to cultural awareness. | |
| **Weapons and effects**<br>A weapon is a measure used to attain a certain goal in an operational setting. Weapons come in many forms. They can be lethal or non-lethal, carried by troops or be part of a platform, etc. Weapons that are used in electronic warfare or psychological operations also belong to this knowledge theme. | Non-conventional weapons |
| **Protection**<br>Protection entails all measures taken to prevent and/or minimise the impact of threats from opponents and/or local conditions directed at the own military effort. Besides physical protection, activities such as (counter)intelligence and information and media operations also contribute to protection. | |

| Strategic Knowledge Areas (push)<br>Research Initiatives | New Technology Areas |
|---|---|
| **ICT and cognitive computing**<br>In the present situation, humans usually have to adapt to computers. In an ideal situation, the computer would be able to adapt to humans. To realise this ambition, computers have to be 'taught' to learn from experience. | Quantum capabilities |
| **Advanced simulation & serious gaming**<br>Simulation can be a useful way to train humans to react to fast-changing situations. Simulation can also be used to calculate the environmental effects of specific actions. | |
| **Human sciences and biotechnology**<br>Humans are likely to remain the key element in military operations. Research in human sciences and biotechnology may help to indicate more optimal ways to deploy humans in military operations. | Monitoring & influencing behaviour of (groups of) people in crowds |
| | Human behaviour & performance (enhancement) |
| | Biotechnology |
| | Biology-based solutions (biometrics, biosignatures, broadspectrum therapies) |
| | Virtual reality and neuro-interfaces |
| | Human factors |
| **Advanced materials and nanotechnology**<br>It is expected that research in advanced materials and nanotechnology will continue to produce interesting military applications. Ultra-strong, ultra-light and smart materials, for example, could make an important contribution to the military effort. | Micro-/nano-engineered smart materials |
| **Microsystems and robotics**<br>Microsystems are interwoven with nanotechnology, but are focused on future applications in electronics, photonics and micro-electrical machines. In the future, humans will not be replaced by robots, but rather supported by semi-autonomous systems. This could significantly enhance troop security. | Autonomous intelligent systems and platforms |

## Criteria for R&D choices

The focus countries were also asked in the questionnaire to present the criteria deciding the orientation of their R&D effort. These criteria that were derived from the questionnaire, the presentations of the separate countries and from the international workshop are presented in the table below. Great Britain and Norway did not directly refer to such criteria.

Table 4 **Criteria for R&D choices**

| NLD | DEU | CAN | AUS | GBR | NOR |
|---|---|---|---|---|---|
| Political relevance, MoD-NLD policy and MoD-NLD S&T policy | Individual protection and safety | Progress implementation of the defence S&T strategy | Potential benefit for Australian Defence Organisation | x | x |
| Applicability, requirement and timely availability | Worldwide reconnaissance | Ensure S&T programme alignment with defence priorities | Need for the work to be done in DoD | x | x |
| Efficiency and effectiveness | Effective engagement | Facilitate exploitation of RTA programme outputs | S&T feasibility | x | x |
| Innovative character | NEC | Strengthen internal S&T expertise | Ability of Australian Defence Organisation to exploit outcomes | x | x |
| Availability of MoD-NLD management for S&T programmes | Strategic deployability | Respond to the federal S&T strategy | | x | x |
| | | Support the public security dimension of the defence mission | | x | x |

On the basis of the table above, it seems reasonable to conclude that the sets of criteria used by the individual countries are different and hard to compare.

## Relations knowledge base with Armed Forces Profiles

An important question raised during the international workshop was how to relate the knowledge base to the foreseen Armed Forces Profiles (Appendix B Armed Forces Profiles) of the Netherlands. Part of this question was raised in the questionnaire (Appendix A Questionnaire Format) too.

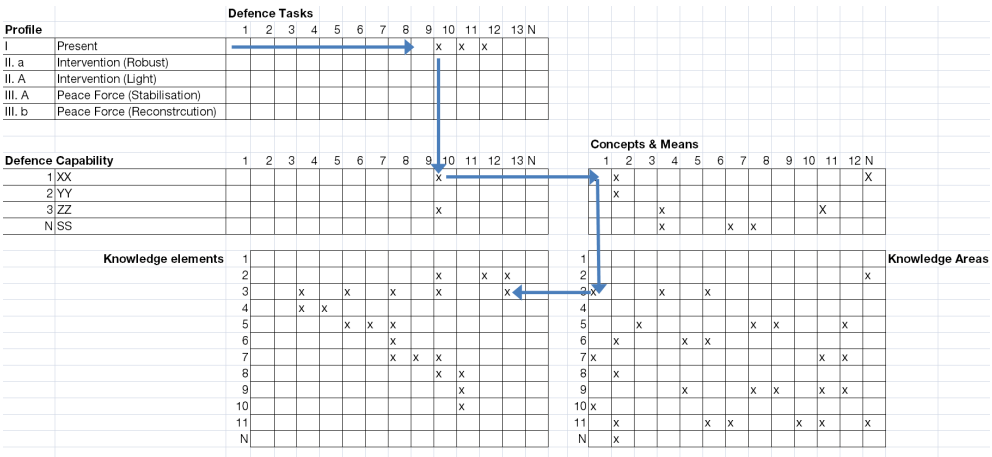
In general, the focus countries agreed that there is no deterministic, let alone explicit relationship between Armed Forces Profiles and the related knowledge infrastructure. Armed Forces Profiles are not the sole determinant of a sensible knowledge base, and tellingly ignore the need to expect and quickly respond to the unexpected.

The zero-base deterministic approach was used in the United Kingdom some years ago. It turned out that the requirements overstretched the possibilities of the S&T budget to the extent that the discriminatory possiblities of the approach were not of any use,

The idea presented in Figure 1 is that when following the arrows step by step, on the crossing of two axes a product is defined as the basis for the question: what is

an important knowledge element for a specific Armed Forces Profile? This is a highly uncertain approach that ignores relevant historical experiences and ends up in having overstated requirements that do not discriminate enough. The participants of the international workshop therefore advised not to use the deterministic approach set forward in Figure 1.

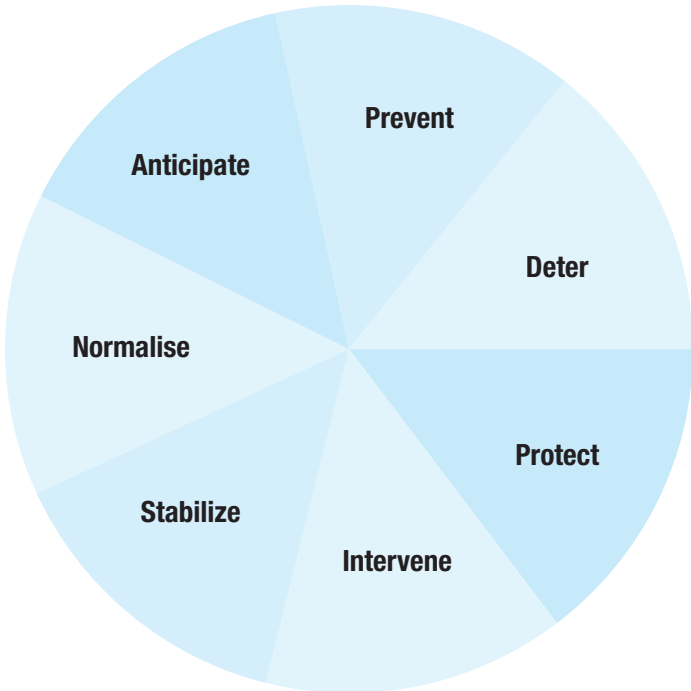
Figure 1 **Example of thinking model for deterministic mapping of Armed Forces Profiles on knowledge elements.**




At the time of the international workshop a key presentation was given by the project leader of the Netherlands Future Policy Survey. In this presentation he used a diagram (a wheel) for so-called strategic functions, seven in all All of these seven functions are important for the defence organisation. The way they are combined, the prioritisation of specific functions above others and the organisational embedding of the functions are subject to change over time. Moreover, although the defence organisation makes an important contribution to each of the functions, other organisations, both private and public, and civilians make their contribution as well. The functions are presented in Figure 2.

These strategic functions could offer more relevance to the analysis of a future S&T base than Armed Forces Profiles. This is mainly because the strategic functions have a broader scope than the Armed Forces Profiles, apart from placing more focus on capabilities. The functions, however, are not entirely disconnected from the profiles. In fact, each Armed Forces Profile could be interpreted as a particular prioritisation of these seven functions. Appendix C Current and Suggested New Knowledge (Sub)areas of MoD-NLD proposes a suggestion for mapping knowledge elements on the strategic functions.

Figure 2 **Strategic functions of the Ministry of Defence in the Netherlands.**




# Defence knowledge and technology areas: conclusions

On the basis of the preceding analysis, the following conclusions were drawn:

- In order to guarantee a satisfactory level of agility without losing sight of important developments in basic research, the knowledge portfolio of the MoD should span the short, medium and long term.
- The significant overlap between the knowledge requirements for defence and security makes a collaborative research effort increasingly profitable.
- Although to the casual observer the knowledge bases of the focus countries may appear to be very different in nature, closer analysis shows that the differences occur in the depth of the knowledge base rather than in the scope.
- The criteria used by the focus countries to decide where to direct their future research efforts are very different and therefore hard to compare.
- Since no explicit, linear relation between Armed Forces Profiles and required knowledge exists, it is neither possible nor advisable to derive a desired knowledge infrastructure from Armed Forces Profiles in a deterministic process.

# Defence Knowledge Investment Quote

There are basically two ways of assigning money for defence knowledge and technology development. The first and most commonly used is fixing a certain percentage of the defence budget (the knowledge investment quote or KIQ) for expenditures on Science and Technology. This is the top-down way todo it. The other method works bottom-up. In this method the first step is to assess the specific requirements for defence knowledge and technology, and then to allocate funds to meet each of these requirements. In practice, almost every defence organisation uses a combination of both methods, meaning that a defence knowledge investment quote usually is a hybrid quote.

As mentioned earlier, allocating funds to knowledge and technology development is not a linear process. There are different factors that could influence the outcome of the budget. Some of these factors may be influenced by the MoD itself, while others cannot. These factors will be addressed in the first part of this chapter.

In the second part of this chapter the national KIQs (*i.e.* R&D investments as a percentage of GDP) of potential adversaries, NATO members and EU member states are benchmarked against each other. The same is done with military expenditure and defence KIQs. To enable comparison with the industry, the R&D percentages of some relevant industrial sectors are also included, although it should be noted that defence knowledge and technology investment is of a special nature due to the extreme – military – conditions under which the results are to be applied.

# Factors influencing the defence KIQ

As mentioned earlier, it is neither possible nor desirable to assign a KIQ solely on the basis of an Armed Forces Profile. Also, internal and external factors should be taken into consideration. It is important to address these factors and to assess how and to what extent they can be influenced by the MoD in order to optimise the defence KIQ.

Table 5 **Factors of possible influence on defence KIQ**

| | Factor | Possible to influence directly by MoD? | | Comments |
|---|---|---|---|---|
| | | Yes | No | |
| **1** | (Potential) adversaries/opponents | | x | Technical skills and ambitions of opponents forcing one to stay leveled. |
| **2** | NATO expectations (defence) | x | | Member states should spend 2% of their GDP on defence. The Netherlands stays below this target. |
| **3** | EU expectations (national) | | x | 3% GERD/GDP by 2010, Barcelona Council 2002. No particular focus on defence R&D, most EU states well below this target, the Netherlands under EU average. |
| **4** | European Defence Agency (EDA) expectations | x | | R&T investment should be 2% of defence spending. |
| **5** | National expectations and defence culture | | x | Overall R&D/innovation strategy, political/government priorities, defence industrial strategy. |
| **6** | Global/regional/national political & economic conditions | | x | Although it seems plausible that defence spending possibilities are linked to political and economic conditions, there generally hasn't been a significant economic conditions link with defence spending during the last decades. |
| **7** | Market volume commercial R&D | | x | Amount invested by private organisations in R&D in defence-relevant areas. The higher the amount, the more capable a market is and the more the defence community will be able to fall back on the investments made in these markets. |
| **8** | Defence/military capability needs | x | | Needs as a result of security strategy ambitions. |
| **9** | Standing availability of national defence/security-relevant (industrial) knowledge base | x | | Technological maturity, market availability, national security restrictions, *quid pro quo* principle. |
| **10** | Defence industrial strategic ambitions | x | | Ambitions to strengthen national industries for economic reasons. |
| **11** | Existing commitments (e.g. long-term contracts) | x | | Long-lasting commitments in contracts fixing R&D investments. |
| **12** | Defence R&D governance model | x | | Effectiveness and efficiency of R&D investment and procurement model. |
| **13** | R&D preference culture in MoD | x | | Is R&D an accepted instrument in the MoD? |

Below, the factors of influence described in Table 5 are explained in more detail.

## 1 – (Potential) adversaries/opponents

States always use (potential) adversaries as a benchmark for their ambitions and capabilities. This is even more relevant for ambitions and requirements in the defence sphere, among which are strategy, procurement, and – of course – R&D investments.

## 2 – NATO expectations (defence)

Although a formal NATO document explicitly stating this percentage was not found, the target of 2% for defence expenditure as a percentage of GDP is widely used among NATO member states.

## 3 – EU expectations (national)

In March 2002, the European Council agreed that overall spending on R&D and innovation (Gross Expenditure on Research and Development – GERD) in the European Union should be increased *"with the aim of approaching 3% of Gross Domestic Product (GDP) by 2010"*. Two-thirds of the required investment should come from the private sector.[11] This decision was related to the so-called Lisbon Strategy, formulated at the European Council session in Lisbon in March 2000, which set the goal for the European Union "*to become the most competitive and dynamic knowledge-based economy in the world, capable of sustained economic growth with more and better jobs and greater social cohesion*" (emphasis original).[12]

## 4 – European Defence Agency (EDA) expectations

On 19 November 2007, the Steering Board of the EDA, consisting of the Defence Ministers of the member states, decided upon objectives and methods for achieving a better collective performance from national defence budgets. As part of the agreement, the ministers stated that expenditure on defence R&T should be increased to 2% of total defence spending. They also stated that 20% of defence R&T expenditure should

11. European Council, "Presidency Conclusions Barcelona European Council 15 and 16 March 2002."

12. European Council, "Presidency Conclusions Lisbon European Council 23 and 24 March 2000."

be allocated to collaborative European defence R&T spending. These targets apply to the collective spending of the member states. They are voluntary.[13]

## 5 – National expectations and defence culture

In terms of general R&D investment, the ambition of the Netherlands is identical to the EU target. Because the original target date of 2010 seemed to be overambitious, the Netherlands Innovation Platform in 2006 stated that private investment in R&D should approach 2% of GDP by 2016. Public R&D investment should reach 1% of GDP by the same year.[14] The Prime Minister is the head of the Innovation Platform, meaning that the Dutch government regards R&D investment as one of its priorities, but until the present date (according to some analysts because of a lack of commitment from the Dutch government) it has not yielded any significant results. For defence R&D investment, political priorities, for example through a defence-industrial strategy, can also make a major difference.

## 6 – Global/regional/national political & economic conditions

The national and/or global economic situation always has an impact on spending. Although it seems plausible that defence spending possibilities are linked to political and economic conditions, during the last decades economic conditions have generally not been significantly linked to defence spending. It is therefore questionable whether economic conditions are an important factor of influence as a basis for strategic planning on R&T investments. The link with the geopolitical situation is more significant. Figure 16 (Appendix D Graphs, Data Collection and Tables) gives an indication of the development of world GDP and global military spending between 1988 and 2007.

## 7 – Market volume commercial R&D

The higher the amount, the more capable a market is and the more the defence community will be able to fall back on the investments made in these markets. This also works vice versa. Money invested by the defence community can also strengthen the market.

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13. European Defence Agency, "Press Release: EU ministers adopt framework for joint European strategy in defence R&T."

14. The Netherlands Innovation Platform, "Kennisinvesteringsagenda 2006-2016; Nederland, hèt land van talenten!"

## 8 – Defence/military capability needs

Requirements and ambitions are the prime drivers for choices in the defence technological and industrial base.

## 9 - Standing availability of national defence-/ security-relevant (industrial) knowledge base

At the centre of any effective programme is the knowledge base. This base is present in science organisations in the government, the industry and universities and other knowledge institutes.

## 10 – Defence industrial strategic ambitions

Depending on the ambitions a nation has regarding its industry, some countries invest R&T money in defence-relevant sectors to boost these industries for commercial purposes.

## 11 – Existing commitments (e.g. long-term contracts)

Long-lasting commitments in S&T programmes provide a solid basis for the R&D community. The flip side of the coin, however, is that long-term contracts significantly reduce the flexibility of the MoD budget.

## 12 – Defence R&D governance model

The R&D governance model and organisational structure in place in a country and/or in the Ministry of Defence influences the way R&T spending is organised. It reflects the factors of influence on defence KIQ. The more flexible the governance and organisational structure, the more adaptable the R&T base may be to specific needs and ambitions.

## 13 – R&D preference culture in MoD

R&D is an accepted instrument in the MoD. Part of the appreciation and ambitions tends to be based on preference and understanding of the foreseen added value of R&T that people have in the defence organisation.

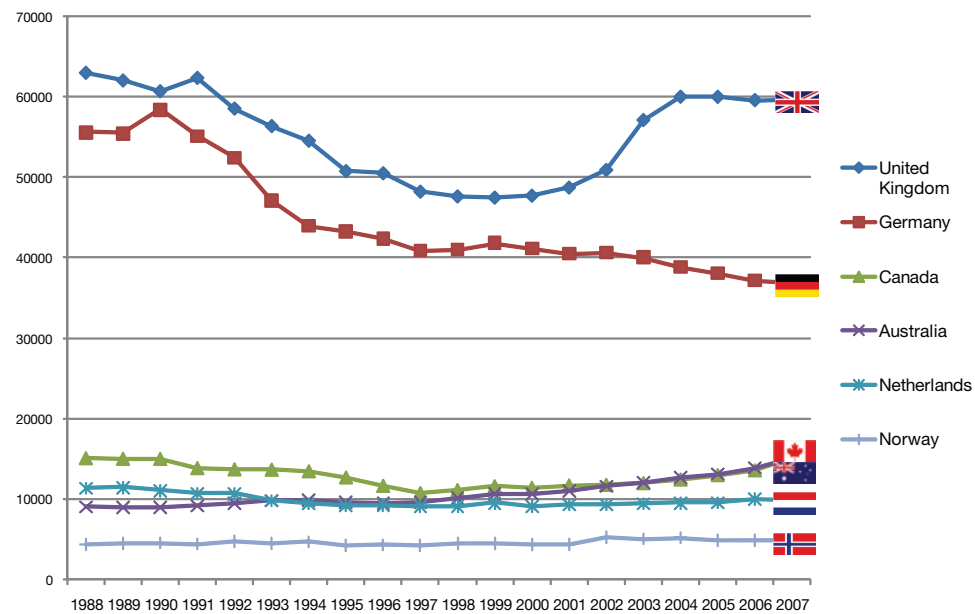
See for related statistics below and Appendix D Graphs, Data Collection and Tables.

# Defence budgets and KIQs

This section will first provide an overview of the trends in military expenditure of the focus countries, both in absolute and relative terms. It will then proceed to give an indication of MoD investments in Science & Technology of the focus countries as a percentage of the total defence budget.

## Defence budgets

Figure 3 **Military expenditure in mln US$, focus countries, 1988-2007.**




*Source:* SIPRI military expenditure database

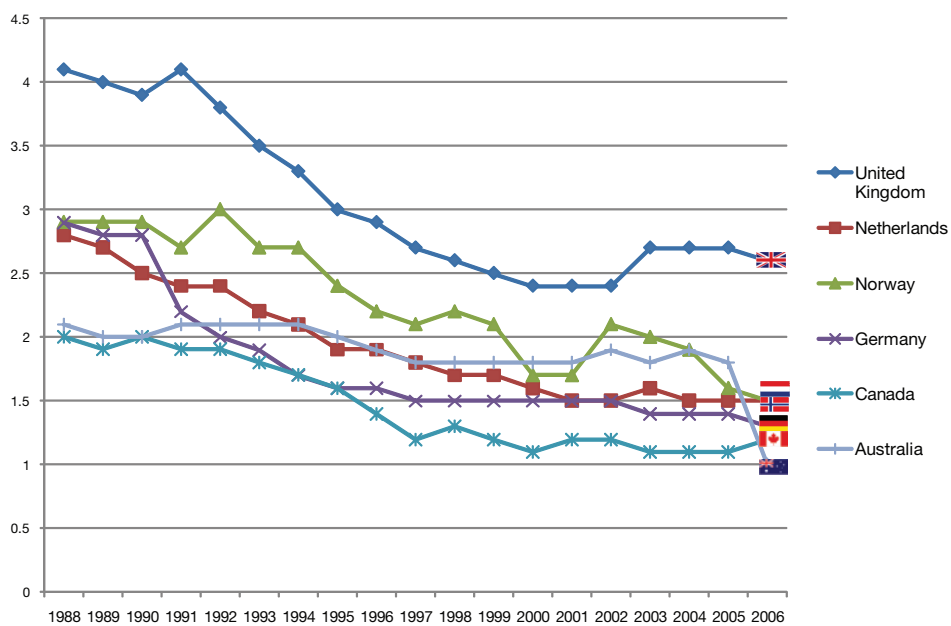
Figure 3 and Figure 4 refer to factor of influence #8 of Table 5 Factors of possible influence on defence KIQ. Figure 3 gives an indication of the military expenditure of the focus countries in the period between 1988 and 2007. It is based on data from the SIPRI military expenditure database.

The figure shows that for most of the focus countries, military expenditure has remained relatively stable throughout this period. German military expenditure (not the same as the defence budget), however, has decreased significantly from 55.6 billion US$ in 1988 to 36.9 billion US$ in 2007, a decline of approximately 34%. A decrease in overall military expenditure is likely to have a negative impact on the MoD budget for R&D investment.

UK military spending also shows an interesting curve. Between 1988 and 1999/2000, military expenditure in the UK declined steadily, but between 2000/2001 and 2004, it increased again. A possible explanation for this development is the UK participation in the US-led operations in Afghanistan and Iraq.

Figure 4 displays the military expenditure of the focus countries as a percentage of GDP. For all focus countries, the military expenditure/GDP ratio has declined significantly between 1988 and 2006.

