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Emerging Technology Concepts and Defence Planning in The Nordic Countries

Authors

Harald Andås, Bjarne Damsgaard, Göran Kindvall, Elisabeth Rönnberg, Svein Otto Solheim, Marko Suojanen

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Approved by

Sigurd Glærum, Research Manager; Espen Skjelland, Director

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Summary

This report communicates results from on-going studies of technology trends and their potential consequences for capability-based defence planning in the Nordic countries. The work is built on the analysis of the NordTech Games, a part of the technology forecasting activity under the Working Group R&T of the NORDFCO Cooperation Area CAPA.

The report briefly outlines what the NordTech game is, how it is played and how the results were analysed. The NORDEFCO team (authors of this report) subsequently selected 11 system sketches, Idea of Systems (IoS) cards, which in the analysis were found to have the highest overall impact when played during the series of NordTech games. These systems have been assessed with regard to what impact they could have on capability-based defence planning in the Nordic countries. A DOTMPLFI-perspective has been included in order to indicate the impact on military operations and organisations.

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1 Introduction

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The NordTech Games have been a series of three scenario-based technology assessment games, intended to provide the basis for analysis of the impact of modern technology trends on military operational concepts. This activity was carried out as part of the technology forecasting co-operation within NORDEFCO with participants from Denmark, Finland, Norway and Sweden. The cooperation was initiated by NORDEFCO under the former COPA SD in 2010. After the reorganisation of 2013, the responsibility was transferred to COPA CAPA. The activity involves participants form Denmark (DALO), Finland (FDRA), Norway (FFI) and Sweden (FMV and FOI). The work is published formally as an annex to this FFI Eksternnotat since there is no current mechanism for publishing technical reports in the NORDEFCO context.

A more detailed account, including experiences, results and analyses from the three games, will appear in the final report from the work in the NORDEFCO technology forecasting cooperation during 2012-2014.

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Appendix – The NORDEFCO Report

Emerging Technology Concepts and Defence Planning in The Nordic Countries

Harald Andås[1], Bjarne Damsgaard[2], Göran Kindvall[3], Elisabeth Rönnberg[4], Svein Otto Solheim[5] and Marko Suojanen[6]

February 2015

Authors' affiliations

1) FFI – *Norwegian Defence Research Establishment*

2) DALO – *Danish Defence Logistics Organisation*

3) FOI – *Swedish Defence Research Agency*

4) FMV – *Swedish Defence Materiel Administration*

5) FFI – *Norwegian Defence Research Establishment*

6) FDRA – *Finnish Defence Research Agency*

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Executive Summary

This report communicates some of the results from on-going studies of technology trends and their potential consequences for capability-based defence planning in the Nordic countries. The work is built on the analysis of the NordTech Games, a part of the technology forecasting activity under the Working Group R&T of the NORDFCO Cooperation Area CAPA.

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It should be emphasised that the range of this study is limited, since there was no room for a more comprehensive approach within the scope of this effort. The results of the assessment of the 11 IoS are summarised below.

<u>Support / Logistics UGV</u> could potentially reduce personnel costs and related expenses. The system could also allow for executing operations with higher risk than one would ordinarily do with manned systems.

<u>High-Energy Laser on Ships</u> has a different cost profile than other weapons. The main cost is in the acquisition of the system, while the cost per shot is negligible. The system has very short response times and allows for multi-targeting due to the continuously available beam. Limitations such as ethical and legal issues need to be explored further. The US Navy has recently announced a laser system (reduced power) to be operational.

Multi-Purpose UAV Swarm could contribute to both enhancing and disrupting C3 and situational awareness/ISTAR. The swarming technology is presently immature, but is expected to become gradually more sophisticated over the years to come.

Situational Awareness Sensor System will improve tactical situational awareness and increase the efficiency of patrols and guards. The system relies on development of intelligent data compression and fusion and progress in battery and/or energy harvesting technologies.

Global Information Satellite Constellation in polar orbits would provide good situational awareness in the territory of the Nordic countries and surrounding areas of interest. Development of microsatellites is on-going in Denmark, Norway and Sweden.

The Multi-Purpose RF System for Tactical UAV/UGV/USV provided highest impact on operations when it was supplementing other assets. This system will expand platform/sensor coverage of the area of operations, significantly enhancing ISTAR capability and improving situational awareness. It was also used successfully for stand-in jamming.

New generations of Unmanned Surface Vehicle will be increasingly autonomous and suitable for a wider range of missions than the current Mine Countermeasure (MCM) mission.

Bionic Autonomous Underwater Vehicle can provide protection in several areas (MCM, harbour protection and force protection) and contribute to subsea ISTAR (Remote Environmental Assessment, coastal surveillance, intelligence and mapping).

Subsea Network-Centric Warfare opens the possibility to include underwater vehicles to be part of real time joint operations.

It is expected that Unmanned Combat Aerial Vehicle technology will have significant potential to reduce costs for education and training since there will be fewer pilots. Furthermore it reduces the risk for loss of personnel and allows for solving difficult and dangerous high-risk missions.

The Stratospheric Surveillance Platform could provide persistent surveillance of large areas. It can be utilized as a node for both military and civilian communication needs.

Contents

1 Introduction

The intent of this report is to communicate the results of on-going studies of technology trends and their potential consequences for capability-based defence planning in the Nordic countries. This work is built on the analysis of the NordTech Games, a part of the technology forecasting activity under the Working Group R&T of the NORDFCO Cooperation Area CAPA; cf. also Chapter 2.

The NordTech Games have been a series of three scenario-based technology assessment games, intended to provide the basis for analysis of the impact of modern technology trends on military operational concepts. The games are scenario-based, with two groups of military players preparing concepts of operations for given scenarios. To help them in their endeavour, they are introduced to new technology in the form of playing cards, i.e. sketches of new or improved military systems conveying technology input based on emerging trends. For more details on the NordTech Games and the associated methodology, see Chapter 3.

In Chapter 0, we describe some features of the sketched systems (Ideas of Systems) which were found to have the highest overall impact in the games, as well as their underpinning technology, and briefly consider the potential impact on defence capabilities and military planning. The different systems' potential for improving current capabilities, as well as the potential for bettering cost efficiency, is addressed. Also, it is observed that some systems have the potential to constitute completely new capacities, some which could replace existing ones. Moreover, it is attempted to include a DOTMPLFI-perspective in order to indicate the impact on present defence concepts.

It should be emphasised that the range of this study is limited, i.e. the discussed topics receive a somewhat cursory treatment. There is no room for a more comprehensive approach within the scope of this effort; hence the ambition is merely to provide some food for thought.

The study does, e.g., not comprise all aspects of emerging technologies, but is rather a direct result of the focus of the NordTech Games series and covers the technologies and systems that were made available in this context. The impact of systems and technologies does also to a large extent depend on the specific scenarios chosen for the games, and the results should be considered with this in mind. The maturity of the considered systems varies, but they are generally believed to be available in the time frame 2015-2030. Whenever possible, investment costs have been discussed in a cursory manner, but these considerations are quite tentative, especially for systems expected to be realised towards the end of the period.

2 NORDEFCO

The NORDEFCO Nordic Defence Cooperation was established at a ministerial meeting by the end of 2009, where it was decided to merge three parallel cooperation (NORDSUP, NORDAC, and NORDCAPS) structures into one. A Memorandum of Understanding (MoU) between the all five Nordic nations on the establishing of NORDEFCO was signed on 4th November.

The main aim and purpose of the cooperation is to strengthen the participating nations´ national defences, explore common synergies and facilitate efficient common solutions. As of 1st January 2015, Sweden is the chair nation.

An organisational restructuring of NORDEFCO took place in 2013. There are at present five Cooperation Areas (COPAs):

- Capabilities (COPA CAPA)
- Human Resources & Education (COPA HR&E)
- Training & Exercises (COPA TR&EX)
- Operations (COPA OPS)
- Armaments (COPA ARMA)

A Working Group Research and Technology (WG R&T) is currently organized under the COPA CAPA to support their study activities but also help to coordinate R&T between the Nordic countries. The chairmanship in the Working Group R&T rotates between Denmark, Finland, Norway, and Sweden.

The Nordic Technology Forecasting Cooperation is an activity in support of the WG R&T with participants from Denmark, Finland, Norway and Sweden. Its first meeting was held in Finland 5th November 2010. The perspective for the technology forecasting activity is long-term. The goal is to share/exchange information about technologies, learn from each country's methods and deliver technology forecasts of interest to the NORDEFCO Armed Forces[1].

As a base for capability development, technology forecasting has been seen as an important way to identify sectors where further R&T is needed. Since technology development is global, it was argued that a combined effort to study the future technology trends should be cost efficient. This was the main reason for the formation of this separate working group within sub-area R&T. The further implementation of any findings can then vary between the Nordic countries and hence the handover should be done without restrictions on how to use the

[1] For more information about NORDEFCO, see http://www.nordefco.org.

result. The results should be seen as a base for planning further research and technology projects, on a national basis or involving Nordic cooperation.

3 The NordTech Games

This chapter gives an overview of the NordTech Games, an activity carried out as part of the technology forecasting co-operation within NORDEFCO with participants from Denmark, Finland, Norway and Sweden. Three games were played – in Riihimäki in Finland 22-26 October 2012, in Copenhagen in Denmark 28 October-1 November 2013 and in Kjeller in Norway 27-31 October 2014. A more detailed account, including experiences, results and analysis from the three games, will appear in the final report from the work in the NORDEFCO technology forecasting cooperation during 2012-2014[2]. This report will also present possible ways forward for the cooperation.

The games were based on the DTAG (Disruptive Technology Assessment Game) methodology developed in two NATO studies performed within the framework of the NATO STO System Analysis and Studies (SAS) Panel, SAS-062 and SAS-082[3]. Sweden and Norway participated in these two studies, in various roles – technologists, analysts and players. This means that familiarity with the methodology existed in the two nations prior to the NordTech co-operation context. Moreover, the main participants from Sweden and Norway in the SAS-082 task group have also been participating in the NordTech activities.

The three NordTech Games focused on, respectively, unmanned systems, maritime surveillance and air- and space-based systems, while the two NATO activities studied a wider area of possible systems on the future battlefield.

The objectives of the NordTech Games were to:

- Assess the disruptive potential of systems (illustrated by IoS cards[4]) systematically
- Gain understanding of the operational characteristics of the systems

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[2] FMV Report, to be published March 2016.
[3] For more information on the NATO studies see the respective 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.

A thorough presentation and discussion (written in Swedish) of the methodology can also be found in:
Kindvall, G., *Värdering av disruptiv teknik: Erfarenheter från två NATO-studier*, FOI-R--3655--SE, December 2013.
[4] Idea 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.

- Identify ideas for new IoS that might be disruptive in a scenario/vignette

The potential new IoS thus identified could then be analysed in subsequent games.

3.1 Playing the games

The games start with a presentation of the objective, the analytic framework and the IoS that are to be used, to make the players familiar with the material. After that the first vignette is presented and the play begins.

The DTAG type game has the following characteristics, cf. also Figure 1.1 below:

- It is a two-sided game with a Blue and a Red side who develop their plans in separate rooms
- A number of vignettes are played at a pace of approximately one vignette a day. During a normal week (three days of gaming) three vignettes are played.
- For each vignette the game is carried out in two steps, one without and one with a number of innovative IoS.

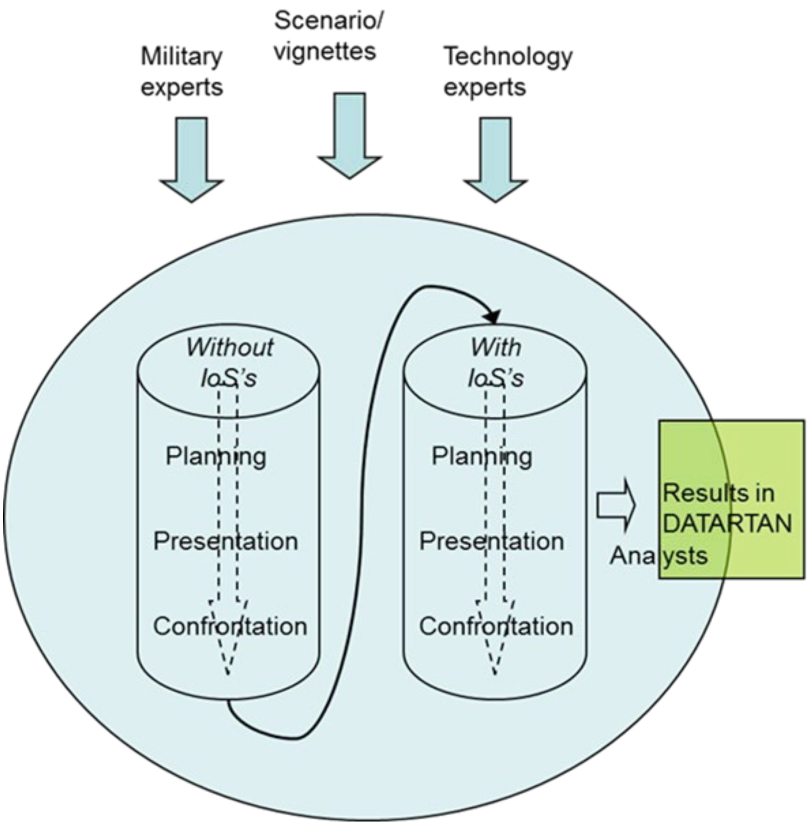

Figure 1.1 Features of the NordTech Game.

