FOI

Exploring future technology development

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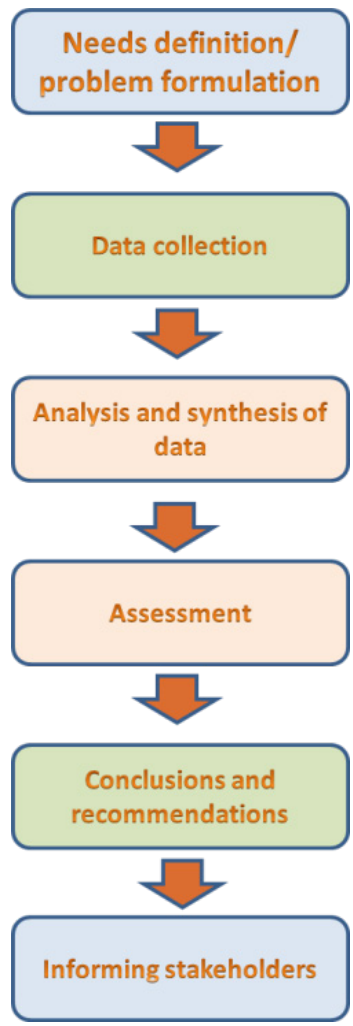

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Sammanfattning

Denna rapport syftar till att beskriva processer och metoder som används eller kan användas för att identifiera forskningsframsteg och utforska framtida teknikutveckling, speciellt sådan teknikutveckling som kan vara av väsentlig betydelse för Försvarsmakten i Sverige.

För detta ändamål har en litteraturstudie genomförts. Litteraturstudien har undersökt vad som görs av andra nationer och aktörer inom detta område och dess fokus har varit på tillvägagångssätt och metoder för utforskning av framtida teknikutveckling snarare än på möjliga framtida tekniker/teknikområden.

När olika existerande ramverk/processer i litteraturen analyseras framträder vissa gemensamma drag:

- Flertalet ramverk kombinerar metoder med fokus på avskanning eller utforskning av teknikutvecklingen med metoder som fokuserar på värdering av konsekvenserna av teknikutvecklingen
- Flertalet ramverk föreslår användning av flera olika metoder för såväl avskanning som värdering
- Flera av metoderna har utvecklats eller anpassats för att identifiera och värdera framväxande eller disruptiva teknikområden.

I rapporten beskrivs ett förslag till process för genomförande av avskanning och värdering. Det föreslås att denna testas och utvärderas under de närmaste åren. Fortsatt arbete bör också inkludera att söka svar på frågor rörande syfte och behov som identifierats, samt att sammanställa de exempel på framväxande och disruptiva teknikområden som beskrivs i litteraturen.

Nyckelord: Avskanning, teknisk prognos, framtidsstudier, disruptiv teknik, framväxande teknik, värdering

Summary

The ambition of this report is primarily to describe methodologies that are or could be used to identify research breakthroughs and explore future technology development, especially technology development that may be of significant importance for the Swedish Armed Forces.

For that purpose we have performed a literature survey. The literature survey has investigated what is being done by other nations/actors, and has focused on methodologies to explore future technology development rather than future technologies.

When examining different existing or proposed frameworks in the literature there are some common features:

- Most frameworks combine methods that focus on scanning or exploring technology development with methods focusing on assessing the consequences of technology development
- Most frameworks use multi-method approaches, i.e. use several different methods for scanning and/or assessment
- Several of the methods have been developed or adapted to identify and assess emerging or disruptive technologies.

In the report a tentative process is outlined and it is proposed that this is further developed and tested during the next few years. Continued work should also include trying to achieve answers to the questions posed concerning scope and needs, and to collect findings about possible emerging or disruptive issues from literature.

Keywords: Horizon scanning, technology watch, future studies, disruptive technologies, emerging technologies, assessment

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1 Background

> *"The Nautilus was piercing the water with its sharp spur, after having accomplished nearly ten thousand leagues in three months and a half, a distance greater than the great circle of the earth. Where were we going now, and what was reserved for the future?"*
>
> From Jules Verne "Twenty Thousand Leagues Under the Sea"

Exploring or trying to understand the opportunities offered by technological development is not a novel idea – the concept has a long history. Writers like Jules Verne (during the 19th century) and Arthur C. Clarke (during the 20th century) have contributed to the debate on this, but there have also – especially after World War II – been a lot of academic discussions on how to explore the future, from technological as well as other viewpoints. Research on which activities, approaches and methods provide for useful exploration of the future has received considerable attention and effort.

Throughout history, technology has played a critical role in warfare. During the last decades we have e.g. seen how unmanned systems – especially so called drones – have started to play a more and more important role both as sensor platforms and as weapon carriers.

Many nations and organisations are currently trying to find future "game-changers" – disruptive technologies that will fundamentally change the way we do things. But is it possible to predict these future disruptive technologies? And if we are successful in doing this, are we ready to change the way we do things accordingly and can we afford to do it (or not to do it)?

Nations and organisations within the defence and security sector, with which Sweden co-operate on a regular basis, are doing future studies of technology development – often horizon scanning and/or technology watch activities in combination with assessment of the identified technologies. Co-operation with others may therefore be a possible way forward for us in the field of exploring and assessing future technology development.

Whatever view one may have on technology development it is nevertheless important to try to understand both the possibilities and the risks it may imply as well as how these can and should interact with societal evolution. Assessing the impact of new technologies is therefore a complex task. But nevertheless a necessary one.

By exploring the future, we can get accustomed to the unexpected, be better prepared to face the unknown and hopefully avoid poor decisions in areas where technology development could be an influential factor.

2 Introduction

"In conflict, direct confrontation will lead to engagement and surprise will lead to victory. Those who are skilled in producing surprises will win. Such tacticians are as versatile as the changes in heaven and earth."

Sun Tzu, 544-496 BC

The ambition of this report is primarily to describe methodologies that are or could be used to explore future technology development, especially technology development that may be of significant importance for the Swedish Armed Forces.

To achieve this ambition it is necessary to learn both from approaches used within the defence sector, in Sweden and other nations or organisations, and those used within other parts of society. For that purpose we have performed a literature survey, focusing on methodologies, in which we investigated what is being done by other nations/actors.

Hopefully this work can be used to inspire new or improved ways for the Swedish defence sector to include understanding of future technology development and the consequences of this in its short, medium and long-term planning processes.[1]

When looking at how analysis of future technology development is done today it is obvious that there are many different approaches and a lot of different methods, ranging from extrapolation by using historical data and utilizing large focus groups to net-based solutions like text or data mining. These different methods can be used separately as well as together with each other and can also be used in different stages of processes aiming at studying technology development. We will discuss a number of potentially interesting methods in this report, but do not attempt to provide a broader overview of available methods. For the reader wanting such an overview we list references to literature where more methods are presented.

Attempting to explore future technology development can be considered a more or less limitless task. To move forward from a more common ground we will start by discussing the terminology (definitions) used in the field. Efforts to look ahead at the future come in a variety of names; horizon scanning, technology watch, technology foresight, technology forecast and technology prognosis to mention a few. Are they just different names for what is basically the same thing? Or do these activities at the core have different focuses?

We will also discuss how to identify technologies that are believed to provide a basis for disruptivity. The potential disruptivity of a technology, or a combination of technologies, is most easily identified through performing assessment. We will

[1] To achieve this it is necessary to do a national analysis of potential actors/stakeholders involved in technological development as well as an analysis of the defence planning processes in these different time perspectives.

therefore not only discuss how technology development can be identified but also to some part how the assessment process might be met. An example of the latter is the Disruptive Technology Assessment Game (DTAG) process developed by NATO.[2]

Identification of potential technologies that could be important in the future and assessment of these are two sides of the same coin and are both necessary capabilities within a future studies process for the purpose of meeting future defence challenges.

When assessing technologies there are more than mere technological aspects to consider. It is also important to investigate aspects relating to e.g. legal, ethical, medical and economic matters[3], as well as to appreciate that new technology will form part of new and complex socio-technical systems that may look different depending on the type of society. We will not go deeply into these matters in this report, since that is a task that needs more time and effort. It is, however, something that must be met by anyone proposing implementation of new technological solutions, especially if these are of a disruptive nature.

2.1 Content

The contents of this report is organised as follows. The background of the study is presented in chapter 1. Chapter 2 gives a brief introduction to the study, the report and what it contains. Chapter 3 presents the methodology. Chapter 4 discusses the definitions in the field, while chapter 5 discusses disruptive and emerging technologies.

Chapter 6 presents different methods which can be used to explore future technology development. The chapter also presents some common pitfalls when trying to predict future technology development.

Chapter 7 presents how identification and assessment of technology development is done today in the Swedish defence community, while chapter 8 discusses how it is done in some other nations (with focus on nations with which Sweden often co-

[2] The work was performed by the two studies:
- *Assessment of Possible Disruptive Technologies for Defence and Security*, AC/323(SAS-062)TP/258, NATO RTO, February 2010.
- *Disruptive Technology Assessment Game – Evolution and Validation*, AC/323(SAS-082)TP/427, NATO RTO, April 2012.

[3] An example of such limitations are laser-based weapons. Protocol IV, from 1995, of the Convention on prohibitions or restriction on the use of certain conventional weapons which may be deemed to be excessively injurious or to have indiscriminate effects (CCW), the so-called Inhumane weapons convention, has this focus. Protocol IV states that "It is prohibited to employ laser weapons specifically designed, as their sole combat function or as one of their combat functions, to cause permanent blindness to unenhanced vision, that is to the naked eye or to the eye with corrective eyesight devices". See e.g. http://www.unog.ch/80256EDD006B8954/(httpAssets)/8463F2782F711A13C12571DE005BCF1A/$file/PROTOCOL+IV.pdf

operates). Chapter 9 revisits the main conclusions from the study and discusses some ways forward for the Swedish defence community and proposes follow-on activities.

Chapter 10 list relevant references.

Annex A lists some methods and tools. Annex B presents some frameworks from literature.

3 Methodology

”*The best way to predict your future is to create it.*”

Abraham Lincoln

This study is based on a selection of available literature. The references to the selection is presented in chapter 10. The literature study has used input from various sources. The main source is more than 40 books and articles retrieved by searching online including words such as game-changers, disruptive, technology, future, forecast, foresight, horizon scanning in the title or retrieved through personal communication. The results cover traditional processes and methods as well as newer ones.[4]

Since we are mainly interested in methods and technologies of importance to the defence community (and especially the Swedish Armed Forces) this means that we have emphasized searching for literature with a defence or force origin. In addition, the Swedish Defence Research Agency (FOI) has a long tradition of combining a defence perspective with methodologies looking towards the future. Therefore, in addition to the books and articles mentioned above a selection of FOI reports has been used. Reports from the Swedish Defence Material Administration (FMV) and NATO have also been sources to the literature study. Personal experiences and contacts with persons working in the field in Sweden and other nations are also woven into the report.

[4] The selection of literature is limited to publications in English and Swedish.

4 Looking towards the future

"If one does not know to which port one is sailing, no wind is favorable."

Seneca, Roman philosopher, 4 BC - 65 AD

There are many terms describing activities relating to the field of exploring technology development. Future studies, forecasting, foresight, horizon scanning, futures research, technology prognosis (as the activity within the Swedish Armed Forces is called), futurology, technology watch, future-oriented technology analysis[5], emerging technologies, disruptive technologies, military disruptive technologies, to name a few. This may reflect the idea that the domain of future studies is not a discipline with rigid boundaries and fixed theories.[6] A few of the above terms and what they represent are further described in this report. This aims to provide some basic acquaintance to terms appearing in activities trying to "systematically look ahead". Some of these terms appear as somewhat of semantic magnets when scanning the current literature. But are they contributing to new insight and perspectives or are they mere flavors of the current season? How these different terms may or may not reflect slightly different viewpoints on looking at the future will also be a topic of the next few chapters.

This chapter discusses terms relating directly to the way in which the analysis of technology development is performed. Disruptive and emerging technologies, being more of the wanted result from, or focus of, a forward-looking analysis process, are discussed in chapter 5.

4.1 Technology forecasting and foresight

The first serious attempt to apply scientific methods to forecasting of technological change was the work of Lenz, who coined the term technological forecasting for this activity (Lenz, 1962).[7]

The terms forecasting and foresight may be seen as two names for what is basically the same thing, while others point to the existence of important differences between them, where forecasting is more about extrapolating developments.

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[5] A. Eerola, A., & Miles, I., *Methods and tools contributing to FTA: A knowledge-based perspective*, Futures 43, p. 265–278, 2011. "Future oriented technology analysis (FTA) is an umbrella term for a broad set of activities that facilitate decision-making and coordinated action, especially in science, technology and innovation policy-making."

[6] Ziauddin, S., *The Namesake: Futures; future studies; futurology; futuristic; foresight – What's in the name?*, Futures 42, p. 177-184, 2010.

[7] Martino, J.P., *Handbook of futures research*, 1978.

With that view the degree of success of forecasters in any field may to a high degree depend upon the extent to which (1) there are reliable patterns in past events, (2) these patterns are known to forecasters, and (3) forecasters can obtain the data needed to utilize these patterns in the generation of forecasts.[8] The focus of the forecaster is therefore on deriving patterns from past experiences and trying to apply them on the future.

During the 1960's, there was considerable activity within the US government, particularly the Department of Defense, in the application of technology forecasting.

In the article "The development of technology foresight: A review", publications featuring the terms *technological forecasting* and *technology foresight* in their titles from 1970-2009 were collected.[9] The results showed a drastic decrease in the use of the term technological forecasting (from about 160 per year to 30) during the timespan, while there is a large increase in the use of technology foresight (from zero articles in 1970 to a peak in the nineties of about 120 articles per year, to about 90 articles in 2009). Where the introduction of a new word, foresight rather than forecasting, can indicate a novel thought or statement, terms can also be introduced simply as a matter of fad and fashionable labels and the term foresight is claimed to simply having been introduced as a humorous counterpart to hindsight.[10]

As mentioned above some argue that there is an actual and important difference in meaning between foresight and forecasting such that "intuitive thinking is used more in technology foresight than in technology forecasting"[11] and that "forecasting is about making more or less linear systematic estimations, statements, extrapolations, projections, or predictions of highly probable future events"[12] while foresight processes are not aiming at trying to predict the future, but rather to explore the range of plausible futures that may emerge and to help identify assumptions and strategies that are robust in preparing for an uncertain future.[13]

The European Commission (2002) has provided the following definition of foresight: "*Foresight can be defined as the application of systematic, participatory, future intelligence gathering and medium-to-long-term vision-building processes to informing present-day decisions and mobilising joint actions. Foresight brings together key agents of change and various sources of knowledge in order to develop strategic visions and anticipatory intelligence".*[14]

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[8] Martino, J.P., *Handbook of futures research*, 1978.
[9] Miles, I., *The development of technology foresight: A review*, Technological Forecasting & Social Change 77, 2010.
[10] Miles, I., *The development of technology foresight: A review*, Technological Forecasting & Social Change 77, p. 1449, 2010.
[11] http://www.innovation-portal.info/toolkits/technological -forecasting/
[12] Kuosa, T., *Towards Strategic Intelligence - Foresight, Intelligence, and Policy-Making*, 2014.
[13] Next stop Scanning and Foresight, Horizons, www.horizons.gc.ca
[14] http://www.foresight-platform.eu/community/forlearn/what-is-foresight/, http://www2.warwick.ac.uk/fac/soc/csgr/green/foresight/scienceinnovation/2009_forsknings-

Foresight has been criticized for being "intrinsically singular in nature" [15], i.e. that only one or a few similar scenarios is being used. Foresight methods can however range from downplaying the role of scenario work, to the opposite, with divergent scenarios that set the stage for thinking about alternative futures.