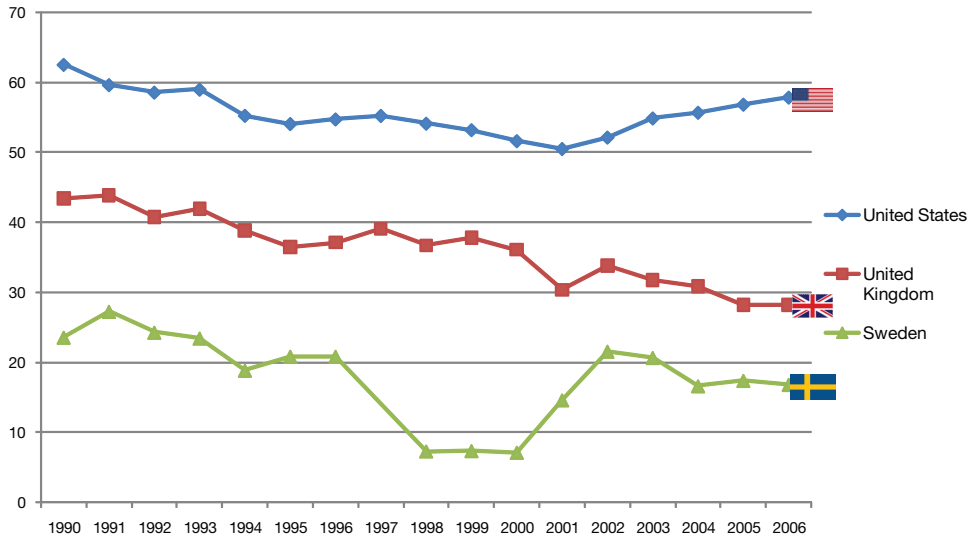
Figure 4 **Military expenditure as a percentage of GDP, focus countries, 1988-2006.**




*Source:* SIPRI military expenditure database

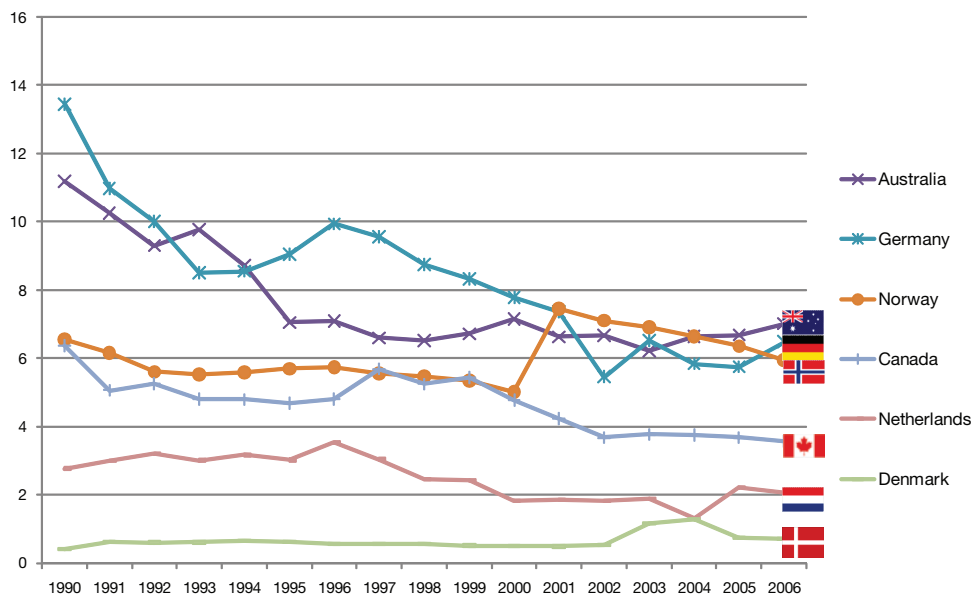
# Defence R&D budgets as a percentage of total GBAORD

Figure 5 **Defence R&D budget as a percentage of total GBAORD, high end.**




*Source:* OECD Main Science and Technology Indicators 2008/I

Figure 6 **Defence R&D budget as a percentage of total GBAORD, low end.**



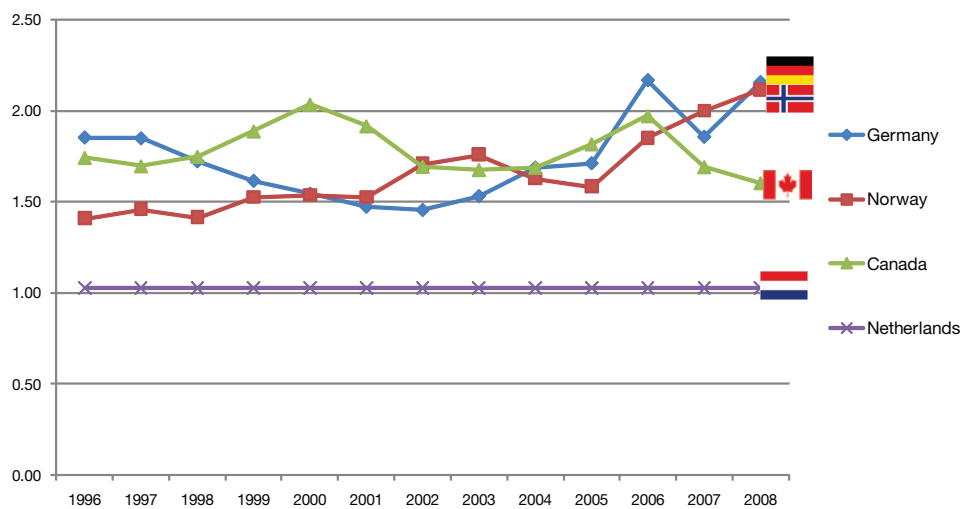

*Source:* OECD Main Science and Technology Indicators 2008/I

Figure 5 and Figure 6 refer to factors of influence #2, 5, 9 and 10 of Table 3 Factors of possible influence on defence KIQ. They give an indication of the percentage of total government expenditure on R&D invested in defence-related R&D activities (Government Budget Appropriations or Outlays for R&D – GBAORD). The figure includes the focus countries as well as the United States, Sweden and Denmark. For reasons of comparison, especially the US is interesting as an outlier. In 2006, almost 58% of US GBAORD was defence-related. For the Netherlands, the share of defence R&D in total GBAORD was slightly above 2% in the same year. This percentage is one of the lowest among the focus countries.

## Defence S&T quote

Figure 7 gives an indication of the defence S&T quote of some of the focus countries. The figure is based on data submitted by the MoDs of the nations involved. Since Australia and the United Kingdom did not submit these data, they are not included in the graph. Because of major internal reorganisations in the Dutch MoD, it is not possible to effectively compare pre-2002 data on S&T expenditure with post-2002 data.

Figure 7 **Defence S&T quote, focus countries, 1996-2006.**




*Note:* The quote of the Netherlands is based on structural budgets. The line represents the quote of 2008 (1.00). Because of internal reorganisations, it has not been possible to retrieve earlier data.
*Source:* Based on data submitted by the MoDs of the concerned states. Austrlia and United Kingdom did not submit data.

Although some differences in the measurement of S&T are likely to have occurred, the overall trend is clear. Whereas Germany, Norway and Canada invest approximately 2% (or at least 1.5%) of their defence budgets on S&T, the Netherlands spends a (much) smaller part of its defence budget.

## Defence KIQ: conclusions

- On the basis of the above analysis, the following conclusions were drawn:
- It is not possible to derive the volume and KIQ of the S&T base from Armed Forces Profiles or required capabilities in a linear process. Rather, this decision-making process is influenced by a number of factors, some of which cannot be directly influenced by the Ministry of Defence.
- The two most important conclusions regarding the KIQ are first, that it is a political strategic choice, and second, that it is influenced by demand.
- S&T/R&D is an instrument for leverage of military capabilities, international relevance ranking, effective collaboration between likeminded nations and for the national (defence) industrial base.
- Compared to the focus countries, the Netherlands MoD has a relatively low KIQ. The KIQ of most focus countries is around 2%, against 1.2% for the Netherlands. It may therefore be wise to review the current percentage and raise it to approximately 2% too.

# Defence Knowledge Infrastructure

For Ministries of Defence spending R&D money it is important to have a clear vision of how R&D expenditure and performance are organised and managed. The commonly used business model has two dimensions, the internal vs. external aspect (what to spend intramural and extramural), and collaboration (multinational and/or multidisciplinary) vs. self-sustainment.

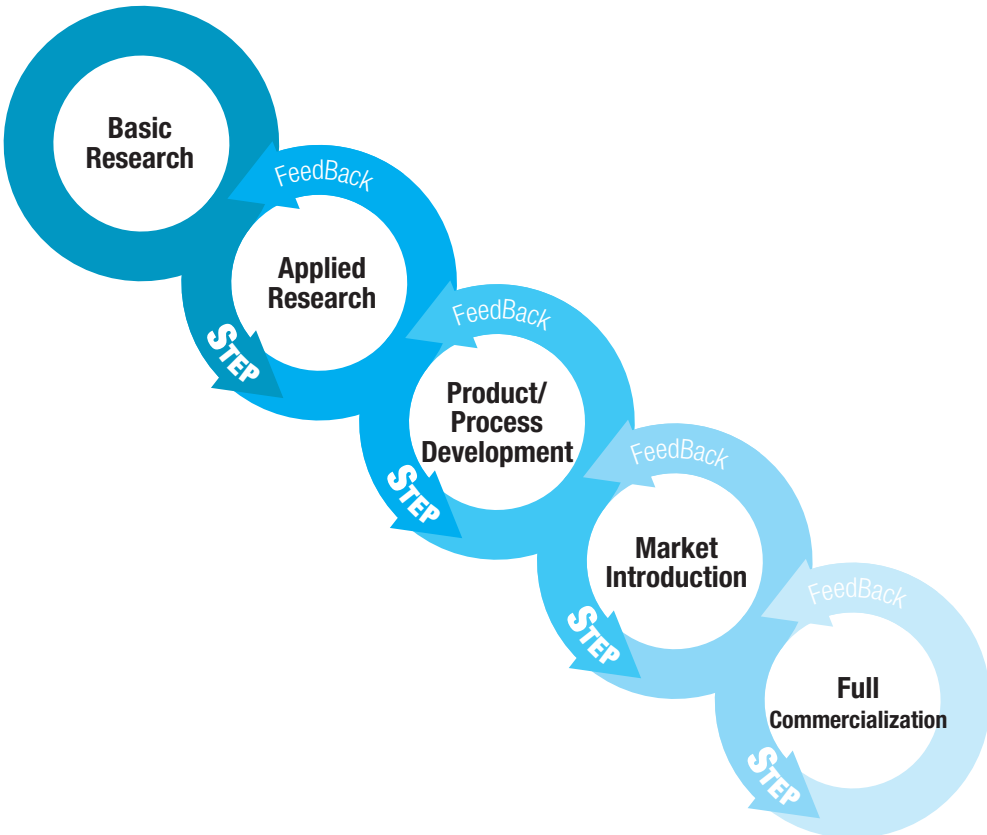
As a basis for the analysis of the possible external and internal knowledge infrastructure there are three models. An R&D structure organised entirely within the Ministry of Defence, a structure based entirely on outsourcing and a combination of both.

The purpose of this chapter is threefold. First, it explores possible governance models and analyses which criteria are used in the process of determining which governance model suits the situation of any specific MoD best. Second, it provides an analysis of the current defence knowledge infrastructure of the Netherlands, comparing this to the knowledge infrastructures of the focus countries (described in more detail in Appendix G Defence knowledge infrastructures focus countries). Third, it provides a list of criteria that are commonly used for making decisions with regard to international collaboration in R&D.

## Possible defence-relevant knowledge infrastructures

The traditional research value chain is used as a basis for analysing defence S&T. Although there may be differences in the exact configuration, every country has the various S&T activities represented in its value chain.

Figure 8 **The S&T value chain.**




For this study the focus is primarily on the first three steps of the value chain: basic and applied research and product/process development. The last two steps are of less relevance to this study.

## Five models

In practice, five generic models are used for the organisation of national knowledge infrastructures: MoD-owned and -operated; publicly owned defence-oriented; publicly owned civilian-oriented, privately owned defence-oriented, privately owned civilian-oriented.

**MoD-owned and -operated**: in-house lab; governance, research agenda and implementation are under direct control of the MoD (examples are the DRDC, DSTO, DSTL, FFI, FOI).

**Publicly owned, defence-oriented**: an institute that has a specific focus on defence research, but is at arms length from the MoD (examples are TNO Defence, Security and Safety in the Netherlands and ISL in Germany/France). Ultimate governance is conducted by federal government or parliament (e.g. FHG) through the appointment of members of the Board of Directors/Board of Governors.

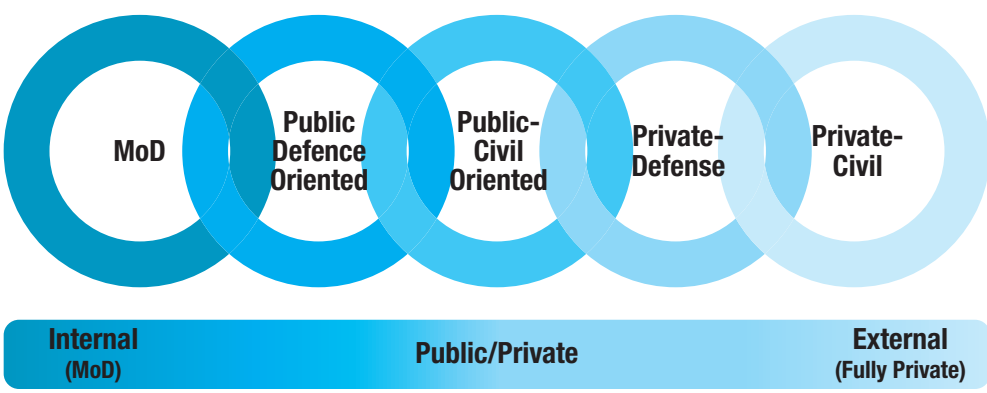
**Publicly owned, civilian-oriented**: research institutes that are in the public domain, but do not specifically focus on defence research; contributions follow from broader applications of their research to the defence domain, e.g. in logistics, ICT, or even human factors (examples are NRC in Canada and VTT in Finland).

**Privately owned, defence-oriented**: private (profit as well as not-for-profit) research institutes that work predominantly in the field of defence; most often they have a more diversified clientele than the 'home' MoD esp. compared to the public defence research institutes. They may be tasked with longer-term research agendas for the MoDs (e.g. RAND's Project Air Force; this is a Federally Funded R&D Center [FFRDC], but also QinetiQ and IABG).

**Privately owned civilian-oriented**: private research institutes, either independent or as part of private corporations. Their research can contribute to defence operations, often as a spin-off of more applied or commercial research (e.g. Daimler, think tanks, etc.).

The order in which the governance models are listed above indicates the closeness to the Ministry of Defence. Indeed, in the 'MoD-owned and -operated' model, the entire research effort is directly controlled by the MoD, whereas the 'privately owned civilian-oriented' model does not leave room for MoD control. Figure 9 shows the relative closeness of these models to the MoD.

Figure 9 **S&T operators.**



## Criteria

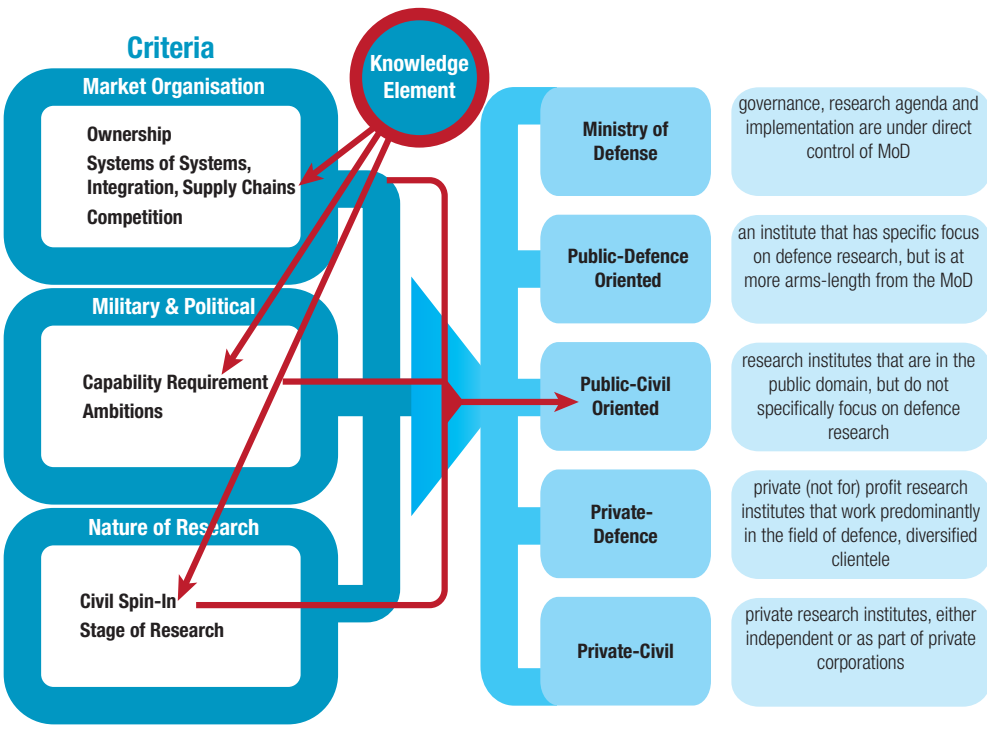
In reality, different governance models may be applied to different areas of research, since the criteria for the selection of a particular model may also vary between different knowledge areas or knowledge elements. The criteria used to determine which organisational framework should be applied to a particular knowledge area and/or element can be divided into three categories: military & political considerations, market organisation and nature of research. The criteria are presented in Table 6.

Table 6 **Criteria for development of an ideal type of defence-relevant knowledge infrastructure.**

| Criteria | Description | MoD | Public-defence | Public-civilian | Private-defence | Private-civilian |
|---|---|---|---|---|---|---|
| **Military & political considerations** | | **Scale** | | | | |
| Capability requirements | What level of technology is required for the current configuration of the armed forces? | Superior systems----------Standard | | | | |
| National ambitions | What level of technology is required for future ambitions?* *Including national industrial ambitions | Strategically Relevant----------COTS | | | | |
| **Market organisation** | | | | | | |
| Ownership | Is S&T research: primarily privileged (inter) nationally controlled (GOTS/MOTS) vs. primarily civilian-controlled | Privileged----------Civilian-controlled | | | | |
| Systems of systems, integration, supply chains | Does the market operate as an integrated system or do actors operate in isolation? | Modular Specificity----------Integration | | | | |
| Competition | To what extent is the market characterised by a high level of competition and a level playing field? | Closed----------Open | | | | |
| **Nature of research** | | | | | | |
| Civilian spin-in | To what extent is civilian technology available/applicable? | Defence-specific----------Civilian A/A | | | | |
| Stage of research | Basic vs. applied | Basic----------Applied | | | | |

An ideal plot of a knowledge infrastructure can thus be generated by stating which of these criteria are applicable to a specific knowledge area or knowledge element. Depending on the actual possibilities and ambitions in time, the ideal S&T effort can be adjusted to this outcome. In Figure 10, the process that leads to the choice for a governance model is displayed graphically. The red arrow is an example of a possible outcome of this process, which takes into account the three sets of criteria for the analysis of an ideal type of infrastructure for a knowledge element (K-element).

Figure 10 **Possible knowledge infrastructures.**



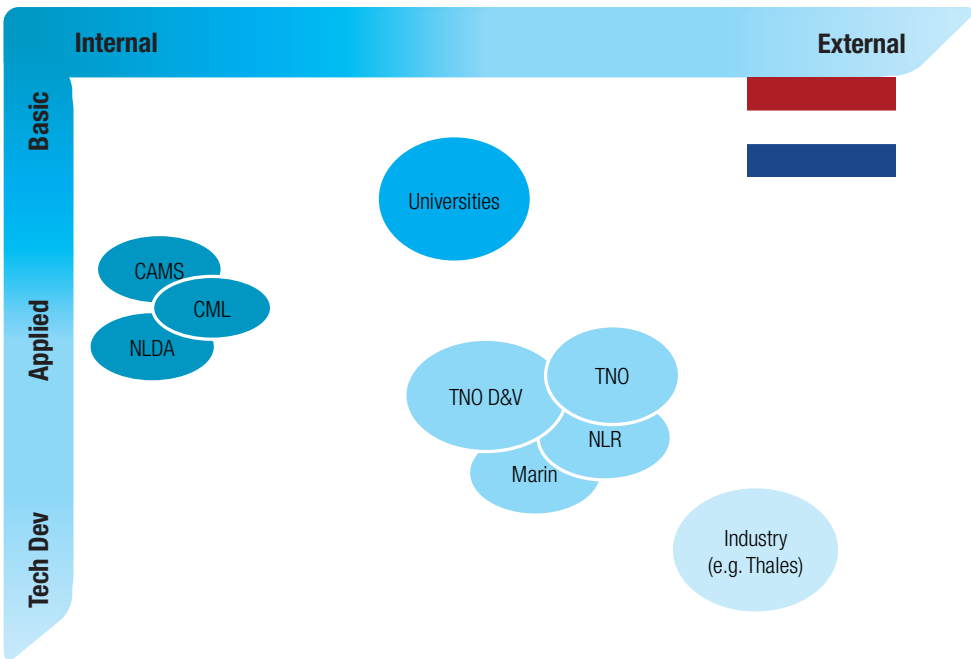

# Defence knowledge infrastructures compared

This section aims to provide a generalised description of the current knowledge infrastructure of the Netherlands, comparing it with the knowledge infrastructures of the focus countries. It provides a textual description of the knowledge infrastructures of these countries (see also Appendix G Defence knowledge infrastructures focus countries) as well as a plot of the main actors involved in the S&T effort. The axes used in the plots (basic research – technological development and internal – external) are derived from Figure 8 and Figure 9.

## The current Netherlands knowledge infrastructure

MoD-NLD has a strategic relationship with TNO Defence, Security and Safety, with the National Aerospace Laboratory (NLR) and with the Maritime Research Institute of the Netherlands (MARIN). In these institutes almost all the defence-relevant knowledge is built up and maintained in a manner that is mainly not-for-profit. As these institutes are not a part of the Ministry of Defence, administrative relations have been established.

Figure 11 **The current Netherlands defence knowledge infrastructure plotted.**




Of the total volume of defence R&T in the Netherlands about 10% is spent on explorative long-term research, about 15% is allocated to medium-term research and about 75% goes to applied research and support. The explorative part of the research mainly resides with the institutes themselves, whereas the other research activities are customer-driven.[15]

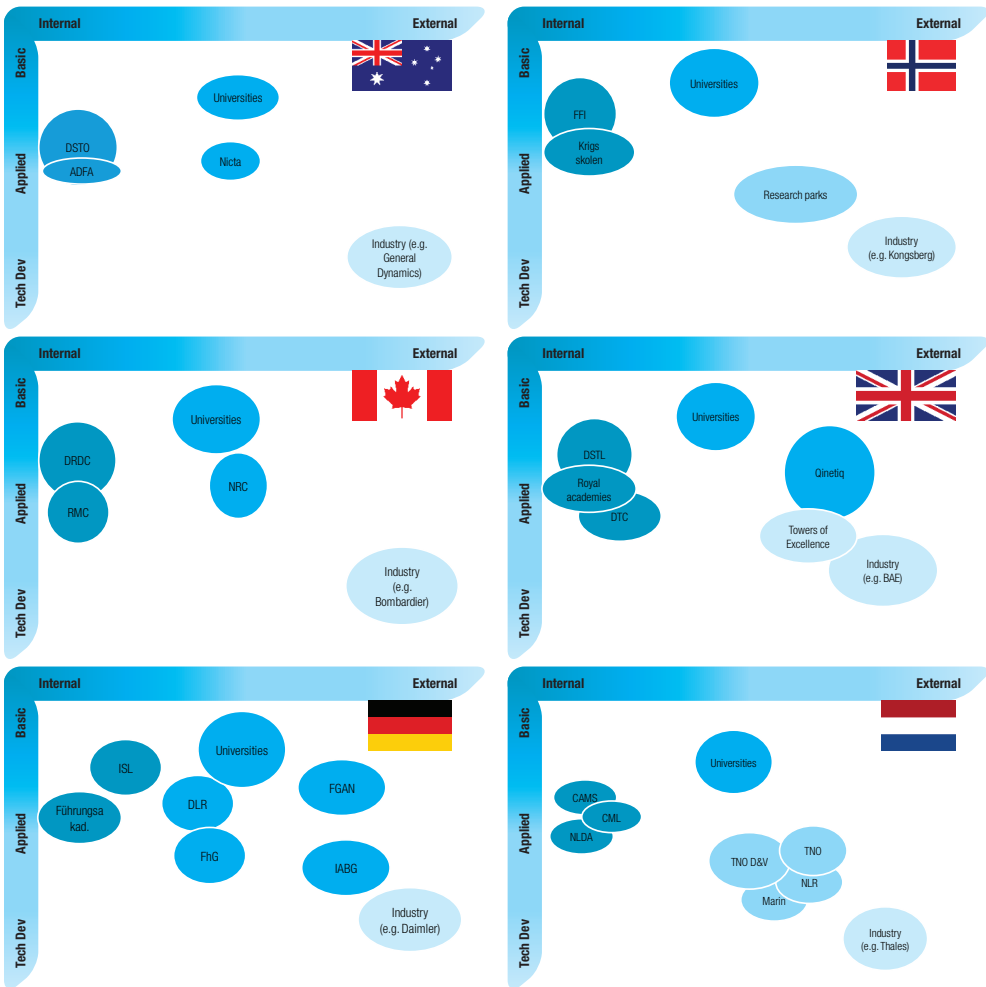
The Dutch defence-related industry (DRI) may be characterised as relatively modest in scope. It is also niche-oriented. It comprises of approximately 250 medium- and small-sized companies, most of which embark on both civilian- and defence-related activities.

15. Ministry of Defence, Government of the Netherlands, *Defence R&D Business Model*.

The Dutch DRI is gradually evolving into a 'normal' industrial sector that may increasingly be characterised as an open market. On the one hand, the MoD-NLD procurement strategy appears to be shifting toward a more open tender-based approach. On the other hand, the MoD increasingly seeks civilian solutions, buying 'off the shelf' (Commercial off the Shelf – COTS), causing an increase in competition and integration with civilian markets.[16]

## Summary of KIs of the focus countries

Figure 12 **The defence knowledge infrastructures of the focus countries plotted.**




16. Ministry of Defence, Government of the Netherlands and Ministry of Economic Affairs, Government of the Netherlands, "Defensie Industrie Strategie, Eindrapportage."