- 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.
- After the first confrontation the Blue and Red sides are allowed to use the forward looking IoS that are to be assessed in the game. The two sides are tasked to analyse which of the IoS they want to use (and why) and then how these IoS influence their planning and their way of reaching the objectives for the mission at hand.
- 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 (DaTARTAN[5]) but also in a more free form through notes mainly by the analysts (but also by the rest of the participants).

3.2 IoS Cards

A number of different systems are made available to the players in the form of Ideas of Systems cards, IoS. Some of these had already been used within the NATO studies SAS-062 and SAS-082, while others were developed specifically for the context of the NordTech Games. The new IoS were made to suit the focus for the games, i.e., respectively; unmanned systems, maritime surveillance and air- and space-based systems.

All of the IoS are described in the same format, and including (amongst others) the following main topics:

- A short first page summary, including a picture of how it could look
- Description and operational interest
- Critical performances of the IoS
- Underpinning technologies

All information about an IoS is collected on three PowerPoint slides to make it easy to use during the game.

[5] During the SAS-062 and SAS-082 studies a data collection tool named TARTAN was used. This tool was not available during the NordTech games, and thus a similar tool was developed especially for the NordTech work. Since the Danish representative in the core group did this development the name DaTARTAN (Danish TARTAN) was used during the game.

3.3 Analysis

Data collection is essential for a successful game, since the analysis relies totally on the successful capture of data. It is important to know why something is assumed (why is e.g. the effect on doctrine medium instead of low or high). This was also the reason why the computer tool DaTARTAN was developed, to ensure that sufficient information was provided in similar form by both Blue and Red and in a consistent way through the game and the different vignettes. To further achieve this there were analysts present in both groups (Blue and Red) to ensure that the necessary data was reported and that there were no misunderstandings while doing that. The analysts also noted down important things that were hard to capture within the computer tool. Among data collected were:

- Description and operational interest
- Why and in which combat functions the IoS was used
- The impact of the IoS on DOTMPLFI and why that impact was achieved
- Whether the IoS did change CONOPS/TTP (and to what extent)
- Whether there were limitations, which these were and if there were suggested improvements to meet these limitations
- Whether there were countermeasures used against the IoS and, if so, which these were
- Whether a combination of IoS changed CONOPS and which combinations that had such effect

The overall impact of each system is then judged on the basis of frequency of use, the influence on DOTMPLF and to the extent it changes CONOPS/TTP.

4 Potential Impact on Defence Planning of Selected Technology Concepts

4.1 Introduction to technology systems descriptions

In the following, we present some of the systems (described by IoS cards) based on future technologies which analysis shows had the highest impact on operational planning during the NordTech Games. Additionally, an attempt is made to link these systems to military capabilities, a process that is challenging in many ways. Several, if not most, current capabilities are defined with existing technologies, systems and operational concepts in mind. Hence, it is not to be expected that future technologies can be mapped to present-day capabilities in a direct, linear way. Military capabilities are also redefined at irregular intervals, so such a mapping will also be expected to change over time. Furthermore, capability definitions will depend on who is defining them, so they will be different for each of the Nordic countries. Here, the ambition is merely to indicate a correspondence between the presented system technology and the current capability list for each nation.

In the tables of capability categories below, we have used the following versions of the capability catalogues for Finland, Norway and Sweden respectively: Finland — JCA 2010 Refinement, approved 8. April 2011; Norway — FFI Kapabilitetskatalog 29.10.2012; Sweden — Försvarsmakten - Uppgifter och insatsförmågor[6], 2013-02-28. Due to the high number of levels in the JCA, sublevel 3 is chosen as representative for the Finnish capabilities, since this level is assessed to be at a comparable level of detail.

The analysis results will also be used to evaluate the consequences of each of the systems described in a DOTMPLFI-perspective. Due to the limited resources that were dedicated to this task during the games, this assessment cannot be comprehensive, but is merely intended to raise some salient points.

4.2 Support / Logistics Unmanned Ground Vehicle

Over the last decade, there has been a rapid development of small, unmanned platforms, not least in the field of unmanned ground vehicles (UGV), which have been introduced into most countries' military forces at an accelerating rate (the US Army already disposes over 12,000 ground robots). A common feature of these systems is that they are complementing larger, manned platforms rather than replacing them. Disposal of suspicious objects (EOD) is still the main task, but over the last few years it has become increasingly common to employ UGVs in support of military operations. This expansion has been prompted by the operations in Iraq and Afghanistan, where unmanned vehicles have been used for general surveillance and intelligence by examining the streets, houses and caves in addition to searching for home-made bombs (IEDs).

The current trend towards increased level of automation and collaboration is expected to result in increased efficiency of unmanned platforms, e.g. by making it possible for a single operator to control multiple UGVs. There is also a development towards using unmanned vehicles as part of the solution to secure communications in military operations. This is for example the case for DARPA's LANdroids programme, which is studying the possibility of small inexpensive UGVs to self-configure a robust local communications network.

[6] A review of the capabilities is being done as part of the work on a new "Traceability model", which links tasks, missions and capabilities for the Swedish Armed Forces. The capability list from February 2013 is in principle abolished, but since no new comprehensive list is currently available, we have decided to use the list from February 2013.

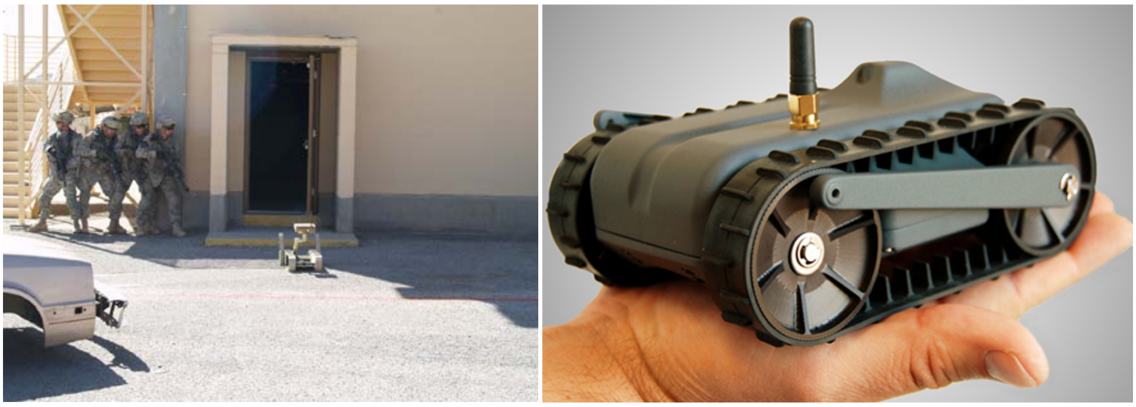

*Figure 1.2 Left: Support UGV (Packbot) assisting soldiers in operations.
Right: LANdroids (photos: iRobot Corporation).*

There is also substantial on-going work on systems to relieve the foot soldier's burden while carrying equipment and supplies in order to improve the mobility and endurance of dismounted (non-mechanised) military units, also in rough terrain. *BigDog* from Boston Dynamics is one of the best known projects within this field. The system has been under development since 2005, and the ambition for the system was to be able to cover a distance of 32 km in 24 hours with a load of 180 kg by 2014. The Marine Corps Warfighting Lab (MCWL) successfully tested two of these systems in a realistic exercise which took place as part of the Rim of the Pacific (RIMPAC) that year.

Figure 1.3 BigDog is an example of a UGV under development that can carry equipment and supplies for dismounted soldiers in rough terrain. It is at the foundation of DARPA's prototype Legged Squad Support System, LS3 (photo: Boston Dynamics).

The complex operational environment is still expected to make the UGV less widespread with respect to military use than for example UAVs. Earlier US goals, based on the FCS (Future Combat Systems) programme of the US Army, stated that 1/3 of all vehicles in the battlefield should be unmanned by 2015. The level of ambition in the US has since been reduced, and all the large UGV programmes have now been postponed or cancelled. This is mainly due to escalating costs and the unexpected technological complexity within the field of (semi-) autonomous UGVs.

Nevertheless, even if the progress in UGV-technology so far has not lived up to its fullest military potential, one should keep an eye on any development that can contribute to reduced risk and lower costs. In many ways the technology for smaller UGVs is mature, with several products available in the market. For larger vehicles, the development has not yet progressed that far, but the evolution in the civilian sector of this area of technology is currently of particular interest, since innovation from the civilian sector in many cases can be directly transferred to military use.

This applies especially within logistics and engineering, as exemplified by the semi-automated ("leader-follower") logistical column, shown in Figure 1.4, where the front vehicle is manned with a driver while a number of unmanned (robotic) vehicles follow. Moreover, UGVs could be operated remotely in critical areas, which they access autonomously or through a robotic delivery vehicle (e.g. UAV), while using other platforms (e.g. the delivery vehicle) as a relay between the UGVs and the human operator. UGV technology thus significantly complements manned systems in these essential areas.

Figure 1.4 Left: Three trucks with one lead driver conducting a test in 80 km/h (photo: NEDO). Right: Remotely controlled shovel and dumper at Hjerkinn firing range (photo: Geir Olav Slåen).

The Unmanned support/logistics Ground Vehicle is a technology that has the potential to contribute to several capabilities, cf. Table 1.1.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Support/Logistics UGV	*Movement – 401* *Landmine clearance* *Movement – 403 EOD* *Movement – 407* *Transport to and from AOO* *Movement – 408* *Transport within AOO* *Movement – 409* *IED neutralisation and clearance* *Support – 707* *Logistic support in AOO* *Support – 712 MEDEVAC* *Support – 723* *Other combat engineering tasks*	*Mobility - land – route clearance* *Mobility - terrain* *Mobility - road*	*4.1.2 – Sustain the force* *4.6.2 – Combat engineering*

Table 1.1 Support/Logistics UGV can contribute to 16 capability categories within the areas of Mobility, Logistics and Support.

Moreover, it is expected that UGV technology will have significant potential for savings in personnel cost and related expenses, also indirectly due to elimination of various design aspects related to service requirements. For the time being it is, however, still uncertain how procurement costs for these vehicles relate to the cost of more traditional platforms. What is clear is that the introduction of unmanned systems will have considerable impact on the conduct of military operations, first by affecting TTP, but eventually changes will be become pervasive in the armed forces, cf. also Table 1.2.

Technology: Support / Logistics UGV	
Doctrine	Doctrine and tactical concepts will be affected by automation of key functionalities on a bigger scale. Legal aspects of automated operations and driving must be investigated
Organisation	N/A
Training	Education and training needs to be developed when introducing larger numbers of robotic systems
Materiel	Comprehensive procurement of new and /or modified materiel
Personnel	Reduced need for personnel in several functions. Will also need to add dedicated operators for some systems
Leadership	Introduction of automated systems will support thinking in new ways – taking higher risks etc.
Facilities	Consequences will depend on scale and on type of unmanned systems
Interoperability	N/A

Table 1.2 Assessment of impact on DOTMPLFI for the Support / Logistics UGV.

4.3 High-Energy Laser on Ships

The development of laser weapons has primarily taken place in the United States, with a number of impressive demonstrations during the last decades. The best-known programme was the Airborne Laser programme (ABL), where a very advanced chemical laser gun was built into a jumbo jet. The weapon was intended for engagement of ballistic missiles in the boost phase, at distances of up to several hundred kilometres. After 14 years of development, an ABL system was tested in February 2010, demonstrating successful shoot-down of a boosting ballistic missile at a distance of about 80 km. Other well-known laser weapon programmes include the Advanced Tactical Laser (ATL); a short range laser weapon built into a C-130 for use against ground targets, and the ground-based Tactical High Energy Laser (THEL) used to demonstrate shoot down of rockets and artillery shells. All these systems were based on chemically driven lasers, which can provide output powers in the MW-range, but which pose serious problems related to size and logistics. These programmes have therefore all been abandoned.

In recent years, emphasis has shifted towards development of electrically-powered solid-state lasers for laser weapons applications. Such lasers can be much more compact and practical in use than chemical lasers, and power levels of more than 100 kW have recently been achieved. This is still more than an order of magnitude below the power level of chemical lasers, but it is possible that this could be sufficient against many air targets and “soft” surface targets, at least at short range. An important task in this respect will be to establish detailed knowledge of the effects of laser weapons against the wide variety of possible targets and establish requirements for laser power and beam control. A successful further scaling of efficient and compact solid-state lasers would certainly open up for a wide use of this technology. A number of development programmes are underway, aiming at integrating such weapons on a variety of platforms, including aircraft, ships, and land vehicles. Best known among these are the High Energy Laser Mobile Demonstrator for land vehicles and the Maritime Laser Demonstrator for ships.

An alternative laser technology is the free electron laser (FEL), where a linear particle accelerator is used as the source of the laser beam, cf. Figure 1.5. Electrons are released from the source at the lower left, and are accelerated in a superconducting linear accelerator (linac). After emerging from this linac, the electrons pass into a laser cavity which has a wiggler at its centre. This wiggler causes the electrons to oscillate and emit light which is captured in the cavity, and used to induce new electrons to emit even more light.