The use of foresight as a term is also to some considered valuable since it is assumed to be easier to understand for the lay public and managers than the term future studies**,** even though their meanings are alike.[16]

4.2 Horizon scanning

While foresight is more about emphasizing the exploration of how changes may evolve and interact to create new policy challenges and opportunities, horizon scanning emphasizes identifying changes in the environment that could have significant implications for government policy and programmes.

Horizon scanning is frequently used in future studies, to help us to think about the future. The goal is often to "help identify assumptions and strategies that are robust in preparing for an uncertain future."[17]

Horizon scanning aims at improved understanding of the change in the (external) environment. This is achieved through systematic exploration and identification of opportunities, challenges and developments relevant to organisations, thus identifying changes in the environment that could have implications for policies.[18] [19]

Almost all work aiming at exploring the future starts with or involves horizon scanning. "Horizon, or environmental, scanning is the art of systematically exploring the external environment to (1) better understand the nature and pace of change in that environment, and (2) identify potential opportunities, challenges, and likely future developments relevant to your organization."[20]

Another way of describing horizon scanning is: "Horizon scanning is generally understood to refer to the active, ongoing and systematic monitoring and assessment

_og_innovationsstyrelsen_review_of_science_and_technology_foresight_studies_and_comparison_with_gts2015.pdf

[15] Sarder, Z., *The Namesake: Futures; future studies; futurology; futuristic; foresight – What's in the name*? Futures 42, p. 177-184, 2010.

[16] Sarder, Z., *The Namesake: Futures; future studies; futurology; futuristic; foresight – What's in the name*? Futures 42, p. 177-184, 2010.

[17] Government of Canada - Policy Horizons Canada, *Next Stop: Scanning and Foresight*, PH4-100/2011E-PDF.

[18] Government of Canada - Policy Horizons Canada, *Next Stop: Scanning and Foresight*, PH4-100/2011E-PDF.

[19] Jackson, M., *Shaping Tomorrow. Practical Foresight guide, chapter 4 – scanning.* 2013.

[20] Jackson, M., *Shaping Tomorrow. Practical Foresight guide, chapter 4 – scanning.* 2013.

of a technological, commercial or other type of environment with a view to anticipating the changes that are likely to occur in it ... It is thus of use in detecting and assessing emerging threats and opportunities and in guiding decision- and policymaking ahead of actual events."[21]

Horizon scanning is therefore about gathering information on emerging issues and trends and is looking further into the future than other future studies activities, this to provide a basis for decision making by identifying opportunities and threats implied by different developments, which are being tracked, in relation to an organisation's limitations and strengths.[22]

According to the UK Government Office for Science's "The Futures Toolkit"[23], horizon scanning is presented as one method to use across a projects lifecycle (where Delphi and scenarios are two examples of other methods). The definition suggested by Day[24] describes horizon scanning as a "systematic examination of information", "to identify potential threats, risks", "allowing for better preparedness" [25]. Horizon scanning seems, in most cases, to be considered as an activity rather than a method. Horizon scanning should preferably be a continuous and systematic process to follow and detect changes in environments of interest for the actor to facilitate decision-making with regard to threats and opportunities in the future.[26]

In a presentation from DRDC[27] in Canada, horizon scanning is defined as "identify scientific and technological advances in potentially disruptive defense and security relevant areas that are not currently being watched"[28]. Here it is seen as a complement to technology watch which is defined as "understand what science and technology areas are being tracked by SME's[29] over time; track scientific and

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[21] http://www.dictionnaire.enap.ca/dictionnaire/docs/definitions/definitions_anglais/horizon_scanning.pdf Cabinet Office and Government Office for Science First published 8 July 2014.

[22] Jackson, M., *Shaping Tomorrow. Practical Foresight guide, chapter 4 – scanning.* 2013.

[23] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/328069/Futures_Toolkit_beta.pdf, Cabinet Office and Government Office for Science First published 8 July 2014. The Futures Toolkit claims that over 25 methods (techniques) could be considered part of future analysis, ranging from workshops to long term processes. The Toolkit aims to bring together the best ideas and suggestions for ways to approach futures thinking.

[24] Day, J., *Review of cross-government horizon scanning*, UK Cabinet Office, 2013. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/79252/Horizon_Scanning_Review_20121003.pdf

[25] "A systematic examination of information to identify potential threats, risks, emerging issues and opportunities, beyond the Parliamentary term, allowing for better preparedness and the incorporation of mitigation and exploitation into the policy making process."

[26] http://www.dictionnaire.enap.ca/dictionnaire/docs/definitions/definitions_anglais/horizon_scanning.pdf, Cabinet Office and Government Office for Science First published 8 July 2014

[27] Defence Research and Development Centre.

[28] EDT Impact Assessment Initiative, Dr Alain Auger, October 2014.

[29] Subject Matter Experts.

technological advances in potentially disruptive, known defense and security-relevant areas."

Pre-requisites for scanning are considered to be:

- "Out of the box thinking, an open mind, and a desire to discover new things.
- Exposure to many sources, ideas, and challenges.
- Looking beyond personal and organizational comfort zones and specializations.
- Noting opportunities and risks in an ordered fashion."[30]

A critical part of horizon scanning is being able to read a scanning hit for what it says about the future and being able to extend one's worldview beyond today's paradigms.

4.3 Technology watch

The common denominator for technology watch is studying technology areas and the technology development within these. Whereas horizon scanning searches for areas which are not yet being watched, technology watch focuses on technology areas of known importance.

Technology watch consists of an: "*organised and structured system for the searching, detection and analysis of the environment, [aimed at disseminating and transmitting information and knowledge in a continuous manner, at the required time], so that the target group can be made aware of the main activities in their sector, within the technology field*".[31] Technology watch emphasizes the search and capturing of relevant information to make decisions regarding areas of science and technology that are already followed today. [32]

In the Swedish defence sector technology prognosis[33] has traditionally been used to name activities that are basically technology watch, i.e. exploring development within a number of technology areas (the ones defined to be of importance for defence research activities[34]). Chapter 7 describes how the technology prognosis

[30] Jackson, M., *Shaping Tomorrow. Practical Foresight guide, chapter 4 – scanning.* 2013.
[31] http://www.opti.org/en/vigilancia_tec.asp
[32] Cristòfol, R., *Technology Watch and Competitive intelligence for SEM-SEO* [en linea]. "Hipertext.net", num. 6, 2008. http://www.upf.edu/hipertextnet/en/numero-6/vigilancia-tecnologica.html
[33] Teknisk Prognos.
[34] Basically the R&D areas that are tasked to FOI, FMV and the defence industry as part of the Swedish Armed Forces R&D programme.

activity has been performed in Sweden during the last decades (and how it is done today).

4.4 Terms used in this report

In this report we will mostly use the terms *technology watch*, for exploring technology development in selected and known technology areas, and *horizon scanning*, for a more "out-of-the-box" search for new technological solutions that are not yet followed.

When referring to references using words like forecast or foresight we will of course also use those terms, but when it is not obvious which term is the accurate one to use we will use the term *future studies*.

5 Disruptive and emerging technologies

"I have a great respect for incremental improvement, and I've done that sort of thing in my life, but I've always been attracted to the more revolutionary changes. I don't know why. Because they're harder. They're much more stressful emotionally. And you usually go through a period where everybody tells you that you've completely failed."

Steve Jobs

Much interest today within the defence community is focused on identifying emergent or disruptive technologies, i.e. finding or getting a glimpse of the truly new technologies and the ones that fundamentally changes the preconditions for conflict management and wars.

Emerging and disruptive technologies are different in nature, but disruptive technologies can originate from emerging technologies.

From a technological viewpoint disruptive technologies "cause one or more discontinuities in the normal evolutionary life cycle of technology" [35] and the technologies can be viewed as low-probability, high-impact innovations.

NATO has a vocabulary for "Emerged/Emerging Disruptive Technologies" (E2DT's). These are technologies which are either disruptive or deemed to be potentially disruptive, either from the opportunity they present to the Alliance or from the threat they pose in the hands of potential adversaries. NATO also has a list of such E2DT's, which is updated regularly. The list from August 2012 consists of 18 such E2DT's.[36]

5.1 Emerging technologies

Emerging technologies have been defined as "new technologies that are currently developing or will be developed over the next five to ten years, and which will substantially alter the business and social environment."[37] However, as is written by Alford et. al "It is also fair to say that emerging technologies are often vaguely defined, such as purely by perceived novelty or as commercially important areas of emerging science."[38] Alford et. al presents key themes in emerging technologies and among these are:

[35] Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies--Report 2*, ISBN 978-0-309-14904-4. p. 2, 2010.
[36] Compendium on Technology Trends and Challenges 2012, NATO AC/323-D(2012)0009.
[37] http://www.businessdictionary.com/definition/emerging-technologies.html
[38] Alford, K. et. al, *The Complex Futures of Emerging Technologies: Challenges and Opportunities for Science Foresight and Governance in Australia*. Journal of Futures Studies, 16(4), p. 67-86, June 2012.

- New, emerging, developing (the technology or underpinning science is a new discovery or application, or not yet well understood)
- Enabling capabilities, applications (the application of the technology facilitates a solution)
- Convergence, multidisciplinary (comprises knowledge from multiple disciplines, and most likely crosses over traditional science disciplines)
- Integration, systemic (the technology is likely to be partnered with other technologies and knowledge as part of a broader solution).[39]

Emerging technologies, according to the National Research Council (NRC), are those that are currently gaining prominence or importance, may become disruptive early or late in their life span, or in a region far from their origin, or they may not become disruptive at all.[40]

5.2 Disruptive technologies

In the mid 1990's a new term was coined by Bower and Christensen[41], disruptive technology. As the name disruptive implies it emphasizes one specific characteristic of technology development, namely the appearance of non-linear effects ("leaps"). According to the NRC the word "disruptive" connotes an interruption or upset to the orderly progression of an event, process, or activity, or a break in service. The word can also imply confusion or disorder, or a drastic alteration in structure. A disruptive technology, according to NRC, is "an innovative (although not necessarily new) technology that triggers sudden and unexpected effects. Because these technologies are characteristically hard to predict and occur infrequently, they are difficult to identify or foresee." [42] The difficulties in foreseeing have not hindered the hunt for disruptive technologies both in the civil[43] and military sector. Today, citing

http://www2.warwick.ac.uk/fac/soc/csgr/green/foresight/scienceinnovation/2012_alford_keeniham_mcgrail_the_complex_futures_of_emerging_technologies.pdf

[39] Alford, K. et. Al, *The Complex Futures of Emerging Technologies: Challenges and Opportunities for Science Foresight and Governance in Australia*. Journal of Futures Studies, 16(4), p. 67-86, June 2012.
http://www2.warwick.ac.uk/fac/soc/csgr/green/foresight/scienceinnovation/2012_alford_keeniham_mcgrail_the_complex_futures_of_emerging_technologies.pdf

[40] Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies--Report 2*, ISBN 978-0-309-14904-4. p. 13, 2010.

[41] Bower, J. L.. & Christensen, C. M., *Disruptive Technologies: Catching the Wave*, *Harvard Business Review*, January–February 1995.

[42] http//:www.nap.edu/catalog/12557.html, 2009

[43] Manyika, J., Chui, M., Bughin, J,. Dobbs, R., Bisson, R,. Marrs, A., *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

Christiansen's work on disruption in business has become popular among almost anyone studying military innovation.[44]

5.2.1 Disruptive military technologies and their impact

Within two NATO studies[45], that have developed a methodology for identifying and assessing disruptive technologies, a disruptive technology is defined as: "A disruptive technology stands for a technological development which changes the conduct of operations (including the rules of engagement) significantly within short time and thus alters the long-term goals for concepts, strategy and planning".[46] Another proposed definition of military disruptive technology is "A military technology that provides strategic, operational, or tactical advantage over an adversary."[47]

Perhaps the most devastating example of a disruptive technology in recent history is nuclear weapons. Other often mentioned disruptive technologies in the literature are unmanned vehicles and improvised explosive devices (IED's)[48]. Are there characteristics that disruptive technologies have in common?

One observation to keep in mind prior to attempting to describe common characteristics, is that a technology which may be disruptive does not need to be a new innovation in itself. The technology can be existing, new or a combination of new and/or existing technologies. From a capability perspective the technologies

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[44] Hasik, J., & Callan, B., *Disrupt or Be Disrupted: How Governments Can Develop Decisive Military Technologies*, Atlantic Council Disrupting Defense: Dynamic Security in an Age of New Technologies. May 2014.
http://www.atlanticcouncil.org/images/publications/Disrupt_or_Be_Disrupted.pdf

[45] These two studies are:

- *Assessment of Possible Disruptive Technologies for Defence and Security*, AC/323(SAS-062)TP/258, NATO RTO, February 2010
- *Disruptive Technology Assessment Game – Evolution and Validation*, AC/323(SAS-082)TP/427, NATO RTO, April 2012.

[46] Another definition within NATO is (RTA/DIR (2010) 41): "The Emerged/Emerging Disruptive Technologies (E2DT) are technologies which are either disruptive or deemed to be potentially disruptive, either from the opportunity it presents to the Alliance or from the threat it poses in the hands of potential adversaries. The nature of the disruptive effect may not yet be fully identified."

[47] Mitchell, S. T., *Identifying disruptive technologies facing the United States in the next 20 years*, Fort Leavenworth, Kansas, 2009.