In order to compare the Netherlands knowledge infrastructure, the same plot is also made for the focus countries. A summary of the plots is displayed in Figure 12. The individual plots are presented in Appendix G Defence knowledge infrastructures focus countries

The above plot of the defence knowledge infrastructure of the focus countries shows substantial differences.

Using our S&T operator dimension first, two main characteristics can be distinguished. A number of countries have a clear emphasis on in-house defence-specific R&D capabilities. These countries, Norway, Australia and Canada, maintain dedicated defence research institutes under direct control. The UK has a similar research institute that operates in combination with a large private defence institute, itself being a spin-off from the publicly operated organisation. The German and Dutch governance structures are much more distant from the government. They are operating in the public domain, having both a specific defence and a civilian research orientation.

The second dimension, the type of S&T activities conducted, presents a much more uniform picture across the countries surveyed. Many of the defence-related R&D activities are right in between basic research and technology development, in most instances focusing on applied research. In Germany, there is a more explicit relationship between basic-applied and public-private characteristics.

## Choices in collaboration

The S&T infrastructure does not necessarily have to be located entirely within a single specific country. In fact, international cooperation in S&T is an increasingly common phenomenon. During the international workshop,[17] several criteria for government-to-government international collaboration in S&T were discussed. The participants confirmed that the following criteria influence the selection of an international partner:

- Mutual benefit: opportunities in collaboration areas that benefit both parties. This could mean collaboration on a specific topic with both countries investing in S&T, or cross-S&T investment, with country 1 investing in topic A and country 2 in topic B, both profiting from the results.

17. *International workshop on Knowledge Investment Quote and Knowledge Infrastructure*.

- Tradition: an overlap in military cultures and traditions enhances mutual understanding and facilitates cooperation.
- Geography: it is practical to cooperate with countries that are geographically near.
- Political alliances: a political alliance lowers the threshold for cooperation.
- Ambitions: if defence organisations have comparable levels of ambition, S&T efforts may show overlap.
- Partners/strategic partnerships: if cooperation is institutionalised in a strategic partnership, this generally indicates that there exists a history of constructive cooperation.
- Cultural background: sharing a comparable cultural background facilitates interaction and mutual understanding.
- Operational relationship: if defence organisations conduct joint operations, a need for interoperability of the armed forces naturally arises. Cooperation in S&T has the potential to significantly improve interoperability.
- Personal chemistry: if key actors in two (or more) countries get along very well, this may greatly enhance the potential for meaningful and effective interaction.

## Defence knowledge infrastructure: conclusions

On the basis of the preceding analysis and the results of the international workshop the following conclusions can be drawn:

- The MoD should use a broader scope for its S&T base.
- There should be more possibilities for fast track development and procurement.
- Higher representation of the S&T community within the MoD would be helpful.
- A closer relationship between Operations and R&D is required to enhance interactive engagement and guidance. This would lead to a sharper focus on system concept development by both MoD and S&T operators.
- In general, the gap in communication and understanding between planners and military operators versus researchers is wide. Strategic conversations regarding the goals, means and possible research solutions are vital to address an effective and efficient path to day-to-day and long-term solutions. By organising this in a natural way it influences both effectiveness and appreciation of R&D and the usefulness of the defence knowledge infrastructure in a positive way.

# Conclusion

In the preceding three chapters analyses have been presented of the knowledge areas, the knowledge investment quote and the knowledge infrastructure involved. At the end of each chapter, a number of conclusions were formulated, based on desk research, the results of the questionnaire and the international workshop. In addition to these 'subconclusions', the present section provides an overview of the main findings of the research. These are listed below.

- A strong Science and Technology (S&T) base is necessary to mitigate uncertainty.
- The S&T base is not purely national anymore. Enhanced international collaboration would help in sustaining an appropriate S&T knowledge base.
- In the short term the S&T base in the Netherlands is adequate, but the Ministry of Defence is still too much focused on a small number of traditional suppliers. This also calls for more flexibility in the R&D budgets.
- Integral security (internal and external security together) has become increasingly important. Examples are countering the effects of IEDs and protecting major events like the Olympic Games. Such activities require a strong defence S&T knowledge base, including e.g. terrorist profiling, forensics, explosives, protection, human behaviour (individuals and crowds), human networks, CBRN, vital infrastructure, electronic warfare and info ops. Mutual investments with other security-related ministries in R&D are useful and will enhance synergies.
- A change in the Netherlands defence S&T business model is the most important subject to look into. The security and defence S&T base of the Netherlands *needs to engage the total knowledge base*, including the industry and universities.
- At the senior levels, collaboration helps to confirm national priorities and future directions. A higher representation of the S&T community within the Netherlands

Ministry of Defence is therefore very important. This will then reflect the position of S&T in the defence value chain.

- Balancing of investment is necessary, meaning where to invest in the short term and where in the longer term. Both in operational as well as in supporting activities. This has to do with the operational tempo of an organisation:
  - When not in combat: S&T for the longer term could gain weight.
  - When in combat, S&T for the shorter term is very important: crisis action teams, concentration of brain power, urgent operational requirements, fast track procurement and fast track development need extra focus.
- The Armed Forces Profiles themselves are not sufficient to define the defence-relevant S&T base from scratch (this is called 'zero-basing'). In other words, an S&T base serves more purposes besides supporting an Armed Forces Profile. Examples are S&T intelligence to predict threat levels and dealing with uncertainty through 'S&T insurance'. Zero-basing S&T is not a good idea, as it disregards experience from the past and the S&T budget requirements become too large.
- The most fundamental question and the hardest thing to do will be the formulation and the delivery of the programme. The direct relation with the military customer is very important; this could be arranged through client groups supported by roadmaps.
- There is a need for in-house Operational Research and Analysis support, as well as for people who understand system concepts. The focus must be such that the strategic directions are right.
- The current knowledge area Taxonomy needs some adjustments, reflecting the future needs and technology developments in combination with the ambitions of the Netherlands Ministry of Defence.
- A clear and internationally agreed definition for research, development, science and technology is useful especially for international collaboration and benchmarking purposes.

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# Appendix A Questionnaire Format

An important part of the study is the international comparison and judgement of relevant future knowledge and technology. For this reason a questionnaire was developed and sent to relevant parties in Australia, Canada, Germany, Norway, and the United Kingdom. Answering the questionnaire gave these countries the opportunity to participate in a peer-reviewed assessment of the relevance and significance of the areas of knowledge important for future defence and security. It was also used to highlight the investment quotes of the participating countries and use them as a benchmark for this study.

In this appendix the format of the questionnaire is presented on the basis of screenshots. After each of the screenshots, a brief explanation is provided.

## Format

| Defence Knowledge Investment Questionnaire | NOTE that some field are automatically linked to others | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **What field driven and customer driven knowledge and technological areas are of importance?** | **Funded from Defence annual budget** | | | | | | **Funded from other than Defence annual budgets (Security)** | | | |
| What are the heights (%) and types (TRL) of annual budgets for S&T?<br><br>(S&T annual budget is the integral annual budget which includes a.o. pensions, infrastructure, experimental facility investments, salaries of staff etc.) | What is the annual budget used for those needs? | | What is the annual budget used for those needs? | | | | What is the annual budget used for those needs? | | What is the annual budget used for those needs? | |
| Your own National Defence and Security Knowledge Areas (Taxonomy) List | TRL 1-3 | TRL 1-3 | TRL 4-6 | TRL 4-6 | Overall | % of total S&T annual budget | TRL 1-3 | TRL 1-3 | TRL 4-6 | TRL 4-6 |
| Define definitions in sheets Your National Knowledge Areas AND give a reference to the UK6 | M€ or M$ | % | M€ or M$ | % | M€ or M$ | % | M€ or M$ | % | M€ or M$ | % |
| | € 0,00 | 100,0% | € 0,00 | 100,0% | € 0,0 | 100,0% | € 0,00 | 100,0% | € 0,00 | 100,0% |
| | € 0,00 | 0,0% | € 0,00 | 0,0% | € 0,0 | 0,0% | € 0,00 | 0,0% | € 0,00 | 0,0% |

In the first section of the questionnaire, the focus countries were asked to specify their knowledge areas and the annual budget spent from the MoD budget as well as other budgets (in the realm of security) in those knowledge areas. These budgets were to be further specified on the basis of Technological Readiness Levels (TRL). When classifying knowledge and technology it is important that the same maturity level is used as a reference. In NATO it is a well-established method to use Technology Readiness Levels as a reference. In order to provide more detail, an overview of the TRL is presented in the Table 7.

Table 7 **Descriptions of Technology Readiness Levels.**[18]

| Technology Readiness Level | Description |
|---|---|
| 1. Basic principles observed and reported | Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Example might include paper studies of a technology's basic properties. |
| 2. Technology concept and/or application formulated | Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies. |
| 3. Analytical and experimental critical function and/or characteristic proof of concept | Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. |
| 4. Component and/or breadboard validation in laboratory environment | Basic technological components are integrated to establish that the pieces will work together. This is relatively 'low-fidelity- compared to the eventual system. Examples include integration of 'ad hoc' hardware in a laboratory. |
| 5. Component and/or breadboard validation in relevant environment | Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include 'high-fidelity' laboratory integration of components. |
| 6. System/subsystem model or prototype demonstration in a relevant environment | Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment. |
| 7. System prototype demonstration in an operational environment | Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle or space. Examples include testing the prototype in a test bed aircraft. |
| 8. Actual system completed and 'flight qualified' through test and demonstration | Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications. |
| 9. Actual system 'flight proven' through successful mission operations | Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last 'bug fixing' aspects of true system development. Examples include using the system under operational mission conditions. |

18. Department of Defense, Government of the United States, "Defense Acquisition Guidebook."

| Knowledge investment annual budget & Percentage | | | | |
|---|---|---|---|---|
| The term 'knowledge investment' refers to an explicit investment in the development of knowledge (so knowledge managament is not considered) by:<br>• conducting basic exploratory research and/or research to demonstrate the feasibility of a solution (TRL1-3);<br>• developing and/or demonstrating technology (TRL4-6);<br>including materiel-focused research and 'soft' research into such matters as personnel, doctrine and organisational matters in the above regime (TRL 1-6);<br>by means of structurally allocated budgets (central and/or local).<br><br>Note 1: So research in TRL1-6 from a (materiel) procurement budget is counted out, as this is ad-hoc research funding for that specific type of (materiel) procurement.<br>Note 2:In principle the Defence organisation invests in the development of knowledge only if the knowledge required is unavailable 'off-the-shelf'.<br>Note 3: Intergral costs should be considered, i.e. including additional costs for pensions, experimental facilities, organisational apparatus and infrastructure, salaries of staff etc. | | | | |
| Present Defence annual budget M€ or M$ | Present Overall S&T annual budget M€ or M$ | Present S&T annual budget as % Defence annual | Present Defence investment annual budget (not exploitation annual budget)<br>M€ or M$ | Present S&T annual budget as % Defence Investment annual budget |
| € 0,00 | € 0,00 | 100,0% | € 0,00 | 100,0% |

Second, the MoD's overall annual budget and its annual budget for knowledge investment were specified. On the basis of this information, the MoD's S&T quote (knowledge investment budget as a percentage of the overall budget) was calculated.

| Legenda scoring | | | | | | | |
|---|---|---|---|---|---|---|---|
| Category definition<br><br>Cat 1 National strategic relevance (there will always be invested in this area nationaly)<br>Cat 2 Primarily privileged (inter)national controlled access (GOTS/MOTS)<br>Cat 3 Primarily civil (not 'government' controlled) access possible | -- defence & security investment relevance is getting less compared to other areas | - defence & security investment relevance is still relevant but less compared to other areas | 0 defence & security investment relevance is still significant | + defence & security investment relevance is getting more significant compared to other areas | ++ defence & security investment relevance is of vital significance compared to other areas | | |
| **What field driven and customer driven *SUB* knowledge and technological areas are of** | | | | | | | |
| Present<br>What National Defence and Security ***SUB*** Knowledge Areas needs are addressed | Present<br>Are those domains easy accessible? | Present<br>Ambition Level<br>1 Smart user/customer<br>2 smart specifier<br>3 Smart developer | Present<br>Tick the relevant box with an **X** | Present<br>Tick the relevant box with an **X** | Future<br>What National Defence and Security ***SUB*** Knowledge Areas needs should be addressed ?<br>Tick the relevant box with an X | Future<br>(for Defence) | Future<br>Are those domains easy accessible? |
| In what sub areas is research structured | Cat 1, Cat 2 or Cat 3 | | Defence focus | National innovation focus | On what sub areas should research focussed | Importance (--, -, 0, +, ++) | Cat 1, Cat 2 or Cat 3 |
| | | | | | | | |
| | | | | | | | |

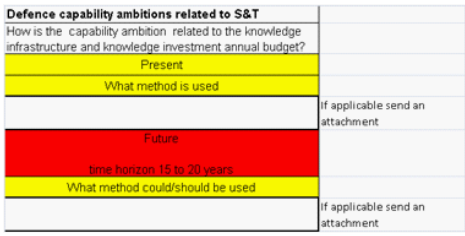
Third, the focus countries were requested to list the knowledge elements (defined in the questionnaire as subareas) they work with. They were further asked for the accessibility, ambition level, defence focus, national innovation focus and future expectations for each of these elements.

| What part of the knowledge is provided by Defence itself and what parts are not and which % for | Present | Present | Present | Future | Future | Future |
|---|---|---|---|---|---|---|
| Your National Defence and Security Knowledge Areas List | Self in % of Total S&T annual budget | International Cooperation in % of Total S&T annual budget | Outsourced in % of Total S&T annual budget | Self in % of Total S&T annual budget | International Cooperation in % of Total S&T annual budget | Outsourced in % of Total S&T annual budget |
| 0 | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| 0 | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |

Fourth, the focus countries were given the opportunity to provide an indication of the sourcing of knowledge and technology per knowledge area. They were asked to specify which percentage of their annual S&T budget is devoted to own production of knowledge, which percentage is spent on international cooperation, and which percentage of the budget is outsourced. This question covered both the present and the future situation.

| What criterions for prioritisation are used (How is the "relevance (impact)" identified? E.g. military need, | |
|---|---|
| Present | Future |
| | |
| | |

Fifth, the questionnaire asked for the criteria used by the focus countries for prioritisation of certain knowledge areas above others. Again, this question was asked for both the present and the future situation.



| **Defence capability ambitions related to S&T** | |
|---|---|
| How is the capability ambition related to the knowledge infrastructure and knowledge investment annual budget? | |
| Present | |
| What method is used | |
| | If applicable send an attachment |
| Future<br>time horizon 15 to 20 years | |
| What method could/should be used | |
| | If applicable send an attachment |

Finally, the question was raised how capability ambitions are currently related to the knowledge investment annual budget and which methods the focus countries believe could be useful for the future.

# Appendix B Armed Forces Profiles

As an important aspect of and a reference for all the studies in the interdepartmental Future Policy Survey[19] so-called Netherlands Armed Forces Profiles were developed. An Armed Forces Profile is a typical description of generic capabilities of the armed forces as a function of its ambitions. These profiles are also used as a reference for this study. They form part of the basis qualifying the relevant knowledge areas for the future and, together with al other elements, the necessary investments in these areas.

Armed Forces Profiles are generic descriptions of the armed forces taking into account fundamental choices on doctrine, equipment and composition. In other words “what does MoD-NLD want to be” and “how should MoD-NLD organise itself”?

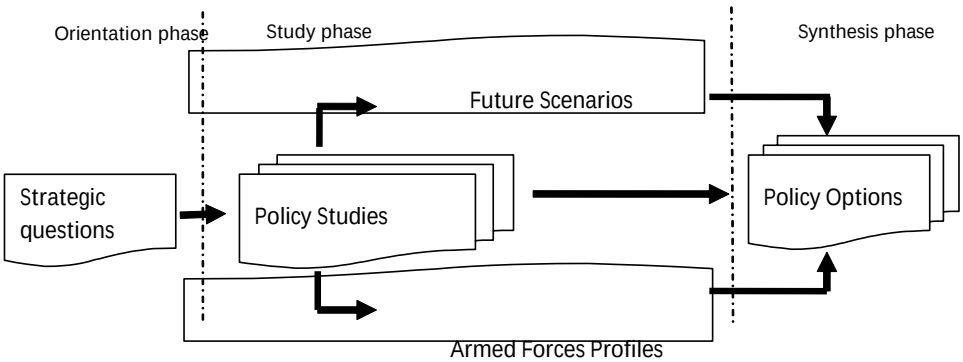
Insights from policy studies in the research phase of the Survey will be used for the further development of future scenarios and Armed Forces Profiles. In the synthesis phase of the Survey future-tight policy options are sought/developed, by checking the effectiveness of the Armed Forces Profiles against the scenarios.

In this appendix the Armed Forces Profiles are represented.

The Figure 13 shows the set-up of the Future Policy Survey:

19. This appendix contains information of the Future Policy Survey: Ministry of Defence, Government of the Netherlands, *Future Policy Survey (forthcoming)*.

Figure 13 **Set-up Future Policy Survey**




The project started in March 2008, and is now in the research phase.

The project plan was approved by the Ministers of Defence, Foreign Affairs, Development Cooperation, Home Affairs, Justice and Finance in July 2008.

The synthesis phase will start around March 2009.

# Future scenarios

Future scenarios are internally consistent descriptions of what the future could look like, not intended to predict but as a possible outcome of important (worldwide) developments. These scenarios are built up from driving forces and core (un)certainties, containing a description of the most important security issues and actors. Furthermore, attention is given to the possible deployment of the NLD armed forces and the type of military operation involved. The Future Policy Survey looks 20 years ahead in time, i.e. to the 2030 timeframe. This timeframe requires an open eye for possible unexpected and influential events that could lead to a change in society that was not foreseen (wildcard).

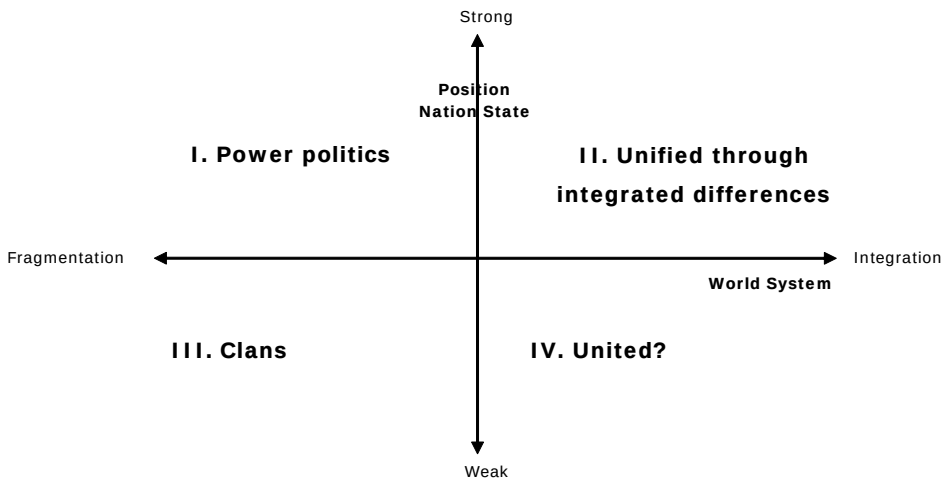
The development of future scenarios partly also hinges on two core uncertainties:

**The World System**: will the world develop into a direction of integration and increasing collaboration (cooperation) or fragmentation and decreasing collaboration (cooperation) instead?

**The Position of a Nation State**: will the world develop into a direction characterised by strong and weak nation states, and non-state actors?

Plotting the two core uncertainties leads to a scenario framework that is shown in the figure below:

Figure 14 **Four future scenarios.**




## Four future scenarios

An initial sketch of the four scenarios is presented below. It is expected that the upcoming two decennia will probably show elements from all scenarios. The scenarios will be enriched by driving forces (drivers), such as developments in technology, demography, wealth distribution, ideology, scarcity and climate change.

So, in this stage of the future policy study this is a first step towards scenarios that will be described in more detail in the time to come. This will be done by analysing the security implications of each scenario along the following lines:

## Global security

- Over the national border security issues (such as emerging terrorism, proliferation of WMD, consequences of shortages, consequences of climate change, emerging organised crime);
- The role and functioning of nation states (such as the affairs between superpowers and the role of risk nations and of fragile states);
- The role and functioning of international and regional security organisations;

- The security and the well-being of individual civilians ('human security').
- European security. Make an inventory of the consequences for European security including the role and the functioning of the European Union.
- The security of the Kingdom of the Netherlands. As part of a scenario the position and the status of the Kingdom will be described, taking into account international and national security implications. What interests and values are at stake? This will not only include geographical security implications, but also Dutch and Netherlands Antilles societies.
- The use made of the NLD armed forces. Finally, the expected deployment of the NLD AF will be derived from the above lines of analysis. What type of operation and what type of task for the NLD AF are likely to happen, based on a scenario? What will be the expected quantitative aspects (for peacekeeping and peace-enforcing)?

**Scenario I. Power politics.** The world is dominated by a competition between strong nation states and power blocks, looking for economic and military superiority, not trusting each other (too much). In this scenario the international order will be mainly determined by four to six power blocks: USA, EU and compositions around the BRIC-nations. Many of these nation states are to a great extend self-supporting, the mutual dependency has decreased. This has been made possible by a proactive protection of raw materials supply chains within or towards its own power block, including technological breakthroughs in the fields of water, food and energy generation. Medical science will overcome the negative effects of older populations.

As the composition and stability of the own power block is important, this needs to be protected proactively and where possible the power base needs to be expanded, to gain status and influence in the world. In this competition ideological differences between nation states are sharpened. Along this way every nation state seeks the support of its own citizens, also for the support to high defence budgets. In this type of world armed conflicts are likely to happen. Wars by proxy are fought in those areas of the world where none of the power blocks are dominantly present (at that moment). In this way large flows of refugees and guerrilla wars will be introduced into the system. Furthermore, there are new uninhabited conflict areas: oceans, North and South Poles and the universe (space).

Multilateral organisations are not in play, the power blocks determine the state of affairs. Between those power blocks there are many temporary bilateral alliances. The international power distribution is multipolar or even non-polar.

**Scenario II. Unified through integrated differences.** Strong nation states work closely together on a worldwide scale, e.g. through regional organisations such as EU, NATO and AU (African Union). Almost everything is working quite well in this world, that centres around effective climate politics and a thriving globally intertwined economy. The G8 has been expanded to a G20 with new economic superpowers. On a global scale democracies form the absolute majority as a government type. This type of government is not primarily focused on itself, but on the security and well-being of its citizens, who hope to see this good fortune spread across the rest globe. These wealthy free world citizens carry international collaboration through networking, thus leading to a strong global culture. The role of multilateral organisations is therefore reinforced to solve common issues (such as climate change, financial-economic turbulence, shortages and space (room)). Solar power will thrive, Africa being the main supplier. Mainly because of a fair worldwide distribution of drinking water there is a globally balanced demographic development.

The mutual dependence between strong nation states has contributed to constructive but in many cases also competitive relations. National interests are not always in line with global interests. Some nation states seek their success outside the international community, through bilateral arrangements. Some are aggressive to other (neighbour) states, including the facilitation of the internal enemies within these states. A threat to worldwide harmony is however not tolerated in this scenario. The collaborating nation states may sometimes look weak (because of their peace-mindedness), but they will not shy away from coordinated military action if deemed necessary. The false impression of weakness is reinforced by free riding nations ('free riders') and the rarity of urgent across the border security issues.

**Scenario III. Clans.** Nation states and collaborative entities thereof have a quite limited meaning in this scenario, in which the world has failed to solve common problems and is not able to deal with new difficulties in an effective way. One example is the massive migration from Africa to the EU and to the USA, amongst others also triggered by climate change that introduces more deserts into this continent.

In most parts of the world people start to become more self-centered. Societies collapse in competitive clans. At stake are usually essential economic interests, survival being the most important. It crystallises around ethnic and religious themes and/or ownerships. Individuals mistrust state organisations. They no longer consider themselves to be a citizen, they are now part of a group or clan. The influence of organised crime, continuing unrest in society and sharp ideological separation contribute to a

strong feeling of insecurity in this type of society that cannot be solved anymore by state organisations.