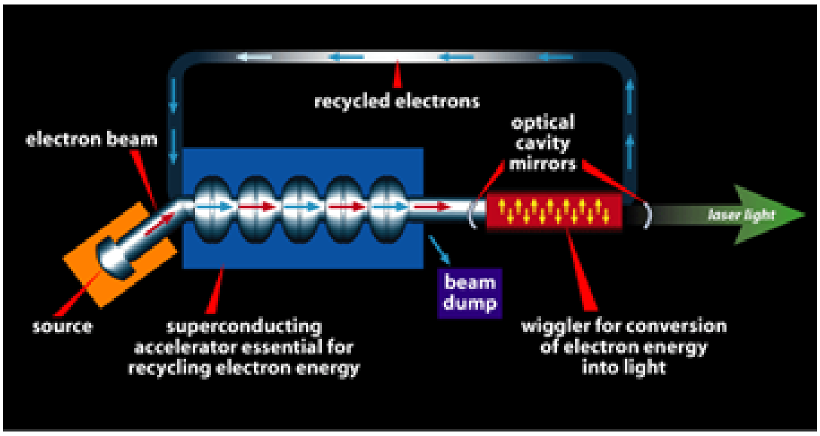

Figure 1.5 Illustration of the of free electron laser concept (source: Jefferson Lab, jlab.org).

This technology requires higher (electric) power consumption and a larger footprint than solid-state laser, but gives the advantage of enhanced beam power (although current output is comparable to solid-state lasers), tuneable frequencies and continuous beam availability. This technology probably would be more suitable for larger vessels, since the power and space requirements would be easier to handle for such platforms. Thus, the FEL power requirement fits the trend towards the “all-electric ship”.

A High-Energy Laser system for ships (HEL) consists of the light source (the laser), the aiming device, and a power supply as well as the carrying vessel. Its main operational capability would most likely be force protection in the form of short-to-medium range air defence, not least because the atmospheric attenuation of the beam limits its effectiveness at longer ranges. The system can be used to protect against difficult (asymmetric) threats by damaging or destroying targets from sensors to attack devices (small aircraft, fast patrol boats, missiles, mines, grenades) and to damage unprotected coastal infrastructure (power lines etc.). It is considered as a potentially very effective weapon against swarming threats. Thus, at the operational level, this system allows planning with higher risk (better defences against incoming threats). The variable beam strength provides graduated lethality with minimum collateral damage and a low cost-per-engagement when compared to the projectile and logistics support costs of conventional explosive munitions. Because of the continuous beam availability, it has very short response times and allows for multi-targeting, making saturation of the weapon system difficult.

Figure 1.6 Illustration of ship-based HEL in action (source: Office of Naval Research, www.onr.navy.mil).

As for other laser based systems, there are limitations and caveats as the target needs to be within line of sight and the laser beam is influenced by processes in the atmosphere (absorption, scattering, turbulence), as well as weather conditions, which tend to weaken the beam and increase the beam spot size on the target. Moreover, aiming the device is difficult in any conditions, as the laser beam must be focused on a relatively small spot on the target to give the desired damaging effect. This requires extremely precise tracking and pointing stability, which could make the system vulnerable to countermeasures in this phase. In so far as lasers are not targeting the human eye, HELs are ethically acceptable, but the occurrence of an accident might of course change this.

The high-energy laser technology on ships that has the potential to contribute to several capabilities, cf. Table 1.3.

Technology	*Capability SE*	*Capability NO*	*Capability FI*
High-Energy Lasers on Ships	*Engagement – 201 Sea targets* *Engagement – 204 Air targets* *Protection – 504 Sea and subsea objects*	*Engagement - air – GBAD short range* *Engagement - air – sea-based* *Engagement - maritime – ASuW littoral* *Engagement - maritime – less-than-lethal*	*3.2.2 – Non-Kinetic Means* *7.1.1 – Prevent Kinetic Attack*

Table 1.3 High-Energy Lasers on Ships can contribute to 9 capability categories within the areas of Engagement and Protection.

It should be noted that laser weapon systems have a completely different cost profile than other weapon systems (e.g. missiles) because the main cost is constituted by the acquisition of the weapon, which would be considerable, while the cost per shot is very low (claimed to be less than one U.S. dollar for a currently fielded laser system, the 30-kilowatt LaWS).

	Technology: High-Energy Lasers on Ships
Doctrine	This system allows planning with higher risk (better defences against incoming missiles and projectiles), particularly with regard to swarming/saturation attacks, thus affecting doctrine and leadership. Multi-targeting doctrine also may need to be revised, as well as the system's non-lethal targeting capabilities. Limited impact if the system is subject to weather restrictions
Organisation	N/A
Training	Comprehensive education and training needed to optimise and learn limitations of the system. The potentially short reaction times imply need for frequent training/exercises
Materiel	Comprehensive procurement of new materiel or considerable impact on existing materiel if need for modification of current vessels
Personnel	Will likely need dedicated operators and maintenance personnel
Leadership	Introduction of high energy laser systems will support thinking in new ways – taking higher risks etc. (cf. doctrine). The ethical and legal issues using laser weapons needs to be discussed at high level
Facilities	The laser generating device used by this weapon system will demand unique test and maintenance facilities with special attention to safety barriers and procedures. Maintenance may be demanding. Secure firing and testing ranges for laser weapon required
Interoperability	N/A

Table 1.4 Assessment of impact on DOTMPLFI for High-energy Laser on Ships.

Furthermore, the laser weapon system can be used as long as the weapon platform carrying it is able to provide enough energy to power the laser. This enables a far higher number of engagements compared to using e.g. missiles. Thus, once acquired, the cost of using the weapon is low, which gives a great flexibility in that one can afford to use the weapon against diverse target types. It also relieves some of the logistics burden when compared to traditional weapon systems (missiles, shells, etc.).

High energy laser systems are not yet a mature technology. Managing power and thermal aspects are major engineering concerns, but the maturity of laser weapons has developed to an extent where the U.S. Navy, after comprehensive testing in a field environment, recently has declared LaWS to be operational. If successful, it is evident that the introduction of laser weapon systems will have considerable impact on the military, cf. Table 1.4.

4.4 Multi-Purpose UAV Swarm

In recent years, the investigation of swarm technology concepts has proliferated, also with respect to military applications. At its foundation is the study of swarm intelligence; the collective behaviour of decentralized, self-organised and autonomous systems, natural or artificial. While the definition of swarm intelligence can be somewhat fuzzy; in principle, it should involve multi-agent systems that have self-organised behaviour that shows some emergent intelligent characteristics. A key-component is the communication between the members of the group, enabling feedback in order to modify both individual behaviour in agents co-operating with others, as well as the behaviour of the group as a whole. This does, however, not necessarily have to be a continuous or even frequent process.

Figure 1.7 Illustration of UAV-swarm attacking (source: 21stcenturywire.com).

The application of swarm principles to robots, such as unmanned aerial vehicles (UAVs), is called swarm robotics. It is inspired but not limited by the emergent behaviour observed in social insects, which communicate with each other and assist other members of the swarm in their tasks. Swarm robotics emphasises a relatively large number of robots, and promotes scalability, for instance by using only local communication. That local communication could be achieved by wireless transmission systems, like radio frequency or infrared.

UAV swarms, autonomous UAVs that work together to accomplish goals based on the principles of swarm robotics, are an emerging technology that can provide a solution to a variety of problems on the modern battlefield. One obviously suitable mission for swarms is searching areas and transmitting information to ground troops. A swarm of UAVs should be capable of mapping an area quickly, using communications technology to assign different areas to different UAVs while sending data to designated recipients. There is also a development towards using unmanned vehicles as part of the solution to secure communications in military operations, i.e. by letting swarming vehicles act as nodes in self-configuring, robust local (but not necessarily small) communications networks. Conversely, they could be configured to disturb sensor and communication networks (stand-in jamming). Swarming UAVs thus could contribute both to enhancing and disrupting C3 and situational awareness / ISTAR.

Search and rescue operations are also relevant, with multiple UAVs being able to search an area for people in danger, relaying the information to rescuers and even marking the area visually.

Figure 1.8 Swarming boats experiment by the Office of Naval Research, 2014 (photo: nationaldefensemagazine.org).

There are also offensive capabilities that swarms are well suited for, such as overwhelming air defence through sheer volume. Most current defensive systems are not designed to defend against massive attacks carried out by dozens, even hundreds of unmanned vehicles. Thus, inexpensive UAVs that can communicate with each other to carry out attacks may e.g. prove to be a safe and economical way to disrupt (e.g. jam) or remove anti-aircraft defences. It is also possible to conceive swarms used in ambush/denial operations: Dormant UAV swarms, stored in suitable locations, could suddenly be activated and disperse into a designated area to act like a flying (or ground settling) minefield. Such a concept could be very effective against e.g. helicopter operations.

When used to enhance ISTAR or C3, UAV swarms do not pose major controversy other than those concerning unmanned airborne systems in general, but the use of autonomous and automated force in the battlefield raises serious ethical concerns which have to be addressed on a broad basis. Moreover, for unmanned, and especially automated, airborne systems, there are also significant challenges in airspace management that have to be resolved.

The multi-purpose UAV swarm technology has the potential to contribute to several capabilities, cf. Table 1.5.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Multi-Purpose UAV Swarm	*C4 – 105 Communication* *Engagement – 201 Sea targets* *Engagement – 203 Ground targets* *Engagement – 204 Air targets* *Engagement – 208 SEAD/DEAD* *Engagement – 210 Electronic attack* *ISTAR – 310 IMINT* *ISTAR – 311 SIGINT* *ISTAR – 312 MASINT* *Protection – 503 Ground objects* *Support – 715 SAR* *Support – 717 CSAR* *Support – 718 CR*	*Protection - land –- anti-mobility* *Engagement - air –- electronic warfare*	*2.2.1 – Signals Collection* *2.2.2 – Imagery Collection* *2.2.3 – Measurements and Signatures Collection* *3.2.1 – Kinetic Means* *3.2.2 – Non-Kinetic Means* *4.1.2 – Sustain the force* *6.1.2 – Wireless Transmission* *7.1.1 – Prevent Kinetic Attack*

Table 1.5 Multi-Purpose UAV Swarms can contribute to 33 capability categories within the areas of Engagement, C4, ISTAR, Protection and Support.

Once the challenges related to swarming intelligence and control has been resolved, the acquisition of UAV swarms would be scalable to swarm size and composition (type of UAV). Hence, significant cost reductions are possible, especially if this technology can replace conventional elements in current defence structures.

Currently, swarming technology is rather immature, with significant challenges regarding autonomy and when trying to operate the systems outside the controlled laboratory environment. However, steady progress is being made, as the recent (August 2014) demonstration of swarming boats by the Office of Naval Research (U.S.) has shown. This development is likely to continue. Thus, we should expect a gradual, though non-linear, increase in sophistication over the years to come, proceeding from simpler to more complex applications. For UAV swarming concepts, this could mean that ISTAR applications would be the first to become operational. If successful, it is evident that the introduction of UAV swarms will have considerable impact on the military, cf. Table 1.6.

	Technology: Multi-Purpose UAV Swarms
Doctrine	Networked autonomous systems technology will significantly change doctrine on a high level since it permits combining assets, sensors and effectors in a novel way, reducing risk of own personnel and materiel. Special attention must be given to airspace management issues
Organisation	Effect on organisation if "swarming assets " are replacing conventional elements in current defence structures
Training	Comprehensive education and training needed to optimise and learn limitations of the system with respect to logistics, mechanics and operations. Safety issues regarding multiple systems in confined space demand special attention
Materiel	Comprehensive procurement of new materiel, particularly if "swarming assets" are replacing conventional elements in current defence structures
Personnel	Will likely need dedicated operators and maintenance personnel. Potential for personnel reductions if "swarming assets" are replacing conventional elements in current defence structures
Leadership	Swarms operating (semi-)autonomously in a network represent an entirely new way of thinking operations (e.g. targeting) and influence risk assessment. Enhanced situational awareness may centralise decision making. The ethical and legal issues using unmanned and automated force needs to be discussed at high level
Facilities	Consequences will depend on scale and on type of unmanned systems and whether "swarming assets" are replacing conventional elements in current defence structures
Interoperability	The perceived ubiquity of unmanned systems will demand focus on the interoperability issue in connection with co-operative ventures

Table 1.6 Assessment of impact on DOTMPLFI for the Multi-Purpose UAV Swarm.

4.5 Situational Awareness Sensor System

The advances in microelectronics and micro-electro-mechanical systems (MEMS) in recent years, and the perceived future development these technologies, promise a wealth of possibilities for continued miniaturisation of sensors and a proliferation of their uses. Particularly powerful results can arise from combining this trend in device technology with the progress in artificial intelligence methods for data fusion and analysis and energy supply, e.g. battery technology.