[48] Some of the more important technologies being implemented for military use over time are sometimes collected under the heading Revolution in Military Affairs (RMA). "A Revolution in Military Affairs (RMA) is a major change in the nature of warfare brought about by the innovative application of new technologies which, combined with dramatic changes in military doctrine and operational and organisational concepts, fundamentally alters the character and conduct of military operations". The number of RMA's are debated but often cited ones are the invention of gunpowder, the steam engine, the submarine, the internal combustion engine, the aeroplane, the aircraft carrier, and the atomic bomb. Some, however, mean that the true ones are those depending on the large transitions of society.

might provide totally new capabilities, such as the PC when first introduced to the market, or replace existing technology as the DVD which replaced the VHS.[49]

The strategy for certain actors might in themselves be disruptive by providing technological surprise in comparison to traditional strategy (conventional warfare), insurgencies (irregular strategy) or mass destruction (catastrophic strategy).[50]

In order to further explore what a disruptive technology can be some ideas from "The NeXTech project"[51] will be presented. The NeXTech project however uses the word "game-changers". Firstly "game-changers" have to offer capabilities that were not available – and were in many ways unimaginable – a generation earlier. Secondly, these technologies provides for capabilities that do disrupt traditional ways of executing military operations. The NeXTech project loosely defined game-changing technology as "technology or [a] collection of technologies applied to a relevant problem in a manner that radically alters the symmetry of military power between competitors. The use of this technology immediately outdates the policies, doctrines and organizations of all actors."[52] "Game-changers" thus can be considered analogous to "disruptive technologies".

The above definition is notable for two main reasons. First, it reinforces the point that a game-changing technology is disruptive, representing a *discontinuous shift from the prevailing paradigm*. Second, it stresses that technology itself is *merely one*, albeit vital, component of a game-changer, or a disruption. A scientific breakthrough or a new manufacturing method, power source, weapon system or platform provides potential; a variety of other factors determine that technology's game-changing value. The NeXTech project also describes these additional factors that all must converge for a technology to be truly game-changing. These factors are: congruence, perspectives, societal values and organisational culture, and time.

- *Congruence* emphasizes that the technology itself, a concept for its use and a relevant problem, together provides the opportunity or potential for a new technology to have game-changing impact. The NeXTech project exemplifies congruence with Blitzkrieg, where integrating fast tanks, aircraft and two-way radios into an operational concept of advanced manoeuvre warfare created synergies that produced a discontinuous shift in the balance of military power in Europe.

[49]Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies,* ISBN 978-0-309-11660-2. p. 35, 2009.
[50] Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies,* p. 8, 2009.
[51] The NeXTech project was an effort to better understand the implications of potentially game-changing technologies in an effort to be better prepared for their disruptive impact. The NeXTech project was performed by consulting firm Noetic Solutions.
[52] Brimley, S., et al., *Game Changers, Disruptive technology and U.S: Defense Strategy*, September 2013.

- *Perspectives* emphasizes that different actors derive different benefits from technology based on their strategic circumstance, operational environment and preferred concepts of operation.
- *Values and Organisational Culture* emphasizes that societal values and organisational culture are important factors that enable or constrain the adoption of a game-changing technology. The NeXTech project exemplifies Values and Organisational Culture with the active denial system (ADS)[53], a technology that can be considered to have the capability to act as a non-lethal weapon, yet it is also seen as a "pain ray", which causes perception issues and concerns from human-rights lawyers about collateral damage.[54]
- *Time* emphasizes that technology takes time to mature but can then advance rapidly after it reaches *a tipping point.* The NeXTech project exemplifies with the Predator system. It flew for the first time in 1995, but did not become a game-changer until it was enabled with GPS technology.

The meaning and usefulness of these particular four factors can be discussed. However, these factors illustrate and stress that the shift from being "merely" a technology to becoming a disruptive technology may not necessarily be linked to the technology as such. For a technology to be disruptive several other factors also need to be in place.

In the NRC report needs and challenges for a disruptive forecasting system was framed and aspects underpinning the needs and challenges originating from for example the uncertainty in what war will be in the future were discussed – how future wars will be waged, new applications of technologies which are hard to predict, the ever increasing speed of technology development, the spread and access to technologies which may be or become disruptive, the use of technologies which differs between cultures and the impact of technologies on societies. [55] Technologies can be used by a variety of actors with different strategies and value systems.[56] Therefore, both low-tech and high-tech technologies may prove to be disruptive, and the technologies must therefore be placed in a context as the societal effects of technologies needs to be explored to assess what might become disruptive.[57]

[53] The Active Denial System (ADS) is a non-lethal directed energy weapon. Informally, the weapon is also called the heat ray since it works by heating the surface of targets, such as the skin of targeted human subjects. http://en.wikipedia.org/wiki/Active_Denial_System

[54] The ADS was eventually deployed to Afghanistan but was never employed there.

[55] Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies--Report 2*, ISBN 978-0-309-14904-4. p. 3, 2010.

[56] Brimley, S., et al., *Game Changers, Disruptive technology and U.S: Defense Strategy*, September 2013.

[57] Committee on Forecasting Future Disruptive Technologies; National Research Council, *Persistent Forecasting of Disruptive Technologies--Report 2*, ISBN 978-0-309-14904-4. p. 3, 2010.

6 Methods that support future studies

"Vision is not enough; it must be combined with venture. It is not enough to stare up to the step; we must step up the stairs."

Vaclav Havel

The studies of the future to identify technology development can be performed in various ways, e.g. emphasizing the exploration of how changes may evolve (foresight) or identifying changes in the environment that could have significant implications (horizon scanning). There are however commonalities in the reviewed literature regarding the flow, or the process, in which the work of future studies is done.

First, the starting point is defining the needs, determining the aim and the scope of the study. The problem must be understood and assumptions identified. This involves structuring the problem area.

Secondly, alternative futures can be used to explore and identify technology areas of future interest. Thereafter, roadmaps and assessment of technologies and futures to determine impact is feasible. Depending on the characteristics of the process the results can serve as decision support only, but the activity can also continue by gathering data on interesting themes which are considered worthwhile to follow. That is, if the process is persistent, one might choose to continue to actively follow technology areas of interest to produce data for analysis of the emergence of new technologies and as input for the next "round of work". However, the work may also be of a periodical character or even a "one timer" which makes this type of continuous data gathering inessential.[58]

Another commonality is the advice to use a combination of methods. To create robust results a combination of methods are generally proposed, but this does not only imply that the methods which are being used in the work should be different (different names). It means that the foundation for the methods, the methodology itself, should be different. For example, the methods can be exploratory, normative or predictive[59] with data based on experts, evidence or assumptions. This implies that

[58] Literature points to the necessity of a continuous (persistent) approach.

[59] The predictive mode of thought try to explore the probable futures, the exploratory try to explore the possible futures, while the normative try to explore the preferred futures. The predictive mode of thinking attempts to get an indication of what will happen by trying to find the most likely development in the future, in order to be better prepared. The explorative (or eventualities) mode of thinking is characterised by the openness to several possible events and different developments. The purpose is to be better prepared to handle emerging situations with the idea that it is impossible to predict what will actually happen. The normative (or visionary) mode of thinking means to envisage how society or some sector or activity could be designed in a better way than its present mode of functioning. This mode of thinking suggests solutions to fundamental societal problems by taking normative goals into account and exploring the paths leading to these goals. For further reading see

data can be quantitative and qualitative, which is another way to classify methods (quantitative, semi-quantitative, and qualitative methods).[60] Using a combination of methods is the trend in futures studies, due to the complexity of the area.

It is recommended in the literature on future studies that a wide representation of actors, including stakeholders and representatives from the community, are involved in order to produce relevant outputs.

Also, the emphasis of the assessment and thus the result of the work, should be on whether the predictions at the time have *enabled good decision making.* The most accurate forecast is not necessarily the most useful one.

6.1 Some useful methods

In this section some examples of methods that can be used to explore future technology development are presented. There are a wide range of methods used within the futures field and there are many collections, "toolkits", where different methods have been described and categorized, see e.g. The Futures Toolkit[61], FUTURREG Toolkit[62], Futures Research Methodology[63] and Practical Foresight Guide[64]. A few examples of such collections/"toolkits" are shown in Annex A.

Though different toolkits list quite a few methods, many more have been proposed and used within the field. Attempting to find the most relevant set of methods to reach appropriate results for the problem at hand may seem an overwhelming task. One possible approach to this, apart from choosing methods with different characteristics as already mentioned, is to "bet safe", and as outset use well-tried methods where there is access to experience of what can go methodologically wrong and where the most sensitive steps are.

The methods presented in this report fit one or both of the following criteria: 1) There is considerable experience of the method at FOI and the method has been applied to quite a great extent at FOI; 2) The method is considered to consist of particularly relevant and interesting elements for exploring future technology development.

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e.g. Dreborg, K. H., *Scenarios and structural uncertainty: Explorations in the field of sustainable transport*, 2004.

[60] *Exploring the impact of technology foresight studies on innovation: Case of BRIC countries*, Futures, 44(6): 618–630, August 2012.

[61] The Futures Toolkit: Tools for strategic futures and for policy-makers and analysts by the UK Government Cabinet Office and Government Office for Science, First published:8 July 2014 https://www.gov.uk/government/publications/futures-toolkit-for-policy-makers-and-analysts.

[62] FUTURREG Toolkit by the Urban and Regional Innovation Research Unit in Greece, http://www.urenio.org/futurreg/toolkit.html

[63] Futures Research Methodology Version 3.0, 2009. *http://www.millennium-project.org/millennium/FRM-V3.html*

[64] Jackson, M., *Practical Foresight guide,* 2013. *http://www.shapingtomorrow.com/media-centre/pf-complete.pdf*

The following methods are presented in this chapter:

- Structured brainstorming
- Text-mining
- Morphological analysis
- Scenario building
- Delphi
- The NATO DTAG methodology
- War gaming
- Multicriteria analysis
- Crowdsourcing.

As can be seen above we present both methods with an emphasis on identifying technology development and methods with an emphasis on assessing the impact of technology development (and e.g. its potential disruptivity), since both these kinds of methods are essential within a futures studies process aiming at identifying not just what technologies may be possible in the future but also the impact these may have. There are of course several other methods that could have been included on the list above, and that fit the criteria above. Examples of such methods are backcasting and roadmaps.

6.1.1 Structured brainstorming

Structured brainstorming is a method attempting to spur and harness peoples' creativity and has been applied to many different problems over the years at FOI[65]. It can be used as a method to quickly identify key factors and determine different future possibilities. In a workshop setting, a group of 8-20 people are encouraged by a facilitator to generate ideas. All ideas are encouraged, criticism of ideas offered is not allowed. Ideas are recorded without regard to ordering or priority. When the group is satisfied that the generation of ideas is finished, the facilitator and/or the participants can cluster, sort, order and rank according to priority.

6.1.2 Text mining

Once upon a time written information was available in confined spaces like libraries or archives. Today large quantities of written data can be collected from open sources

[65] Eriksson, A. E., *Metoder för strukturerad brainstorming*. FOI-R--0662--SE, 2002.

on the web. FOI has ongoing research and applications within the data-driven analysis field [66], though not to the most part directed at the specific task of exploring future technology development.

Data-driven analysis is becoming increasingly relevant within the intelligence domain. The techniques are different forms of computerized text analysis, social network analysis, techniques for detecting if a user has multiple aliases, how digital traces can be used in the hunt for lone wolf terrorists, integrity preserving data mining and how information credibility can be assessed.

Companies use text mining to spot growing trends, e.g. to identify outbreaks of disease by Google Flu Trends[67] [68]. Text mining has also been used to find critical and emerging security technologies using patent data[69].

Text mining is about identifying patterns and breakthrough occurrences in large amounts of raw data and the focus can be on either the interpretation of existing data or on the creation of models aiming at making predictions or classifications from new data. In 2011 Intelligence Advanced Research Projects Activity (IARPA) initiated a four year program called Foresight and Understanding from Scientific Exposition (FUSE)[70]. Rather than working *ad hoc* "The FUSE Program seeks to develop automated methods that aid in the systematic, continuous, and comprehensive assessment of technical emergence using information found in published scientific, technical, and patent literature." [71] A technology watch/horizon scanning program[72] was initiated in 2014 "to apply advanced data analytics to try to isolate and identify emerging "hot" science and technology areas".[73] The technology watch part tracks key technology buzzwords, and the horizon scanning part looks for emerging scientific concepts and technology applications with disruptive potential. The idea behind the technology watch is to start with a technology in mind and then try to evaluate whether it is emerging or staying at a low level of maturity, while the horizon scanning activity demands precursor words that can be used for software to nominate technological areas as potential candidates. Two algorithms to identify emerging areas are employed, one focusing on patent data search and the other on

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[66] Franke, U., Johansson, F., Mårtenson, C., *Datadriven underrättelseanalys*, FOI-R--3680--SE, 2013 and Franke, U., Johansson, F., Jändel, M., Kaati, L., Garcia Lozano, M., *Tekniker för analys av data från webben*, FOI-R--3532--SE, 2012.

[67] Ginsberg, J. et.al. *Detecting influenza epidemics using search engine query data*, Nature 457, 1012-1014, 19 February 2009.
http://www.nature.com/nature/journal/v457/n7232/full/nature07634.html

[68] http://www.google.org/flutrends/

[69] Burbiel, J., & Schietke, R., *Etcetera (Evaluation of Critical and Emerging Security Technologies for the Elaboration of a Strategic Research Agenda) Final Report*, Fraunhofer Institute, 2014.

[70] http://ip-science.thomsonreuters.com/m/pdfs/fed-res/20130319-fuse-tr.pdf, 2013.

[71] http://www.iarpa.gov/index.php/research-programs/fuse

[72] Mitchell, B., *Pentagon Has Its Eyes Glued on Chinese Innovation*, 2014.
http://inthecapital.streetwise.co/2014/01/10/pentagon-has-its-eye-glued-on-chinese-innovation/

[73] http://www.acq.osd.mil/chieftechnologist/publications/docs/FY14_ASDRE_ST-Testimony.pdf, p. 19, 2013.

bibliometric data[74]. Despite the focus on automation in finding these potential game-changers, the system itself will not assess whether a technology is likely to be disruptive, this is a human analytical process.

6.1.3 Morphological analysis

Morphological analysis is a method to frame, structure and study wicked problems and has since the mid 1990's been applied to about one hundred projects at FOI[75] [76]. The method is mainly used in a group setting enabling dialogue among the participants who most often are subject matter experts in various fields. In an iterative process of analysis and synthesis the wicked problem is apprehended and thereby reduced to a problem possible to act upon. In short, the participants work on answering a selected focus question with the help of a facilitator and using the computer tool MA/Casper. The answers (the information) are captured, visually presented and structured in a morphological field. The evolving morphological field aids participants' discussions and stimulate thinking, thereby enabling the participants to create solutions to the wickedness, i.e. creating a workable problem. Morphological analysis has often been used for new product development but also in constructing scenarios and creating strategies. The method is said to have been applied for the first time in the "Man on the Moon" project, where a desirable but unlikely future came true (normative approach).