**Scenario IV. Unified?** The consequences of globalisation have penetrated deeply into the societies, but not always in a positive sense. Politically, socially and economically there is further intertwining. Collaboration takes place on a global scale. Non-nation state actors, such as multinational enterprises and non-governmental organisations play an important role here, as well as the individual citizens. They arrange a lot by and for themselves, organising themselves around themes. However, this has also caused social fragmentation. There is collaboration, but mostly between richer individuals. They are less interested in supporting the less well-off. Nation state organisations have stepped back in this scenario, but the globally connected civilians, for whom everything seems to develop quite well, have barely noticed this. Almost unanimously they see the state as a facilitator that should let the assertive and globally connected civilians organise and develop themselves as much as possible.

Global integration is, however, not for everybody, as these richer people will discover (and experience) when confronted with the immigration from less developed parts of the world. A direct consequence of this gap is a sharp increase in 'haves' and 'have-nots'. A large part of the world (still) feels left behind. In a geographic sense this large part of the world (the 'rest') could be Africa, the Middle East, Caucasus, Russia, Central Asia, China, Southern Asia, Middle America and the Andes mountain region. This gap also hides a latent source for various security issues, partly sharpened by non-state actors such as crime syndicates and terrorist organisations, that seek action frequently.

## Defence tasks

The level of ambition addressed in generic terms defines the nature of the defence tasks. To bridge the gap between ambition and means, a specification is needed of the nature of the defence tasks (DT). The defence tasks are addressed here, and not just the military tasks. This underlines the fact that MoD-NLD is also supporting civilian authorities, in a formal way and under the leadership of the civilian authorities, upon their request.

DT1-DT23 have in common that they occur under (emanating) fighting conditions. For DT24-DT35 this is not the starting point, but local and/or temporary protection is not ruled out (for example DT26 host nation support, protection of objects).

DT1 Control of sea areas

*To assure the dominance in a sea area, in such a way that NLD and coalition forces are able to operate without hindrance of enemy navy forces. In case necessary enemy means will be destroyed or neutralised.*

DT2 Control of land areas

*Ibid for land*

DT3 Control of air areas

*Ibid for air*

DT4 Fighting navy forces

To destroy or neutralise regular and irregular battle forces, above and under water including direct confrontation with enemy forces.

DT5 Fighting land forces

Ibid for land

DT6 Fighting air forces

Ibid for air

DT7 Guard sea areas

*Systematically guard sea areas and objects therein to acquire information that can be shared with other units. In case necessary suspicious objects/units will be brought-up.*

DT8 Guard land areas

*Ibid for land*

DT9 Guard air areas

*Ibid for air*

DT10 Protection at sea

Take measure from sea or from the air to assure safety and security and free manoeuvre at sea, and to avoid damage or destruction by attacks/mines, also against non-military ships or installations.

DT11 Protection on land

*Ibid for land*

DT12 Protection in the air

*Ibid for air*

DT13 Command and control operation

*Military campaign of which the core is the command and control of units provide for by third parties.*

DT14 Evacuation

DT15 Extraction

*Military campaign to withdraw military units from enemy territory, under fighting conditions.*

DT16 Military support

Support of civil authorities by the military, upon request of the civil authorities and under the command of the civil authorities, including counter-terrorism.

DT17 Protection of persons

DT18 Pre-emptive, forward deployment

*To deploy units in or close to a crisis area, to underline the political will to start a militayr campaign, and in case necessary quickly start that campaign.*

DT19 To separate parties

*With, or without military force, (keep) separate opposing parties.*

DT20 Stabilisation

*Usually through longer military presence help local parties to establish stability and order.*

DT21 Special operations

DT22 Strategic targets destruction

*The ability to destroy at very large distances, essential targets. How specific as it is, this includes the nuclear tasks of the NLD F-16 as well.*

DT23 Strategic transport

DT24 Ceremonial performance

DT25 Explosive ordnance disposal

DT26 Host nation support

DT27 Coast guard

DT28 Royal NLD Constabulary tasks

DT29 Hydrography and geography

DT30 Military help

*Upon request of civil authorities for public good, other than military support.*

DT31 Emergency help

*Quickly on the spot preparation and deliverance of help when disasters/infernos, including refugee accommodation on the spot.*

DT32 Training and education of foreign units

DT33 Fighting disasters

DT34 Strategic Military Intel

DT35 Verification

*Weapons control treaties.*

# Defence capabilities

To identify relationships between ‘tasks’ and ‘capabilities’ the NATO definitions are used as much as possible. For the NLD situation the NATO set is extended by the ‘capabilities’ in support of civilian authorities (NATO does not have this reference).

## Defence capabilities

DC1 Air Assault Capability

Operation of specially educated, trained and equipped ground component and helicopter component do integrated operations.

DC2 Airborne Operation Capability

Deploy units through the air

DC3 Airborne Command and Control Capability

DC4 Airdrop Capability

DC5 Air Interception Capability

DC6 Air Interdiction Capability

DC7 Air Mechanised Capability

Attack helicopter campaign, with or without support of ground component

DC8 Airmobile Combat Capability

Tactical deployment of army units through the air in the operational theatre, including immediate battle after landing.

DC9 Air Policing Capability

Protect air space integrity in peace time.

DC10 Air Reconnaissance Capability

DC11 Air Staging Capability

Air field/airport coordination, part of Reception, Staging and Onward Movement (DC 80).

DC12 Air Strike Capability

Attacks on (strategic) targets and vital elements of enemy fror political, economical and industrial objectives.

DC13 Air Surveillance Capability

DC14 Air-to-Air Refuelling Capability

DC15 Air to Ground Surveillance Capability

For land and sea.

DC16 Air Traffic Control Capability

DC17 General military capability

This capability is necessary to support the Government in general and the Defence Minister and Deputy Minister specifically to ascertain a responsible implementation of other tasks; includes international military representation.

DC18 Amphibious Assault Capability

DC19 Amphibious Debarkation/embarkment Capability

DC20 Amphibious Raid Capability

DC21 Amphibious Reconnaissance Capability

DC22 Anti-Submarine Warfare

DC23 Anti-Surface Warfare Capability

DC24 Area Clearance Capability

DC25 Area Interdiction Capability

DC26 Armoured Ground Attack Capability

DC27 Base Development Capability

To develop infrastructure/facilities/compounds for the units that do the campaigns.

DC28 Battle Damage Assessment Capability

DC29 Battle Damage Repair Capability

DC30 Battlefield Management Capability

DC31 Battlefield Surveillance Capability

DC32 Boarding Capability

To go onboard ships, with or without explicit permission.

DC33 Civil-Military Cooperation Capability

Collaboration and coordination with local people, government and non-government institutions, also in support of military campaigns.

DC34 Close Air Support Capability

DC35 Crowd and Riot-control Capability

DC36 Combat Air Patrol Capability

DC37 Combat Search and Rescue Capability

DC38 Counterbattery Fire Capability

Location determination of enemy field artillery and destruction of it.

DC39 Counter-guerilla Warfare Capability

Includes counter terrorism.

DC40 Counter Intelligence and Security Capability

DC41 De- and Embarkation Capability

DC42 Defensive Counter Air Capability

DC43 Demolition Capability

DC44 Disarmament, Demobilization and Re-integration Capability

To help local authorities to re-establish this capability.

DC45 Disaster Relief Capability

Humanitarian help

DC46 Early Entry Battle Capability

Bridge head.

DC47 Electronic Intelligence Capability

DC48 Escort Capability

For persons, means and equipment (civil and military).

DC49 Evacuation Capability

DC50 (Extended) Air Defence

DC51 Fire Support Capability

DC52 Fire Fighting Capability

DC53 Forward Air Controlling Capability

DC54 Border protection

DC55 Ground Observer Capability

In support of the implementation of agreements.

DC56 Ground Reconnaissance Capability

Short and mid-range.

DC57 Harbour Defence Capability

On and under water. Not from air.

DC58 Human Intelligence Capability

DC59 Information Operations Capability

Offensive and defensive.

DC60 Interpreter Capability

DC61 Joint/Mission Intelligence Capability

DC62 Joint Mobile C4I Capability

DC63 Coastguard Capability

DC64 Liaison Capability

DC65 Light Forces Attack Capability

Not heavily armoured units, only having some self-protection.

DC66 Maritime Mine Counter Measures Capability

DC67 Medical Support Capability

For other military units and/or civilians.

DC68 Medical Evacuation Capability

DC69 Military Geografic Information Capability

DC70 (Military) Hydrographic Information Capability

DC71 Military Police Capability

DC72 Mine and Explosives Removal Capability

DC73 Mobile Short Range Air Defence Capability

DC74 Movement Control Capability

Supply line management for personnel and materiel.

DC75 Naval Co-operation and Guidance for Shipping

Support to civil shipping in support of military operation.

DC76 Nuclear Biological, Chemical Defence Capability

DC77 Object security

Locally arrange for security of an object.

DC78 Offensive Counter Air Capability

DC79 Quick Reaction Alert Capability

DC80 Reception, Staging and Onward Movement' Capability (RSOM)

Strategic sea/land/air capability.

DC81 Sea Basing Capabilities

DC82 Sea Control Capability

DC83 Sea Denial Capability

DC84 Search and Rescue Capability

DC85 Sea Surveillance Capability

DC86 Sea-to-Sea Re-supply and Re-fuelling Capability

DC87 Signal Intelligence Capability

DC88 Special Operations Capability

DC89 Strategic Intelligence Capability

DC90 Strategic Strike Capability

DC91 Strategic Transport Capability

DC92 Suppression of Enemy Air Defences Capability

DC93 Tactical Mine- and Explosives Clearance Capability

DC94 Tactical Recovery Capability

Under battlefield conditions.

DC95 Urban Warfare Capability

*Capabilities for campaigns under special circumstances, such as urban, cold, jungle and desert, will only be addressed separately when this leads to independent capabilities for this specific goal. In all other cases these capabilities will be translated without the other relevant capabilities.*

# Three types of Armed Forces Profiles

The project plan of the Future Policy Survey foresees three lines from which Armed Forces Profiles could be developed.

First, the present profile of the armed forces. This profile will be calculated through, and will be checked for future robustness against the future scenarios.

Second, other Armed Forces Profiles are conceivable that may serve as an alternative to the present profile.

Third, from the scenarios other profiles could emerge as well.

## Profile I: The present profile of the armed forces

This profile represents the present NLD armed forces, but then positioned in 2030 with all present shortcomings solved, such as improved expeditionary power, intelligence gathering and analysis, national tasks, security sector reform, jointness and efficiency.

The NLD armed forces in 2030 are able to conduct military operations in all phases of a conflict, across the globe with (mainly) independent national units in an international coalition. All three national main tasks have a comparable interest. Thus the NLD armed forces cover a wide range of missions, tasks and capabilities, albeit that the size, sustainability and quality will not be the same across the full range (spectrum).

Even within a broad and versatile NLD force choices have to be made, focusing on areas to excel in. This can be followed up by taking NLD strengths or (inter)national needs (requirements) as a starting point.

The alternative Armed Forces Profiles will be developed on the basis of variables, by taking into account choices with respect to ambition level and the composition and equipment of the NLD armed forces.

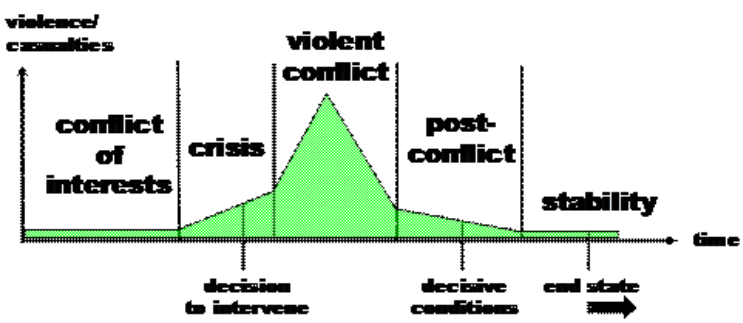
Each variable has an axis with two extremes, allowing the selection of a position anywhere on the axis. The ambition level of an Armed Forces Profile is based on a set of selections per variable.

## Two core variables

The rather large set of possible selections may be limited in advance by taking into account consistency and discrimination. As far as the development of alternative Armed Forces Profiles is concerned, there are two core variables that form the cornerstone for the meaning of this profile, including the composition and equipment of the forces. These core variables are violence spectrum and independence.

**Violence spectrum.** Per profile the question now is in what part of the violence spectrum the armed forces should be able to operate, because this fully determines their composition and equipment. Apart from the sort of military tools and the training and education of the armed forces, this also determines the necessary technological level of the forces.

Figure 15 **Violence spectrum in a security crisis of a conflict.**[20]




If an answer is required to the question on what part of the violence spectrum a profile should be primarily focused, there are three relevant basic options:

20. This figure simplifies a complex reality. The time axis is not scaled: the total duration and the duration per phase will differ per situation. Furthermore, outside of a conflict phase there will be locally and temporary peaks of higher levels of violence.

1. Armed forces that cover as much as possible of the entire violence spectrum.
2. Armed forces that are focused on operations in the higher parts of the violence spectrum.
3. Armed forces that are focused on operations in the lower parts of the violence spectrum.

Within the last two options two variations are possible: robust and light.

**Independence.** The question of independence also heavily determines the composition and equipment of the armed forces. Who will be the collaborating partner nations, and how deep will collaboration go? Fundamental considerations are relevant: what are the core competencies of the armed forces, where is (most) added value to be gained? How dependent should armed forces be on third parties, both nationally and internationally? To what extent is work to be outsourced? But there are also practical considerations: how can armed forces organise their capabilities in such a way that they will absorb as little time and resources as possible the moment they aren't needed? Also, in case these capabilities will be needed in the required quantity and quality and on the right moment, how long would it take to make them available?

Determining the degree of independence within the three basic profiles and their variations effectively means one will have to address a number of questions:

- Within the profile, what will most certainly have to be done?
- Is collaboration with other parties possible or preferred (other armed forces, other ministries, NGOs, etc.)?
- What could be outsourced to third private parties, and/or could public-private partnerships be set up?

This leads to the following overview of alternative Armed Forces Profiles and variants:

## Profile II: Intervention force.

**A. Robust variant:** An expeditionary force to maintain and establish international law and order and to defend allied territory and interests. A force that is able to operate 'first-in' for the entire duration of a conflict, in the highest ends of the violence spectrum. The objective is to contribute to a quick and successful ending of the conflict in the context of NLD national main task 1 (conflict where NATO allies are threatened) or NLD national main task 2 (other conflicts where international intervention is necessary).The focus is on quick and successful ending of especially

interstate conflicts, after which a stabilisation force will take over in the (very) short term (a stabilisation force is not an occupation force). This type of armed forces is also able to deter and to enforce, and to carry out NLD national task 3 (support civilian authorities under their command).

**B. Light variant:** Instead of the maintenance and promotion of international law and order, the primary focus is the protection of the interests of the Kingdom. Deployment takes place with pinpoint precision within and outside of the NLD Kingdom's territory, for instance with Special Forces, in case of concrete threats or any undermining of national interests. Action will take place independently if necessary. The armed forces will operate in all phases of the conflict, but strongly focused, limited in size and time. Strong national centric fulfilment of the three NLD national tasks. This type of armed forces is able to fit within a more altruistic type of foreign policy in which other instruments than military force are used to promote sustainable growth in the world.

## Profile III: Peace force

**A. Stabilisation force.** This profile is focused on the prevention phase in areas where a conflict is imminent. It operates quickly after the ending of the conflict, on the way to lasting stability. The armed forces have enough escalation dominance to guarantee stability under all circumstances. Orientation towards control of intrastate conflicts, peace enforcement between states and security sector reform. Emphasis on comprehensive approach together with other ministries and civilian organisations. NLD main task 2 is central.

**B. Reconstruction force.** This profile aims at prevention before the conflict starts or otherwise at the reconstruction phase after the conflict. Focus is on peacekeeping rather than peace-enforcing. Compared with III.a this type of armed forces has more sustainability and limited escalation dominance or force self-protection. Next to NLD national main task 2 the main task 3 stands central, partly also because comparable capabilities are suitable for the two main tasks.

# Appendix C Current and Suggested New Knowledge (Sub)areas of MoD-NLD

The current knowledge area clustering as used for R&D management.

On the basis of analysis and desk study a suggestion for a restructured set of knowledge areas and knowledge elements is developed. This new set needs to be evaluated and adjusted but can be seen as a first attempt to integrate insights for requirements for (future) technology developments, defence ambitions and armed forces profiles.

Table 8 **The current Netherlands MoD knowledge area clustering**

| # | Knowledge Area | Description | Knowledge Elements |
|---|---|---|---|
| K01 | Sensors | Knowledge of sensors and subsystems for detection and observation. Also includes the first signal processing track insofar as it takes place in the embedded processing capacity of/on the sensor system itself. Note: the demarcation with K02 - Situational Awareness regarding target recognition shifts if the sensor systems receive more own intelligence. | Radar sensors<br>Electro-optical sensors<br>ESM sensors<br>Sonar and acoustical sensors<br>Geographical information systems |
| K02 | Generating Situational Awareness | Includes (mainly IT) knowledge for the combining/analysis/interpretation of data from various sources to produce military information and intelligence, both automatically and to support an operator/analyst. Includes IFF.<br>Key notions: sensor & data fusion, target recognition, classification & identification algorithms, building up Situational Awareness and image of enemy forces, Common Recognised Operational Picture. | Sensor fusion and data fusion<br>Classification and identification<br>Building up (common) recognised operational picture |
| K03 | Operational decision making | Knowledge of the support of decision-making and human actions, including the automated decision-making for e.g. weapon use in closed sensor to shooter loops. Also includes airspace management. Relates to the preparation, planning, execution and aftercare of individual operations, not to decision-making at management level (for the latter, see K10 - Policy and planning).<br>Key notions: decision support, group functioning. | Operational decision support<br>Decision-making in teams<br>Air space management |
| K04 | Communication | Includes knowledge of the adequate and reliable information exchange between systems. Also includes frequency management.<br>Key notions: communication systems, networks, information transport, distribution and security. | Communication systems & networks<br>Information transport, distribution & protection/security |
| K05 | Platforms | Knowledge of the construction, functioning, operation and maintenance of platforms, albeit that the following functional subsystems are discussed in separate knowledge areas: sensor systems (see K01 - Sensors), information and command systems other than those used for the actual operation of the platform itself (see K02 - Situational Awareness and K03 - Operational decision-making), armament (see K06 - Weapons and munitions) and protective systems (see K07 - Protection and K08 - CBRN detection and protection). Also includes knowledge of the facilities for the implementation of man – and workload reduction – into the platform system, as well as of the soldier system viewed as a platform.<br>Knowledge of the construction of platforms and platform installations (excluding weapon systems; see K06 - Weapons and munitions), the materials used and the knowledge of platform maintenance and life cycle monitoring, as well as the environmental aspects of platform operation and maintenance.<br>Key notions: construction materials, hydrodynamics/sailing behaviour, seaworthiness, aerodynamics/flight behaviour, airworthiness/certification, driving behaviour/all-terrain properties, vibrations, Simulation-Based Design, camouflage, stealth and signature reduction. | Construction & materials<br>Operation & operational use<br>Propulsion & energy supply<br>Environmental aspects of platform use & maintenance |

| | | | |
|---|---|---|---|
| K06 | Weapons & munitions | Includes the (technical) knowledge of the functioning of all weapon types and forms, including all soft kill and non-lethal options. Also includes the environmental aspects of weapon use.<br>Includes the (technical) knowledge of the functioning of all weapon types and forms, including all soft kill and non-lethal options. Also includes the environmental aspects of weapon use.<br>Key notions: ballistics, propulsion, guidance, control, activation of conventional weapons, life cycle monitoring. | Kinetic & explosive weapons<br>Directed energy weapons<br>Non-lethal weapons<br>Offensive EW<br>Offensive Info Ops<br>Environmental aspects of weapons use |
| K07 | Protection | Knowledge of the protection of people, platforms and infrastructure against threats and offensive actions. The detection of and protection against CBRN weapons fall under K08 - CBRN detection and protection. | Armour & reinforcement<br>Deception<br>Defensive EW<br>Defensive Info Ops |
| K08 | CBRN detection and protection | Knowledge of the detection of and protection against chemical, biological, radiological and nuclear weapons.<br>Key notions: detection and identification of CBRN warfare agents, physical and medical (counter)measures to protect personnel (medical CBRN organisation), materiel and infrastructure. | Nuclear & radiological defence<br>Biological defence<br>Chemical defence |
| K09 | Logistics and LCM | Knowledge of the organisation of supply, transport and medical care, as well as of the organisation of logistics chains. Further includes knowledge of LCM techniques and methods.<br>Key notions: ERP, ILS/CALS, e-business. | Logistics<br>Life cycle management |
| K10 | Policy and planning | Knowledge of models and structured working methods to support the Defence organisation. Includes applications for the operational requirements specification, acquisition and recruitment, development of policy and doctrines (independent of the single operation; for the latter, see K03 - Operational decision-making).<br>Key notions: business management, policy analysis, conceptual studies, decision support (at management level), Simulation-Based Acquisition, knowledge management. | Strategic survey<br>(Governance) policy analysis<br>Planning cycle support |
| K11 | Personnel readiness | Knowledge of personnel selection and training and education. | Selection, education & training<br>Deployment & operational campaigns |

Table 9 **New knowledge areas and elements of MoD-NLD. - 1**

**Sub Themes**

**NKG1 Situational Awareness**

- sensor and sensor suite design, requirements & performance
  - radar
  - electro-optical & laser
  - ESM
  - sonar/acoustic
- knowledge base
  - geographical and environmental data
  - cultural, social, economical, political data
  - stakeholder, actor and coalition data
  - other data relevant to the security environment
- threat analysis [incl. BC]
- signatures
- (real or near real time) image / data / information fusion
- change detection, classification, identification
- common operational picture
- shared situational awareness
- intelligence 'networks' – producing, obtaining, disseminating, sharing intelligence

**NKG2 C2**

- C2 / decision making concepts
  - under stress
  - in teams
  - for (semi-) automated (closed) decision loops
- effects based approach
  - defining effect measures
  - measuring and assessing effects
  - sense & respond feedback
- decision support systems & tools – e.g. what-if analysis, system dynamics analysis
- concepts of C2 flexibility, adaptivity and robustness
- NEC - conceptually

**NKG3 Network Information & Infra**

communication network architectures and design, incl. issues concerning interoperability; reliability; transmission speeds & bandwidth; frequency management
information networks – producing, obtaining, disseminating, sharing information
reach back
information and network security & protection
defensive EW – protection / shielding against offensive EW
concepts of self-organisation in networks
concepts of network flexibility, adaptivity and robustness
NEC - technically

**NKG4 Platform Design & Performance**

- platform design, signature, requirements & performance
  - construction & materials
  - protection – e.g. passive and active armour, compartmentalisation, but also camouflage, flares
  - propulsion and energy supply
  - combat management, navigation and control
- monitoring & diagnosis; repair, maintenance & overhaul; and update / upgrade and version management concepts
- unmanned platforms - specific design and operational use considerations for the design and use
- environmental aspects of platform production, use, maintenance and disposal, including scarcity issues

**NKG5 Weapons & Effects**

- munitions & weapon design, requirements & performance
  - kinetic & explosive
  - directed energy
  - less/non lethal weapons and scalable weapons
- cyber / information warfare
- weapon-target interaction / effects
- weapon delivery – line of sight, ballistic, over-the-horizon
- monitoring & diagnosis; maintenance; and update / upgrade and version management concepts
- automated engagement routines and smart weapons
- minimizing fratricide and collateral damage
- environmental aspects of weapon & munitions production and use, including scarcity issues

**NKG6 Personnel & Infra Protection**

- (critical) infrastructure protection
  - kinetic & explosive
  - BCNR
  - area / entrance access denial
- soldier protection
  - bullets, stabbing
  - explosives
  - BC(R)
- medical services – preventive, diagnostic, recovery and recuperation

**NKG7 Deployment & Sustainment**

- Rules of Engagement analysis
- Mission preparation & mission readiness
- Tactical flexibility, adaptivity & resilience
- Damage control
- Deployment tactics
- strategic stock / supply models
- labour market communication, recruitment, selection, retention
- operational logistics
- contract(or) and SLA (service level agreement) management

**NKG8 Defence Analysis**

- strategic foresight & analysis
- geopolitical environment
  - technology and military application (road mapping)
  - military concepts
  - military history and analysis
- doctrine development
- policy analysis ex ante & ex post, benchmarking
- defence planning
  - force structure studies, force planning
  - capability requirement specification
  - RTD portfolio management
- knowledge management and organisational learning
- business management processes – incl. ERP
- life cycle management
- force generation & mission planning (general)
- concepts of organisational flexibility, adaptivity and robustness (general)
- reconstitution issues – how to (re) generate capabilities relatively quickly in a changing security environment

**NKG9 Human Performance**

- competence management & individual performance
- team performance
- human enhancement – physiological, psychological, pharmaceutical
- resilience
- education & training (generic)
- mission-oriented training & mission rehearsal (specific)
- leadership concepts
- man-machine interfaces, incl. brain-machine interfaces
- veterans care, trauma treatment
- testing, training and preparing for special conditions – cold, heat, long hours, disorientation etc.