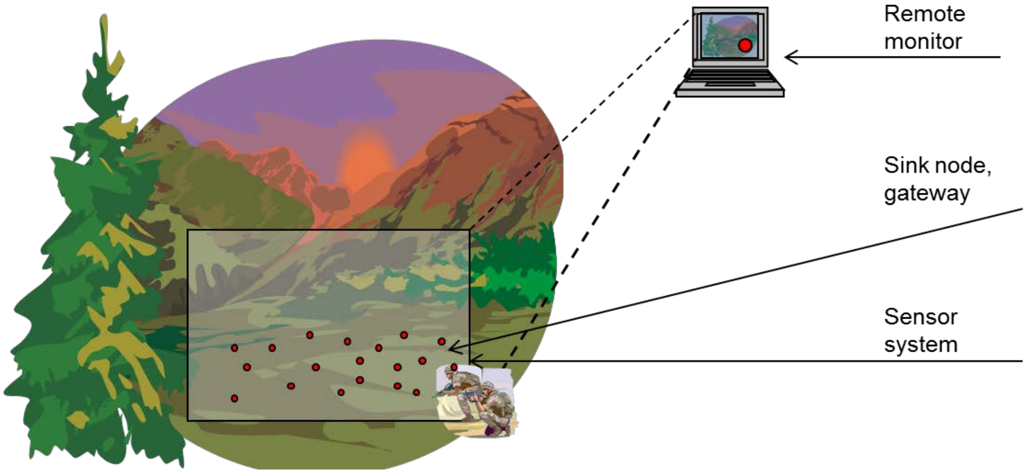

Figure 1.9 Depiction of a Situational Awareness Sensor System (source: FFI).

One such interesting concept is the Situational Awareness Sensor System (SASS), an easily deployable sensor system, with RF communication gateways, for perimeter defence and area surveillance, cf. Figure 1.9. It is conceived as an autonomous, self-configuring surveillance network of disposable, hidden unattended ground sensor (mixed field of magnetic, acoustic, seismic, ABC and RF sensors) and wireless communication nodes, connecting to a remote analysis facility. These nodes are powered by batteries or some energy harvesting process, ensuring prolonged lifetime. The system is designed to have low volume and weight, so as to easily be carried and deployed (within minutes) by a single soldier. Alternatively, it could be deployed remotely from air or by artillery. Typical field size should be sufficient to cover an area of about 50 000 m^2.

The system would mainly be employed in surveillance and perimeter defence around critical assets, e.g. intruder detection. The expected effect is significantly improved situational awareness, by moving from point measures to a (joint) picturing capability, and more effective use of personnel resources (e.g. reduced need for patrolling or guard duty). Furthermore, a conceivable combination with unmanned systems (UAV, UGV) could enable identification of intruders and would allow the sensor network to add a kinetic element to its force protection capability, possibly to the degree of enabling (semi-)automated targeting.

The foremost operational challenge to the system is a potentially high false alarm rate that would limit its use. Moreover, own forces may cause false alarms without IFF functionality added. The system could be overloaded or its communications jammed, intentionally or by hazard. It is also unsure how the functionality would be under certain weather conditions such as snow, ice, mud, and rain. The obtainable radio range will provide constraints on deployment.

The operational capabilities concerned by this system are primarily related to ISTAR and SOF, cf. Table 1.7.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Situational Awareness Sensor System	*ISTAR – 310 IMINT* *ISTAR – 312 MASINT* *ISTAR – 318 CBRN-related information* *Protection – 503 Ground objects*	*ISTAR - land - tactical – collection* *ISTAR - littoral – tactical collection*	*2.2.3 – Measurements and Signatures Collection* *2.3.2 – Information Categorization (PE)* *7.1.1 – Prevent Kinetic Attack* *7.1.1 – Prevent Non-kinetic Attack*

Table 1.7 Situational Awareness Sensor System can contribute to 12 capability categories within the areas of ISTAR and Protection.

SASS acquisition is scalable to perceived operational needs, i.e. number of required fields and their sizes. Hence, expenditures can be kept under control. If the system’s performance is according to expectations with regard to personnel reductions, there is a potential for savings on personnel costs.

In order to obtain the anticipated effects, there are critical levels of performance related to technology development. The most important are related to the development of intelligent data compression and fusion, further compression of MEMS technology giving smaller detectors and new packing technology to obtain smaller nodes (motes). Moreover, progress in battery and/or energy harvesting technologies are needed to further non-maintenance nodes and transmitters. Challenges to a successful system are predominantly related to the trade-off between detection sensitivity and false alarm rate, low-detectable radio trans-mission and high jamming resistance (if detected). Also, detection algorithms with accept-able detection rates that are tolerant to low power consumption and limited communication between sensors are required. Even so, the introduction of SASS will have impact on the military, cf. Table 1.8.

	Technology: Situational Awareness Sensor System
Doctrine	Mainly impact on TTP level. Will improve tactical situational awareness. Increases the efficiency of patrols/guards
Organisation	N/A
Training	Some tactical training required for operators and analysts
Materiel	New kind of materiel that will have to be handled by the logistic chain
Personnel	Reduced need for personnel in force protection (guard and patrol), but may need dedicated operators/analysis cell
Leadership	Limited impact, but leaders will need to know how to apply the capability
Facilities	N/A
Interoperability	N/A

Table 1.8 Assessment of impact on DOTMPLFI for the Situational Awareness Sensor System.

4.6 Global Information Satellite Constellation

Current technology trends towards increased levels of automation, collaborative networking, artificial intelligence for decision support, and distributed supercomputing power will result in increased efficiency of many unmanned platforms, including satellites, and enable new uses for satellite technology. This development is accompanied by miniaturization of payloads, plug-and-play technology, on-going commercial development efforts and increasingly cost-effective satellite launches.

The satellite market, and space applications in general, has undergone a complete transfor-mation over the past 5 years through injection of new nano-satellite technology and multi-billion dollar investments from Silicon Valley start-up companies. Google Corporation is investing in Elon Musk’s Space Exploration Technologies (SpaceX) to design, manufacture, and build 1,600 communication satellites for global broadband coverage with the aim to eliminate land based communication providers and governmental control. SpaceX is already the largest commercial space launch provider, being the first private company to deliver cargo to the International Space Station on a commercial contract by the NASA.

In addition to communications, commercial actors are investing heavily into Earth Observation satellites. The motivation is linked to a vast amount of applications that are derived from change detection, forestry, agriculture, and private-public-partnerships with national defence agencies. Such nano-satellite constellations can be lofted and released in massive numbers. Figure 1.10 shows a photograph of Planet Labs' "Flock 1". These electro-optical 4.5 kg spacecraft are built at a rate of 4 satellites per day and launched 28 at a time providing a down-link data rate at 40 Mbit/second or more on X-band frequencies.

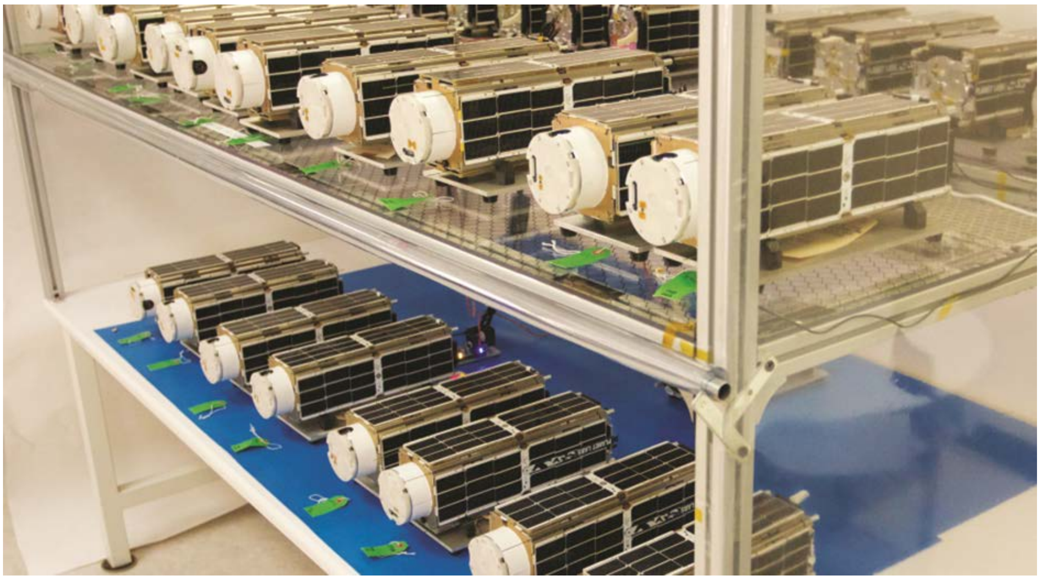

Figure 1.10 Planet Labs' "Flock 1" of electro-optical CubeSats with 10 meter ground resolution (photo: Planet Labs Inc.).

The value of existing commercial nano-satellites for conventional military applications is difficult to assess. However, based on currently available solutions from 15-20 qualified vendors, it seems feasible that very advanced small spacecraft could be procured and tailored to support advanced payloads, possibly of indigenous (i.e. Scandinavian) origin, for applications such as:

- Virtual Network ad-hoc sensor fusion capability
- Secure telecommunication (store-forward, up to 1 hours delay of data)
- AIS Ship tracking with Marine Search and Rescue (SAR)
- ADS-B Aircraft flight tracking, Next Generation Air Transportation System
- Artic Satellite Navigation Augmentation System (GPS)
- Earth Observation, Visual and Hyperspectral
- Communication and Electronic intelligence (COMINT/ELINT).

The trend towards nano-satellites is mainly motivated by the need to reduce mass and volume in order to reduce the cost for launch. As this miniaturization almost inevitably reduces the performance of sensors, expansible apertures can be used, or satellites can be flown in constellations forming a synthetic aperture. The latter puts high demands on accurate positioning and communication between the satellites and of synchronized movements of the satellites in the constellation.
Nevertheless, such small satellites could, as indicated above, be fitted with a multitude of sensors and communication systems. Besides visual sensors, passive radars are possible already today. Active radars could be feasible within 5-year timeframe. AFRL have shown in internal reports that it is possible to make small radars for small satellites, although with short duty-cycles due to power limitations.

In a defence context, Satellite Constellations could be used for ISTAR, particularly to enhance/maintain situational awareness. It can also be used to constitute part of the C4-infra-structure. With such a system, it is possible to gain situational awareness superiority and to provide a clear advantage in decision making processes.

Since micro- and nano-satellite technology will significantly reduce the cost of using space assets, operators of defence assets should be acutely aware of the potential of using such satellites to de-orbit or alter the orbit of satellites, or even to attack other satellites.

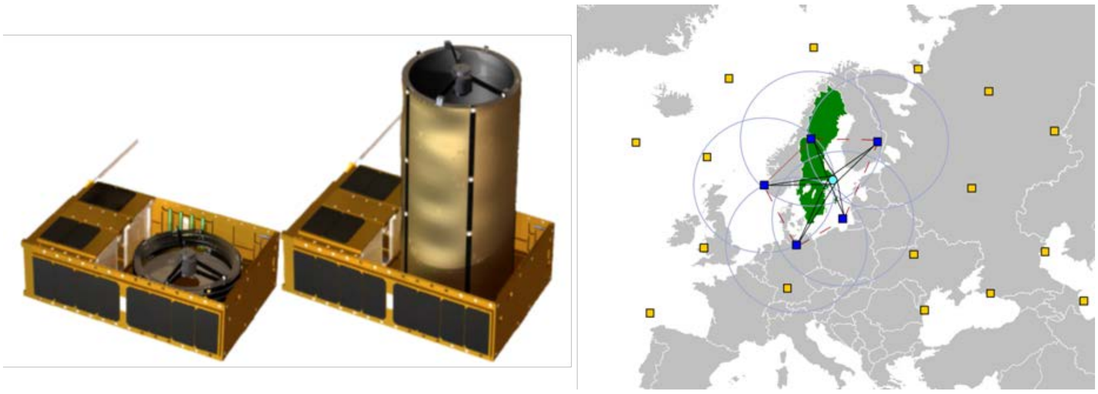

Figure 1.11 Left: Depiction of a 10 x 20 x 30 cm^3 nano-satellite featuring better than 3 meter ground resolution collapsible Dobson telescope (source: NASA).
Right: Illustration of a Virtual Communication and Radar satellite constellation concept (source: Bruhnspace AB).

Figure 1.11 captures two examples from “new space”. On the left, an illustration of a NASA-designed nano-satellite for earth observation in the visual spectrum, using a collapsible Dobson telescope with 18 cm aperture and a focal length of 1 meter for better than 3 meters ground resolution images. On the right an illustration of a collaborative, low orbiting small Satellite Constellation, that uses ad-hoc networking to provide intelligent decision support by fusing sensor information from elements of the constellation. The particular illustration illustrates a collaborative ground and space based bi-static (passive) radar for stealth vehicle detection over the Baltic Sea, based on a concept developed by the Swedish company BAP (Bruhnspace Advanced Projects).

The discussion above suggests that the operational capabilities concerned by this system are primarily related to ISTAR and C4, cf. Table 1.9.

Technology	Capability SE	Capability NO	Capability FI
Global Information Satellite Constellation	*C4 – 105 Communication ISTAR – 301 Geographical information ISTAR – 303 Meteorological information ISTAR – 304 Target information ISTAR – 310 IMINT ISTAR – 311 SIGINT ISTAR – 312 MASINT ISTAR – 313 RADINT*	*ISTAR - land - operational – EO/IR stand-off ISTAR - land - operational – SAR deep ISTAR - land - operational – SIGINT deep ISTAR - land - operational – SIGINT stand-off ISTAR - littoral - operational – AIS ISTAR - littoral - tactical – collection ISTAR - air - operational – robust early warning ISTAR - air - operational – early warning ISTAR - maritime - operational – AIS ISTAR - maritime - operational – EO/IR ISTAR - maritime - operational – SAR ISTAR - maritime - tactical – collection C2 - joint – operational*	*2.2.2 – Imagery Collection 2.2.3 – Measurements and Signature Collection 6.1.2 – Wireless Transmission*

Table 1.9 The Global Information Satellite Constellation can contribute to 24 capability categories within the areas of C4 and ISTAR.

