



## Report

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14 September, 2012

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### **Technology Forecast 2012Military utility of ten technologies** **- a report from seminars at the SNDC Department of Military-Technology** One annex – SwAF list of capabilities (in swedish)

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## Summary

Ten technology forecast reports from the Fraunhofer Institute have been reviewed by staff at the Department of Military-Technology at the Swedish National Defence College (**Note** that there probably are other technology areas, equally interesting, but not included in this study). The task given by FMV was to assess the military utility of the chosen technologies in a time frame from 2025 to 2030, from a SwAF viewpoint.

The method used was first to make a summary of each forecast report. The technology was then put into one or more scenarios that are assessed to be the best in order to show possible utility as well as possibilities and drawbacks of the technology. Based on a SWOT-analysis, the contribution to SwAF capabilities and the cost in terms of acquisition, C2 footprint, logistic footprint, doctrine/TTP, training, facilities and R&D were assessed. Conclusions regarding the military utility of the technology were drawn.

We introduce our definition of **military utility** as being activities that efficiently and with the lowest cost in terms of lives and materiel lead to fulfilment of the mission objectives.

The technologies were grouped in three classes; technologies with a significant potential, with uncertain potential and with negligible potential.

The following technologies were assessed to have a **significant** potential for military utility;

- Augmented Reality
- Nano air vehicles
- Solid State Laser weapons

In the scenarios studied, Augmented Reality (AR) is assessed to have a positive impact on several SwAF capabilities, especially for C2 and intelligence. AR is a relatively mature technology, applicable in many different branches. There are examples where AR is already applied with great success, e.g. Head-Up-Displays, HUD. The technology has proven its value. However, there are well known drawbacks to the technology such as weaknesses regarding models, increased weight for dismounted soldiers, power consumption etc. There is also a risk that personnel will have problems solving their tasks when AR systems fail, not being used to fighting without supporting systems.

Nano air vehicles (NAV's) have been assessed to contribute to a large range of capabilities, primarily intelligence. Their lifecycle cost has been assessed to be low, since development in this area is commercially driven, bringing down acquisition costs. Also, FAA has decided to allow NAV's in controlled air space from 2015, which is expected to lead to an increase in civilian use of NAV's. The technology is relatively mature even though there are obstacles concerning

suitable materials, energy efficient propulsion systems as well as miniaturized microprocessors and software to control them.

In the scenario studied, High Energy Solid State Lasers are assessed to have a positive impact on SwAF capabilities to engage targets on surface and in the air. The technology can be used to protect vessels on the surface and thereby increase survivability. The development of SSL in the given timeframe is expected to lower cost per shot and avoid the environmental problems with use of chemical lasers. Neighbouring military powers are expected to use laser weapons in the future, therefore SwAF should monitor the development of the laser weapons technology and develop and purchase adequate countermeasures.

The following technologies were assessed to have **uncertain** potential for military utility;

- Metamaterial cloaking
- Electromagnetic gun
- Small satellites
- Ultra-violet communication

Metamaterial cloaking, if realisable in the future, is assessed to be firstly implemented in the acoustic spectrum, since manufacturing of small structured cloaks for the shorter wavelengths in the optic and radar spectra is believed to be more difficult. Cloaking of submarines is primarily assessed to increase the survivability against torpedoes having active sonar. The use of cloaked mines could pose a deterring threat, even to advanced amphibious operations against Sweden. The technological development in this area should be closely monitored and compared to existing, maturing techniques for countermeasures and for the development of broad spectrum active torpedoes. The greatest concern is that cloaking will have negative impact on submarine manoeuvrability.

The electro-thermal chemical (ETC) gun seems to be a first step towards a fully electrical gun such as the rail-gun or the coil-gun. The fully electrical guns have been a work in progress for some decades and there are still remaining challenges both concerning electrical power supply and design materials. When or if, they will be operational is difficult to say.