FOI has developed two computer tools to support morphological analysis. The MA/Casper (Computer Aided Scenario and Problem Evaluation Routine) tool is used to visualize the information thereby allowing for a common understanding and structuring of the information. The tool is also used to make the cross-consistency assessment of the information, thus reducing the problem space to a solution space. The tool Optima is used to aid in the creation and selection of scenarios using algorithms to ensure maximum divergence (maximizing diversity in the scenario space).[77]

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[74] Boland, R., *Military Trolls for Disruptive Technologies* July 1, 2014 http://www.afcea.org/content/?q=node/13006. The patent data search was created by the company 1790 Analytics. The Naval Surface Warfare Center Dahlgren Division, in Virginia, developed the second, which focuses on bibliometric data.

[75] Stenström, M., *Morphological Analysis in Groups: A Personal Guide*. FOI-R--3678--SE, 2013.

[76] Stenström, M., Bra morfdimensioner – några tankar till dig på FOI som arbetar med morfologisk analys, FOI-D--0647--SE, 2015.

[77] Carlsen, H., *Climate change and the construction of scenario sets that span the range of societal uncertainties*, Paper for International Studies Association Annual Convention, 2009. http://citation.allacademic.com/meta/p_mla_apa_research_citation/3/1/3/5/3/pages313532/p313532-1.php

6.1.4 Scenario building

A scenario has been defined as "a consistent and plausible picture of a possible future's alternative reality that informs the main issues of a policy debate"[78], a "story" illustrating a possible future or aspects of a possible future. FOI has a long tradition of working with scenarios in various fields.[79]

Scenarios are one of the most well-known and most cited techniques for thinking about the future. Scenarios are often created in workshop settings, and methods used to find informative "stories" can be such methods as have been presented previously in this chapter, e.g. brainstorming and morphological analysis, and the contents and character (i.e. explorative, normative or predictive) of the scenarios are of course directly related to the study. Many authors and experts recommend the construction of four scenarios to obtain a range of plausible futures to consider. Using only one scenario can be considered a forecast, two would most likely limit competing uncertainties and three may cause people to assume one is the forecast.

The construction of scenarios frequently requires the examination of developments in many different fields (e.g. economic, political, social or technological developments).

The Cross-impact balances (CIB)[80] method is a technique for constructing internally consistent qualitative scenarios. In the construction of scenarios consistency is one aim. Another important goal is diversity: given a set of internally consistent scenarios, a diverse set covers the space of possibilities, and thereby helps users of the scenarios to avoid underestimating or overestimating the potential for change in key factors[81]. This could include formal techniques such as "scenario diversity analysis", which maximizes a quantitative measure of the spread of a set of qualitative scenarios defined by states of driving forces, and can for example be done with the FOI computer tool Optima.

6.1.5 Delphi

The Delphi method was presented in the 1960's[82] and is still widely used in long-term studies of the future. Japan has used the Delphi method periodically since 1969, and their latest foresight, "9th Science and Technology Foresight", was published in

[78] European Environment Agency, *Looking back on looking forward: a review of evaluative scenario literature,* Technical Report 3, p 6, 2009.
[79] See e.g. Wulff, P., *FOI Viewing the future*, FOI-D--0374--SE, 2010.
[80] http://www.cross-impact.de/english/CIB_e.htm
[81] Carlsen, H., *Climate change and the construction of scenario sets that span the range of societal uncertainties,* Paper for International Studies Association Annual Convention, 2009.
http://citation.allacademic.com/meta/p_mla_apa_research_citation/3/1/3/5/3/pages313532/p313532-1.php
[82] Dalkey, N. C., *Predicting the Future*, October 1968.

English in 2010.[83] In Europe e.g. Germany in 1993, and later France and the United Kingdom, ran Delphi studies.[84] However, in none of these countries, a sole resort to the Delphi method was considered useful.[85] The Delphi method has been scarcely applied at FOI.

Characteristics of the Delphi method are feedback and anonymity. It is an expert survey in two or more 'rounds' in which, in the second and later rounds of the survey, the results from the previous round is given as feedback to the experts answering the questions. The idea is that feedback between the rounds eventually will achieve convergence of opinion.

In the most common form of Delphi, opinions sought from the experts concern particular developments that are likely to take place. “How many submarines will we have in 2035?” “How important, on a scale 1-10, is our membership in the European Union 2025 from a security perspective?” These questions are constructed as an initial step, and then the experts answering the survey are involved. One way to find relevant questions can be desktop studies using literature, patent analysis and surveys that are already available. A more creative way is to set up working groups who have the task to structure the field and formulate topics, using creativity methods such as brainstorming and more structured methods such as scenarios and morphological analysis. One may argue that the Delphi method is more of an assessment method, but Delphi can also, from a wide spectrum of fields, for example help to identify which technologies a large group of experts consider most relevant. This way of utilizing the Delphi method has been applied in future studies on technology and other exercises. It can be seen as a method to bring together the opinions or judgments of a large number of persons and the goal (and the result) of a Delphi study can be to organise a debate, to collect and synthesize opinions and to achieve a degree of convergence.

The opinions and knowledge of the experts answering the questionnaire is thus what is reflected in the Delphi method. Experts in non-technological fields can be included to ensure that trends in military, economic, social and other fields are not overlooked. These kinds of surveys are useful in a process where the exchange of opinions and the communication effect is important. Being a consensus method[86], paradigm shifts

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[83] Science and Technology Foresight Center, National Institute of Science and Technology Policy, *Contribution Science and Technology to Future Society -Summary on the 9th Science and Technology Foresight*, NISTEP Report No. 145, 2010.
http://www.nistep.go.jp/achiev/ftx/eng/rep145e/pdf/rep145e.pdf

[84] Brandes, F., *The UK technology foresight programme: An assessment of expert estimates*, Technological Forecasting & Social Change 76,p. 869-879, 2009.

[85] Cuhls, K., *Delphi method*, Fraunhofer Institute for Systems and Innovation Research, Germany. http://www.unido.org/fileadmin/import/16959_DelphiMethod.pdf

[86] There are however implementations of Delphi that are explicitly designed to identify different clusters of opinion, rather than zones of consensus.

may be problematic to capture. “In conclusion, it might be said that Delphi is a rational way of obtaining a collective judgment uninfluenced by the psychological obstacles that influence conventional panel meetings.”[87]

6.1.6 The NATO DTAG methodology

The DTAG methodology was developed within the two NATO studies SAS-062 and SAS-082.[88] Sweden participated in these two studies, in different roles: technologists, analysts, players.

The main elements of the DTAG process are:

- *Identification of future technology development*. The important thing here is a standardized and systematic way of describing this technology development. Starting with a description of basic technology development, Ideas of Systems (IoS) cards are created.[89]
- *War gaming (DTAG)*. The most significant result of SAS-062 and SAS-082 is the gaming process named *Disruptive Technology Assessment Game* (DTAG). In these games military and technology experts gather for 3-4 days in order to analyse a number of vignettes in a systematic way.
- *Analysis*. During the analysis after the games the main aim is to assess what systems (and hence technologies) that have a truly disruptive effect when used in the vignettes.

The game starts with a presentation of the objective, the analytic framework, the scenario and the Ideas of Systems cards that are to be used, to make the players familiar with the material. After that the first vignette is presented and the game begins.

The characteristics of a DTAG type game are (see also the figure below):

- It is a two-sided game with a Blue and a Red side who develops their plans in separate rooms.

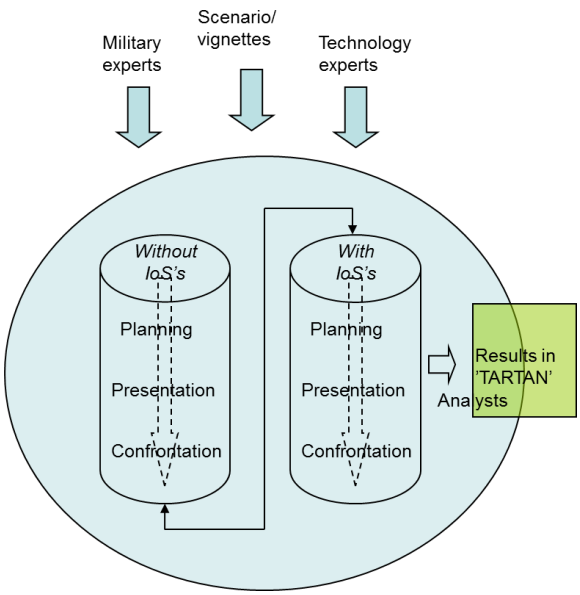
[87] Coates J. C., *Handbook of futures research*, 1978.

[88] Reference data for the two NATO studies:
- *Assessment of Possible Disruptive Technologies for Defence and Security*, AC/323(SAS-062)TP/258, NATO RTO, February 2010.
- *Disruptive Technology Assessment Game – Evolution and Validation*, AC/323(SAS-082)TP/427, NATO RTO, April 2012.

For a discussion on methodology in the two NATO studies, see Kindvall, G., *Värdering av disruptiv teknik – Erfarenheter från två NATO-studier*, FOI-R--3655--SE, December 2013.

[89] Ideas of Systems (IoS) cards are descriptions of potential future military systems, based on emerging technology trends, in a form developed in the two NATO studies SAS-062 and SAS-082. In the NATO studies each of the participating countries were responsible for developing a few Ideas of systems.

- The game uses a number of vignettes that are played (during a normal week three vignettes are played). These vignettes are often developed from a common scenario frame.
- For each vignette the game is carried out in two steps, one without and one with a number of innovative IoS.
- After each step there is a confrontation, where Blue and Red plans are put against each other in front of the whole group. This means two confrontations for each vignette.
- The two groups (Blue and Red) consist of military players (at least 3, normally 3-4) supported by technology experts and analysts. The importance of having military and technology experts meet over vignettes cannot be stressed enough when it comes to evaluating the effect of new and innovative technological solutions.
- Focus is on systematic capture of data. This is mainly done through using a computerized tool but is also done in a more free form through notes mainly by the analysts (but also by the rest of the participants).



The figure shows some features of the game.

This methodology has also been used by Sweden, Norway, Denmark and Finland within the NordTech co-operation context. This work was initiated by NORDEFCO (The Nordic Defence Co-operation) in 2010. The NordTech co-operation has seen some further developments of the DTAG methodology during three NordTech games, the most significant being a web-based tool for collecting results. This tool is named DaTARTAN since it has been developed by the Danish representative in the group and is used as a substitute for the data collection tool TARTAN[90] that was used in the NATO DTAG studies. The results from the NordTech games is being reported during 2016.[91]

6.1.7 War gaming

In the NATO DTAG method war gaming was used in the assessment of the disruptiveness of technologies. War gaming has a long tradition at FOI[92], and its application to analyze problems has seen an increase during the past 10 years. War games at FOI are often structured facilitated group discussions[93], where the game as such is tailored when it comes to e.g. scenario, game participants, inclusion or exclusion of an active red team, according to aim and available resources. The scenario may portray the past, present or the future. For most of the applications of war gaming at FOI the scenario is a ”story” of the future divided into time steps. In an FOI report that describes some methods for analysis of technological forecasts war-gaming is one possible approach for assessment (the other two approaches mentioned in the report are literature reviews and the use of subject matter experts, where the experts can either be interviewed[94] or participate in a group setting)[95].

6.1.8 Multicriteria analysis

Methods for multicriteria analysis aims to compare different alternatives according to a variety of criteria based on expert judgment. One multicriteria method that has been used in various works at FOI is Analytical Hierarchy Process (AHP)[96], but there are many other similar methods using other algorithms. These kinds of methods can be used to select or hierarchise alternatives, e.g. to assess different technological

[90] Tool to Assess Revolutionary Technologies and Assets for NATO.
[91] The report *Emerging Technology Concepts and Defence planning in the Nordic Countries* (FFI Externnotat 16/00336) is already avaliable at www.ffi.no. A final report from the co-operation will be published later in 2016.
[92] Isacson, T., *Spel för värdering av Försvarsmaktsstrukturer*, FOI-R--1195--SE, 2004.
[93] Nordstrand, E., *Spel som metod för att analysera problem - Handbok för spel i seminarieform*, FOI-D--0351--SE, 2009.
[94] Wiss, Å., Ödlund, A., *Öppna intervjuer - Att intervjua med en kvalitativ ansats*, FOA-R--99-01014-170, 1999.
[95] Alvå, P., Dahlén, L., Lundgren, L., *Metodik för konsekvensanalys av teknisk prognos,* FOI-R--853--SE, 2005.
[96] Bosaeus, L., *Analytical Hierarchy Process as a tool for long-term requirements management*, FOI-R--3233--SE, 2011.

alternatives – for example whether stealth capacity or long range missiles has potential to be game-changers in a particular scenario. Multicriteria analysis can also be used to find out which of the scenarios that best matches decision makers' expectations. For the comparison of alternatives according to a weighted set of criteria, decision makers have to agree or reach a consensus.

6.1.9 Crowdsourcing

Most of the methods presented above include data contributions by experts. The accuracy of expert judgment has however been challenged. In the largest test of the accuracy of expert predictions, a study reported in Philip Tetlock's book *Expert Political Judgment: How Good Is It? How Can We Know?* the average expert was found to be only slightly more accurate than a dart-throwing chimpanzee[97]. Many experts would have done better if they had made random guesses. For either relatively complex or relatively simple problems, experts don't outperform novices as they do for intermediate problems[98]. This has spurred development of methods where, rather than to consider experts, the wisdom of the many is used to obtain more successful predictions of future events.

A few interesting ventures will be described here, all related to programmes run by IARPA (the U.S. Intelligence Advanced Research Projects Activity). IARPA sponsors crowdsourcing initiatives where the public judge the likelihood of potential future events and their probability of occurring, in so called forecasting tournaments. In 2011, five teams began participating in IARPA's forecasting tournament. Each team developed their own tools for harnessing and improving collective intelligence, with the goal of predicting major trends and events around the world. These teams were assembled by researchers and different teams had different qualifications that the participants had to meet in order to become part of their team[99]. Each team also could design methods for training forecasters, shaping judgments and aggregating the predictions of individual forecasters. These methods were then put to the test when the volunteer forecasters were asked to predict the future. Since 2011, IARPA has posed about 100-150 questions each year on topics such as the Syrian civil war or the stability of the Eurozone[100]. 5 000 forecasters made more than 1 million forecasts[101].