It should be noted that the geo-location of Scandinavia is optimal for polar and near polar retrograde orbits providing good coverage of northern regions, but can be complemented with low inclination orbits for improved coverage for international missions. This has been demonstrated by Norway's excellent small space assets defence capability for Maritime Domain Awareness (MDA), obtained through public procurement and collaboration with premier Canadian institutions, Norwegian industry, and military C^2I collaboration between different branches. The evolution of small space assets capabilities beyond MDA is rather straightforward and a natural step to take. The Nordic countries have a possibility to engage into interoperable small space assets capabilities through a combination of advanced payload capability industry and favourable communication infrastructure in Svalbard and Kiruna, as well as mobile terminals.

It has been argued that the satellite market, and space applications in general, has undergone a complete transforming over the past 5 years through the injection of disruptive technology. With some further development, it is evident that the introduction of global nano-satellite constellations will have considerable impact also on defence operations, cf. Table 1.10. This system could be launched and operated by a nation/alliance or the service could, at least to some extent, be made available by a commercial actor, cf. the above discussion. These two cases have different implications for the DOTMPLFI.

Technology:	Global Information Satellite Constellation
Doctrine	A space doctrine must be developed – needed in any future scenario
Organisation	Staff officers with a specialization on space operations are needed at headquarters. A "Space Command" may have to be established. If the system is launched and operated by a nation or an alliance, a control and analysis organisation will have to be established
Training	Comprehensive education and training needed, especially on the tactical level
Materiel	Procurement of customer-tailored advanced payloads. Standardised satellites and services could be commercially available. If not, these will have to be acquired as well
Personnel	Personnel for satellites operations and collecting and analysing data. Standardised services may be commercially available. If the system is launched and operated by a nation or an alliance, a control and analysis organisation will have to be established and dedicated personnel is needed
Leadership	Staff officers with a specialization on space operations are needed at headquarters. A "Space Command" might be established.
Facilities	Has considerable effect on facilities if the control and analysis organisation is operated by a nation or an alliance. A ground segment for satellite control and information management will be needed (or operated commercially). Satellite launch services are commercially available
Interoperability	Interoperability will be an issue in connection with co-operative ventures (e.g. establishing a shared capability)

Table 1.10 Assessment of impact on DOTMPLFI for the Global Information Satellite Constellation.

4.7 Multi-Purpose RF System for Tactical UAV/UGV/USV

Traditionally, radio frequency (RF) systems are based on dedicated hardware, such as ASIC-circuits. Such hardware offers little or no possibility of using the same hardware for other functionality, and the possibility of reusing the system for other applications is limited. The development of generalized commercial-off-the-shelf (COTS) hardware modules has changed this situation. Modules incorporating high speed and high bandwidth analogue-to-digital converters (ADC) and digital-to-analogue converters (DAC), conformal array antennas, along with ample digital signal processing resources, especially field-programmable gate arrays (FPGA), ease the implementation of such multi-purpose systems. An FPGA can be reconfigured in a matter of seconds, enabling rapid switching between the different functions[7].

Over the last decade, there has been significant development on communications technologies. Widespread use of 3G and 4G cellular technologies, as well as software-defined radio technologies, has been enabled by strong investments on R&D in both government and commercial sectors. Development in different areas has enabled low power consumption, increased processing capability, better interoperability and advanced antenna structures.

Figure 1.12 A Stratix IV FPGA from Altera Corporation (photo: Wikimedia Commons)

The Multi-Purpose RF (MuPuRF) System for Tactical UAV/UGV/USV is a system that provides different types of communication, combat (targeting, SEAD) and electronic warfare (surveillance, intelligence, jamming) capabilities in a single, unmanned platform. The main technological components of this type of system are wideband RF transceivers enabling high data rates, frequency scanning speeds and connectivity to multi-antenna structures. A MuPuRF system is therefore available for a variety of tasks, e.g. surveillance, intelligence, scanning of terrain utilizing SAR sensors, and provision of communication relays and targeting.

[7] H. Nicolaisen, T. Holmboe, K. V. Hoel, S. Kristoffersen: *High Resolution Range-Doppler Radar Demonstrator Based on a Commercially Available FPGA Card*, Proceedings of the 2008 International Conference on Radar, (Adelaide, Australia, 2008), IEEE RADAR '08, pp. 676-681, 2008.

When there is a need to relay data between different units on land, at sea and in the air, then, if the relay is in the air, limitations on terrain and foliage can be mostly avoided. A deployable wideband communications link could provide improvement on communications between ground-based stations. In connection with the NordTech Games, this system was therefore mainly based on a UAV platform.

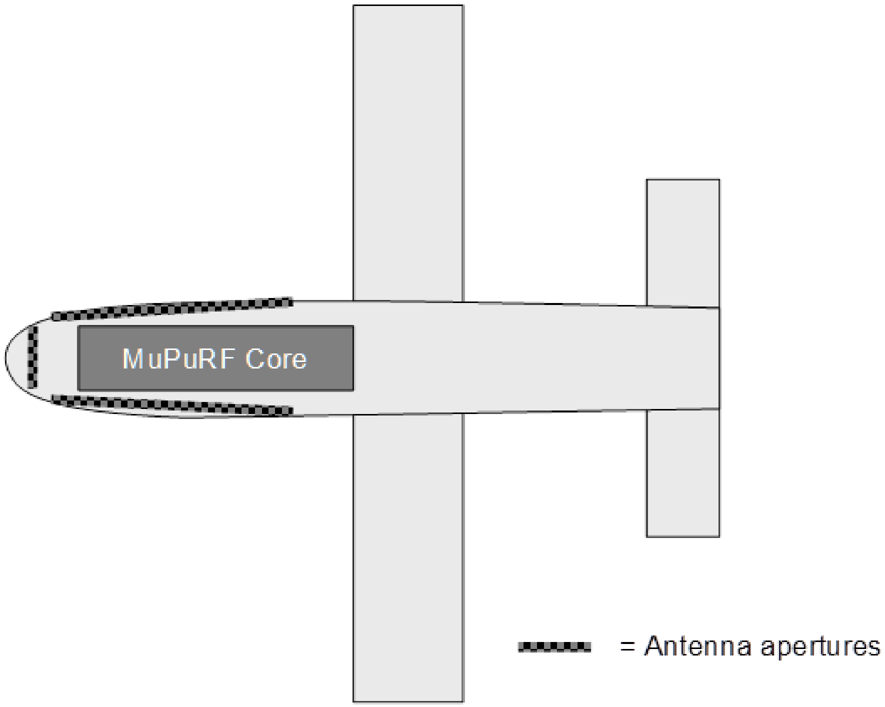

Figure 1.13 Sketch of principle for a MuPuRF system installed on a UAV platform.

Based on evidence from the NordTech Games, the MuPuRF System for Tactical UAV/UGV/ USV provided high impact on operations where it was supplementing other assets. As one element in an “autonomy complex”, combining various autonomous unmanned platforms into a networked command structure, this system will expand platform/sensor coverage of the area of operations, significantly enhancing ISTAR capability and improving situational awareness. It was also used successfully for challenging missions, such as stand-in jamming. This type of system will therefore most likely be complementing existing capacities rather than replacing them. Moreover, an unmanned relay vehicle will be vulnerable in hostile environment, even if it reduces risks to human life compared to manned platforms. It is expected that this type of system will be considered a high value target in hostile environments. A mechanism to mitigate such risks would be to use the system on swarms of suitable unmanned vehicles, cf. section 4.4.

The Multi-Purpose RF System for Tactical UAV/UGV/USV is a system that has the potential to contribute to the capabilities shown in Table 1.11 below.

Technology	Capability SE	Capability NO	Capability FI
Multi-Purpose RF System for Tactical UAV/UGV/USV	*C4 – 105 Communication* *Engagement – 210 Electronic attack* *ISTAR – 305 Common operational picture* *ISTAR – 311 SIGINT* *ISTAR – 312 MASINT* *ISTAR – 313 RADINT*	*C2 - maritime – tactical* *C2 - land – tactical* *ISTAR - maritime - operational – SAR* *ISTAR - air - operational – early warning* *Engagement - land – electronic warfare* *Engagement - air – electronic warfare*	*2.2.1 – Signals Collection* *2.2.3 – Measurements and Signatures Collection* *3.2.2 – Non-Kinetic Means* *6.1.2 – Wireless Transmission* *6.1.3 – Switching and Routing* *7.1.1 – Prevent Kinetic Attack*

Table 1.11 Multi-Purpose RF System for Tactical UAV/UGV/USV can contribute to 18 capabilities within the areas C4, ISTAR, Engagement and Protection.

Hence, it is expected that the Multi-Purpose RF System for Tactical UAV/UGV/USV will be particularly significant as a potential communications solution, extending the communications range between ground units and supporting the situational awareness of ground-based units. Moreover, stealth properties of unmanned vehicles will likely improve over time, as will other aspects of unmanned platforms, cf. also Section 4.2; increased efficiency of unmanned platforms, e.g. by making it possible for a single operator to control multiple platforms, (semi-) autonomous operation, collaboration between other unmanned and manned systems, and switching between different missions on the run without time-consuming configuration at maintenance posts.

It is still uncertain how procurement costs for these systems relate to the cost of more traditional platforms, since introduction of this type of capacity does not remove the need for ground-based communication. What is clear is that the introduction of unmanned systems will have considerable impact on the conduct of military operations, first by affecting TTP, but eventually changes will be become pervasive in the armed forces.

Technology:	Multi-Purpose RF System for Tactical UAV/UGV/USV
Doctrine	Doctrine and tactical concepts will be affected by automation of key functionalities. System also allows for centralized control from the headquarters.
Organisation	Organic asset that may be integrated into C2 structures.
Training	New rules of communication and configuration of networks. Frequency planning is crucial for the capability.
Materiel	Procurement of new materiel.
Personnel	Reduced need for personnel in several functions. Will also need dedicated operators, e.g. EW.
Leadership	System allows for centralized control from the headquarters
Facilities	N/A
Interoperability	N/A

Table 1.12 Assessment of impact on DOTMPLFI for the Multi-Purpose RF System for Tactical UAV/UGV/USV.

4.8 Unmanned Surface Vehicle

So far, remote-controlled Unmanned Surface Vehicles (USVs) have principally been used for mine countermeasures (MCM) and as exercise targets. New generations of USVs will be increasingly autonomous and suitable for a wider range of missions.

The spectrum of USV concepts covers a range from floating reconnaissance sensors to large (> 10.000 t) mobile bases for unmanned air- and surface vehicles. However, the major efforts in development are aimed at boats with a hull length between 2 and 12 m. Typically these are derived from existing rigid-hulled inflatable boats but this will change in the future to more purpose-built designs. Boats of that size can be deployed from ships or could even be dropped from transport aircraft.

While todays USVs are operating as single, remote-controlled units, half-autonomous systems are being developed that can perform pre-defined tasks and evade obstacles. In the long term USVs or groups of USVs with a high degree of autonomy will be able to conduct even offensive operations. Swarming and collaboration between unmanned vehicles will likely be important in the future naval missions. The Office of Naval Research (ONR) in the United States has recently demonstrated this type of concept, cf. also section 4.4.

USV-platforms could use exchangeable payloads for missions like anti-submarine warfare, mine countermeasures, harbour protection, coastal surveillance, mapping and surveying, force protection (escort), precision strike against surface and land targets, SAR, and in various communication roles (OTH relaying and others). USV could also operate as a mother ship for underwater unmanned systems to provide communication gateway and energy resources to UUVs and /or AUVs. In comparison to AUVs, USVs can be powered with air-breathing machinery. This makes it easier to accomplish high speed and long endurance.

Figure 1.14 The Interceptor™ USV (photo: searobotics.com)

The USV is thus a system concept that can provide various communications, warfare, protection and intelligence functionality by means of different payload configurations. They offer military capacities where loss of life is unacceptable. This flexibility will make USVs important assets, especially in littoral warfare, as predicted in many studies. They are, however, vulnerable in hostile environments but could use swarming techniques to overload targeting functions.

Based on evidence from the NordTech Games, the MuPuRF System for Tactical UAV/UGV/ USV provided high impact on operations where it was supplementing other assets. As one element in an "autonomy complex", combining various autonomous unmanned platforms into a networked command structure, this system will expand platform/sensor coverage of the area of operations, significantly enhancing ISTAR capability and improving situational awareness.

Thus, the Unmanned Surface Vehicle is a system that has the potential to contribute to the capabilities shown in Table 1.13 below.