Table 10 **New knowledge areas and elements of MoD-NLD. - 2**

| NKG1 Situational Awareness | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| sensor and sensor suite design, requirements & performance<br>radar<br>electro-optical & laser<br>ESM<br>sonar/acoustic | multi spectrum sensor suites | low cost sensor pay loads for 24/7 / long endurance monitoring and change detection | CBNR detection | low cost sensor pay loads for 24/7 / long endurance monitoring and change detection | |
| knowledge base<br>geographical and environmental data<br>cultural, social, economical, political data<br>stakeholder, actor and coalition data<br>other data relevant to the security environment | | building and using broad knowledge bases | incorporation of 'intelligence' from non-governmental sources (banks, credit card companies, telecom providers etc.) | incorporation of 'intelligence' from non-governmental sources (NGOs, World Bank etc.) | building and using broad knowledge bases<br>technology watch & assessment |
| physical models: propagation, signal/noise etc. | | | | | |
| signatures | | | | | |
| (real or near real time) image / data / information fusion | real time data fusion | | 'crowd sourcing' techniques to enhance and validate info / intelligence | | |
| change detection, classification, identification | 'networked' target detection, classification and identification | | identification and status monitoring of vital infrastructure | | |
| blue force tracking, IFF | advanced blue force tracking in coalition warfare to avoid fratricide | | | | |
| threat analysis (incl. BC) | | | open source intelligence analysis tools | open source intelligence analysis tools | government-wide id and assessment of security risks and consequences |
| common operational picture | joint common operational picture | interagency common 'effects' picture | | | |
| shared situational awareness | shared 'military' sense making | shared 'interagency' sense making at the strategic, operational and tactical level | | | shared 'intergovernmental' strategic security vision |
| intelligence 'networks' – producing, obtaining, disseminating, sharing intelligence | | | interdepartmental data models for intelligence sharing | | intelligence 'networks' across broad range of public and private stakeholders |

| NKG2 C2 | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| C2 / decision making concepts<br>under stress<br>in teams<br>for (semi-) automated (closed) decision loops | 'mission command' in a high optempo environment | 'sense & respond' concepts to reflect real-world dynamics in the 'command intent' | | | portfolio management for S&T and R&D<br>multi-agent intelligence planning |
| effects based approach<br>defining effect measures<br>measuring and assessing effects<br>sense & respond feedback | | collective course of action analysis and collaborative decision making with interagency partners | | models and analysis for escalation or de-escalation decisions – e.g. from prevention to deterrence | |
| decision support systems & tools – e.g. what-if analysis, system dynamics analysis | (near) real time decision support tools | complex stakeholders, interrelations and interactions models | | | |
| concepts of C2 flexibility, adaptivity and robustness | C2 in coalition warfare | C2 in small teams | C2 in interdepartmental decision structures and processes | | |
| NEC - conceptually | NEC concept development and experimentation – in a joint & combined environment | NEC concept development and experimentation – internationally embedded and/or in an interagency environment | NEC concept development and experimentation – in an interdepartmental and/or first responder environment | | |

| NKG3 Network Information & Infra | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| communication network architectures and design, incl. issues concerning interoperability; reliability; transmission speeds & bandwidth; frequency management | robust, high-bandwidth networks | use of high-end COTS / GOTS standards<br>spectrum management in a civil / military environment | use of high-end COTS / GOTS standards<br>spectrum management in a civil environment | use of civil infrastructure, incl. guaranteed availability | technology watch & assessment |
| information networks – producing, obtaining, disseminating, sharing information | high-end coalition interoperability – standards and protocols for information exchange | ad-hoc coalition & interagency interoperability – standards and protocols for information exchange | interdepartmental & first responder interoperability – standards and protocols for information exchange | | |

| | | | | | |
|---|---|---|---|---|---|
| reach back | | reach back capacity | | | |
| information and network security & protection | operational security in networks | | critical infrastructure protection – cyber security | use of civil infrastructure - security issues | |
| defensive EW – protection / shielding against offensive EW | | | | | |
| concepts of self-organisation in networks | | self-organisation in dynamic coalition/ interagency networks | | | |
| concepts of network flexibility, adaptivity and robustness | highly mobile, ad-hoc networks and network nodes | flexible and adaptive (coalition) networks | | | |
| NEC – technically | NEC concept development and experimentation – joint & combined<br>'net-ready' validation tests | NEC concept development and experimentation – internationally embedded and/or in an interagency environment | NEC concept development and experimentation – in an interdepartmental and/or interagency environment | | |
| **NKG4 Platform Design & Performance** | **Intervention & Deterrence** | **Stabilisation & Normalisation** | **Protection** | **Prevention** | **Anticipation** |
| platform design, signature, requirements & performance<br>construction & materials<br>protection – e.g. passive and active armour, compartmentalisation, but also camouflage, flares<br>propulsion and energy supply<br>combat management, navigation and control | material characteristics exceeding high end civil standards<br>self protection suites - passive and active<br>NBC hardening<br>alternatives for GPS reliance<br>reduced manning | cost-effective designs, using civil high-end standards where possible<br>robust designs for harsh physical environments and 'bare base' operations<br>robust designs for extended use<br>relatively light weight designs and limited / minimal logistic footprint<br>reduced manning | legal and practical requirements for use in a civil environment<br>shared requirements with first responders | | security of supply: industrial and technical base and regeneration issues<br>technology watch & assessment |
| monitoring & diagnosis; repair, maintenance & overhaul; and update / upgrade and version management concepts | rapid and cost effective technology insertion<br>'graceful degradation' and self-repair capacities | 'fast track' development & procurement | | | |

| | | | | | |
|---|---|---|---|---|---|
| unmanned platforms - specific design and operational use considerations for the design and use | unmanned vehicles deployed in manned-unmanned concepts | unmanned vehicles deployed in manned-unmanned concepts | | low cost unmanned systems for 24/7 / long endurance monitoring and change detection | |
| environmental aspects of platform production, use, maintenance and disposal, including scarcity issues | | 'green' life cycles and characteristics (e.g. fuel consumption, noise levels) – incl. materials scarcity issues | 'green' life cycles and characteristics (e.g. fuel consumption, noise levels) – incl. materials scarcity issues | | |
| integration issues (incl. sensors, weapons, C2) | balance between 'hard wired' integration and modularity | modular, flexible designs that allow for mission-specific 'add-ons' | modular designs | | |

| NKG5 Weapons & Effects | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| munitions & weapon design, requirements & performance<br>kinetic & explosive<br>directed energy<br>less/non lethal weapons and scaleable weapons | high performance weapons & munitions<br>directed energy weapons | 'non-obtrusive' escalation dominance<br>non / less lethal weapons / munitions<br>scaleable weapons / munitions | non / less lethal weapons / munitions<br>shared requirements with police | | security of supply: industrial and technical base and regeneration issues<br>technology watch & assessment |
| cyber / information warfare | cyber warfare – defensive, possibly offensive | (military contribution to) information campaigning ('hearts & minds') | (military contribution to) public awareness and resilience | (military contribution to) public awareness and resilience | |
| weapon-target interaction / effects | | dynamically (in-flight) scaleable weapons / munitions | | | |
| weapon delivery – line of sight, ballistic, over-the-horizon | smart stand-off weapons – incl. alternatives for GPS reliance<br>anti-stealth | | | | |
| monitoring & diagnosis; maintenance; and update / upgrade and version management concepts | | monitoring and conditioning munitions storage during extended deploymeny | | | |
| automated engagement routines and smart weapons | 'networked' target acquisition<br>automatic engagement routines | | | | |

| | | | | | |
|---|---|---|---|---|---|
| minimizing fratricide and collateral damage | | limited acceptance of collateral damage and of blue-on-blue engagements | no acceptance of collateral damage and of blue-on-blue engagements | no acceptance of collateral damage and of blue-on-blue engagements | |
| environmental aspects of weapon & munitions production and use, including scarcity issues | | 'green' life cycles and characteristics – incl. materials scarcity issues | 'green' life cycles and characteristics – incl. materials scarcity issues | | |

| **NKG6 Personnel & Infra Protection** | **Intervention & Deterrence** | **Stabilisation & Normalisation** | **Protection** | **Prevention** | **Anticipation** |
|---|---|---|---|---|---|
| (critical) infrastructure protection<br>kinetic & explosive<br>BCNR<br>area / entrance access denial | TBMD and EAD, incl. associated NBC warhead issues<br>forward operating base protection<br>main ports and logistic node protection | compound / base protection against e.g. mortar and RPG attacks<br>compound / base access control – perimeter, access points | critical infrastructure protection – physical<br>CBNR protection & decontamination | | technology watch & assessment |
| soldier protection<br>bullets, stabbing<br>explosives<br>BC(R) | protection as part of an integrated 'soldier system' | soldier protection<br>bullet & stab proof suits | bullet & stab proof suits<br>shared requirements with first responders for e.g. protective suits | protection of personnel (individuals) in high risk civil environment | |
| medical services – preventive, diagnostic, recovery and recuperation | real-time individual medical diagnosis and aid (in suit) | real-time individual medical diagnosis and aid (in suit) | | | |
| concealment, camouflage, deception | stealth | | unobtrusive monitoring of public space | | |
| NKG7 Deployment & Sustainment | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
| Rules of Engagement analysis | | | | | pre-positioning<br>technology watch & assessment |
| mission preparatrion & mission readiness | forward presence | | | | |
| tactical flexibility, adaptivity & resilience | | | | | |
| total 'blue' asset visibility, tracking & tracing | | | | | |
| damage control | | | | | |
| deployment tactics | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| strategic stock / supply models | strategic stock / supply models | | | | |
| labour market communication, recruitment, selection, retention | | recruitment and retention<br>selection methods and tools<br>mission-specific use of reserve forces and non-military experts | mission-specific use of national reserve and non-military experts | mission-specific use of reserve forces and non-military experts | |
| operational logistics | coalition logistic networks | coalition logistic networks<br>open logistic networks | open logistic networks | | |
| contract(or) and SLA (service level agreement) management | | activity based costing | activity based costing | | |

| NKG8 Defence Analysis | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| strategic foresight & analysis<br>geopolitical environment<br>technology and military application (road mapping)<br>military concepts | assessment of potential disruptive technologies that may jeopardize operational dominance | analysis of security requirements for sustainable development processes<br>technology watch & assessment – spin-in of high-end civil technology (smart 'value for money' buyer) | | models for and analysis of 'early warning' signals | analysis of geopolitical power politics and security arrangements<br>analysis of 'hot spots' of failing states and of 'black holes' where state control lacks<br>military technology watch & assessment – to define niches for own research thrusts (smart developer)<br>general technology watch & assessment – to seize spin-in opportunities and incorporate best standards and practices (smart buyer and user)<br>analysis of core competences, value-added and role definition of defence organisation in various security chains |
| military history and analysis | | | | | |

| | | | |
|---|---|---|---|
| doctrine development | joint (& combined) doctrine development | interagency 'doctrine' development from security perspective | interdepartmental 'doctrine' development<br>joint 'doctrine' development with first responders |
| policy analysis ex ante & ex post, benchmarking | | | |
| defence planning<br>force structure studies, force planning<br>capability requirement specification<br>RTD portfolio management | force-on-force models | | ICMS+ - areas for enhanced civ-mil collaboration for (national) crisis management and disaster relief |
| knowledge management and organisational learning | | | |
| business management processes – incl. ERP | public-private constructions with defence industry in developmentand production of major weapon systems | concepts for smart 'fast track' development & procurement processes<br>concepts for subcontractor management through service level agreements (SLAs) | |
| life cycle management | public-private constructions with defence industry in life cycle support of major weapon systems | | |
| force generation & mission planning (general) | | | |
| concepts of organisational flexibility, adaptivity and robustness (general) | | concepts for enhancing 'FRANKness' – Flexible, Robust, Adaptive, Networked, and Knowledge-based solutions | |
| reconstitution issues – how to (re)generate capabilities relatively quickly in a changing security environment | public-private constructions with knowledge centres and defence industry in maintaining technological and industrial base for major weapon systems | | |

| NKG9 Human Performance | Intervention & Deterrence | Stabilisation & Normalisation | Protection | Prevention | Anticipation |
|---|---|---|---|---|---|
| competence management & individual performance | | co-operation and collaboration in an interagency environment<br>personal education & training concepts, e.g. personalized virtual tutor | co-operation and collaboration in an interdepartmental and/or interagency environment | | technology watch & assessment |
| team performance | | teaming concepts for small, multi disciplinary (civ / mil) teams | teaming concepts for small, multi disciplinary (civ / mil) teams | | |
| human enhancement – physiological, psychological, pharmaceutical | human performance enhancing measures | | | | |
| resilience | | techniques and tools for training indigenous forces | | | |
| education & training (generic) | live-virtual training and exercises at the (joint) task group / force level | live- virtual training and exercises at the (joint and interagency) task group level | | | |
| mission-oriented training & mission rehearsal (specific) | virtual mission rehearsal | virtual mission rehearsal<br>mission specific training of language and culture skills | virtual and life training and exercises with first responders | mission specific training of language and culture skills | |
| leadership concepts | | leadership concepts for small, multi disciplinary (civ / mil) teams | leadership concepts for small, multi disciplinary (civ / mil) teams | | |
| man-machine interfaces, incl. brain-machine interfaces | brain-machine interfaces | | | | |
| veterans care, trauma treatment | | home front care<br>veterans care | | | |
| testing, training and preparing for special conditions – cold, heat, long hours, disorientation etc. | | | | | |

# Appendix D Graphs, Data Collection and Tables

This appendix provides background information on R&D investment, also presenting the data from the charts in this report in tables. Most of these tables are based on data from the OECD Main Science and Technology Indicators 2008/I (hereafter referred to as MSTI) database.[21] Where possible, this database has been used as primary source, but since it only covers OECD member states and a small selection of other focus countries, it is not complete. Therefore, in specific cases the OECD data have been supplemented with data from the UNESCO Institute for Statistics (UIS) Science and Technology database.[22] In some cases, GDP indicators from the World Bank's World Development Indicators database[23] have been used in order to calculate averages. Note that, for reasons of comparison, all tables presented in monetary values refer to standardised (current) currency values.

The OECD and the UIS base their data mainly on reports from government agencies. Although they generally derive their data from the same sources and use shared definitions of key concepts, some slight variation in measurement may occur. Data presented in the tables below (and in the charts in the main text) should therefore be seen as approximations rather than exact representations of reality.

It should also be noted that some tables contain fields with the value 'n/a'. This indicates that the value for a particular country/year combination is missing, *i.e.* that data are unavailable in both the OECD and the UIS databases as well as on the website of the Bureau of Statistics (or a comparable agency) of the country involved.

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21. Organisation for Economic Co-operation and Development, "Main Science and Technology Indicators 2008-1."

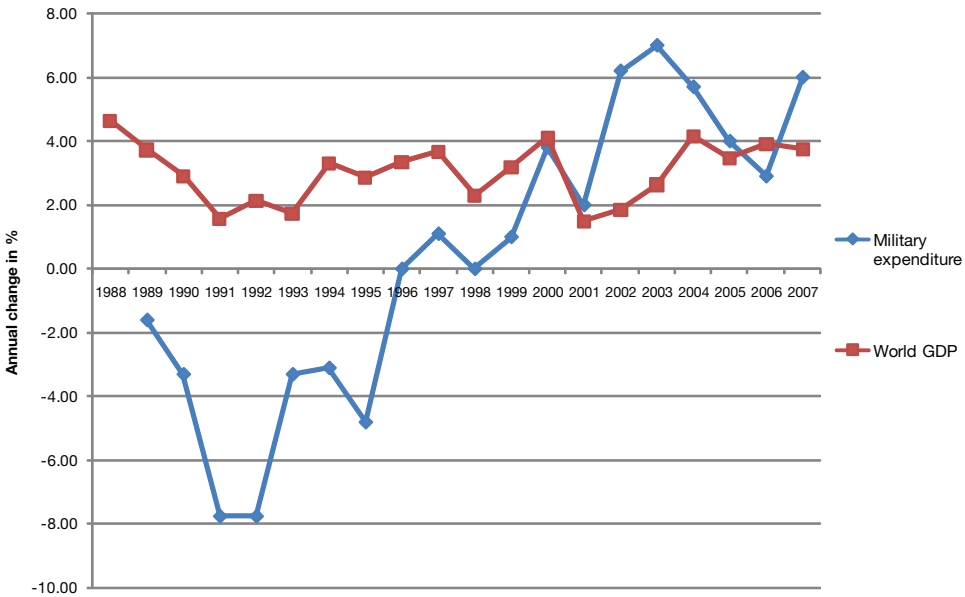
22. UNESCO Institute for Statistics, "Database on Science & Technology."

23. World Bank, "World Development Indicators 2009."

# Graphs

Figure 16 World GDP and military expenditure, 1988-2007. refers to factor of influence #6 of Table 5 Factors of possible influence on defence KIQ.

Figure 16 **World GDP and military expenditure, 1988-2007.**




*Note*: The precise values for 1991 and 1992 military expenditure are not available. The figure presented here is the average of this period.
*Source*: World Bank World Development Indicators, SIPRI Military Expenditure Database

Although it seems plausible that defence spending possibilities are linked to political and economic conditions, there generally hasn't been a significant economic conditions link with defence spending during the last decades. Until the end of the Cold War, a political event would generally have more influence.

After two decades of relative quiet, military expenditure is on the rise again since 2001, mainly influenced by terrorism being seen as an important new threat.

## The national KIQ as a percentage of the GDP of the focus countries

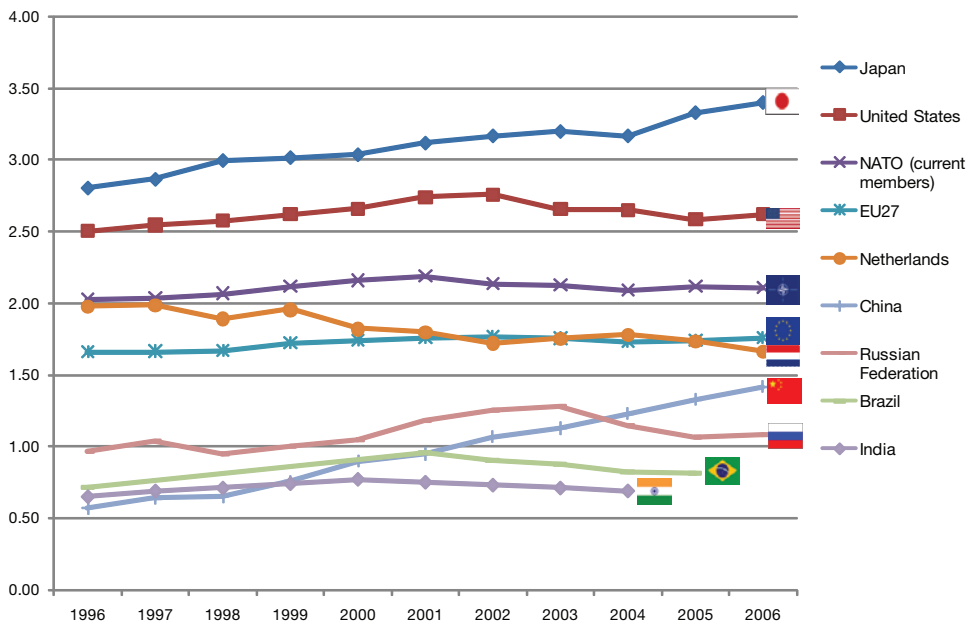
Figure 17 GERD/GDP ratio selected states and organisation totals, 1996-2006. refers to factors of influence #1 and 2 of

Table 5 Factors of possible influence on defence KIQ. The BRIC (Brazil, Russian Federation, India, China) states have been included, because they are generally regarded

as the world's prime upcoming powers and – since they are not included in either the NATO or the OECD framework – could become potential future adversaries (factor #1). The NATO average is included as a reference to factor #2. Japan and the United States have been included in the figure because their relatively high GERD/GDP ratios are interesting for reasons of comparison.

The figure gives an indication of the development of GERD as a percentage of GDP for a selected number of states between 1996 and 2006. GERD is calculated by adding together the intramural R&D expenditures of four different performing sectors, namely business enterprise, government, private non-profit, and higher education. It includes R&D performed in a country but financed from abroad, while excluding payments for R&D carried out abroad. R&D-related activities, such as training and education, are also excluded.

Figure 17 **GERD/GDP ratio selected states and organisation totals, 1996-2006.**




*Source*: OECD Main Science and Technology Indicators 2008/I; UNESCO Institute for Statistics database; World Bank World Development Indicators

The figure shows that of the BRIC states, only China has managed to significantly increase its GERD/GDP ratio. In 2006, however, it was still well below the NATO[24] and EU27 totals. It should be noted that in absolute terms R&D expenditure in Brazil, the Russian Federation and India did increase significantly between 1996 and 2006. The

24. In this figure, the NATO GERD/GDP ratio includes all 26 current member states, regardless of dates of accession.

lack of increase in the GERD/GDP ratio for these countries should be attributed to high GDP growth.

The development of the Netherlands GERD/GDP ratio is also notable. In 1996, it was only slightly below the OECD and NATO ratios and well above the EU27 total, but from the end of the 1990s it has shown a decline. In 2006, the Netherlands ratio was well below the NATO total and slightly lower than the EU27 total. It is for this reason that the Netherlands Innovation Platform addressed its ambitions for increasing R&D investment for 2016.

Table 11 **Targets for R&D spending**[25]

| Targets for R&D spending | | | |
|---|---|---|---|
| **Country/region** | **Target** | **Target date** | **Most recent expenditure (2006)** |
| Austria | 3.0% of GDP | 2010 | 2.45% of GDP |
| Belgium | 3.0% of GDP | 2010 | 1.83% of GDP |
| Czech Republic | 2.0% of GDP | 2010 | 1.54% of GDP |
| Denmark | 3.0% of GDP | 2010 | 2.43% of GDP |
| Finland | 4.0% of GDP | 2011 | 3.45% of GDP |
| France | 3.0% of GDP | 2012 | 2.11% of GDP |
| Germany | 3.0% of GDP | 2010 | 2.53% of GDP |
| Greece | 1.5% of GDP | 2015 | 0.57% of GDP |
| Hungary | 1.4% of GDP | 2010 | 1.00% of GDP |
| Ireland | 2.5% of GNP | 2013 | 1.32% of GDP |
| Netherlands | 3.0% of GDP | 2010 | 1.67% of GDP |
| Norway | 3.0% of GDP | 2010 | 1.52% of GDP |
| Poland | 2.2–3.0% of GDP | 2010 | 0.56% of GDP |
| Portugal | 1.8% of GDP | 2010 | 0.83% of GDP |
| Spain | 2.2% of GDP | 2011 | 1.20% of GDP |
| Sweden | 4.0% of GDP | 2010 | 3.73% of GDP |
| United Kingdom | 2.5% of GDP | 2014 | 1.78% of GDP |
| European Union | 3.0% of GDP | 2010 | 1.76% of GDP |

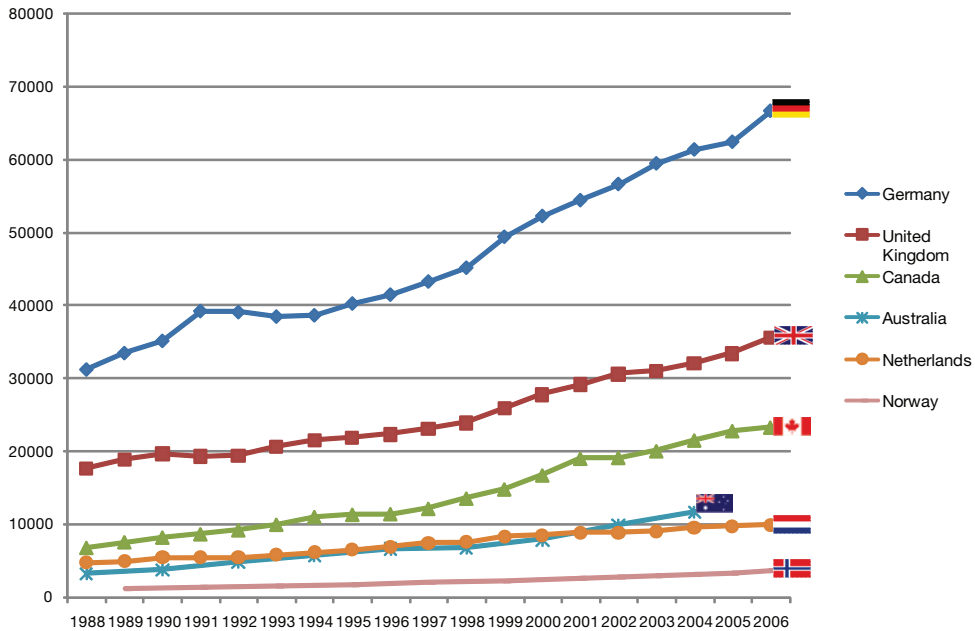
Table 11 Targets for R&D spending refers to factor of influence #3 of Table 5 Factors of possible influence on defence KIQ. It gives an indication of the specific targets of selected European countries and their respective GERD/GDP ratios[26] in 2006. It shows

25. Organisation for Economic Co-operation and Development, *OECD Science, Technology and Industry Outlook 2008*.

26. The target for Ireland, however, is stated as a GERD/GNP ratio.

that of the selected countries, only two aim to achieve a GERD/GDP ratio higher than the EU target of 3.0% by 2010. These two, Finland and Sweden, are also the only two countries in the list with a ratio higher than 3.0% in 2006.