[97] Philip Tetlock *Expert Political Judgment: How Good Is It? How Can We Know?* 2006
[98] Expert Status and Performance. Burgman, M. et.al. PLoS ONE 6(7) 2011.
[99] http://freakonomics.com/2011/03/29/calling-all-predictors-to-a-new-forecasting-tournament/
[100] http://www.washingtonpost.com/blogs/monkey-cage/wp/2013/11/26/good-judgment-in-forecasting-international-affairs-and-an-invitation-for-season-3/
[101] http://www.economist.com/news/21589145-how-sort-best-rest-whos-good-forecasts

The team that won the tournament was the Good Judgment Project[102] [103], and they used a number of different approaches to enhance the predictions of the team, e.g. prediction markets and skimming top talent into elite collaborative teams of "super forecasters".[104]

The ability to test empirically the forecasting accuracy against real events, can provide insight into the usefulness of different methods used to train and aggregate individual future studies. The thesis of "super forecasters" may in time be altered or reinforced, and so will the usefulness of crowdsourcing to predict the future.

6.2 Assessment of the success of foresights

The outmost aim of all activities related to looking at the future, regardless of their emphasis on e.g. disruptivity, prediction, foresight etc., is of course to be successful. But what is regarded as "success"? Can the success of foresights be evaluated and in that case, are some approaches more efficient than others depending on what is considered successful?

It may at a first glance seem quite straightforward what success is and also quite straightforward to make an assessment. Consider for example a weather forecast. When the prognosis is rain and drops of water are falling from the sky, the process, with its inputs and models, have produced a successful output. According to the Swedish Meteorological and Hydrological Institute their 1-day prognosis has an accuracy of 85 %[105]. Is it as straightforward to assess a ten-year-prognosis of how technology will develop? Perhaps it could be, depending on the level of detail in the predictions. An article attempting to assess the estimates from the UK technology foresight programme 1994 for their status 12 years later raises three questions of importance to ask about future estimates.[106]

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[102] IARPA is sponsoring the Good Judgment Project through the Aggregative Contingent Estimation (ACE) Program initiated 2010. This aims "*to dramatically enhance the accuracy, precision, and timeliness of forecasts for a broad range of event types, through the development of advanced techniques that elicit, weight, and combine the judgments of many intelligence analysts*." http://www.iarpa.gov/index.php/research-programs/ace

[103] During 2015 the Good Judgment Inc. has been formed by Philip E. Tetlock and a few other people. This is a commercial spinoff from the Good Judgment Project. Good Judgement Inc, "look for means to improve crowd-sourced geopolitical and economic forecasts for policymakers". They bring "the science of accountable forecasting to public and private sector clients through training programs and "in-house tournaments," and plans to offer forecasts from its "superforecasters"– selected from the top 2% of all forecasters in the IARPA tournament." Good Judgement Inc. plan to start in the fall 2015.

[104] Philip E. Tetlock, Barbara A. Mellers, Nick Rohrbaugh, Eva Chen, Tools for Increasing Transparency and Improving the Quality of Debate. Current Directions in Psychological Science August 2014 vol. 23 no. 4 290-295

[105] http://www.smhi.se/kunskapsbanken/meteorologi/kan-man-lita-pa-vaderprognoser-1.4653

[106] Brandes, F., *The UK technology foresight programme: An assessment of expert estimates*, Technological Forecasting & Social Change 76,p. 869-879, 2009.

1. Did the forecasted items come about as forecasted?
2. If not, have the items still a chance of occurring, or did they occur earlier than expected?
3. What items occurred that were not forecasted?

In the UK foresight programme 1994 the Delphi method was used to make predictions concerning topics to be realized in 2004. The assessment shows that the realization rates were low. For the foresight in the energy domain 15 % of the items were realized 2006, while only 5 % in the chemical domain were realized. The article compares these rates to the realization rates of the 1971, 1976 and 1981 Japanese Delphi survey. Addressed in 2001 their realization rates where 30 % (1971), 25 % (1976) and 20 % (1981).

However, it can be argued that it is completely irrelevant whether the predictions have turned out to be realized (correct). That is no measure of the success of the foresight activity. Whether the rain that the weather forecast predicts occurs or not, can be considered irrelevant if it does not help your decision on how to dress adequately when going outdoors. The emphasis of the assessment should be on whether the predictions at the time have enabled good decision making. The most accurate forecast is not necessarily the most useful one. Many future studies do also point to the benefit of being prepared for something different, something unexpected, although what that unexpected might be or imply may be unknown. The relevance does not have to be the accuracy of the prediction.

One might further argue that forecasts should be evaluated on their ability to capture high-impact, disruptive outcomes, rather than on the ratio of correct-to-incorrect predictions that they make.[107] Nevertheless, it seems relevant to investigate how the process/methods can influence the accuracy (and usefulness/success) of the predictions. Can the pitfalls described in the next section, and the over-optimistic future estimates made in the UK foresight programme from 1994, be reduced provided an insightful choice of methodology? The assessment work is key to a more informed choice of method(s) and also key to deeper knowledge and understanding of the validity of the output provided by the selected method(s).

In 2008 a Catalogue of 15 technological focus areas[108] was presented by the GTS institutes in Denmark[109]. The material for the catalogue was"…*adapted and*

[107] "Persistent Forecasting of Disruptive Technologies – Report 1", US National Research Council, 2009

[108] GTS 2015 – Catalogue of technological focus areas, GTS – Advanced Technology Group, 2008 http://en.gts-net.dk/wp-content/uploads/2014/04/GTS-2015-Catalogue-of-technological-focus-areas.pdf

[109] GTS stands for "Godkendt Teknologisk Service" in Danish. It means "approved technological service provider". The GTS institutes are independent not-for-profit organisations whose purpose is

expanded so that the technological focus areas are reflected in the GTS's fields of expertise"[110], i.e. the focus was broad and non-military, aiming to provide input for the future development activities. The Catalogue hence represents a technology watch activity. In 2009 a comparison of this Catalogue to seventeen other foresight studies on science and technology was performed. The comparison reviewed four international studies, three national-level studies and ten Danish-specific technology foresight projects, all conducted between 2002 and 2008.[111] One interpretation of the results from this comparison was that "*Looking across the foresight studies reviewed, it is apparent that one study is often used as a source of inspiration for other foresight exercises. In this way, expectations can be replicated from one study to another, blurring their origin and perhaps also without the expectations themselves being questioned. Hence, critical reflections on the role of expectations are needed before decisions can be made based on interpretations of the results*."[112]

6.3 Pitfalls

In some studies the authors list the numerous difficulties that may occur and that could be a problem when trying to achieve relevant predictions of technology development. We choose to include two such lists here as these include the most common pitfalls.

In one of the earlier works on technological forecasting the following aspects of failure are listed[113]:

1. Lack of imagination and/or "nerve".
2. Overcompensation.
3. Failure to anticipate converging developments and/or changes in competitive systems.
4. Concentration on specific configurations, rather than extrapolating aggregated figures of merit.
5. Incorrect calculation.
6. Intrinsic uncertainties and historical accidents.

to spread technical know-how, new methods and knowledge to industry and society in order to create and increase development according to http://en.gts-net.dk/about-gts/who-is-gts/.

[110] GTS 2015 – Catalogue of technological focus areas, GTS – Advanced Technology Group, 2008, p. 6.

[111] Report: Review of science and technology foresight studies and comparison with GTS2015, Forsknings- og Innovationsstyrelsen, Birgitte Rasmussen, Per Dannemand Andersen, ISBN: 978-87-923-7277-2, 2009.

[112] Report: Review of science and technology foresight studies and comparison with GTS2015, p. 7.

[113] Ayres, *Technological forecasting and long-range planning*, Chapter 2, Failures of technological forecasting, 1969.

In the Swedish technology foresight reported in 2000[114] a separate study on technological hindsight was performed. This study discusses various difficulties and sources of errors that should be borne in mind. Among the factors contributing to the failure of previous predictions, it found;

1. The belief that new technology will replace existing technology, and that this will happen relatively fast.
2. The belief that new technology will only solve old problems and supplement existing technological systems.
3. The belief that new technology will function as a panacea for various social problems.
4. The difficulty of seeing important links between different fields of technology in cases where this combination of fields is precisely what will offer major developmental opportunities.
5. That those who have tried to predict the future have become bogged down in the actual technology and thus neglected the economic aspects.
6. That people have been prisoners of the spirit of their times (or Zeitgeist), believing that the big issues of today will also be the big issues of tomorrow.
7. That rational economic considerations are not the only factors behind the choice of a new technology.
8. That the information on which future studies are based has often been insufficient.

When performing future studies it is therefore important to be aware of these (and other) potential pitfalls. There are numerous ways to draw the wrong conclusions from data.

[114] Björn, L., & Lübeck, L.. *Swedish Technology Foresight - a successful project, with many lessons learned*, paper from The Second International Conference on Technology Foresight, February 2003. The conference was arranged by the National Institute of Science and Technology Policy (NISTEP) in Japan, The study on technological hindsight (Teknisk baksyn) was performed by Lars Olsson.

7 Exploring technology development in the Swedish defence

"Control your own destiny, or someone else will"

Jack Welch, Former CEO of GE.

The focus of this report is on future studies activities for the benefit of the Swedish defence community, mainly the needs of the Swedish Armed Forces.

In this chapter we look at how the task of following and analyzing the technology development is done today, and how it has been done during the last few decades. We also discuss assessment activities aimed at analyzing the consequences of technology development on the strategic, operational or tactical level.

It is worth pointing out that there have always been activities aimed at understanding future technology development within the R&D activities that the Armed Forces tasks FOI to perform. It must however be stressed that less resources is put into these activities today than a few decades ago, making it necessary to prioritize.

7.1 The 80's and onwards

If we go back a few decades the technology watch (technology prognosis) activities within the Armed Forces were done through producing broad trend reports for the relevant technology areas every 4 years or so.[115] The work was done in co-operation between the Armed Forces, the Defence Materiel Administration (FMV) and the Defence Research Agency (FOI, before 2001 FOA), with much of the work being done by research personnel at FOI/FOA. These documents consisted of a large binder that contained descriptions of the future trends for the technology areas. The document was classified as secret. The classification led to the document not being used in studies or for other purposes as much as it should have been. This way of describing technology trends was abandoned after the report in 2005.[116]

From the end of the 1990´s and well into the first decade of the 21st century long term planning within the Swedish Armed Forces was heavily influenced by acronyms such as DBA (Dominant Battlespace Awareness), RMA (Revolution in Military Affairs) and NCW (Network Centric Warfare). This meant that a lot of focus was given to sensor and command and control system development and hence to technological aspects of these. A lot of ideas of systems were described and analyzed through war

[115] Technology Prognosis (TP) were produced for example 1987, 1991 and 1995.
[116] This was the first one after the one in 1995. The report in 2005 was also the first Technology Prognosis that was not classified.

gaming and other measures. This work involved a lot of personnel from the Armed Forces, the Defence Materiel Administration (FMV) and FOI.

During the 1990´s a number of studies named Technical Strategical Studies were performed, led by FOI's predecessor FOA but performed in close co-operation with other defence agencies. The focus was often on technology or capability. An example of the former is a study on potential use of High Power Microwave (HPM) technology, while an example of the latter is potential technologies that might be implemented in new air defence radar systems.[117] These studies were large activities with ambitious programmes and many participants.

Assessment, often through war gaming, was also an important part of the work during this period. One report describes three different ambition levels for performing consequence analysis of technology development:

- Literature studies. Compare different written sources.
- Analysis done by Subject Matter Experts. Experts are asked to describe the development in the different technology areas. This can be done individually or as facilitated discussions in groups.
- War gaming with support from Subject Matter Experts. The technology development is described by experts and presented e.g. as ideas of systems where a certain technology is implemented. These are then used and analysed in different scenarios or vignettes.[118]

Several other assessment activities have also been proposed and performed over the years. During the 1990's there were several assessments done within the electromagnetic weapons technology area. A special project was formed to do these assessments.[119] For telecommunication systems a specific assessment method – COAT (COmmunications AssessmenT) – has been developed.[120] The COAT method has also been used within the sensor technology area.[121]

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[117] Experiences from the first Technical Strategical Study is reported in Wikström, P., Isacson, T. och Lindström, H., "Tekniska-Strategiska Studier, TSS, Pilotprojekt HPM, Metod/erfarenhetsrapport", FOA rapport C 10351-1.1, april 1993.

[118] Alvå, P., Dahlén, L., Lundgren, L., *Metodik för konsekvensanalys av teknisk prognos*, FOI-R--1853--SE, december 2005. This report mentions that the aim of the proposed technological consequence analysis is to put results from technology watch activities (Technology Prognosis) into a strategic, operational and tactical perspective.

[119] Andersson, C., Wiss, Å., *Slutrapport för VEV-projektet. Verksamheter under 1994-2002.* FOI-R--0665--SE, 2003

[120] Asp, B., Carling, C., Hunstad, A., Johansson, B., Johansson, P., Nilsson, J., Waern, Å., COmmunications AssessmenT. COAT is described in, *COAT användarguide*, FOI-R--240--SE, December 2007.

[121] Söderström, J., Asp., Näsström, F., Rindstål, P., *Taktisk värdering av sensorsystem – en metodförstudie,* FOI-R--2654--SE, December 2008.

For more about assessment activities, see for example Kindvall (2013).[122]

7.2 Today

During the last 5-10 years the focus within the Swedish Armed Forces has shifted again. Less focus is given to technology development in long term planning. Instead, matters such as global strategic developments (actors, regions, themes) are studied.

The technology watch activities (Technology Prognosis) for the benefit of the Armed Forces long term planning has played a smaller role and for the last couple of years been aimed at understanding areas such as cyber, space and unmanned platforms, that are believed to have a large influence on future defence capabilities. These areas are therefore given priority not only within the Technology Prognosis process but are also the focus of targeted studies and research projects. From 2016 the analysis of technology development is given a higher priority in the Swedish Armed Forces long term planning, aiming at co-ordination of ongoing activities and looking wider and deeper on the defence consequences the ongoing technology development may have.

A new process for the Technology Prognosis activity was introduced in 2009. It focuses on being relevant and easily available (avoiding mostly classified material). The products delivered annually by the Technology Prognosis process are:

- Analysis of a selection of interesting technology areas.
- Reports with references – classified or unclassified, depending on technology area.
- Short unclassified summaries on two pages to make the reports more easily available within the defence community.
- Use of figures to enhance understanding of the subject.[123]

There have mostly been positive reactions to this new format even though some of course argue that more resources should be put into the process to make it possible to dig broader and deeper.

[122] Kindvall, G., *Värdering av disruptiv teknik – Erfarenheter från två NATO-studier*, FOI-R--3655--SE, December 2013.