Technology	Capability SE	Capability NO	Capability FI
Unmanned Surface Vehicle	*C4 – 105 Communication* *Engagement – 201* *Sea targets* *Engagement – 203* *Ground targets* *Engagement – 210* *Electronic attack* *Engagement – 212* *Amphibious terrain* *ISTAR – 301* *Geographical information* *ISTAR – 302* *Oceanographic information* *ISTAR – 304* *Target information* *ISTAR – 305* *Common operational picture* *ISTAR – 310 IMINT* *ISTAR – 311 SIGINT* *ISTAR – 312 MASINT* *ISTAR – 318* *CBRN-related information* *Movement – 402* *Sea mine clearance* *Movement – 408* *Transports within an AOO* *Protection – 504* *Sea and subsea objects* *Protection – 513* *Sea escort* *Support – 715 SAR* *Support – 717 CSAR*	*C2 - maritime – tactical* *ISTAR - littoral - tactical – collection* *ISTAR - maritime - operational – EO/IR* *ISTAR - maritime - operational – SIGINT* *ISTAR - maritime - tactical – collection* *ISTAR - underwater - tactical – collection* *Engagement - maritime – ASuW littoral* *Engagement - maritime – ASuW stand off* *Engagement - maritime – ASW* *Protection - maritime – mine clearance* *Protection - littoral – HVA protection*	*2.2.1 – Signals Collection* *2.2.2 – Imagery Collection* *2.2.3 – Measurements and Signatures Collection* *3.1.4 – Maneuver to Secure* *3.2.2 – Non-Kinetic Means* *4.1.2 – Sustain the Force* *4.6.2 – Combat Engineering* *6.1.2 – Wireless Transmission* *6.1.3 – Switching and Routing* *7.1.1 – Prevent Kinetic Attack*

Table 1.13 Unmanned Surface Vehicle can contribute to 40 capabilities within the areas C4, ISTAR, Engagement, Mobility, Support and Protection.

USVs have the potential to perform many missions better and more cost effectively than traditional platforms. However, these systems will initially be complementing existing platforms rather than replacing them. It is therefore still uncertain how procurement costs for these systems relate to the cost of more traditional surface assets. What is clear is that the introduction of unmanned systems will have considerable impact on the conduct of military operations, first by affecting TTP, but eventually changes will be become pervasive in the armed forces.

	Technology: Unmanned Surface Vehicle
Doctrine	Doctrine and tactical concepts will be affected by automation of key functionalities on a bigger scale
Organisation	Could be an organic asset in naval operations, or organised as separate divisions
Training	Comprehensive education and training needs when introducing larger numbers of USV systems. Need for training for collaboration between manned and unmanned surface systems.
Materiel	Comprehensive procurement of new materiel
Personnel	Will likely need dedicated operators and maintenance personnel. Potential for personnel reductions if USVs are replacing conventional elements in current defence structures
Leadership	Possible swarming and autonomous operation has high impact on leadership. Introduction of automated systems will support thinking in new ways – taking higher risks etc.
Facilities	Consequences will depend on scale and on configuration of the systems
Interoperability	The perceived ubiquity of unmanned systems will demand focus on the interoperability issue in connection with co-operative ventures

Table 1.14 Assessment of impact on DOTMPLFI for the Unmanned Surface Vehicle.

4.9 Bionic Autonomous Underwater Vehicle

A topic of special interest within the area of unmanned, autonomous vehicles is constituted by the Bionic Autonomous Underwater Vehicle (Bionic AUV). Bionics is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. Of particular importance for such applications is the field of bio-mechatronics[8], an applied interdisciplinary science that aims to integrate mechanical elements, electronics and parts of biological organisms. It encompasses the aspects of biology, mechanics, electronics, robotics, and neuroscience; i.e. essentially the many of the same technologies that are significant for other applications of unmanned vehicles (cf. sections 4.2, 4.4 and 4.8).

The main technological challenges for this type of system when intended for defence applications are related to fish-like propulsion, sophisticated sensors, autonomous operation and long endurance. Greater degrees of autonomy are needed to overcome physical

[8] Wikipedia, see http://en.wikipedia.org/wiki/Bionics.

limitations of maritime environment in the areas of communications, dynamic navigation, data processing / dissemination and command and control. Moreover, autonomic features of unmanned systems extend and complement human performance, reducing risks to forces and improving capacity to process masses of data. Real-time sensor processing is still seen as a long-term goal to improve AUV capabilities. As another important factor, progress in energy technologies could provide long-endurance AUV missions[9].

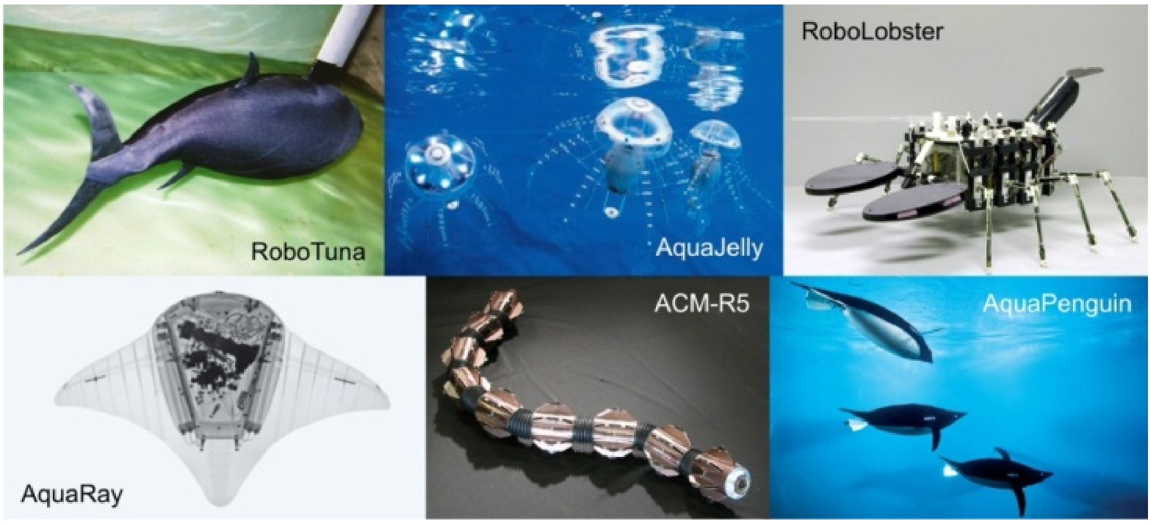

Figure 1.15 Illustration of various types of bionic UUVs: RoboTuna (source: web.mit.edu/towtank/www), AquaJelly, AquaRay, and AquaPenguin (source: www.festo.com), RoboLobster (source: www.neurotechnology.neu.edu), ACM-R5 (source: www-robot.mes.titech.ac.jp).

The Bionic AUV is a system that can provide several protection (MCM, harbour protection, force protection) and ISTAR (REA, coastal surveillance, intelligence, and mapping) capabilities. The important role of future AUVs/UUVs, especially in underwater covert operations, is indicated in many studies. As for all unmanned systems, Bionic AUVs would be most valuable in dangerous tasks, such as mine countermeasure missions. They could assist high value assets, e.g. warships, by scanning the underwater environment for mine threats before transiting through straits etc. The collaboration between unmanned vehicles (e.g. swarming) will likely be important also in the context of AUVs.

In contrast to USVs, AUVs operate most of the time under the surface, relying on acoustic communications below the surface. When near the surface, they can rely on e.g. RF communications. However, a mother ship would usually be needed to provide a

[9] Department of Defense Board, Task Report: The Role of Autonomy in DoD Systems, July 2012.

communications gateway to AUVs and to (re-)supply their energy resources, especially if the area of operations is far away from the home base. Most of the benefits concerning USVs listen in section 4.8 above apply to this section as well, since unmanned platforms have common properties, although underwater domain poses limitations to communications.

Based on evidence from the NordTech Games, the Bionic AUV provided high impact on operations where it was supplementing other assets. As one element in an "autonomy complex", combining various autonomous unmanned platforms into a networked command structure, this system will expand platform/sensor coverage of the area of operations, significantly enhancing ISTAR capability and improving situational awareness.

The Bionic Autonomous Underwater Vehicle is a system that has the potential to contribute to the capabilities shown in Table 1.15 below.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Bionic Autonomous Underwater Vehicle	*ISTAR – 301 Geographical information* *ISTAR – 302 Oceanographic information* *ISTAR – 304 Target information* *ISTAR – 312 MASINT* *Movement – 402 Sea mine clearance* *Protection – 504 Sea and subsea objects*	*ISTAR - littoral - tactical – collection* *ISTAR - maritime - tactical – collection* *ISTAR - underwater - tactical – collection* *Engagement - maritime – ASW* *Protection - maritime – mine clearance* *Protection - littoral – HVA protection*	*2.2.2 – Imagery Collection* *2.2.3 – Measurements and Signatures Collection* *3.1.4 – Maneuver to Secure* *7.1.1 – Prevent Kinetic Attack*

Table 1.15 Bionic Autonomous Underwater Vehicles can contribute to 16 capabilities within the areas ISTAR, Mobility and Protection.

Once more, as with USVs, the Bionic AUV has the potential to perform various missions better and more cost effectively than traditional platforms, and again these systems will initially be complementing existing platforms rather than replacing them. It is therefore still uncertain how procurement costs for these systems relate to the cost of more traditional assets. However, several of the relevant technologies, e.g. bio-mechatronics in the way of prosthetics, are relevant technologies for commercial actors in the health sector. This constitutes a driving force towards making the technology more affordable with a considerable potential for cost reductions.

What is clear is that the introduction of unmanned systems will have considerable impact on the conduct of military operations, first by affecting TTP, but eventually changes will be become pervasive in the armed forces.

	Technology: Bionic Autonomous Underwater Vehicle
Doctrine	Doctrine and tactical concepts will be affected by automation of key functionalities on a bigger scale
Organisation	Organic asset in underwater missions
Training	Comprehensive education and training needs when introducing larger numbers of AUV systems. Need for training for collaboration between manned and unmanned surface systems.
Materiel	Procurement of new materiel
Personnel	May reduce need for divers, but will need handling personnel
Leadership	Possible swarming and autonomous operation has high impact on leadership. Introduction of automated systems will support thinking in new ways – taking higher risks etc.
Facilities	Consequences will depend on scale
Interoperability	The use of this asset must be de-conflicted with own submarine operations

Table 1.16 Assessment of impact on DOTMPLFI for the Bionic Autonomous Underwater Vehicle.

4.10 Subsea Network-Centric Warfare

In recent years, technology development has brought the prospect of bringing the network-centric approach to warfare into the underwater realm closer to reality. It is now conceivable to set up an untethered subsea network, based on acoustic communication, with RF links to surface components. Among the relevant contributing developments have been new transducers for short range detection, non-acoustic sensors with low noise and low power consumption, and battery technology. This has been supplemented by the development of new detection algorithms, based on low-power PCs, for both acoustic and non-acoustic detection.

Introducing Subsea Network-Centric Warfare (Subsea NCW) could ultimately resolve many challenges for today's navies. MCM could be conducted more efficiently and safer than today, letting unmanned platforms do the job rather than the traditional, manned MCM units. Moreover, the introduction of underwater networks enables submerged platforms to participate in joint operations such as over-the-horizon-targeting; submarines could in the future report position, course and speed on enemy targets to missile units in the littorals, or own fighter jets, from a submerged position.

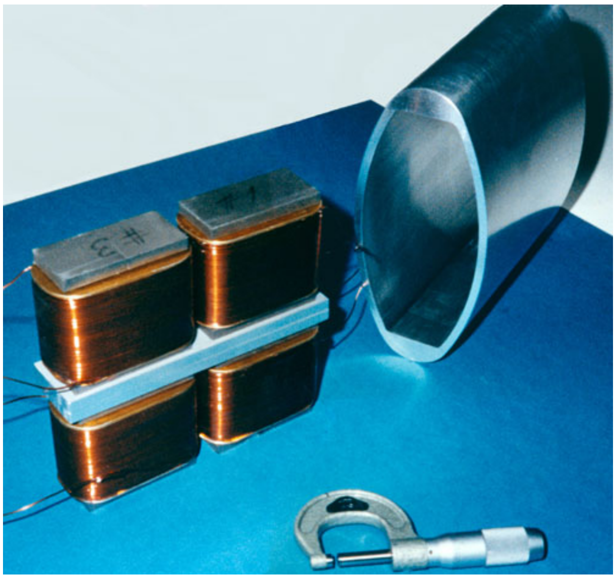

Figure 1.16 Driver assembly for flextensional underwater acoustic transducer (photo: activesignaltech.com)

A Subsea NCW system could range from a single, long endurance AUV using underwater communications with subsurface and/or surface/air units, to a fully-fledged integrated subsea network with deployable sensors and effectors (see Figure 1.17 and Figure 1.18). The system is composed of a field of (untethered) acoustic and non-acoustic sensor and communication nodes, semi-autonomous and intelligent (deployable) mines or torpedoes, and acoustic-to-RF communication gateway(s). It could be deployed from air, surface or submerged platforms. A typical field size should be sufficient to cover an area of about 200 km^2, while the endurance of deployed seafloor and drifting nodes could be in the order of weeks to months.

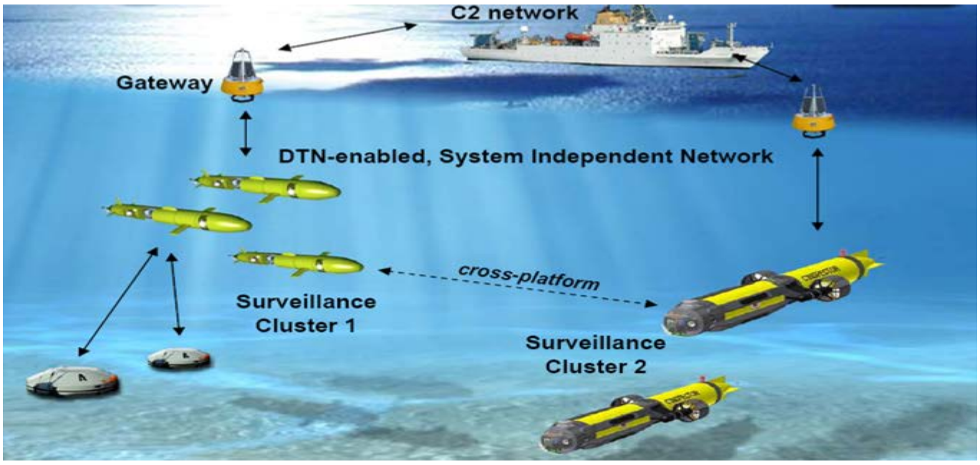

Figure 1.17 System concept illustration of a system with both fixed and mobile nodes using disruption tolerant networks (source: NURC/CMRE).