Figure 18 **GERD in millions US$, focus countries, 1988-2006.**

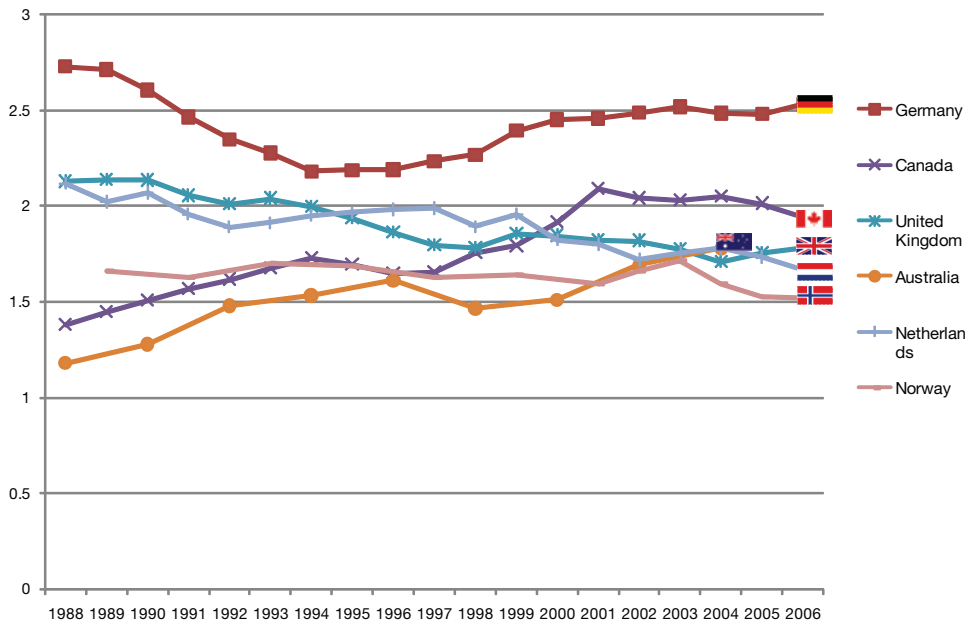



*Source:* OECD Main Science and Technology Indicators 2008/I

Figure 18 GERD in millions US$, focus countries, 1988-2006. refers to factors of influence #2, 3, 4 and 5 of Table 5 Factors of possible influence on defence KIQ. It shows the total GERD of the focus countries in the period from 1981 to 2006. As expected, the countries with the largest economies (Germany, United Kingdom, Canada) invest most in R&D.

The figure displays upward trends in R&D expenses for all focus countries. Although the scale of the figure makes it difficult to appreciate the development of the countries with lower overall R&D investment, the countries at the bottom of the chart are well-performing in relative terms. Norway, for example, has the lowest GERD throughout the entire period, but has managed to increase its GERD with a factor 8, from 509 million US$ in 1981 to 3,686 million US$ in 2006. German R&D expenses increased most in absolute terms, but were slightly more than 3.5 times as high in 2006 as in 1981.

Figure 19 **GERD/GDP ratio focus countries, 1988-2006.**




*Source:* OECD Main Science and Technology Indicators 2008/I

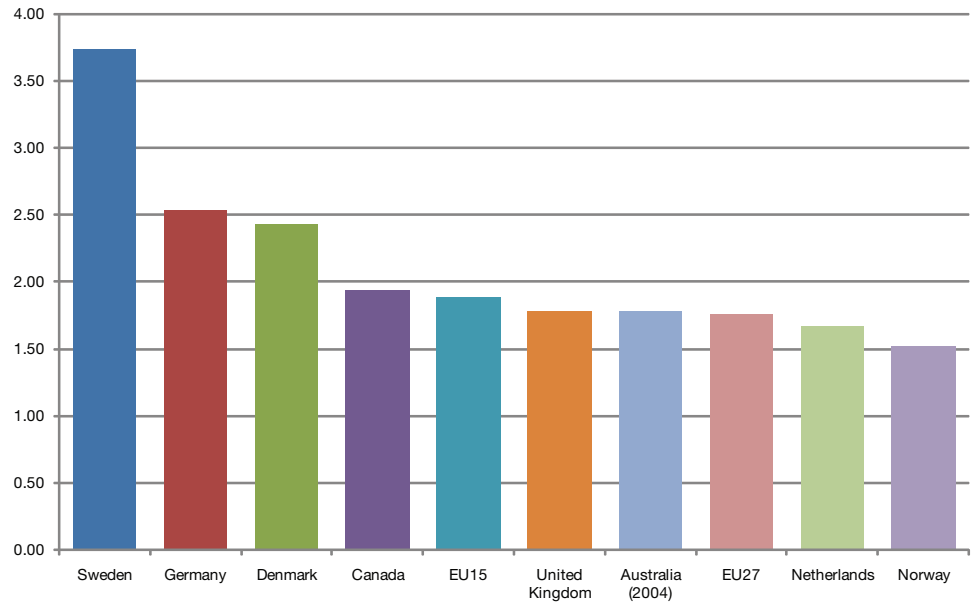
Figure 19 GERD/GDP ratio focus countries, 1988-2006, refers to factors of influence #2, 3, 4 and 5 of Table 5 Factors of possible influence on defence KIQ. It gives an indication of the development of the GERD/GDP ratios of the focus countries during the period from 1981 to 2006.

The figure shows an interesting development in the relative position of the Netherlands. During the early 1980s, the Dutch ratio was in the middle segment of the focus countries. From that moment, however, the relative position of the Netherlands has declined. In 2006, only the Norwegian GERD/GDP ratio was lower than the Netherlands (for Australia no data are available after 2004). In fact, the Netherlands and the United Kingdom are the only focus countries in which the share of R&D expenditure relative to the GDP was lower in 2006 than in 1981.

A possible explanation for the relatively low GERD/GDP ratio of the Netherlands is the low share of the industry sector in the Dutch economy. Especially when compared to countries such as Germany and Sweden (in 2006 the two most R&D-intensive countries in terms of GERD/GDP ratio), the relative contribution of the industrial sector to the GDP in the Netherlands is low. Instead, the Dutch economy is dominated by the service sector, which is far less R&D-intensive. The downward trend in the Dutch GERD/GDP

rating can be partly explained by the significant increase in the share of the service sector in the Dutch economy.[27]

Figure 20 **GERD/GDP ratio focus countries, EU, OECD, 2006.**




*Source*: OECD Main Science and Technology Indicators 2008/I

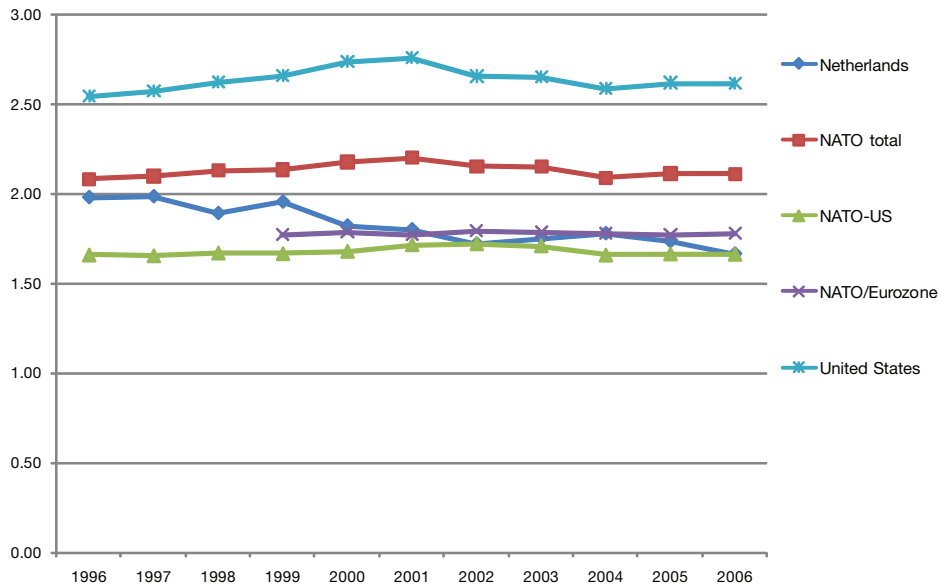
Figure 20 GERD/GDP ratio focus countries, EU, OECD, 2006. refers to factors of influence #2, 3, 4 and 5 of Table 5 Factors of possible influence on defence KIQ. It gives an indication of the most recent available data on the GERD/GDP ratios of the focus countries (2006) as well as the averages of the EU and the OECD. Interestingly, it shows that the Netherlands and Norwegian ratios are lower than the EU27 ratio. Since the latter includes all new EU members, which generally invest a smaller portion of their GDPs in R&D, this indicates that the relative position of the Netherlands in terms of its GERD/GDP ratio is rather weak.

Figure 21 GERD/GDP ratios Netherlands, NATO (adjusted for dates of accession), US, 1996-2006. refers to factors of influence #2 and 3 of Table 5 Factors of possible influence on defence KIQ. It compares the GERD/GDP ratios of the Netherlands and the US with the NATO total, the NATO total excluding the United States, and the total of the NATO member states located in the Eurozone. In calculating these totals, the dates of

27. Het Nederlands Observatorium van Wetenschap en Technologie, *Wetenschaps- en Technologie-Indicatoren 2008*.

accession to NATO and the Eurozone have been taken into account. Since the Eurozone came into existence in 1999, the NATO/Eurozone line starts in that year.

Figure 21 **GERD/GDP ratios Netherlands, NATO (adjusted for dates of accession), US, 1996-2006.**




*Source*: OECD Main Science and Technology Indicators 2008/I; UNESCO Institute for Statistics Database

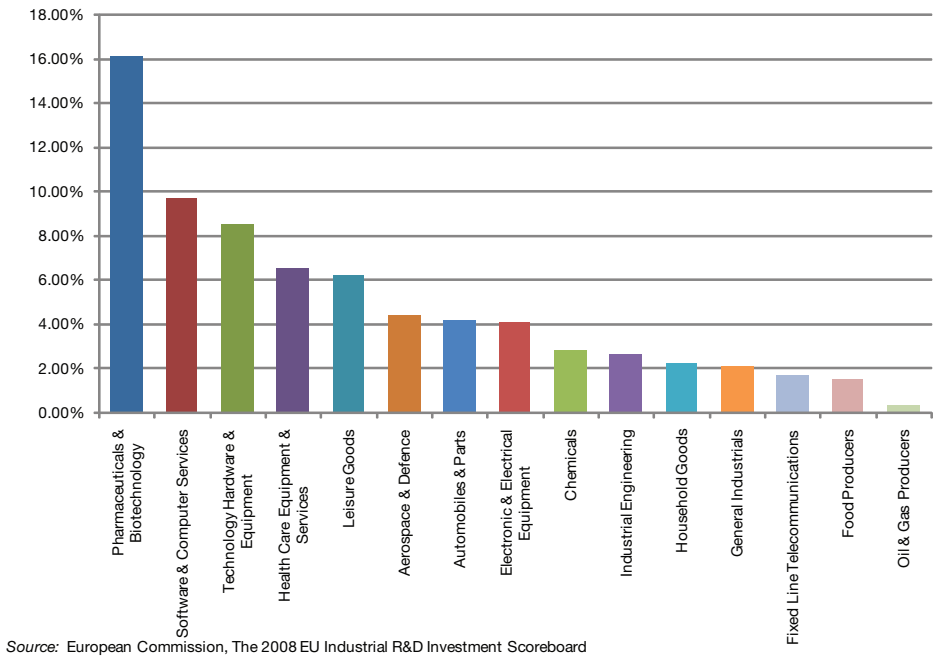
The development of the Netherlands ratio relative to the different NATO totals confirms the observation that the position of the Netherlands has deteriorated during recent years. Between 1999 and 2006, NATO ratios did not change significantly. In 2006, the Dutch ratio approximated the 'NATO minus US' ratio, which by that time also included new Eastern European NATO member states.

Another interesting observation that can be derived from this figure is that the US contributes to the NATO GERD/GDP ratio in a significant way. During the entire 1996-2006 period, the gap between the NATO total and the 'NATO minus US' total has remained constant at almost half a percentage point.

## What are the R&D investments and the KIQs of industries as percentage?

As a benchmark for the defence KIQ a series of industries is used. Figure 22 R&D intensity per industrial sector, world top 1,402 companies. refers to factors of influence #6 and 7 of Table 5 Factors of possible influence on defence KIQ. The figure gives an indication of the R&D intensity (R&D investment as a percentage of net sales) of various industrial sectors. The figure is based on data from the 2008 EU Industrial R&D Investment Scoreboard,[28] which uses data from the world's top 1,402 companies in terms of R&D investment.

Figure 22 **R&D intensity per industrial sector, world top 1,402 companies.**




*Source:* European Commission, The 2008 EU Industrial R&D Investment Scoreboard

As a result, the figures are probably higher than they would be for a random sample of companies in the same industrial sectors. Nevertheless, it indicates which industries are R&D-intensive and which are not. For our purposes, especially the R&D intensity (4.4%) of the Aerospace & Defence industry is interesting, in view of their strong connection with defence-related activities.

28. European Commission, *The 2008 EU Industrial R&D Investment Scoreboard*.

Given the fact that the industry generally does not carry out high-risk defence R&D in-house, an external supporting or funding base is important to create the potential for innovations that come from these investments. Generally, this role is performed by governments or venture capitalists.

However, the public defence R&D levels (both in percentage of total R&D levels as in relationship to total defence expenditures) in Europe are relatively low and decreasing. In addition, they are significantly lower than in the United States. As a result, the European industrial sectors are much more dependent on their own R&D intensity than in other sectors or than in the US. This could mean that the potential for innovations in this industry in Europe is modest and forced to focus on gradual, evolutionary developments rather than breakthrough innovations.

# Data tables

Table 12 **Data for Figure 3 Military expenditure in mln US$, focus countries, 1988-2007.**

| Country / Year | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|
| United Kingdom | 62,982 | 62,027 | 60,696 | 62,348 | 58,560 | 56,393 | 54,579 | 50,818 | 50,554 | 48,276 |
| Germany | 55,627 | 55,475 | 58,464 | 55,134 | 52,436 | 47,139 | 43,962 | 43,238 | 42,395 | 40,854 |
| Canada | 15,097 | 15,021 | 15,007 | 13,859 | 13,706 | 13,671 | 13,470 | 12,699 | 11,658 | 10,748 |
| Australia | 9,077 | 9,000 | 9,045 | 9,200 | 9,468 | 9,827 | 9,937 | 9,625 | 9,508 | 9,675 |
| Netherlands | 11,365 | 11,472 | 11,060 | 10,752 | 10,690 | 9,824 | 9,473 | 9,189 | 9,242 | 9,147 |
| Norway | 4,382 | 4,498 | 4,535 | 4,398 | 4,766 | 4,441 | 4,670 | 4,217 | 4,275 | 4,203 |

| Country / Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| United Kingdom | 47,691 | 47,542 | 47,778 | 48,786 | 50,963 | 57,140 | 60,018 | 60,003 | 59,595 | 59,705 |
| Germany | 40,993 | 41,822 | 41,147 | 40,474 | 40,604 | 40,044 | 38,816 | 38,060 | 37,133 | 36,929 |
| Canada | 11,122 | 11,603 | 11,412 | 11,709 | 11,771 | 11,984 | 12,441 | 12,986 | 13,588 | 15,155 |
| Australia | 10,150 | 10,648 | 10,617 | 11,038 | 11,609 | 12,008 | 12,638 | 13,122 | 13,885 | 15,097 |
| Netherlands | 9,114 | 9,557 | 9,116 | 9,352 | 9,344 | 9,479 | 9,549 | 9,568 | 10,015 | 9,853 |
| Norway | 4,482 | 4,506 | 4,358 | 4,385 | 5,269 | 5,066 | 5,194 | 4,887 | 4,826 | 4,920 |

Table 13 **Data for Figure 4 Military expenditure as a percentage of GDP, focus countries, 1988-2006.**

| Country / Year | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|
| United Kingdom | 4.1 | 4 | 3.9 | 4.1 | 3.8 | 3.5 | 3.3 | 3 | 2.9 | 2.7 |
| Netherlands | 2.8 | 2.7 | 2.5 | 2.4 | 2.4 | 2.2 | 2.1 | 1.9 | 1.9 | 1.8 |
| Norway | 2.9 | 2.9 | 2.9 | 2.7 | 3 | 2.7 | 2.7 | 2.4 | 2.2 | 2.1 |
| Sweden | 2.6 | 2.5 | 2.6 | 2.5 | 2.4 | 2.5 | 2.4 | 2.3 | 2.3 | 2.1 |
| Denmark | 2.1 | 2 | 2 | 2 | 1.9 | 1.9 | 1.8 | 1.7 | 1.7 | 1.6 |
| Germany | 2.9 | 2.8 | 2.8 | 2.2 | 2 | 1.9 | 1.7 | 1.6 | 1.6 | 1.5 |
| Canada | 2 | 1.9 | 2 | 1.9 | 1.9 | 1.8 | 1.7 | 1.6 | 1.4 | 1.2 |
| Australia | 2.1 | 2 | 2 | 2.1 | 2.1 | 2.1 | 2.1 | 2 | 1.9 | 1.8 |

| Country / Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| United Kingdom | 2.6 | 2.5 | 2.4 | 2.4 | 2.4 | 2.7 | 2.7 | 2.7 | 2.6 |
| Netherlands | 1.7 | 1.7 | 1.6 | 1.5 | 1.5 | 1.6 | 1.5 | 1.5 | 1.5 |
| Norway | 2.2 | 2.1 | 1.7 | 1.7 | 2.1 | 2 | 1.9 | 1.6 | 1.5 |
| Sweden | 2.1 | 2 | 2 | 1.9 | 1.8 | 1.7 | 1.6 | 1.5 | 1.5 |
| Denmark | 1.6 | 1.6 | 1.5 | 1.6 | 1.5 | 1.5 | 1.5 | 1.3 | 1.4 |
| Germany | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.4 | 1.3 |
| Canada | 1.3 | 1.2 | 1.1 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.2 |
| Australia | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.8 | 1.9 | 1.8 | 1 |

Table 14 **Data for Figure 5 Defence R&D budget as a percentage of total GBAORD, high end.**

| Country / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| United States | 62.60 | 59.68 | 58.60 | 59.03 | 55.27 | 54.08 | 54.75 | 55.25 | 54.13 |
| United Kingdom | 43.49 | 43.94 | 40.78 | 41.99 | 38.88 | 36.54 | 37.22 | 39.15 | 36.79 |
| Sweden | 23.62 | 27.32 | 24.33 | 23.49 | 18.88 | 20.89 | 20.89 | n/a | 7.31 |
| Country / Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | |
| United States | 53.20 | 51.62 | 50.49 | 52.14 | 54.89 | 55.71 | 56.87 | 57.89 | |
| United Kingdom | 37.91 | 36.19 | 30.46 | 33.91 | 31.88 | 31.02 | 28.30 | 28.30 | |
| Sweden | 7.35 | 7.12 | 14.63 | 21.61 | 20.71 | 16.64 | 17.43 | 16.85 | |

Table 15 **Data for Figure 6 Defence R&D budget as a percentage of total GBAORD, low end**

| Country / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| Australia | 11.21 | 10.26 | 9.31 | 9.78 | 8.72 | 7.06 | 7.11 | 6.61 | 6.53 |
| Germany | 13.47 | 10.98 | 10.03 | 8.52 | 8.56 | 9.06 | 9.95 | 9.57 | 8.76 |
| Norway | 6.56 | 6.18 | 5.61 | 5.55 | 5.59 | 5.70 | 5.75 | 5.57 | 5.47 |
| Canada | 6.38 | 5.07 | 5.26 | 4.80 | 4.80 | 4.70 | 4.82 | 5.70 | 5.25 |
| Netherlands | 2.78 | 3.01 | 3.22 | 3.02 | 3.18 | 3.03 | 3.55 | 3.05 | 2.47 |
| Denmark | 0.42 | 0.62 | 0.61 | 0.61 | 0.65 | 0.62 | 0.57 | 0.57 | 0.56 |

| Country / Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|
| Australia | 6.73 | 7.17 | 6.64 | 6.68 | 6.23 | 6.65 | 6.69 | 7.03 |
| Germany | 8.33 | 7.79 | 7.37 | 5.46 | 6.52 | 5.84 | 5.75 | 6.48 |
| Norway | 5.35 | 5.02 | 7.47 | 7.11 | 6.92 | 6.65 | 6.36 | 5.95 |
| Canada | 5.45 | 4.78 | 4.23 | 3.68 | 3.77 | 3.75 | 3.68 | 3.57 |
| Netherlands | 2.43 | 1.84 | 1.87 | 1.83 | 1.90 | 1.33 | 2.22 | 2.08 |
| Denmark | 0.52 | 0.51 | 0.49 | 0.53 | 1.16 | 1.28 | 0.74 | 0.71 |

Figure 17 GERD/GDP ratio selected states and organisation totals, 1996-2006. is based on various sources. The figures for OECD members (the Netherlands, Japan, United States) as well as the OECD and EU27 averages are derived from the MSTI database. The other national ratios are based on data from the UIS database. The NATO total is calculated on the basis of data from the OECD (GERD and GDP of OECD member states and Romania, Slovenia), the UIS (GERD of non-OECD members), and the World Bank (GDP of non-OECD members).

Table 16 **Data for Figure 17 GERD/GDP ratio selected states and organisation totals, 1996-2006.**

| Country / Year | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Japan | 2.81 | 2.87 | 3.00 | 3.02 | 3.04 | 3.12 | 3.17 | 3.20 | 3.17 | 3.33 | 3.40 |
| United States | 2.51 | 2.55 | 2.58 | 2.62 | 2.66 | 2.74 | 2.76 | 2.66 | 2.66 | 2.59 | 2.62 |
| NATO (current members) | 2.03 | 2.04 | 2.07 | 2.12 | 2.16 | 2.19 | 2.14 | 2.13 | 2.09 | 2.12 | 2.11 |
| EU27 | 1.66 | 1.67 | 1.67 | 1.72 | 1.74 | 1.76 | 1.77 | 1.76 | 1.73 | 1.74 | 1.76 |
| Netherlands | 1.98 | 1.99 | 1.90 | 1.96 | 1.83 | 1.80 | 1.72 | 1.76 | 1.78 | 1.74 | 1.67 |
| China | 0.57 | 0.64 | 0.65 | 0.76 | 0.90 | 0.95 | 1.07 | 1.13 | 1.23 | 1.33 | 1.42 |
| Russian Federation | 0.97 | 1.04 | 0.95 | 1.00 | 1.05 | 1.18 | 1.25 | 1.28 | 1.15 | 1.07 | 1.08 |
| Brazil | 0.72 | n/a | n/a | n/a | n/a | 0.96 | 0.91 | 0.88 | 0.83 | 0.82 | n/a |
| India | 0.65 | 0.69 | 0.71 | 0.74 | 0.77 | 0.75 | 0.73 | 0.71 | 0.69 | n/a | n/a |

Since all focus countries are OECD members, Figure 18 GERD in millions US$, focus countries, 1988-2006. is entirely based on the MSTI database.