[123] The reports from Technical Prognosis from the last four years are:
- *Teknisk Prognos 2011*, 11FMV2150-18, 2011-12-01
- *Teknisk Prognos 2012*, 12FMV1949-15, 2012-12-11
- *Teknisk Prognos 2013*, 13FMV4481-18, November 2013
- *Teknisk Prognos 2014*, 14FMV2487-19, 2014-12-08
- *Teknisk Prognos 2015*, 15FMV8156-15, November 2015

To broaden the work and to achieve more within a limited budget, a number of international co-operations have been established. Among these are:

- Joint work within the Nordic Defence Co-operation (NORDEFCO) context, the last few years focusing on assessment of technologies in DTAG type war games (see section 6.2.6).
- Exchange with Germany and the Netherlands, e.g. making it possible to use material from the Fraunhofer Institute in Germany.
- Contacts with Massachusetts Institute of Technology (MIT), e.g. through participation in a yearly conference.

Examples of subjects that have been covered in the Technology Prognosis reports during the last few years are:

- Body sensors and their integration into textile materials (2011)
- Combat identification systems for dismounted soldiers (2011)
- Unattended sensors and sensor networks (2011)
- Energy systems for the dismounted soldier (2011)
- Nano air vehicles (2012)
- Biomimetic UUV (2012)
- Small satellites (2012)
- Evolutionary robotics (2012)
- Alternative fuels (2013)
- Cyber defence (2013)
- High-altitude platforms (2013)
- Walking machines (2013)
- Unmanned combat aerial vehicles (2014)
- Kinodynamic motion planning (2014)
- Bioinspired adaptive camouflage surfaces (2014)
- Quantum informatics (2014)
- Cognitive systems (2015)
- Structural health monitoring (2015)
- Unmanned surface vessels (2015)
- Deep learning (2015)
- 3D printers (2015).

7.3 FOI activities

Since 2014 there have been targeted activities aimed at exploring the potential development in interesting areas, mostly of a technological nature. These so called scanning projects are jointly funded by the Swedish Armed Forces and FOI and done by researchers at FOI. This can be seen as a research rejuvenation programme and the projects look at the research frontier within their respective areas.

For the first year (2014) these projects were the ones chosen:

- Assessment methodology
- Over-the-horizon radar technology
- Small arms guided projectiles
- Next generation of warfare
- New material concepts for protection, propulsion and weapon applications
- Electric weapons on the battlefield
- Materials offering better soldier comfort and protection
- Moving target defence
- Personnel economics
- Methods for exploring future technology development
- Uncertain databases
- Information security and economics
- CBRN analysis utilizing micro-UAV
- Quantum informatics
- Atomic interferometry for precise inertial navigation

This present report on methodologies to explore future technology development is one of these scanning projects above. For 2015 these new projects were selected:

- Defence specific inflation
- Deep learning: concepts and selected applications
- Visual data analysis
- Concepts and conditions for the future soldier
- Space-based imaging radar
- Genetic analysis

Some resources was also used for establishing a horizon scanning process based partly on the material and recommendations in this report.

We are convinced that these projects, if used in the right way, can be of importance to help build a better understanding of the military use of new technologies. For that to happen the choice of studies to perform during a year must build on a common perception of what may be found around the corner (i.e. a horizon scanning process), and the technologies studied should feed an assessment process.

Of course all future oriented research performed at FOI in a way can feed a future studies process focusing on technology development. If that is to be done in an effective way the outputs from individual projects must be collected and assessed somewhere – which would require more resources than currently are available for such programmes.

8 International outlook

"Logic will get you from A to B. Imagination will take you everywhere."

Albert Einstein

While performing this study it has become obvious that many nations and organisations are investigating how best to identify potential future technology development of importance for the defence community. Special interest is given to so-called disruptive technology development, i.e. such that either directly changes the preconditions or that, in combination with other technologies, has this effect.

8.1 NATO activities

NATO has been performing studies looking into identification and assessment of disruptive technological development for almost ten years[124] and today keep and update a list of Emerged and Emerging Disruptive Technologies (E2DT), which consist of 18 technology areas that have potential to be disruptive in one of the ways mentioned above.[125] Technology is also seen as a means to solve other essential defence related problems, as described by the NATO list of so called Science and Technology Hard Problems (STHP).[126]

Within NATO's Science and Technology Organization (NATO STO) there are regularly new proposals for studies of horizon scanning methodologies or other matters relevant for understanding technological development. Horizon scanning was also one of NATO´s strategic S&T initiatives during 2015, the other being maritime security.

8.2 European Union activities

In 2014 the European Defence Agency (EDA) posted an invitation to tender titled "Technology watch pilot study". The overall aim is described as:

"EDA has a large number of activities that rely on a systematic understanding of evolving technical trends and their effect on future European Defence Capabilities, both long and short term. Within the programme of work EDA is proposing to

[124] The work started with the two studies:
- *Assessment of Possible Disruptive Technologies for Defence and Security*, AC/323(SAS-062)TP/258, NATO RTO, February 2010.
- *Disruptive Technology Assessment Game – Evolution and Validation*, AC/323(SAS-082)TP/427, NATO RTO, April 2012.

[125] Compendium on Technology Trends and Challenges 2012, NATO AC/323-D(2012)0009.
[126] Compendium on Technology Trends and Challenges 2012, NATO AC/323-D(2012)0009.

establish a Technology Watch activity from 2015. This study was a pilot project for that activity.

This will provide the input for the EDA process of evaluation of technologies. This process can be described in three phases: identification and collection of technology trends, assessment of technologies' importance, and action/prioritization if appropriate. This study will address the first element (identification and collection of technology trends)."[127]

This points to the will to establish a persistent technology watch activity as well as a potential for assessing technologies.

The European Commission is also supporting foresight and horizon scanning activities through the Joint Research Centre (JRC) "to look into the longer-term impact of policies and technologies and anticipate emerging societal challenges".[128]

8.3 LoI activities

The LoI/FA EDIR (Letter of Intent/Framework Agreement for European Defence Industrial Restructuration) is a treaty that was signed in July 2000 by France, Germany, Italy, Spain, Sweden and the United Kingdom. Its objective is to facilitate the restructuring of the European defence industry, and thus promote a more powerful and competitive industrial and technological base.[129]

Within this framework it is possible to co-ordinate research activities. One group with such aim is the Disruptive Technologies Group (DTG), which has allowed Sweden to gain information on such activities within the other LoI nations.

8.4 Activities in nations

Technology development, and more specifically identifying disruptive technologies, is also the focus of studies and analyses performed by other actors.

Below we list some of the activities being performed by nations with which Sweden have co-operation on a regular basis:

- Finland is currently establishing the capability to perform qualified technology watch/horizon scanning activities.
- There is a group formed in 2010 within the NORDEFCO context which allows for co-operation and exchange of information and documents on

[127] http://www.eda.europa.eu/procurement-gateway/opportunites/eda-procurement/procurement-view/14.cat.op.076-technology-watch-pilot-study
[128] https://ec.europa.eu/jrc/en/research/crosscutting-activities/foresight
[129] http://www.tecnologiaeinnovacion.defensa.gob.es/en-us/Presentacion/OrganismosInternacionales/Pages/EDIR.aspx

forecast activities between Sweden, Norway, Denmark and Finland (The Nordic Technology Forecasting Co-operation, NordTech). The main task of this group during the last few years has been to build on and further develop the assessment technology based on the DTAG methodology which was developed by NATO 2006-2011.[130] The countries have also exchanged information about their different activities. Norway did, for example, produce a report on military technologies in 2013.[131]

- Canada, the United Kingdom, the United States and Australia are co-operating on horizon scanning activities aimed at identifying significant defence technology development.[132] Canada aims to take that further, by implementing future technologies in so-called ideas of systems and assessing them in DTAG inspired war games.
- The Netherlands has been doing its first large technology watch activity for some years, aiming at also proposing a persistent and continuous methodology for this during 2015. The current technology watch is based on the existing technology areas under research at TNO.[133]
- The Defence Science and Technology Laboratory (Dstl) in the United Kingdom do work to identify emergent science and technology. The horizon scanning part, aiming at collecting data on S&T development, will probably be outsourced to a contractor. The focus at Dstl is on using the delivered S&T data (collected in a database) for assessment to identify implications for defence and security. There is also work being done to develop futures scenarios for testing of ideas. The Cabinet office and Cranfield University also perform horizon scanning activities.

8.5 Discussion

From the activities listed above it is obvious that this is a good time to collaborate both in identifying defence relevant technology development and in developing

[130] Documentation and assessment of three war games performed respectively 2012, 2013 and 2014 is currently being done and this, together with a proposal for the way forward for this work, will be published during 2016. One report (*Emerging Technology Concepts and Defence planning in the Nordic Countries*, FFI Externnotat 16/00336) is already avaliable at www.ffi.no.
[131] MilTech Report 2012, Norwegian Defence Research Establishment (FFI), FFI-rapport 2013/01139.
[132] This co-operation is done within The Technical Co-operation Program (TTCP), see http://www.acq.osd.mil/ttcp/. TTCP is an international organisation that collaborates in defence scientific and technical information exchange; program harmonization and alignment; and shared research activities for the five nations (Australia, Canada, New Zealand, United Kingdom and USA).
[133] The Netherlands Organisation for Applied Scientific Research, see https://www.tno.nl/en/.

methods to assess the threats and opportunities that may arise from this technology development. Co-operation does also, at least if the aim is similar, mean pooling resources, possibly leading to a more cost-effective result.

One way forward is continuing the already existing co-operation with Canada and the Netherlands within the existing trilateral MoU. This allows for exchange and co-operation within the fields technology watch and technology assessment. One aim of such an activity could be to help in exploitation of new technology in the respective national S&T processes. A trilateral workshop with this focus was organised in the Netherlands late March 2015, resulting in a joint horizon scanning pilot project that started during the second half of 2015.

Another (or parallel) opportunity is to continue the ongoing Nordic co-operation. Since the work done during the last few years is currently being reported it is possible to try new ways of gaining understanding of the future technology development within this co-operation context.

Other opportunities offered are co-operation in a bilateral context within existing MoU's or within the frameworks of NATO or EU.

9 Proposals for how to go forward

The future belongs to those who prepare for it today.

Malcolm X

In this chapter we discuss how frameworks, or processes, for future studies of technology development could and should be constructed.

9.1 Common features in existing or proposed frameworks

When examining different existing or proposed frameworks in the literature there are some common features:

- Most frameworks combine methods that focus on scanning or exploring technology development with methods focusing on assessing the consequences of technology development
- Most frameworks use multi-method approaches, i.e. use several different methods for scanning and/or assessment
- Several of the methods have been developed or adapted to identify and assess emerging or disruptive technologies.

Some other important features are:

- Identifying and describing the objectives, performing a needs analysis including problem formulation and "research questions", i.e. putting the right questions and identifying what is to be explored and in which context.
- Identifying stakeholders and engage some of them in the work.
- Data collection. This can be done by automatic or semi-automatic methods or through using humans (experts or "crowds").
- Analysis and synthesis of data, i.e. structuring the often vast amounts of data that has been collected and drawing conclusions from the data.
- Assessment, which places the technology and other findings in a context. Assessment can be done using e.g. war gaming and/or assessment in relation of scenarios.
- Analysis, synthesis, collection and presentation of conclusions and recommendations.
- After going through the process, start all over again – iteration!

It is also pointed out as important to combine human and machine involvement in the process. Computers are effective when performing tasks like data mining, automated data gathering, statistical computations, data management and visualization, while humans are best at intuition, creative thinking, pattern recognition, natural language interpretation (so far) and qualitative analysis.

In Annex B we present a number of actors and their existing or proposed frameworks:

- The US National Research Council (NRC) produced two reports on forecasting of disruptive technologies a few years ago.[134] The aim of this work was to propose a persistent method for forecasting disruptive technologies.
- Policy Horizons Canada. The main elements in the process for scanning and foresight used by Policy Horizons Canada are presented. [135]
- ETCETERA. Methods used in this EU project to identify and assess emergent technologies influencing the security arena are listed.[136]
- Meta-Foresight. This is a technique marketed by the Hague Centre for Strategic Studies.[137] The main elements of this technique are listed.

9.2 A framework proposal

Based on the features of a scanning and assessment process given above we propose that the following process is further developed and if possible in part tested within the FOI scanning activities. It is however important to start this work by developing and proposing a process in more detail, which should include methods to support it and how to handle information and knowledge throughout the process. A process and

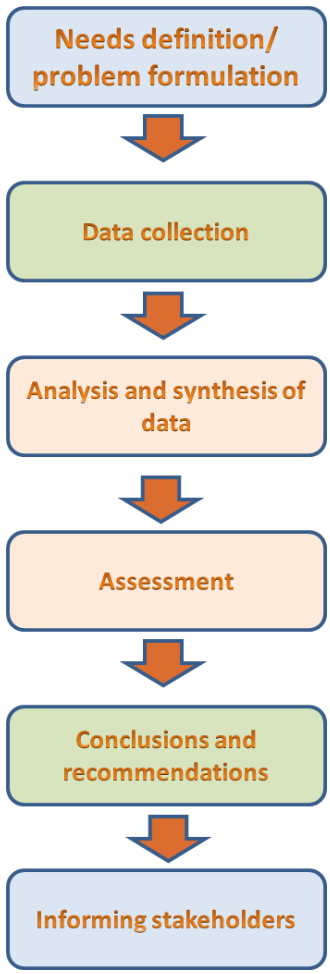
[134] The two reports were:
- "Persistent Forecasting of Disruptive Technologies – Report 1", US National Research Council, 2009
- "Persistent Forecasting of Disruptive Technologies – Report 2", US National Research Council, 2010

[135] Policy Horizons Canada describes themselves in these words: "Policy Horizons Canada, also referred to as Horizons, is an organization within the federal public service that conducts strategic foresight on cross-cutting issues that informs public servants today about the possible public policy implications over the next 10-15 years. Horizons is committed to building the scanning and strategic foresight capacity across the federal government in order to help meet the future needs of departments and agencies. Through collaborative events, workshops and activities, Horizons bridges people and ideas to co-create knowledge across government and other sectors both in Canada and internationally." See http://www.horizons.gc.ca/eng.

[136] Etcetera Final Report, Evaluation of Critical and Emerging Security Technologies for the Elaboration of a Strategic Research Agenda, Joachim Burbiel, Ruth Schietke Fraunhofer Institute for Technological Trend Analysis INT, 27 May 2014

[137] See http://www.hcss.nl/.

the choice of methods is never static. Therefore the process needs to be further tested and developed when used on a regular basis.