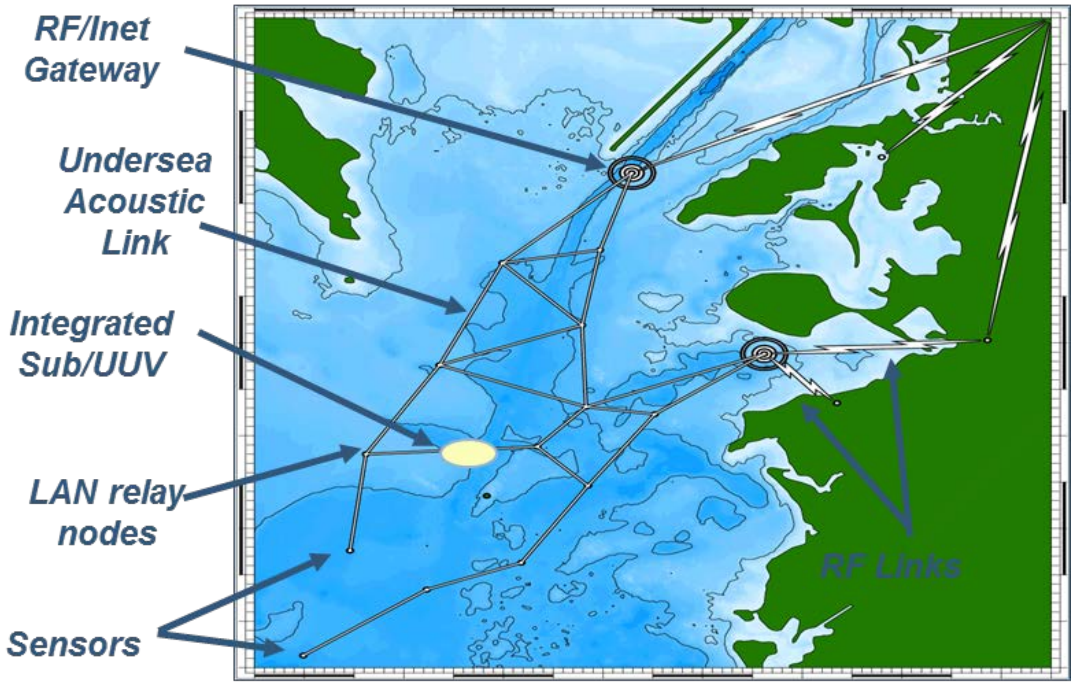

Figure 1.18 Illustration of a deployed Subsea NCW network with sensor and communication nodes and RF gateways (source: SPAWAR).

The system should significantly improve the ISTAR capacity in the littorals, including hidden ISTAR/REA, possibly as part of preparations for amphibious operations. It could also be used to provide long-endurance, sub-surface acoustic fences (first warning) in shallow and littoral waters, or to maintain Safe Areas/Sea Lanes through long endurance surveillance of previously cleared areas/lanes. Other operational interests include harbour protection and Mine Warfare operations ("intelligent minefield"). Of particular interest is that the system should allow submerged platforms to participate in in (close to) real time joint operations (ASW/ASuW).

Further technology development is still needed to achieve full functionality and optimal operational performance of the system. Additional advances are desired or required within:

- Battery technology, fuel cell technology and energy harvesting technology
- Short-distance, high data-rate underwater communication, including non-acoustic methods, with low probability of intercept
- Intelligent data compression system for underwater acoustic communication
- Distributed sensor processing and detection algorithms, taking advantage of small, low-power clocks, with very low false alarm rates
- Accurate underwater navigation systems and procedures

Based on evidence from the NordTech Games, the Subsea Network-Centric Warfare system improves situational awareness in the maritime domain, e.g. in harbour areas and mine-fields, and provides C2 functionality for underwater assets. With the system, it is possible to use force protection resources more efficiently. As one element in an "autonomy complex", this system will expand platform/sensor coverage of the area of operations, significantly enhancing ISTAR capability.

The Subsea NCW system has the potential to contribute to the capabilities shown in Table 1.17 below.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Subsea NCW	*C4 – 105 Communication* *Engagement – 201 Sea targets* *Engagement – 202 Undersea targets* *Engagement –212 Amphibious terrain* *ISTAR – 301 Geographical information* *ISTAR – 302 Oceanographic information* *ISTAR – 304 Target information* *ISTAR – 312 MASINT* *Movement – 402 Sea mine clearance* *Protection – 504 Sea and subsea objects*	*C2 - maritime – tactical* *ISTAR - littoral - tactical – collection* *ISTAR - maritime - tactical – collection* *ISTAR - underwater - tactical – collection* *Protection - littoral – HVA protection* *Engagement - maritime – ASW* *Engagement - maritime – ASuW littoral*	*2.2.2 – Imagery Collection* *2.2.3 – Measurements and Signatures Collection* *2.3.2 –Information Categorization* *3.1.4 – Maneuver to Secure* *3.2.1 – Kinetic Means* *6.1.2 – Wireless Transmission*

Table 1.17 Subsea Network-Centric Warfare can contribute to 23 capabilities within the areas C4, ISTAR, Mobility, Protection and Engagement.

The Subsea NCW system could be employed in important areas of the littorals (i.e. reception points of allied reinforcements), making it difficult for enemy Mine Warfare efforts and submarine operations. It could ultimately replace MCM units and ASW units. The impact matrix on DOTMPLFI (Table 1.18) shows that the introduction of Subsea NCW could heavily affect all elements.

	Technology: Subsea Network-Centric Warfare
Doctrine	Doctrine and tactical concepts will be heavily affected. The possibility to integrate subsurface assets, i.e. submarines, into real-time joint operations will seriously affect doctrine for subsea warfare
Organisation	Could affect traditional submarine C2, demanding a reorganisation of the command structure. Some current units, e.g. MCM, may be replaced and /or new units created
Training	The integration of subsurface assets into real-time joint operations will require training
Materiel	Comprehensive procurement of new materiel. Could ultimately replace units such as MCM units and ASW units. The corresponding platforms could be much simpler and less expensive than today's MCM and ASW platforms
Personnel	Many tasks done manually today will be automated. It might be possible to release personnel to do other tasks or reduce manning, i.e. to use force protection resources more efficiently (could require fewer sonar operators etc.)
Leadership	Introduction of automated systems will allow thinking in new ways – taking higher risks etc. The possibility to integrate subsurface assets, i.e. submarines, into real-time joint operations will affect doctrine for subsea warfare
Facilities	Some storage and maintenance facilities needed
Interoperability	Connects submerged platforms and surface/air platforms real time. The system can be used to de-conflict with own submarine operations, allowing freedom of movement for own submarines

Table 1.18 Assessment of impact on DOTMPLFI for the Subsea Network-Centric Warfare.

4.11 Unmanned Combat Aerial Vehicle

Over the last decade, the military value of armed Unmanned Aerial Vehicles (UAV) that are armed, or otherwise can assist in strike missions against various targets, has been proven. For UAVs being optimized for tasks in non-permissive airspace, i.e. aerial combat against other aircraft or strike against defended targets, the denomination UCAV (Unmanned Combat Aerial Vehicle) is typically used. This definition excludes most of the existing weapon carrying UAVs and instead focuses on future UAVs that are designed to be deployed as capable fighter and bomber aircraft. Some technology demonstrators for ISR, SEAD or Strike exist worldwide. However, for the most demanding roles of unmanned fighter aircraft, comparable efforts are not known at present. One example of existing UAVs capable of completing pre-programmed missions is the autonomous X-47B UAV from Northrop Grumman, which has performed carrier-based launch and recovery without direct human involvement.

Compared to manned aircraft, the UCAV has a smaller volume and weight and allows for a design that can improve range, endurance, speed as well as reduced signatures. This is mainly due to the fact that there is less restriction on the aircraft design, since it is not governed by the need to facilitate a human operator. UCAVs can be designed to withstand larger g-forces than manned aircraft which in combination with improved manoeuvrability could finally improve survivability.

In order for UCAVs to become operational resources, there are technological challenges still to be solved: Artificial intelligence (AI) for combat purposes has yet to prove itself, both concerning reliability and combat effectiveness. Also, development on “Sense and Avoid”-technology is essential for the operation on future autonomous aerial vehicles, in order for them to share airspace with other aircraft. Much research is devoted to both disciplines, and good progress has been made in recent years. Moreover, to take full advantage of platform autonomy, research and development in the field of “motion planning” is required.

Figure 1.19 Boeing’s X-45A UCAV technology demonstrator (photo: Wikimedia Commons).

The fully capable UCAV is an organic airborne ISTAR asset that will carry Active Electronically Scanned Array (AESA) radar, with both Ground Moving Target Indication (GMTI) and Synthetic Aperture Radar (SAR) functionality, operating at a range of 10-20 km. The SAR mode provides imagery in either strip-map or spotlight mode with sub-meter best resolution, whilst the GMTI mode will provide large swath coverage with spotlight, sector and continuous 360 degree azimuth scanning. The system will also have Automatic Target Recognition (ATR) functionality which can be used to recognize ground targets from a specified database. The system will have the capability to automatically track multiple targets through stop / start manoeuvres using interleaved SAR / GMTI modes and target finger-printing. An automated (i.e. without man-in-loop) sensor-to-shooter target engagement for pre-defined high-value targets is also a key capability.

This system can be used for wide-area persistent surveillance / reconnaissance and suppression of enemy activity through automatic engagement of pre-defined high-value, re-locatable, air and ground-based targets in operations of long endurance. Tracking without engagement, and hand-off of lower confidence targets is also a possibility.

Full operational functionality for the system requires an accurate pre-defined database of targets of interest, allowing very-high confidence in the recognition of pre-defined ground targets over a wide area (several square kilometres). The potential for counter-measures, such as false target generation from sophisticated adversaries, must be dealt with. The ethical and legal issues for autonomous systems with targeting functionality must have been explored, rules-of-engagement developed, and the effects of potential incorrect targets (collateral damage, friendly fire) considered.

Automatic target engagement is certainly controversial, and it presently seems unlikely that such an aspect will be featured in initial UCAV operations of a western alliance. Here it seems more probable that the UCAV will detect and track targets; only when it has obtained permission to fire it will engage that particular target. However, if proven combat effective, it cannot be precluded that potential adversaries will exploit this tool; therefore the development in this area should be monitored carefully.

Nordic experience with the use of UCAVs is limited. Sweden has, however, been active in the field of unmanned aerial systems through participation in the nEUROn project, and is conducting research for next generation fighter technology where an autonomous UCAV could be one way of solving future tasks.

The Unmanned Combat Aerial Vehicle is a system that has the potential to contribute to the capabilities shown in Table 1.19 below.

Technology	Capability SE	Capability NO	Capability FI
Unmanned Combat Aerial Vehicle	Engagement – 201 Sea targets Engagement – 203 Ground targets Engagement – 204 Air targets Engagement – 207 Deep interdiction Engagement – 208 SEAD/DEAD Engagement – 210 Electronic attack Engagement – 216 Combat Air support ISTAR – 304 Target information ISTAR – 310 IMINT ISTAR – 312 MASINT ISTAR – 313 RADINT Protection – 502 Air objects Protection – 514 Air escort	Engagement - land – CAS Engagement - land – SEAD Engagement - land – stand-off Engagement - maritime – ASuW littoral Engagement - maritime – ASuW stand off ISTAR - land - operational – SAR/GMTI stand-off ISTAR - maritime - operational – SAR	2.2.2 – Imagery Collection 2.2.3 – Measurements and Signatures Collection 3.1.1 – Maneuver to engage 3.2.1 – Kinetic means 3.2.2 – Non-kinetic means 7.1.1 – Prevent kinetic attack

Table 1.19 The Unmanned Combat Aerial Vehicle can contribute to 26 capabilities within the areas ISTAR, Protection and Engagement.

It is expected that UCAV technology will have significant potential to reduce costs for personnel, education and training since there will be fewer pilots. Furthermore, reduced manning decreases the risk for loss of personnel and allows for solving difficult and dangerous high-risk missions. For the time being it is, however, still uncertain how procurement costs for these vehicles will relate to the cost of more traditional platforms. What is clear is that the introduction unmanned, autonomous systems will have considerable impact on the conduct of air operations, first by affecting TTP, but eventually changes will become pervasive in the armed forces, cf. Table 1.20. “The end result would be a revolution in the roles of humans in air warfare”[10].

[10] Quote from the *United States Air Force Unmanned Aircraft Systems Flight Plan 2009-2047*.