Table 17 **Data for Figure 18 GERD in millions US$, focus countries, 1988-2006.**

| Country / Year | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 31,255 | 33,506 | 35,180 | 39,259 | 39,114 | 38,509 | 38,684 | 40,299 | 41,515 | 43,309 |
| United Kingdom | 17,724 | 18,878 | 19,734 | 19,384 | 19,432 | 20,650 | 21,534 | 21,946 | 22,379 | 23,098 |
| Canada | 6,773 | 7,550 | 8,192 | 8,645 | 9,189 | 9,958 | 11,008 | 11,324 | 11,407 | 12,139 |
| Australia | 3,232 | n/a | 3,777 | n/a | 4,783 | n/a | 5,629 | n/a | 6,644 | n/a |
| Netherlands | 4,775 | 4,943 | 5,466 | 5,490 | 5,514 | 5,781 | 6,200 | 6,572 | 6,989 | 7,485 |
| Norway | n/a | 1,191 | n/a | 1,319 | n/a | 1,538 | n/a | 1,738 | n/a | 2,003 |

| Country / Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| Germany | 45,199 | 49,432 | 52,283 | 54,448 | 56,657 | 59,484 | 61,393 | 62,448 | 66,689 |
| United Kingdom | 23,962 | 25,939 | 27,824 | 29,191 | 30,636 | 31,071 | 32,057 | 33,413 | 35,591 |
| Canada | 13,551 | 14,811 | 16,731 | 19,026 | 19,142 | 20,057 | 21,536 | 22,823 | 23,306 |
| Australia | 6,813 | n/a | 7,929 | n/a | 9,885 | n/a | 11,698 | n/a | n/a |
| Netherlands | 7,584 | 8,339 | 8,533 | 8,914 | 8,891 | 9,042 | 9,641 | 9,843 | 9,959 |
| Norway | n/a | 2,178 | n/a | 2,664 | 2,792 | 2,998 | 3,094 | 3,352 | 3,686 |

Since all focus countries are OECD members, Figure 19 is entirely based on the MSTI database.

Table 18 **Data for Figure 19 GERD/GDP ratio focus countries, 1988-2006.**

| Country / Year | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 2.73 | 2.71 | 2.61 | 2.47 | 2.35 | 2.28 | 2.19 | 2.19 | 2.19 | 2.24 |
| Canada | 1.38 | 1.45 | 1.51 | 1.57 | 1.62 | 1.68 | 1.73 | 1.70 | 1.65 | 1.66 |
| United Kingdom | 2.13 | 2.14 | 2.14 | 2.06 | 2.01 | 2.04 | 2.00 | 1.94 | 1.86 | 1.80 |
| Australia | 1.18 | n/a | 1.28 | n/a | 1.48 | n/a | 1.53 | n/a | 1.61 | n/a |
| Netherlands | 2.12 | 2.02 | 2.07 | 1.96 | 1.89 | 1.92 | 1.95 | 1.97 | 1.98 | 1.99 |
| Norway | n/a | 1.66 | n/a | 1.63 | n/a | 1.70 | n/a | 1.69 | n/a | 1.63 |

| Country / Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|
| Germany | 2.27 | 2.40 | 2.45 | 2.46 | 2.49 | 2.52 | 2.49 | 2.48 | 2.53 |
| Canada | 1.76 | 1.80 | 1.92 | 2.09 | 2.04 | 2.03 | 2.05 | 2.01 | 1.94 |
| United Kingdom | 1.79 | 1.86 | 1.85 | 1.82 | 1.82 | 1.78 | 1.71 | 1.76 | 1.78 |
| Australia | 1.47 | n/a | 1.51 | n/a | 1.69 | n/a | 1.78 | n/a | n/a |
| Netherlands | 1.90 | 1.96 | 1.83 | 1.80 | 1.72 | 1.76 | 1.78 | 1.74 | 1.67 |
| Norway | n/a | 1.64 | n/a | 1.59 | 1.66 | 1.71 | 1.59 | 1.52 | 1.52 |

Table 19 **Data for Figure 20 GERD/GDP ratio focus countries, EU, OECD, 2006.**

| Country / Year | 2006 |
|---|---|
| Sweden | 3.73 |
| Germany | 2.53 |
| Denmark | 2.43 |
| Canada | 1.94 |
| EU15 | 1.88 |
| United Kingdom | 1.78 |
| Australia (2004) | 1.78 |
| EU27 | 1.76 |
| Netherlands | 1.67 |
| Norway | 1.52 |

Table 20 **Data for Figure 21 GERD/GDP ratios Netherlands, NATO (adjusted for dates of accession), US, 1996-2006.**

| Country / Year | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Netherlands | 1.98 | 1.99 | 1.90 | 1.96 | 1.83 | 1.80 | 1.72 | 1.76 | 1.78 | 1.74 | 1.67 |
| NATO total | 2.09 | 2.10 | 2.13 | 2.14 | 2.18 | 2.20 | 2.16 | 2.15 | 2.09 | 2.12 | 2.11 |
| NATO-US | 1.66 | 1.66 | 1.67 | 1.67 | 1.68 | 1.72 | 1.72 | 1.71 | 1.66 | 1.67 | 1.66 |
| NATO/Eurozone | n/a | n/a | n/a | 1.78 | 1.79 | 1.78 | 1.80 | 1.79 | 1.78 | 1.77 | 1.78 |
| United States | 2.55 | 2.58 | 2.62 | 2.66 | 2.74 | 2.76 | 2.66 | 2.66 | 2.59 | 2.62 | 2.62 |

Table 21 **Data for Figure 22 R&D intensity per industrial sector, world top 1,402 companies.**

| Sector | R&D Intensity |
|---|---|
| Pharmaceuticals & Biotechnology | 16.10% |
| Software & Computer Services | 9.70% |
| Technology Hardware & Equipment | 8.50% |
| Health Care Equipment & Services | 6.50% |
| Leisure Goods | 6.20% |
| Aerospace & Defence | 4.40% |
| Automobiles & Parts | 4.20% |
| Electronic & Electrical Equipment | 4.10% |
| Chemicals | 2.80% |
| Industrial Engineering | 2.60% |
| Household Goods | 2.20% |
| General Industrials | 2.10% |
| Fixed Line Telecommunications | 1.70% |
| Food Producers | 1.50% |
| Oil & Gas Producers | 0.30% |

Table 22 **Defence expenditure as a percentage of GDP, NATO members.**

| Year/Country | Average 1985-89 | Average 1990-4 | Average 1995-9 | Average 2000-4 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| United States | 6.3 | 4.8 | 3.4 | 3.4 | 3.7 | 3.9 | 4 | 3.9 | 3.8 |
| Greece | 4.5 | 3.9 | 4.1 | 3.2 | 2.5 | 2.6 | 2.7 | 2.7 | 2.8 |
| Turkey | 4.6 | 5.2 | 5 | 4.1 | 3.8 | 3.1 | 2.8 | 2.8 | 2.8 |
| France | 3.7 | 3.3 | 2.9 | 2.5 | 2.6 | 2.6 | 2.5 | 2.4 | 2.4 |
| Bulgaria | n/a | n/a | n/a | n/a | n/a | 2.5 | 2.5 | 2.3 | 2.3 |
| United Kingdom | 4.7 | 3.8 | 2.7 | 2.4 | 2.4 | 2.3 | 2.5 | 2.5 | 2.3 |
| Poland | n/a | n/a | n/a | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 |
| Romania | n/a | n/a | n/a | n/a | n/a | 2 | 2 | 1.8 | 1.9 |
| Latvia | n/a | n/a | n/a | n/a | n/a | 1.3 | 1.3 | 1.6 | 1.7 |
| Slovak Republic | n/a | n/a | n/a | n/a | n/a | 1.7 | 1.7 | 1.7 | 1.7 |
| Czech Republic | n/a | n/a | n/a | 2 | 2 | 1.8 | 1.8 | 1.7 | 1.6 |
| Estonia | n/a | n/a | n/a | n/a | n/a | 1.6 | 1.5 | 1.4 | 1.6 |
| Norway | 2.6 | 2.4 | 1.9 | 1.8 | 1.9 | 1.9 | 1.7 | 1.6 | 1.6 |
| Slovenia | n/a | n/a | n/a | n/a | n/a | 1.5 | 1.5 | 1.6 | 1.6 |
| Portugal | 2.5 | 2.4 | 2.1 | 1.7 | 1.5 | 1.6 | 1.7 | 1.6 | 1.5 |
| Italy | 2.7 | 2.4 | 2 | 1.9 | 1.9 | 1.8 | 1.7 | 1.5 | 1.4 |
| Netherlands | 2.8 | 2.3 | 1.8 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 |
| Canada | 2.1 | 1.8 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 |
| Denmark | 2.1 | 2 | 1.7 | 1.5 | 1.5 | 1.4 | 1.3 | 1.4 | 1.3 |
| Germany | 3 | 2.1 | 1.6 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 |
| Lithuania | n/a | n/a | n/a | n/a | n/a | 1.5 | 1.3 | 1.3 | 1.3 |
| Spain | 2.1 | 1.6 | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Belgium | 2.7 | 2 | 1.5 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 |
| Hungary | n/a | n/a | n/a | 1.6 | 1.7 | 1.5 | 1.4 | 1.2 | 1.1 |
| Luxembourg | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.8 |

Source: NATO-Russia Compendium on Financial and Economic Data Relating to Defence 2007

# Additional information

Table 22 and Table 23 provide some additional information on the defence expenditure of the members of NATO. Table 22 gives an overview of defence spending as a percentage of GDP between 1985 and 2007, while Table 23 shows the per capita expenditure on defence per member state during the same period. These data have not been used for the analysis in this report, but may serve as background information. The

tables are based on the NATO-Russia Compendium on Financial and Economic Data Relating to Defence.[29]

Table 23 **Per capita defence expenditure in mln US$ (2000 rates), NATO members.**

| Country/Year | 1985 | 1990 | 1995 | 2000 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| United States | 1,643 | 1,589 | 1,172 | 1,068 | 1,317 | 1,415 | 1,468 | 1,465 | 1,460 |
| Norway | 679 | 717 | 650 | 651 | 734 | 741 | 680 | 670 | 663 |
| United Kingdom | 938 | 841 | 635 | 605 | 618 | 608 | 678 | 693 | 657 |
| France | 629 | 642 | 592 | 557 | 568 | 583 | 568 | 563 | 560 |
| Luxembourg | 193 | 241 | 252 | 292 | 334 | 349 | 346 | 342 | 426 |
| Denmark | 488 | 505 | 470 | 448 | 447 | 444 | 421 | 459 | 423 |
| Greece | 484 | 407 | 387 | 506 | 327 | 355 | 387 | 401 | 421 |
| Netherlands | 471 | 473 | 388 | 375 | 376 | 373 | 373 | 388 | 381 |
| Canada | 388 | 389 | 311 | 270 | 285 | 289 | 296 | 305 | 341 |
| Germany | 610 | 609 | 344 | 343 | 334 | 327 | 325 | 322 | 320 |
| Belgium | 445 | 434 | 319 | 311 | 288 | 281 | 269 | 266 | 277 |
| Italy | 389 | 408 | 359 | 394 | 371 | 353 | 322 | 287 | 276 |
| Slovenia | n/a | n/a | n/a | n/a | n/a | 167 | 171 | 197 | 203 |
| Spain | 207 | 196 | 175 | 174 | 186 | 187 | 182 | 189 | 200 |
| Portugal | 160 | 211 | 217 | 216 | 166 | 176 | 188 | 181 | 173 |
| Estonia | n/a | n/a | n/a | n/a | n/a | 88 | 92 | 99 | 122 |
| Czech Republic | n/a | n/a | n/a | 112 | 122 | 115 | 118 | 119 | 116 |
| Poland | n/a | n/a | n/a | 81 | 88 | 92 | 95 | 100 | 113 |
| Latvia | n/a | n/a | n/a | n/a | n/a | 58 | 64 | 89 | 105 |
| Turkey | 98 | 130 | 131 | 148 | 114 | 100 | 96 | 100 | 102 |
| Slovak Republic | n/a | n/a | n/a | n/a | n/a | 76 | 82 | 85 | 93 |
| Lithuania | n/a | n/a | n/a | n/a | n/a | 66 | 62 | 67 | 72 |
| Hungary | n/a | n/a | n/a | 79 | 89 | 84 | 85 | 76 | 68 |
| Bulgaria | n/a | n/a | n/a | n/a | n/a | 50 | 52 | 51 | 55 |
| Romania | n/a | n/a | n/a | n/a | n/a | 44 | 45 | 45 | 49 |

Source: NATO-Russia Compendium on Financial and Economic Data Relating to Defence 2007

29. North Atlantic Treaty Organisation, "NATO-Russia Compendium of Financial and Economic Data Relating to Defence."

# Appendix E Current knowledge area clustering focus countries

This appendix provides additional information about the clustering of knowledge areas that is currently used by each of the focus countries. The information presented in this appendix serves as additional material to the analysis in Chapter 1.

# Australia

Table 24 **The current Australian MoD knowledge area clustering**

| Knowledge area | Knowledge element |
|---|---|
| Human Sciences | Aerospace Human in the Loop Simulation |
| | Aerospace Human Sciences |
| | Individual Protection Nutrition and Performance |
| | Land Human Sciences |
| Operational Analysis | Air Operations Research |
| | Joint Systems Analysis |
| | Joint Operations Analysis |
| | Land Operations Research |
| | Maritime Capability Analysis |
| Electronic Warfare & Signature Management | Radio Frequency Electronic Warfare |
| | Electro-optic Electronic Warfare |
| | Electronic Warfare Systems Integration |
| | Platform Survivability and Signatures |
| Command, Control, Communication & Intelligence | Information Operations |
| | Military Communications |
| | Command and Control (C2) |
| | Intelligence Processing & Analysis |
| Platform Information Systems | Airborne Mission Systems |
| | Land Systems Science & Integration |
| | Maritime Command Systems |
| Surveillance & Detection Sensors | Tactical Radar & Electronic Protection |
| | HF Radar |
| | Imagery Systems |
| | ISR Systems |
| | Undersea Sensing and Systems |
| Weapons & Stores | Undersea Weapons and Countermeasures |
| | Precision Weapon Guidance |
| | Weapon Simulation and Analysis |
| | Energetic Systems and Propulsion |
| | Weapon Effects and Mitigation |
| Propulsion & Energy | Air Vehicle Propulsion, Power & Thermal Signatures & Hypersonics |
| | Mobility and Energy Management |
| Platforms | Aircraft Structural Integrity |
| | Aircraft Material Systems & Diagnostic Technologies |
| | Air Vehicle Aerodynamics and Systems Analyses |
| | Maritime Platform Capability Analysis |
| | Advanced Material & Sensor Systems for Platform Life Management |
| CBRN | Chemical, Biological, Radiological, Nuclear Defence |

# Canada

Table 25 **The current Canadian MoD knowledge area clustering.**

| Knowledge area | Knowledge element |
|---|---|
| 1.0 Command and Control | 1.1 Enhanced decision making in C2 environments |
| | 1.2 Flexible and adaptable C2 concepts and structures for achieving common intent |
| | 1.3 Effects-based visualization and awareness for the decision maker |
| | 1.4 Information Fusion and Knowledge Management and Representation |
| | 1.5 Software Protection and Counter Measures |
| 2.0 Communications Networks | 2.1 Robust, reliable networks |
| | 2.2 Computer Network Operations (CNO) |
| | 2.3 Robust wireless communications |
| | 2.4 Communications Electronic Warfare (CEW) |
| | 2.5 Navigation Warfare |
| 3.0 Intelligence, Surveillance and Reconnaissance | 3.1 Collaborative adaptive sensing |
| | 3.2 Sensing systems to exploit diversity (in phenomena, space, time and spectrum) |
| | 3.3 New sensing technologies |
| | 3.4 Exploitation of target and environment characteristics |
| | 3.5 Exploitation of adversaries' emissive systems |
| 4.0 Complex Systems | 4.1 Smart acquisitions and enhanced materiel support |
| | 4.2 Capability Based Planning |
| | 4.3 Capability Engineering |
| | 4.4 Analysis of Integrating Concepts |
| | 4.5 Analysis of complex systems and concepts |
| | 4.6 Improvements in multi-purpose capability of new and existing systems |
| 5.0 System Autonomy | 5.1 Intelligent Autonomous Systems for operation in complex environments |
| | 5.2 Emergent behavior of simple autonomous systems |

| | |
|---|---|
| 6.0 Mobile Systems | 6.1 Condition-based monitoring and prognostic and health management methodologies |
| | 6.2 Integrated platform models and their application |
| | 6.3 Characterization of effects of environment and expanded operating envelope on vehicles |
| | 6.4 Development of efficient energy storage and power sources |
| 7.0 Weapons Systems | 7.1 Non-lethal weapons |
| | 7.2 Assessment of the effects of weapons and weapon systems |
| | 7.3 Tailored precision weapons |
| | 7.4 Enhanced weapons systems for complex environments, including urban ops |
| 8.0 Personal Protection | 8.1 Evaluation and mitigation of hazards from toxic materials, infectious threats and weapons |
| | 8.2 Diagnostic and Adaptive Systems for Environmental Stresses |
| | 8.3 Personnel Protection Systems and Signature Reduction |
| | 8.4 Casualty Prevention and Management |
| 9.0 Protection of Assets | 9.1 Structures and materials for protection against weapons attacks |
| | 9.2 Reduced observability through active and passive signature management |
| | 9.3 Active countermeasures for platform protection |
| | 9.4 Minimization of impact of military operations, including training, on the environment |
| | 9.5 Decontamination of equipment and structures exposed to toxic and corrosive materials |
| 10.0 Human Systems Integration | 10.1 Human performance models for military simulations |
| | 10.2 Human Systems Integration (HSI) |
| | 10.3 Monitoring, predicting and enhancing psycho-physiological readiness |
| | 10.4 Increased effectiveness and efficiency of the CF HR system |
| | 10.5 Distributed, adaptable, and on-demand learning, training and rehearsal |
| 11.0 Behavioral Effects | 11.1 Understanding, prediction and influence of adversaries' intent |
| | 11.2 Strategies for promoting collaborative behavior among teams, agencies, organizations, and societies |
| | 11.3 Selection and development of leaders and members consistent with the ethos of the CF |
| | 11.4 Strategic Outlook - Tools and models to analyze and assess implications of changes in national and international policy, socio-economic trends and political climate |

# Germany

Table 26 **The current German MoD knowledge area clustering.**

| Knowledge area | Knowledge element |
|---|---|
| Reconnaissance, Navigation, Simulation, Robotics | 1.x.01 Materials & Semiconductor Technologies |
| | 1.x.02 Sensors |
| | 1.x.03 Signal Processing |
| | 1.x.04 Satellites |
| | 1.x.05 Reconnaissance |
| | 1.x.06 Countermeasures Electronic Warfare |
| | 1.x.07 Signature Control & Reduction |
| | 1.x.08 Identification |
| | 1.x.09 Navigation |
| | 1.x.10 Simulators, Training |
| | 1.x.11 Robotics |
| | 1.x.12 Network Enabled Capabilities |
| Platforms (Land) | 3.x.01 Platforms (Land) |
| | 3.x.02 Special Equipment |
| | 3.x.03 Vehicle Guidance, Electronic Weapon Control |
| Platforms (Air) | 4.x.01 Platforms (Air) (general) |
| | 4.x.02 Platforms (Air, Aircraft) |
| | 4.x.03 Platforms (Air, Helicopters) |
| | 4.x.04 UAVs |
| | 4.x.05 Avionics, Regulations, Weapons |
| | 4.x.06 Propulsion |
| Platforms (See) | 5.x.01 Platforms (See) (general) |
| | 5.x.02 Platforms (See, Underwater) |
| | 5.x.03 Command & Control, Weapons |
| | 5.x.04 Underwater-Vehicles, Weapons |
| | 5.x.05 Sonar-Technologies, Maritime Sensors, Maritime Environment |
| | 5.x.06 Underwater Signatures |
| Weapons, Guidance & Control, Lethality & Platform Protection | 6.x.01 Operational Effectiveness & Protection |
| | 6.x.02 Weapons |
| | 6.x.03 Missiles |
| | 6.x.04 Energy Weapons & Countermeasures |
| | 6.x.05 Extended Air Defence |
| | 6.x.06 Intelligent Targeting |

| | |
|---|---|
| Cross Cutting Technologies (environmental, personal CBRN protection) and R&T Planning Support | 7.x.01 Decision Support, Management, Planning Support |
| | 7.x.02 Technology Forecast |
| | 7.x.03 Tribology, Working Materials |
| | 7.x.04 Materials |
| | 7.x.05 CBRN Protection, Fire Protection |
| | 7.x.07 Ergonomy |
| | 7.x.08 Intelligence |
| | 7.x.09 Environment & Safety |
| | 7.x.10 System Soldier |
| Information Technology | 8.x.01 IT Trends |
| | 8.x.02 IT Security |
| | 8.x.03 Platforms IT, Networks, Services |
| | 8.x.04 IT for Command & Control |

# Norway

Table 27 **The current Norwegian MoD knowledge area clustering.**

| Knowledge area | Knowledge element |
|---|---|
| Sensors | Not mentioned |
| Combat Systems | |
| Underwater Technologies | |
| Strategic Analysis | |
| Autonomous Systems | |
| CBRN Detection and Protection | |
| Information Operations | |
| Defence Against Terrorism | |
| Modeling and Simulation | |
| Weapons and Munitions | |
| Communication and Decision-making | |
| Cold Weather Operations | |
| Enabling and Disruptive Technologies | |

# United Kingdom

Table 28 **The current United Kingdom MoD knowledge area clustering.**

| Knowledge area | Knowledge element |
|---|---|
| RF Technologies | Not mentioned |
| EO Technologies | |
| Command, Control, Computers, Communications and Information (C4I) | |
| Materials and Structures | |
| Energetics | |
| Ground Systems Technologies | |
| Aerial Systems Technologies | |
| Naval Systems Technologies | |
| System-of-Systems | |
| CBRN Protection | |
| Electronic Components and Devices | |
| Space Systems | |
| Human Factors | |

# Appendix F New areas of interest

This appendix provides additional information about the new areas of interests that have been specified the focus countries. The information presented in this appendix serves as additional material to the analysis in Chapter 1. Australia, Norway and the United Kingdom did not specify their new areas of interest.

Table 29 **The Netherlands new areas of interest**

| |
|---|
| ICT and cognitive computing |
| Advanced simulation & serious gaming |
| Human sciences and biotechnology |
| Advanced materials & nanotechnology |
| Microsystems & robotics |
| C2 and intelligence |
| Effects Based Operational Analysis (Complex Adaptive Systems) |
| Flexibility and adaptivity in planning & operational decision taking |
| Human behaviour & preformance (enhancement) |
| Monitoring & influencing behaviour of (groups of) people in crowds |

Table 30 **Australian new areas of interest**

| |
|---|
| None mentioned |
| |

Table 31 **German new areas of interest**

| |
|---|
| Biotechnology |
| Human Factors |
| Effects of Climate Change on Military Capabilities |

Table 32 **Canadian new areas of interest**

| | |
|---|---|
| Quantum capabilities | Basic quantum science as well as applied technology such as cryptography and computing |
| Autonomous Intelligent Systems and Platforms | Autonomous sensors, systems, and platforms including reducing manning requirements in large systems such as marine platforms (includes self-organizing, adaptive and collaborative behaviors) |
| Wide-band Mobile Wireless Networking | Rapidly evolving commercial/industrial community with dual use potential including internet exploitation |
| New Sensing (Hyper-spectral, Tera-Hertz) | Rapidly developing conventional and novel sensors including Hyper-spectral imaging (a result of over-laying of sensor information at various frequencies) enabled by MEMS and nanotechnology |
| Micro-Satellites | Universal access to space enabled by technologies that allow for inexpensive imaging satellites capable of 1-2 m resolution (includes both low cost, low and high earth orbit, launches). Spacecraft of a few centimetres in size and a few hundred grams in mass are on the horizon allowing for functional 'clusters or swarms' as simple sensors, networks or persistent surveillance capabilities |
| Virtual Reality and Neuro-Interfaces | Use of simulation and virtual reality in training systems (with novel user-interfaces) could reduce costs and provide more 'realistic' training. Virtual reality provides possible venues for Intelligence exploitation |
| Non-Conventional Weapons | Unconventional, but non-nuclear, kinetic and non-kinetic weapons systems to meet the future needs of the defence and security partners |
| Micro / Nano-Engineered 'Smart' Materials | Engineering of 'meta-materials' that have been produced on a sub-molecular wavelength scale to have highly controllable electromagnetic/acoustic properties |
| Novel Power Sources | Development of 'Super-capacitors' and nano-engineered devices will enable increased performance owing to their high ratio of surface area to volume. Concepts could include: bio-generation, alternate fuels, fuel cells, fusion, and wireless power transmission |
| Biology-Based Solutions (Biometrics, Bio-Signatures, Broad-Spectrum Therapies) | Technologies (that will match sensors with an ability to identify a person by unique physical or behavioral characteristics) can increase ability for surveillance of large crowds/databases of potential adversaries/insurgents. Host of possibilities including broad spectrum 'personalized' gene-based therapies |

Table 33 **Norwegian new areas of interest**

| |
|---|
| None mentioned |

Table 34 **United Kingdom new areas of interest**

| |
|---|
| None mentioned |

# Appendix G Defence knowledge infrastructures focus countries

This appendix presents more detailed information on the knowledge infrastructures of the focus countries. The material provided in this section serves to support the analysis in Chapter 3. Below, the knowledge infrastructures are presented both in writing and graphs.