Below the different phases are described and a number of methods suitable for use in respective phase are given:

- **Needs definition and Problem formulation**. In this phase the needs, objectives and goals are explored and described. Methods used for planning and managing projects are useful. The formal plan for the project is documented and agreed on with the Swedish Armed Forces to ensure that

the aim and desired effects are the right ones. Other actors dealing with the same type of activities within FOI, the Armed Forces, FMV and potential other organisations should be identified. This step also includes scanning, to gather information from different sources in order to create hypotheses and new knowledge in areas of importance to future security and defence. The work in this step is captured and reported separately.

- **Data collection**. A number of methods and sources should be used. Evidence can be gained using for example bibliometrics, text and data mining using various sources. Broad Delphi surveys, surveys among academia, literature studies and interviews are other alternatives to obtain information. Workshops and morphological analysis can be used for obtaining information from expertise. A combination of quantitative, qualitative and semi-quantitative methods is recommended.
- **Analysis and Synthesis of data** in order to discuss, explore and conclude on possibilities and threats and imagine ways of use of the issues found. The work includes workshops and methods to stimulate thinking such as scenarios, brainstorming and morphological analysis, to improve interaction and creativity. Participants with different expertise and backgrounds (not only technology related) should attend. Criteria can be used to prioritize between issues or combinations of issues. The results presented from this step should show transparency and include examples of implementations of the findings.
- **Assessment**. This phase assesses the issues/technology development in a capabilities context and provides further knowledge to guide decision-makers. Among methods that can be used are war gaming, Delphi surveys, scenario analysis, roadmapping and backcasting.
- **Conclusions and recommendations**. In this phase the results from the previous phases are analysed, conclusions are drawn and recommendations are formulated.
- **Informing and spreading knowledge to stakeholders** is done throughout the process and in the end of the process, i.e. presenting the results in a way that makes them useful for the stakeholders.

In general, a multi-methods approach is proposed in the literature for the process of studying technology development and its implications, but the choice and timely use of methods is depending on the results from the needs analysis, available resources and the agenda for the overall work.

9.3 Considerations related to implementation

As mentioned above we propose that the framework is further developed and if possible in part tested within the FOI scanning activities. The first step is to establish the needs, objectives, limitations and wanted effects from the process. This is a basis for concretizing the process and a start for making choices on methods to use.

Two of the major issues for the work are 1) are we to assume a continuous process or not?; 2) should we focus on horizon scanning or try to combine it with technology watch (what do the Swedish Armed Forces consider to be a desirable result)? These issues should be discussed with the Armed Forces.

Firstly, assuming a continuous process is a requisite for the proposed work of creating a process for Horizon scanning. Secondly, technology watch and horizon scanning are complementary approaches to find science and technology areas and issues which might significantly change the Armed Forces' capabilities, or other forces' or adversaries' capabilities.

As previously discussed, technology watch focuses on already identified technology areas. Advances which might become of importance in defence and security relevant areas are identified and tracked. It is therefore based on current knowledge (today) and makes assumptions/extrapolations of the future with knowledge of the past.

Horizon scanning deals with identifying science and technology areas and issues relevant to the security and defence arena which are currently not being watched or even realized to be important by making broad but shallow 360 degree scans, scanning the horizon, the future, for signals and then relating those observations to the present. The resulting issues are such that they might change the capabilities and strategies for the Armed Forces, red forces and/or the civil society. The focus is thus on identifying and analyzing scientific and technological areas/issues which together or combined may significantly change today's strategies and the way in which we provide defence and security.

Thus, methodologically there is a difference between technology watch and horizon scanning. It should be possible to combine the two perspectives and at least, the two need an exchange of information and knowledge.

A third issue to discuss within FOI and with the Armed Forces is the scope of the work. What is the time perspective? Who are the stakeholders and are there actors with which FOI should collaborate? How 'far' should FOI take the work: where does the Armed Forces take over? There are several questions regarding the scope that needs to be discussed in further work.

In parallel to exploring the needs definition and problem formulation the FOI scanning activities could, if time permits, summarize results from other scanning activities. Also, some of the literature used as reference in this report proposes

possible emerging or disruptive technology areas. The project could summarize this information, including information based on international collaborations within the areas of technology watch and horizon scanning. These activities could be seen as work packages in the exploration phase of the process. The activities need to be structured and planned methodologically to enable analysis and synthesis of the gathered information.

As has been stated earlier in this report the ambition of this work is primarily to describe methodologies that are or could be used to explore future technology development, with a focus on technology development that may be of significant importance for the Swedish Armed Forces. As this paragraph shows increased knowledge of frameworks and methods for studying the future, provides a foundation for more informed questions and further knowledge of "what it takes" to reach different solutions to these questions.

It is therefore proposed that this framework is further developed and tested during the next few years, including propositions on which methods to use and prerequisites for their use. Continued work should also include trying to achieve answers to some of the questions posed concerning scope and needs.

Exploring science and technology development is motivated by the possibility of capturing possibilities and challenges that in the future may face e.g. the security and defence sector. By exploring the future, we can get accustomed to the unexpected, better face the unknown and hopefully avoid poor decisions in areas where technology development could be an influential factor.

10 References

10.1 Books and articles

Alford, K. et. Al, *The Complex Futures of Emerging Technologies: Challenges and Opportunities for Science Foresight and Governance in Australia*. Journal of Futures Studies, 16(4), p. 67-86, June 2012. http://www2.warwick.ac.uk/fac/soc/csgr/green/foresight/scienceinnovation/2012_alford_keeniham_mcgrail_the_complex_futures_of_emerging_technologies.pdf

Amanatidou, E. et al. (2011): On Concepts and Methods in Horizon Scanning: Lessons from Initiating Policy Dialogues on Emerging Issues. Submitted paper for the FTA 2011 conference, Seville.

Ayres, *Technological forecasting and long-range planning*, Chapter 2, Failures of technological forecasting, 1969.

Björn, L., & Lübeck, L.. *Swedish Technology Foresight - a successful project, with many lessons learned*, 2003. The study on technological hindsight (Teknisk baksyn) was performed by Lars Olsson.

Boland, R., *Military Trolls for Disruptive Technologies* July 1, 2014 http://www.afcea.org/content/?q=node/13006. The patent data search was created by the company 1790 Analytics. The Naval Surface Warfare Center Dahlgren Division, in Virginia, developed the second, which focuses on bibliometric data.

Bower, J. L.. & Christensen, C. M., *Disruptive Technologies: Catching the Wave*, *Harvard Business Review*, January–February 1995.

Brandes, F., *The UK technology foresight programme: An assessment of expert estimates*, Technological Forecasting & Social Change 76,p. 869-879, 2009.

Brimley, S., et al., *Game Changers, Disruptive technology and U.S: Defense Strategy*, September 2013.

Burbiel, J., & Schietke, R., *Etcetera (Evaluation of Critical and Emerging Security Technologies for the Elaboration of a Strategic Research Agenda) Final Report*, Fraunhofer Institute, 2014.

Burgman, M. et.al. Expert Status and Performance, PLoS ONE 6(7) 2011.

Carlsen, H., *Climate change and the construction of scenario sets that span the range of societal uncertainties,* Paper for International Studies Annual Convention, 2009. http://citation.allacademic.com/meta/p_mla_apa_research_citation/3/1/3/5/3/pages313532/p313532-1.php

Coates J. C., *Handbook of futures research*, 1978.

Contribution Science and Technology to Future Society -Summary on the 9th Science and Technology Foresight, NISTEP Report No. 145, 2010. http://www.nistep.go.jp/achiev/ftx/eng/rep145e/pdf/rep145e.pdf

Cuhls, K., *Delphi method*, Fraunhofer Institute for Systems and Innovation Research, Germany. http://www.unido.org/fileadmin/import/16959_DelphiMethod.pdf

Cristòfol, R., *Technology Watch and Competitive intelligence for SEM-SEO* [en linea]. "Hipertext.net", num. 6, 2008. http://www.upf.edu/hipertextnet/en/numero-6/vigilancia-tecnologica.html

Dalkey, N. C., *Predicting the Future*, October 1968.

Day, J., *Review of cross-government horizon scanning*, UK Cabinet Office, 2013.

Dreborg, K. H., *Scenarios and structural uncertainty: Explorations in the field of sustainable transport*, 2004.

EDT Impact Assessment Initiative, Dr Alain Auger, DRDC, October 2014

Eerola, A., & Miles, I., *Methods and tools contributing to FTA: A knowledge-based perspective*, Futures 43, p. 265–278, 2011. “Future oriented technology analysis (FTA) is an umbrella term for a broad set of activities that facilitate decision-making and coordinated action, especially in science, technology and innovation policy-making.”

Emerging Technology Concepts and Defence planning in the Nordic Countries (FFI Externnotat 16/00336)

Etcetera Final Report, Evaluation of Critical and Emerging Security Technologies for the Elaboration of a Strategic Research Agenda, Joachim Burbiel, Ruth Schietke Fraunhofer Institute for Technological Trend Analysis INT, 27 May 2014

European Environment Agency, *Looking back on looking forward: a review of evaluative scenario literature,* Technical Report 3, p 6, 2009.

Exploring the impact of technology foresight studies on innovation: Case of BRIC countries, Futures, 44(6): 618–630, August 2012.

”Game Changers – Disruptive Technology and U.S. Defense Strategy”, Center for a New American Security, 2014

Ginsberg, J. et.al. *Detecting influenza epidemics using search engine query data*, Nature 457, 1012-1014, 19 February 2009. http://www.nature.com/nature/journal/v457/n7232/full/nature07634.html

GTS 2015 – Catalogue of technological focus areas, GTS – Advanced Technology Group, 2008 http://en.gts-net.dk/wp-content/uploads/2014/04/GTS-2015-Catalogue-of-technological-focus-areas.pdf

Report: Review of science and technology foresight studies and comparison with GTS 2015, Forsknings- og Innovationsstyrelsen, Birgitte Rasmussen, Per Dannemand Andersen, ISBN: 978-87-923-7277-2, 2009.

Hasik, J., & Callan, B., *Disrupt or Be Disrupted: How Governments Can Develop Decisive Military Technologies*, Atlantic Council Disrupting Defense: Dynamic Security in an Age of New Technologies. May 2014. http://www.atlanticcouncil.org/images/publications/Disrupt_or_Be_Disrupted.pdf

"Identifying Disruptive Technologies Facing the United States in the Next 20 Years", U.S. Army Command and General Staff College, 2009

Jackson, M., *Practical Foresight guide,* 2013. *http://www.shapingtomorrow.com/media-centre/pf-complete.pdf*

Kuosa, T., *Towards Strategic Intelligence - Foresight, Intelligence, and Policy-Making*, 2014.

Könnölä, T. et al. (2011): Facing the Future: Scanning, Synthesizing and Sense-Making in Horizon Scanning. Submitted paper for the FTA 2011 conference, Seville.

Manyika, J., Chui, M., Bughin, J,. Dobbs, R., Bisson, R,. Marrs, A., *Disruptive technologies: Advances that will transform life, business, and the global economy*, McKinsey Global Institute, May 2013.

Martino, J.P., *Handbook of futures research*, 1978.

Miles, I., *The development of technology foresight: A review*, Technological Forecasting & Social Change 77, 2010.

MilTech Report 2012, Norwegian Defence Research Establishment (FFI), FFI-rapport 2013/01139.

Mitchell, B., *Pentagon Has Its Eyes Glued on Chinese Innovation*, 2014. http://inthecapital.streetwise.co/2014/01/10/pentagon-has-its-eye-glued-on-chinese-innovation/

"Persistent Forecasting of Disruptive Technologies – Report 1", US National Research Council, 2009

"Persistent Forecasting of Disruptive Technologies – Report 2", US National Research Council, 2010, ISBN 978-0-309-14904-4, 2010.

Sarder, Z., *The Namesake: Futures; future studies; futurology; futuristic; foresight – What's in the name*? Futures 42, p. 177-184, 2010.

Philip Tetlock *Expert Political Judgment: How Good Is It? How Can We Know?* 2006

Philip E. Tetlock, Barbara A. Mellers, Nick Rohrbaugh, Eva Chen, Tools for Increasing Transparency and Improving the Quality of Debate. Current Directions in Psychological Science August 2014 vol. 23 no. 4 290-295

Ziauddin, S., *The Namesake: Futures; future studies; futurology; futuristic; foresight – What's in the name?*, Futures 42, p. 177-184, 2010.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/79252/Horizon_Scanning_Review_20121003.pdf

10.2 FOI reports

Alvå, P., Dahlén, L., Lundgren, L., *Metodik för konsekvensanalys av teknisk prognos*, FOI-R--1853--SE, december 2005.

Asp, B., Carling, C., Hunstad, A., Johansson, B., Johansson, P., Nilsson, J., Waern, Å., COmmunications AssessmenT. COAT is described in, *COAT användarguide*, FOI-R--240--SE, 2007.

Bosaeus, L., *Analytical Hierarchy Process as a tool for long-term requirements management*, FOI-R--3233--SE, 2011.

Eriksson, A. E., *Metoder för strukturerad brainstorming*. FOI-R--066--SE, 2002.

Franke, U., Johansson, F., Mårtenson, C., *Datadriven underrättelseanalys*, FOI-R--3680--SE, 2013 and Franke, U., Johansson, F., Jändel, M., Kaati, L., Garcia Lozano, M., *Tekniker för analys av data från webben*, FOI-R--3532--SE, 2012.

Isacson, T., *Spel för värdering av Försvarsmaktsstrukturer*, FOI-R--1195--SE, 2004.

Kindvall, G., *Värdering av disruptiv teknik – Erfarenheter från två NATO-studier*, FOI-R--3655--SE, 2013.

Nordstrand, E., *Spel som metod för att analysera problem - Handbok för spel i seminarieform*, FOI-D--0351--SE, 2009.

RAHS (2004): Risk Assessment and Horizon Scanning programme of Singapore. Online in: Internet. URL: http://app.hsc.gov.sg/public/www/home.aspx. Last visit 15.7.2011.

Stenström, M., *Morfologisk analys i grupp: En personlig handledning*. FOI-R--3215--SE, 2011.

Stenström, M., Bra morfdimensioner – några tankar till dig på FOI som arbetar med morfologisk analys, FOI-D--0647--SE, 2015

Söderström, J., Asp., Näsström, F., Rindstål, P., *Taktisk värdering av sensorsystem – en metodförstudie,* FOI-R--2654--SE, 2008.

Wikström, P., Isacson, T. och Lindström, H., "Tekniska-Strategiska Studier, TSS, Pilotprojekt HPM, Metod/erfarenhetsrapport", FOA rapport C 10351-1.1, 1993.

Wiss, Å., Ödlund, A., *Öppna intervjuer - Att intervjua med en kvalitativ ansats*, FOA-R--99-01014-170, 1999.

Wulff, P., *FOI Viewing the future*, FOI-D--0374--SE, 2010.