	Technology: Unmanned Combat Aerial Vehicle
Doctrine	Significant revisions of Doctrines/TTP are required to enable the full utilization of UCAV. It will have high impact on both air and support operations; since new possibilities at the operational level must be explored (e.g. mission risk profiles). The international judiciary development regarding unmanned and automated force will have to be implemented.
Organisation	The system will significantly influence the organisation since it needs a unit for control, maintenance/logistics and operation. Could also replace some conventional aircraft
Training	Training in Manned-Unmanned Teaming (MUT) required for pilots, technicians, CRC controllers and staff officers. The interaction between AI and operators has uncertain implications and could affect the need for training. Maintenance of stealth technology requires specialized training.
Materiel	Comprehensive procurement of new materiel
Personnel	Introduction of UCAVs could allow for fewer pilots in the organization while maintaining the same operational capability. Current, remotely piloted aircraft systems (RPAS) indicate significant numbers of personnel, but autonomous UCAVs will most likely reduce this
Leadership	Possible swarming and autonomous operation has high impact on leadership. Introduction of automated systems will support thinking in new ways – taking higher risks etc. Legal and ethical issues regarding the use of attack platforms with or without man-in-the-loop needs to be deliberated at high level.
Facilities	N/A
Interoperability	The perceived ubiquity of unmanned systems will demand focus on the interoperability issue in connection with co-operative ventures

Table 1.20 Assessment of impact on DOTMPLFI for the Unmanned Combat Aerial Vehicle.

4.12 Stratospheric Surveillance Platform

Currently, UAVs such as Global Hawk or Euro Hawk are capable of operating just under 20 km altitude. Having approximately 40 hours of maximum staying power, these systems only offer a very limited operational time on station. The first military applications using light-weight construction winged aircraft with ISR systems for observation of crises areas with a longer time on station are being developed. However, the development in e.g. the USA has been slowed down by budgetary constraints. HALE (High Altitude Long Endurance) / HAP (High Altitude Platform) platforms, based on airship technology, represent a viable alternative. Although significant technological challenges remain, these could be solved within a decade. There is on-going research in several countries, e.g. Italy, Germany, USA and China.

The Stratospheric Surveillance Platform (SSP) is an unmanned, quasi-stationary untethered airship that would operate at high altitude (approximately 20 km) for extended periods of time (12-24 months), and could also be used on patrol. SSPs are to operate at a higher altitude, and for longer time periods, than conventional UAVs. They will be closer to the earth than satellites, and, in contrast to satellites, they can be retrieved for maintenance and when a mission is completed. An SSP can carry up to 500 kg of various payloads, e.g. sensors for observation (IR/VIS, video, camera, radar) and/or equipment for communication and electronic warfare.

The SSP is expected to offer permanent surveillance of large areas of interest with relevant sensor packages, providing automated detection of movements and distinction between persons and animals (only in VIS). The expected ground range is estimated to be about 500 km in diameter at a flight altitude of 20 km (although 1000 km is theoretically possible). The system can also be used as a node for both military and civilian communication needs.

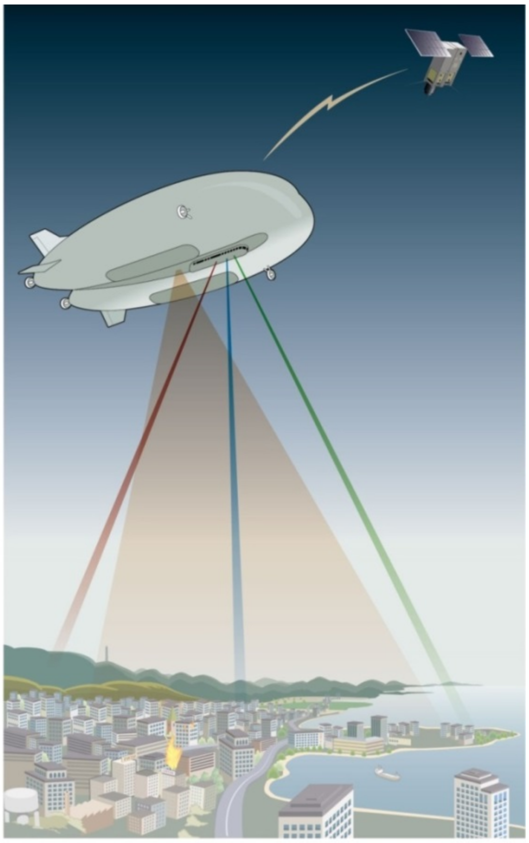

Figure 1.20 Artistic impression of the Stratospheric Surveillance Platform (source: Martin Ek, Framsyn).

The SSP will be subject to several challenges due to its demanding operating environment: It will manoeuvre in the lower stratosphere, where the lowest wind speeds are found. Here the air density, albeit low, is sufficient to support flight, although airships will have to be very large to operate in this environment. In the lower stratosphere, the temperature is low, both the ultraviolet radiation and the cosmic radiation are substantial, and the chemical conditions also make demands on the materials used. The SSPs also have to be able to withstand the strains, such as strong winds, during transport to and from the designated area of operation. Moreover, the lifting gas will be affected by a difference in temperature between day and night of about 30 K.

To maintain an adequate amount of gas in the airship, on board installations for compression and storage of gas are required. Helium and hydrogen are the two options considered for lifting gas. Helium is safer in handling but considerably more expensive than hydrogen. Hydrogen in turn offers better lift, but diffuses more easily through container walls and is highly flammable. A critical point is therefore the development of material for inner or outer cover of the airship in order to keep the uplift gases within the cover for long periods (12-24 months) and to withstand strains. To save weight, it is also desirable to integrate antenna structures into the material, if possible.

Energy supply is a factor that limits operation time. While shorter-mission SSPs may use combustion engines, and could possibly be refuelled by tanker UAVs, the SSP will primarily use electric energy, provided by solar panels, batteries and fuel cells.

The Stratospheric Surveillance Platform is a system that has the potential to contribute to the capabilities shown in Table 1.21 below.

Technology	***Capability SE***	***Capability NO***	***Capability FI***
Stratospheric Surveillance Platform	*C4 – 105 Communication* *ISTAR – 301 Geographical information* *ISTAR – 310 IMINT* *ISTAR – 311 SIGINT* *ISTAR – 312 MASINT* *ISTAR – 313 RADINT*	*ISTAR - land - operational – EO/IR stand-off* *ISTAR - land - operational – SAR/GMTI stand-off* *ISTAR - land - operational – SIGINT stand-off* *ISTAR - littoral - operational – AIS* *ISTAR - littoral - tactical – collection* *ISTAR - maritime - operational – AIS* *ISTAR - maritime - operational – EO/IR* *ISTAR - maritime - operational – SAR* *ISTAR - maritime - operational – SIGINT* *C2 - joint – operational*	*2.2.1 – Signals Collection* *2.2.2 – Imagery Collection* *2.2.3 – Measurements and Signatures Collection* *6.1.2 – Wireless Transmission*

Table 1.21 The Stratospheric Surveillance Platform can contribute to 20 capabilities within the areas C4 and ISTAR.

Experiences from system development indicate that acquisition costs will tend to be substantial, while the cost for operations could be moderate. Providing a commercial service selling high resolution pictures, also to the civilian market, could be a way of controlling operation costs.

Due to its size and low speed, the SSP is a rather vulnerable asset, only protected by its operation in high altitude. If the number of available platforms becomes limited, the loss of one platform would imply considerable consequences to the surveillance task. Thus, in high risk scenarios, the SSPs will have to be a supplement to other surveillance assets. The Stratospheric Surveillance Platform is a system that has the potential to contribute to the capabilities shown in Table 1.22 below.

	Technology: Stratospheric Surveillance Platform
Doctrine	Enhanced situational awareness due to timely (near real time) and reliable information may enable (semi-)automated targeting
Organisation	The system is likely to be operated by novel, dedicated units
Training	Specialised training for operators and maintenance personnel at ground segment
Materiel	Procurement of some systems
Personnel	Personnel needed for handling and maintenance
Leadership	N/A
Facilities	New facilities required for operations, storage and maintenance / repair
Interoperability	N/A

Table 1.22   Assessment of impact on DOTMPLFI for the Stratospheric Surveillance Platform.

List of Acronyms

ABC	Atomic Biological Chemical
ABL	Airborne Laser program
ADC	Analogue-to-Digital Converter
ADS-B	Automatic Dependent Surveillance/Broadcast
AESA	Active Electronically Scanned Array
AFRL	Air Force Research Laboratory (USAF)
AI	Artificial Intelligence
AIS	Automatic Identification System
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATL	Advanced Tactical Laser
ATR	Automatic Target Recognition
AUV	Autonomous Underwater Vehicle
C2	Command and Control
C2I	Command, Control and Information
C3	Command, Control and Communication
C4	Command, Control , Communication and Computers
COMINT	Communication Intelligence
CONOPS	Concept of Operations
COPA	Cooperation Area (NORDEFCO)
COPA ARMA	Cooperation Area Armaments (NORDEFCO)
COPA CAPA	Cooperation Area Capabilities (NORDEFCO)
COPA HR&E	Cooperation Area Human Resources & Education (NORDEFCO)
COPA OPS	Cooperation Area Operations (NORDEFCO)
COPA TR&EX	Cooperation Area Training and Exercise (NORDEFCO)
COTS	Commercial-Off-The-Shelf
CRC	Control and Reporting Centre
DAC	Digital-to-Analogue Converter
DARPA	Defense Advanced Research Projects Agency
DaTARTAN	Danish TARTAN (Tool to Assess Revolutionary Technologies and Assets for NATO)

DOTMPLF	Doctrine, Organisation, Training, Materiel, Personnel, Leadership, Facilities
DOTMPLFI	Doctrine, Organisation, Training, Materiel, Personnel, Leadership, Facilities, Interoperability
DTAG	Disruptive Technology Assessment Game
ELINT	Electronic Intelligence
EO	Electro-Optic
EOD	Explosive Ordnance Disposal
EW	Electronic Warfare
FCS	Future Combat Systems
FEL	Free Electron Laser
FPGA	Field-Programmable Gate Arrays
GBAD	Ground Based Air Defence
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
HALE	High Altitude Long Endurance
HAP	High Altitude Platform
HEL	High Energy Laser
HUMINT	Human Intelligence
HVA	High Value Asset
IED	Improvised Explosive Device
IFF	Identification Friend-or-Foe
IMINT	Imagery Intelligence
IoS	Ideas of Systems
IR	Infrared
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
LaWS	Laser Weapon System
LINAC	Linear Accelerator
MCM	Mine Countermeasures
MCWL	Marine Corps Warfighting Laboratory
MDA	Maritime Domain Awareness
MEMS	Micro-Electro-Mechanical Systems
MoU	Memorandum of Understanding
MuPuRF	Multi-Purpose Radio Frequency
MUT	Manned-Unmanned Teaming
MW	Mine Warfare
NASA	National Aeronautics and Space Administration (U.S.)
NCW	Network-Centric Warfare

NORDAC	Nordic Armaments Cooperation
NORDCAPS	Nordic Coordinated Arrangement for Military Peace Support
NORDEFCO	Nordic Defence Cooperation
NORDSUP	Nordic Supportive Defence Structures
NURC	NATO Undersea Research Centre (now Centre for Maritime Research and Experimentation, CMRE)
ONR	Office of Naval Research (U.S.)
OTH	Over-The-Horizon
PE	Processing/Exploitation
REA	Rapid Environmental Assessment
RF	Radio Frequency
RPAS	Remotely Piloted Aircraft Systems
RTO	NATO Research and Technology Organisation (now NATO Science and Technology Organisation, STO)
SAR	Synthetic Aperture Radar
SAR	Search-And-Rescue
SASS	Situational Awareness Sensor System
SEAD	Suppression of Enemy Air Defence
SIGINT	Signals Intelligence
SOF	Special Operations Force
SPAWAR	Space and Naval Warfare Command
SSP	Stratospheric Surveillance Platform
THEL	Tactical High-Energy Laser
TTP	Techniques, Tactics and Procedures
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UGV	Unmanned Ground Vehicle
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicle
VIS	Visual

About FFI

The Norwegian Defence Research Establishment (FFI) was founded 11th of April 1946. It is organised as an administrative agency subordinate to the Ministry of Defence.

FFI's MISSION

FFI is the prime institution responsible for defence related research in Norway. Its principal mission is to carry out research and development to meet the requirements of the Armed Forces. FFI has the role of chief adviser to the political and military leadership. In particular, the institute shall focus on aspects of the development in science and technology that can influence our security policy or defence planning.

FFI's VISION

FFI turns knowledge and ideas into an efficient defence.

FFI's CHARACTERISTICS

Creative, daring, broad-minded and responsible.

Om FFI

Forsvarets forskningsinstitutt ble etablert 11. april 1946. Instituttet er organisert som et forvaltningsorgan med særskilte fullmakter underlagt Forsvarsdepartementet.

FFIs FORMÅL

Forsvarets forskningsinstitutt er Forsvarets sentrale forskningsinstitusjon og har som formål å drive forskning og utvikling for Forsvarets behov. Videre er FFI rådgiver overfor Forsvarets strategiske ledelse. Spesielt skal instituttet følge opp trekk ved vitenskapelig og militærteknisk utvikling som kan påvirke forutsetningene for sikkerhetspolitikken eller forsvarsplanleggingen.

FFIs VISJON

FFI gjør kunnskap og ideer til et effektivt forsvar.

FFIs VERDIER

Skapende, drivende, vidsynt og ansvarlig.

FFI's organisation