## The current Australian defence knowledge infrastructure

Much of the R&D of the Australian Defence Science & Technology Organisation (DSTO) is directed at helping the Australian Defence Forces (ADF) identify their technology needs and providing defence policy, smart buyer and smart user advice to the department and the ADF.

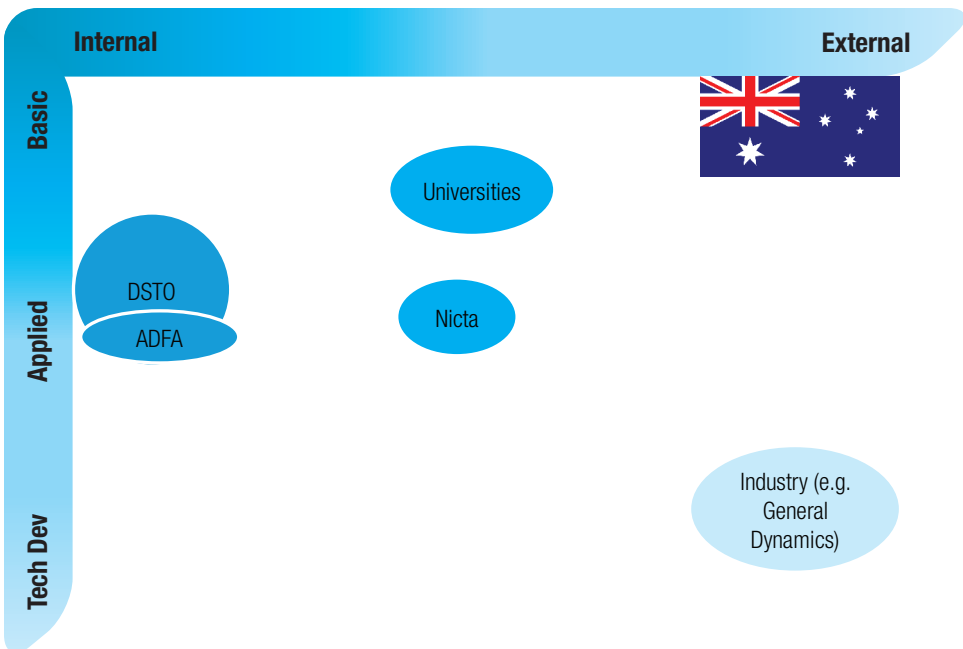
As was noted earlier, most of the DSTO budget is devoted to developing advice that maintains and sharpens the ADF's essential technological edge. This generates a return that, while vital to the nation's defence, rarely shows on any corporate bottom line.

According to ABS statistics cited in ACIL Tasman's 2004 industry study the private sector spent only AUD 31.9 million on defence R&D in 2001-02, compared with AUD 238.6 million by the federal government and AUD 4.46 million by universities. The con-

tribution of the industry to the AUD 274.9 million total defence R&D spent that year was just 11.6% In 2002/03 18.8% of GOVERD went into DSTO. Considering that Defence accounts for less than 2% of Australia's GDP, it attracts a disproportionate amount of GOVERD, although this is paid directly from the defence budget and not from other Commonwealth sources, thus reflecting the critical importance of high technology to the Australian defence capability.

NICTA was established in 2002 as a centre of excellence to boost Australia's long-term strategic research in information and communication technology. NICTA currently has 12 operational research programmes with nearly 140 researchers. The goal is to have 300 researchers and up to 100 PhD students. The Australian government has allocated to NICTA AUD 380 million over ten years from 2001-02.

Figure 23 **The current Australian defence knowledge infrastructure plotted.**

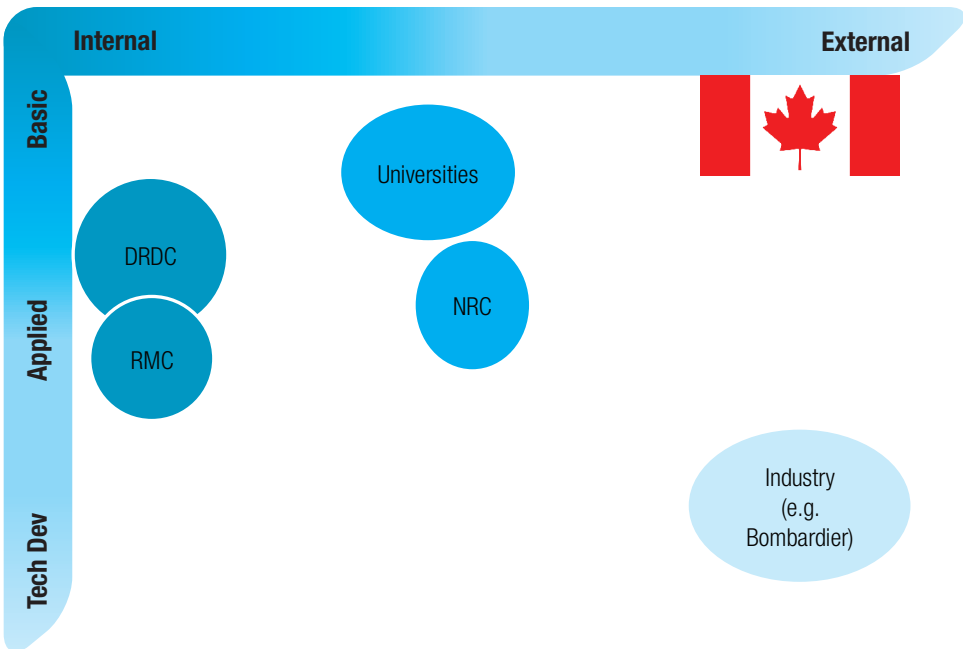



## The current Canadian defence knowledge infrastructure

The S&T effort of the Canadian Department of National Defence (DND) can be roughly divided into two programmes. First, the Research, Technology and Analysis (RTA) programme focuses on the early to mid-TRLs. It attracts about two-thirds of the S&T investment budget. Government funding for this programme mainly supports the internal

capabilities resident in Defence Research and Development Canada, which is a special operating agency of the DND. Defence R&D Canada operates 7 research centres across Canada, each with a unique combination of expertise and facilities to carry out world-class S&T research. Approximately 50% of the Defence R&D Canada budget is invested in collaborative partnerships with Canada's private sector and academic community.

Figure 24 **The current Canadian defence knowledge infrastructure plotted.**




Other departmental RTA performers, such as the Royal Military College, are also supported with RTA programme funding. External S&T performers, such as other government departments, allied governments, the industry and academia also are also engaged in certain parts of the RTA programme.

The second DND programme, which is called Development, Engineering and Evaluation (DEE), is focused on higher TRLs. It is managed primarily on a case-by-case basis, but also provides multiyear funding to support key internal (within the DND) capabilities.[30] Approximately 15% of the S&T investment budget is allocated to the DEE programme.

30. Department of National Defence, Government of Canada , "Defence S&T Strategy: Science and Technology for a secure Canada."

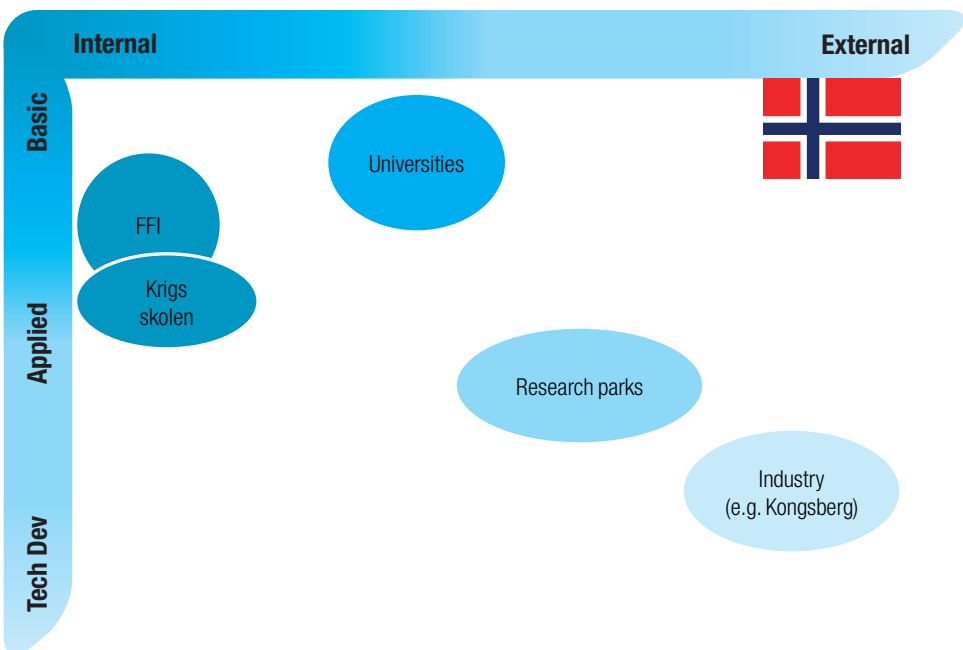
In general, Defence R&D Canada works with three different time horizons. About 43% of the S&T effort focuses on projects with a relatively short time horizon of 0 to 5 years. Another 36% is devoted to medium-term projects with a time horizon of 5 to 10 years. The final 21% focuses on the long term (i.e. longer than 10 years).

Public sector research institute Natural Resources Canada conducts applied research not primarily intended to serve military goals. Its research, however, often contributes indirectly to the defence S&T domain, e.g. in the area of explosives.

## The current Norwegian defence knowledge infrastructure

Overall, approximately 27% of all Norwegian research is being conducted in the six main universities and university colleges. Norwegian universities are predominantly focused on the first (basic research) part of the R&D value chain. They have a particular responsibility for pure research and researcher education, but they are also increasingly facilitating the exploitation of research results for the 'common good', and have recently been given greater responsibility to commercialise these research results.

Figure 25 **The current Norwegian defence knowledge infrastructure plotted.**



Norway also has a large number of public and private research institutes operating in e.g. technology development, medicine and health, the environment, the primary industries, and social sciences. These institutes account for close to 23% of overall R&D expenditure. They are the main producers of user-oriented, applied research. Although the majority of research institutes is independent from the Norwegian government, public funding (in the form of basic funding, strategic institute programmes and national R&D programmes) accounts for approximately 45% of their income, this being the largest source to finance their activities. Another 35-40% of funding is generated by the industry and the remaining 15% comes from foreign sources (including the EU). The SINTEF group is Norway's largest and most important research institute. FFI is also considered one of the research institutes, despite the fact that it is an agency of the Norwegian MoD.

Norway has thirteen research parks, which are closely linked to universities, university colleges and independent research centres. The research parks are important bridge-builders between research institutions and the business sector.

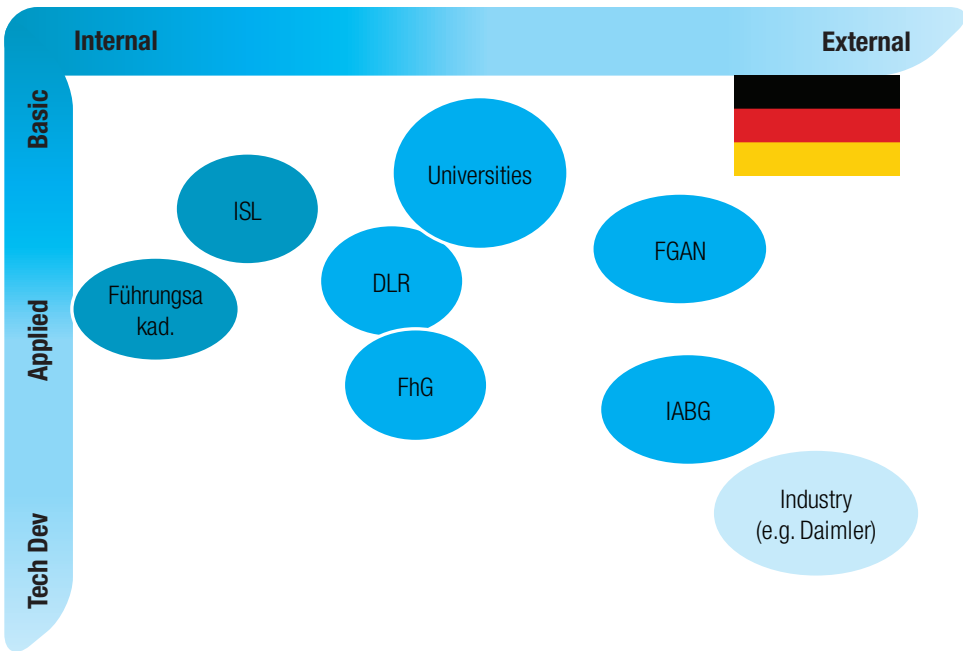
## The current German defence knowledge infrastructure

Germany does not maintain large defence-related, state-owned labs. R&T is often related to individual production projects, performed at private companies or supporting institutions. Contracts tend to focus predominantly on the large enterprises (e.g. Daimler). Most research is of an applied nature (receiving 2/3 of defence R&D expenditures). Generally, the German military R&T effort is conducted in three distinct ways:

First, through customer-focused R&T acquisition at MoD-owned facilities such as *Bundeswehr* research institutes. Second, through application-oriented R&T activities at government-funded institutes such as *Forschungsgesellschaft für Angewandte Naturwissenschaften* (FGAN), *Fraunhofer-Gesellschaft* (FhG) and *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) as well as the Franco-German *Research Institute Saint-Louis* (ISL), and third, through contract activities performed by the industry and universities as well as outside research facilities.

Overall, the German military spends about EUR 300 million on contract R&T activities and EUR 107 million on research conducted at government-funded research institutes.[31]

Figure 26 **The current German defence knowledge infrastructure plotted.**




## The current United Kingdom defence knowledge infrastructure

Until July 2001, there was one major defence research laboratory in the United Kingdom, the Defence Evaluation and Research Agency (DERA). DERA was an agency of the UK Ministry of Defence, incorporating the bulk of the non-nuclear research, technology and test and evaluation establishments of the MoD.

In 2001, the agency was split up into two organisations, one publicly owned, the Defence Science and Technology Lab (DSTL), and the other being relegated to the private sector, QinetiQ Group plc. DSTL remains part of the MoD and continues to handle the most sensitive areas of research.

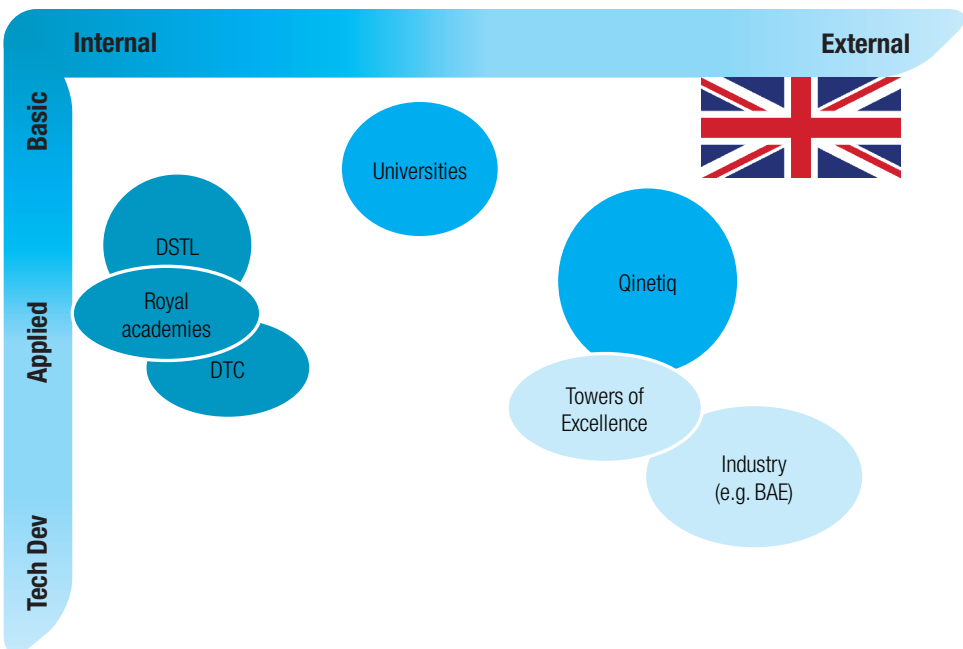
31. Federal Ministry of Defence, Government of Germany , "2006 Annual Research and Technology Report, Defence Research for the German Armed Forces in the Process of Transformation."

QinetiQ's main role is to provide the MoD with expert independent and impartial advice on all aspects of defence technology. However, this role extends to other areas of government and increasingly to civilian and overseas customers.

The Towers of Excellence initiative represents an innovative approach to defence technology development, aiming to encourage an effective technology transfer between MoD and the industry. They are built upon a new level of cooperation and interaction between the Ministry of Defence and the UK's leading equipment supplier base. They also draw upon the particular strengths of UK academia.

Defence Technology Centres are jointly funded by MoD and industry consortia, with MoD earmarking approximately £ 90 million over a five year programme to support the DTCs. DTCs work with a wide range of suppliers, including SMEs and academia, to identify new technologies and innovation where MoD and industry investment may be necessary. A further characteristic of DTCs is a flexible management approach that allows an effective response to different situations and emerging needs and priorities.

Figure 27 **The current United Kingdom defence knowledge infrastructure plotted.**



# Appendix H Description of Terms

In order to enable a full appreciation and comparison of the results of this study a description of the terms used in this report is presented below.

**Armed Forces Profile (MoD-NLD)**

An Armed Forces Profile is a generic description of the (future) armed forces taking into account fundamental choices on doctrine, equipment and composition. See Appendix B Armed Forces Profiles for more details.

**Defence Research and Technology (R&T)**

Defence research and technology is characterised by its applied nature. It is mostly used in operational, harsh settings, often under extreme natural conditions and with high reliability and precision requirements. The overall aims are securing and/or increasing the leverage of own troops and being internationally competitive and/or superior to adversaries. A large share of defence research and technology is used as integrated parts of systems and systems of systems with higher interoperability demands than civilian applications.

**Defence technological and industrial base (DTIB)**

All defence-related companies and knowledge institutes being part of defence-related national and/or international networks (‘supply chains’) for the development, production and sustainment of defence materiel.

**Government Budget Appropriations or Outlays for R&D (GBAORD) (OECD)**

GBAORD covers all government budget appropriations or outlays, intramural as well as extramural, for R&D. It always includes the central or federal government. A provincial or state government is included only when its contribution is significant. Local government funds are always excluded. The two main differences between government-financed GERD (GOVERD) and GBAORD are, first, that the former is based on reports by R&D performers, while the latter is based on reports by funding providers, and second, that GERD-based data cover only R&D performed on national territory, while GBAORD also includes payments to foreign performers, including international organisations.[32]

**Gross Domestic Expenditure on R&D (GERD) (OECD)**

GERD is the total intramural expenditure on R&D performed on national territory during a specific period. GERD is calculated by adding together the intramural R&D expenditures of four different performing sectors, namely business enterprise, government, private non-profit, and higher education. It includes R&D performed in a country but financed from abroad, but excludes payments for R&D performed abroad.[33]

**Knowledge area (KA) (MoD-NLD)**

A knowledge area is a clustering of knowledge and technologies structured in a specific way to enable users to distinguish it from other knowledge areas.

**Knowledge element (KE) (MoD-NLD)**

Part of a knowledge area and thus a clustering of knowledge and technologies, defined for governance reasons in a specific way to enable users to distinguish it from other knowledge elements. The knowledge elements, as are the knowledge areas, are formulated in a way to make them as mutually exclusive as possible.

**Knowledge investment (MoD-NLD)**

The term knowledge investment refers to an explicit investment in the development of knowledge (so knowledge management is not considered) by conducting basic exploratory research and/or research to demonstrate the feasibility of a solution (TRL 1-3),

32. Organisation for Economic Co-operation and Development, *Frascati Manual*.

33. Ibid.

and by developing and/or demonstrating technology (TRL4-6). This includes materiel-focused research and 'soft' research into issues like personnel, doctrine and organisational matters in the above regime (TRL 1-6) by means of structurally allocated budgets (central and/or local).

So research in TRL1-6 from a (materiel) procurement budget is excluded, as this is ad hoc research funding for that specific type of (materiel) procurement.

In principle the Defence organisation invests in the development of knowledge only if the knowledge required is unavailable 'off-the-shelf'.

Integral costs should be considered, *i.e.* including additional costs for pensions, experimental facilities, organisational issues and infrastructure, salaries of staff, etc.

**Knowledge Investment Quote (KIQ)**

A knowledge investment quote is the percentage of a budget spent on S&T.

**Level playing field (MoD-NLD)**

An international market with open competition, without government restrictions focused on protection of national industries and without restrictions posed by cartels.

**Military expenditure (SIPRI definition)**

Where possible, SIPRI military expenditure includes all current and capital expenditure on:

- The armed forces, including peacekeeping forces;
- Defence ministries and other government agencies engaged in defence projects;
- Paramilitary forces if these are to be trained, equipped and available for military operations;
- Military space activities.

Such expenditures should include personnel, operations and maintenance, procurement, military research and development, military construction and military aid. Civil defence and current expenditures for previous military activities are excluded.[34]

34. Stockholm International Peace Research Institute (SIPRI), "SIPRI military expenditure database." (accessed 4 March 2009)

### Research and Experimental Development (R&D) (OECD)

The term Research and (Experimental) Development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. It is used by the OECD. In this study most of the information on KIQ is from that source. The term R&D covers three activities. First, basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Second, applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. Third, experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units. Related activities, such as education and training, other related scientific and technological activities, other industrial activities, and administration and other supporting activities should be excluded when measuring R&D.[35]

### Science and Technology (activities) (S&T) (UNESCO)

S&T activities can be defined as all systematic activities which are closely concerned with the generation, advancement, dissemination and application of scientific and technical knowledge in all fields of science and technology, that is the natural sciences, engineering and technology, the medical and the agricultural sciences, as well as the social sciences and humanities. S&T activities can be divided into three categories:

- Research and Experimental Development (R&D);
- S&T education and training at broadly the third level (comprises specialised non-university higher education and training, higher education and training leading to a university degree, post-graduate and further training and organised lifelong training for scientists and engineers);
- Scientific and technological services (activities concerned with scientific research and experimental development and contributing to the generation, dissemination and application of scientific and technical knowledge).[36]

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35. Organisation for Economic Co-operation and Development, *Frascati Manual*.

36. UNESCO Division of Statistics on Science and Technology, Office of Statistics, *Manual for Statistics on Scientific and Technological Activities*.

**Technology Readiness Levels (TRL) (MoD-NLD)**

A generic ‘maturity scale’ for knowledge that should be considered for the purpose of the study to be applicable also to non-technology-oriented types of research. See Appendix A for more details.

# About the Authors

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**Erik Frinking** is Programme Director National Security and Intelligence at HCSS. His responsibilities and activities focus on identifying and analyzing policy options, evaluating policy outcomes, and developing strategies pertaining to issues of national and international security and intelligence. In the past and present, Frinking has focused his research on policy analysis and strategy development in the fields of organizational change and the knowledge economy, science and technology, and safety and security. Among others, he analysed and advised of strengths, weaknesses, and drivers of international cooperation in R&D and the effects of policy mechanisms to facilitate these types of collaboration.