10.3 Teknisk Prognos

Teknisk Prognos 2011, 11FMV2150-18, 2011-12-01

Teknisk Prognos 2012, 12FMV1949-15, 2012-12-11

Teknisk Prognos 2013, 13FMV4481-18, November 2013

Teknisk Prognos 2014, 14FMV2487-19, 2014-12-08

Teknisk Prognos 2015, 15FMV8156-15, November 2015

10.4 NATO reports

Assessment of Possible Disruptive Technologies for Defence and Security, AC/323(SAS-062)TP/258, NATO RTO, February 2010.

Disruptive Technology Assessment Game – Evolution and Validation, AC/323(SAS-082)TP/427, NATO RTO, April 2012.

Compendium on Technology Trends and Challenges 2012, NATO AC/323-D(2012)0009.

10.5 Web sites

http://www.acq.osd.mil/ttcp/

http://www.acq.osd.mil/chieftechnologist/publications/docs/FY14_ASDRE_ST-Testimony.pdf

http://www.businessdictionary.com/definition/emerging-technologies.html

http://www.cross-impact.de/english/CIB_e.htm

http://www.dictionnaire.enap.ca/dictionnaire/docs/definitions/definitions_anglais/horizon_scanning.pdf

https://ec.europa.eu/jrc/en/research/crosscutting-activities/foresight

http://www.economist.com/news/21589145-how-sort-best-rest-whos-good-forecasts

http://www.eda.europa.eu/procurement-gateway/opportunites/eda-procurement/procurement-view/14.cat.op.076-technology-watch-pilot-study

http://en.wikipedia.org/wiki/Active_Denial_System

http://www.foresight-platform.eu/community/forlearn/what-is-foresight/, http://www2.warwick.ac.uk/fac/soc/csgr/green/foresight/scienceinnovation/2009_forsknings-_og_innovationsstyrelsen_review_of_science_and_technology_foresight_studies_and_comparison_with_gts2015.pdf

http://freakonomics.com/2011/03/29/calling-all-predictors-to-a-new-forecasting-tournament/

http://www.google.org/flutrends/

https://www.gov.uk/government/publications/futures-toolkit-for-policy-makers-and-analysts

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/328069/Futures_Toolkit_beta.pdf,

http://www.hcss.nl/

http://www.horizons.gc.ca/eng.

http://www.iarpa.gov/index.php/research-programs/ace

http://www.iarpa.gov/index.php/research-programs/fuse

http://www.innovation-portal.info/toolkits/technological-forecasting/

http://ip-science.thomsonreuters.com/m/pdfs/fed-res/20130319-fuse-tr.pdf, 2013.

http://www.millennium-project.org/millennium/FRM-V3.html

http//:www.nap.edu/catalog/12557.html

http://www.opti.org/en/vigilancia_tec.asp

http://www.smhi.se/kunskapsbanken/meteorologi/kan-man-lita-pa-vaderprognoser-1.4653

https://www.tno.nl/en/

www.unog.ch

http://www.urenio.org/futurreg/toolkit.html

http://www.washingtonpost.com/blogs/monkey-cage/wp/2013/11/26/good-judgment-in-forecasting-international-affairs-and-an-invitation-for-season-3/

http://www.tecnologiaeinnovacion.defensa.gob.es/en-us/Presentacion/OrganismosInternacionales/Pages/EDIR.aspx

Annex A – Lists of tools

Some tools and methods highlighted in Futures Research Methodology Version 3.0[138] are

- Environmental Scanning
- Text Mining
- Delphi
- The Futures Wheel
- The Futures Polygon
- Cross-Impact Analysis
- Wild cards
- Structural Analysis
- The Systems Perspectives
- Decision Modeling
- Substitution Analysis
- Statistical Modeling
- Technology Sequence Analysis
- Morphological Analysis
- Relevance Trees
- Scenarios
- Robust decision-making
- Participatory Methods
- Simulation and Games
- Genius Forecasting, Intuition, and Vision
- Prediction Markets
- Normative Forecasting
- S&T Road Mapping
- Field Anomaly Relaxation (FAR)
- Agent Modeling
- Chaos and Non-Linear Dynamics
- Multiple Perspective Concept
- Heuristics Modeling
- Causal Layered Analysis
- Personal futures
- State of the future index

[138] http://www.millennium-project.org/millennium/FRM-V3.html.

In chapter 3 of the *Practical Foresight Guide* by Michael Jackson the following methods are listed[139]

- Backcasting
- Brainstorming
- Causal Layered Analysis
- Chaos theory
- Cross-impact analysis
- Decision modeling
- Delphi method
- Environmental scanning
- Expert panel
- Forecasting
- Futures Wheel
- Heuristics
- Modeling, simulation, gaming
- Morphological analysis
- Participatory methods
- Personal future
- Prediction market
- Relevance trees
- Road-mapping
- Scenarios
- Technology sequence analysis
- Text mining
- Trend impact analysis
- TRIZ
- Visioning
- Wild Cards

[139] http://www.shapingtomorrow.com/media-centre/pf-ch03.pdf.

Annex B – Examples of frameworks

US National Research Council

The US National Research Council (NRC) produced two reports on forecasting of disruptive technologies a few years ago.[140] These reports were sponsored by the US Defense Intelligence Agency's Defense Warning Office and the Director of Defense Research & Engineering. The first report "describes disruptive technology, analyzes existing forecasting strategies, and discusses the generation of technology forecasts, specifically the design and characteristics of a long-term forecasting platform", whereas the second report discusses the feasibility of "a hybrid forecasting method tailored to the needs of the sponsors" and which features it should have. Although commissioned by the military, the report and its recommendations are for a more general technology forecasting system and do not delve into the specific needs of a military system. The first report concludes with outlining the steps to building a forecasting system, and the conclusion of the second report contains six important functions of a technology forecasting system: (1) needs definition, (2) collecting and developing alternative futures, (3) roadmapping, (4) engagement, (5) tracking, and (6) feedback.

During a workshop four different designs for a forecasting system were described.[141] These were labeled:

1. Intelligence Cycle Option
2. Roadmapping Option
3. Crowdsourced Option
4. Storytelling Option

The characteristics of these are:

Intelligence Cycle Option

Uses an approach similar to the classic approach used by the intelligence community: hypothesize, task, collect, and analyze. This system design has four functions:

[140] The two reports were:
- "Persistent Forecasting of Disruptive Technologies – Report 1", US National Research Council, 2009
- "Persistent Forecasting of Disruptive Technologies – Report 2", US National Research Council, 2010

[141] "Persistent Forecasting of Disruptive Technologies – Report 2", US National Research Council, 2010

1. The input of a “high-level question” framed by the stakeholder ,
2. Signal identification and hypothesis generation fed by passive data collection and active data-gathering,
3. Hypothesis evaluation and testing (by experts or e.g. by games), and
4. The authoring of potential future narratives of possible events, which are presented to stakeholders.

Roadmapping Option

This system design focuses on developing roadmaps of predicted events proceeding from the present to predicted future scenarios. The roadmaps are based on collected data, including observations of communities of interest. Signposts that can be monitored as the roadmap progresses are generated. Major elements are:

1. Idea generation;
2. Techniques for mapping, processing, and evaluating inputs, and
3. Communication to decision makers.

Ideas collected from different communities plus other traditional data-gathering techniques are employed to develop future scenarios to be explored.

Crowdsourced Option

This system design is organized with a focus on creating clear, actionable outputs in the form of reports. Its name reflects its use of open participation from the “crowd” (either the general public or targeted populations) to gather forecasting inputs. These inputs are analyzed in multiple ways, employing a combination of crowdsourcing techniques and expert analysis. The final analysis is done by an expert forecasting committee or their delegates.

Storytelling Option

One final option was inspired by comments that forecasts should be contextualized by forming associated narratives of possible future events. The system is derived from a functional organization chart released by Walt Disney Studios in 1943 and is based on the storyboard process – bringing a story idea through production to the screen. The model focuses on the development of narratives from broad themes or “big questions”. Using this question as a central theme, a small set of potential scenarios is created that identify possible contexts for exploration. Data relevant to those potential scenarios are then collected using both human and machine based methods. Next, the data undergo critical analysis by teams of scientific, technical, political and economic experts who identify trends and form viable hypotheses, all of which are reported back to a story director. These hypotheses are applied to the initial scenarios to create output in the form of complete narratives that can be used in reports, demonstrations, and entertainment media.

Recommendations

After the analysis of these different system designs a number of key recommendations are listed[142]:

- The 1.0 version of a forecasting system should employ the extensive passive and active data-gathering techniques employed in the Intelligence Cycle Option, using the data to develop roadmaps of potential futures with signals and signposts derived from data inputs (as seen in the Roadmapping Option). The end product of the system should include constant output and objective-driven output as described in the Crowdsourced Option.
- A persistent disruptive forecasting system should be built to help the intelligence community reduce the risk of being blindsided by disruptive technologies.
- The 1.0 version of a forecasting system should begin developing a forecast of future events or conditions by constructing structured narratives describing disruptive impacts within a specific contextual framework related to particular technology use. It should then use backcasting to roadmap potentially disruptive technologies and the triggers that enable these technologies, and then iterate the mileposts for the narrative.
- The responsible organization should develop a repository of narratives of potential futures, organized both globally and by region, that include potential economic, technological, and societal impacts.
- Any forecasting system developed should be insulated to allow users to generate and investigate controversial or uncomfortable ideas. Participants and staff should identify the reasons that an idea is considered implausible and be able to understand what developments will be needed to arrive at that future. These developments should become signposts on the roadmap of the forecast.
- A forecasting system should have two separate teams, one team working on the open external forecasting platform and another team developing an internal forecasting platform that services specific needs of an organization. The external team should encourage broad and open participation and exchange of ideas and scenarios from a broad range of participants and experts. The internal forecasting platform should address scenarios that are specific to the organization and may involve sensitive, proprietary, or

[142] "Persistent Forecasting of Disruptive Technologies – Report 2", US National Research Council, 2010

classified scenarios and data that it is only willing to share with trusted parties.

Policy Horizons Canada

The list below shows the main elements in the process used by Policy Horizons Canada. [143] Recently they have e.g. published a study on the future of Asia and what implication that may have on Canada. In 2014 they published the study Metascan 3 on emerging technologies.[144]

- Assumptions
  - Interviews and reading to frame and understand the problem
  - Track core assumptions to test

- Scanning
  - Identify insights/weak signals that change is occurring
  - Assess relevant trends
  - Elaboration of commonly-held assumptions

- System mapping
  - Identify key elements in the system
  - Describe key relationships

- Change drivers
  - Describe change drivers shaping the system
  - Influence maps of second and third order consequences
  - Preliminary examination of the interaction of drivers

- Scenarios
  - Scenarios to explore range of futures
  - Identify potential challenges and discontinuities

[143] Policy Horizons Canada describes themselves in these words: "Policy Horizons Canada, also referred to as Horizons, is an organization within the federal public service that conducts strategic foresight on cross-cutting issues that informs public servants today about the possible public policy implications over the next 10-15 years. Horizons is committed to building the scanning and strategic foresight capacity across the federal government in order to help meet the future needs of departments and agencies. Through collaborative events, workshops and activities, Horizons bridges people and ideas to co-create knowledge across government and other sectors both in Canada and internationally." See http://www.horizons.gc.ca/eng.

[144] MetaScan 3, Emerging technologies: A foresight study exploring how emerging technologies will shape the economy and society and the challenges and opportunities they will create, 2014. This 2013 foresight study on emerging technologies is a collaborative effort that builds upon the 2012 report: MetaScan 2: Building Resilience in the Transition to a Digital Economy and a Networked Society. See http://www.horizons.gc.ca.

    - Testing for robust assumptions and strategies

- Products
    - Credible assumptions and key uncertainties
    - Policy challenges
    - Emerging issues
    - Data needs

ETCETERA (Evaluation of critical and emerging technologies for the elaboration of a security research agenda)

ETCETERA was a European Union 7th Framework Programme project that delivered its final report in May 2014[145]. The list of emerging technologies that the project described was based on the experience of technology foresight and technology experts. Three scanning methods were employed in parallel:

- Austrian Institute of Technology used a method based on bibliometrics for the survey,
- The Fraunhofer Institute for Technological Trend Analysis exploited its broad technological knowhow gained from activities like the Overall Technology Forecast and the Defence Technology Forecast, and
- A state-owned company in Spain, Isdefe, applied its proprietary technique based on an in-house core team of technology experts supported by external researchers.

The methods to identify relevant technologies were compared and assessed to improve future strategic research planning.

The 2nd Consultation Campaign was characterised by the parallel execution of three methods of expert involvement:

- Workshop methodology based on the Weighted Bit Assessment Method (WBAM),
- Adapted Disruptive Technology Assessment Game (DTAG), and
- Scenario process.

These very different methods to assess future developments were applied in a parallel way to enable methodological comparison. The parallel execution of these methods

[145] Etcetera Final Report, Evaluation of Critical and Emerging Security Technologies for the Elaboration of a Strategic Research Agenda, Joachim Burbiel, Ruth Schietke Fraunhofer Institute for Technological Trend Analysis INT, 27 May 2014

had another advantage: The WBAM and the DTAG/SETAG[146] (a serious gaming approach) were highly innovative and had never been tried before in the context of assessing technologies for civil security. As the risk of failure was thus inherent to both, they were combined with the well-established scenario method to ensure that, even in the worst case, input of sufficient quality could be produced for the further proceeding of the ETCETERA project.

Meta-Foresight

Meta-Foresight is a technique that is marketed by The Hague Centre for Strategic Studies (HCSS) and which aims at identifying emerging strategic issues. Meta-Foresight defines different futures by creating a list of potential developments that are related to the interests of the clients. It investigates best practices, develops new ideas, needs or demands and improves understanding of the future by linking foresight and actual planning.[147]

The HCSS model has six steps:

- Conceptualize. Defining the parameters of the analysis.
- Collect. A broad set of authoritative foresight exercises on the topic are collected with the help of specialist software.
- Code. All relevant pieces of information in every study are coded, in search of key parameters and drivers for future change that are seen to be prevalent. This is done in an automated way through advanced text mining tools, and partially manually through the use of qualitative data analysis software.
- Cogitate. Once all data is collected and verified, the HCSS team discusses the information in a number of in-house sessions (cogitate).
- Commit to paper. The fruits of the previous steps (conceptualization, coding, cogitation) are then committed to paper, if possible in visually intuitive ways. Narratives are also created and large sets of representative scenarios that can be used for strategic planning purposes are constructed.
- Communicate. Finally the findings are communicated by integrating them within the client's decision-making context and providing concrete recommendations.

[146] SETAG - The Security Emerging Technology Assessment Game
[147] See http://www.hcss.nl/.

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