The military utility of small satellites is disputed, despite an assessed contribution to several of the SwAF capabilities. The main reason for this is that there seems to be other alternatives which provide the desired capabilities, at a lower cost. Furthermore, the realisability and performance of small productionline manufactured nanosatellites is uncertain. However the scenario has shown that there are benefits to the military utility not met by other resources, e.g. the capability to perform surveillance and reconnaissance in operational areas globally without risking violation of the territorial integrity of other states or the lives of military personnel. Since there is a great interest in the technology area and several programmes are ongoing internationally the knowledgebase is

assessed to be significantly better in a five year period. Also, the Swedish in depth study of space exploitation is soon to report.

Ultra-violet communication has uncertain potential for military utility within the period, but the technology is assessed to have a positive impact on SwAF capability to maintain communications. The theoretical understanding of the area is low. It is therefore uncertain if systems can be realized in the time frame. However, if commercial applications are developed, the prospect of military applications might change. In that case UV-communication could be a complement to RF-communication but is not foreseen to replace it.

The following technologies were assessed to have **negligible** potential for military utility;

- Biomimetic unmanned underwater vehicles (UUV)
- Automated behaviour Analysis
- Evolutionary Robotics

Biomimetic UUV's could be used for covert surveillance and inconspicuous naval reconnaissance missions at sea or in amphibious missions. Even though the report focuses on fishlike propulsion, the military utility of UUV's is assessed to be mostly dependent on the development of advanced automation and learning systems. As of now, we assess other existing technologies as being preferable due to lower cost and less complexity. The performance of UUV's needed for SwAF capabilities are assessed to be far off into the future. Simpler UUV systems could however be used by potential adversaries for monitoring our own base areas and hence the development should be monitored from a protection point of view.

Automated behaviour analysis may be of some relevance for increased security screening and surveillance. The primary military utility of the technology will however probably be for international activities and to a lesser extent for increased base security in Sweden. Generally the main applications for this kind of technology are assessed to be for civilian use in public spaces and close to high value areas like airports, important official buildings and other similar objects.

Evolutionary Robotics, here restricted to the sub domain Advanced Robotics, has uncertain potential for military utility within the period. In the scenarios studied the technology is assessed to have a positive impact on a broad range of SwAF capabilities. The area is large and inconsistent comprising sub areas that are assessed to have significant potential, but also those that are believed to have negligible potential or where technological obstacles might retard the development.

Our evaluation of the used method shows that there is a risk that the assessment is biased by the participating experts' presumptions and experiences from their own field of research. The scenarios that were chosen do not cover all possible aspects of the technology and their possible contribution to operational capabilities. It

should be stressed that we have assessed the ten technologies' military utility in the presented scenarios, not the technology itself. The chosen definition of military utility clearly affects the result of the study. The definition is believed to be good enough for this report, but could be further elaborated in the future.

The greatest value of the method used is its simplicity, cost effectiveness and the trade off that it promotes learning within the working group. The composition of the working group and the methodology used is believed to provide for a broad and balanced coverage of the technologies under study.

## **Introduction**

### **Scope**

This report is the result of a review of ten technology forecast reports from Fraunhofer Institute. The review was carried out at the Swedish National Defence College by staff at the Department of Military-Technology, on commission by the Swedish Defence Materiel Administration, FMV. The task was to assess the military utility of the different technologies in a time frame from 2025 to 2030.

The review of the technology forecast reports form one chapter each in this report.

### **References**

The following reports, initially elaborated at the Fraunhofer Institute but given FMV document designation, were reviewed:

1. Metamaterial Cloaking, Ed. 1.0, 11FMV2150-29, 2011-11-30 (Fraunhofer INT, Dr. Klaus Ruhlig)
2. Augmented Reality, Ed. 1.0, 11FMV2150-24, 2011-11-30 (Fraunhofer INT, Dr. Klaus Ruhlig)
3. Nano Air Vehicles, Ed. 1.0, 11FMV2150-27, 2011-11-30 (Fraunhofer INT, Dr.-Ing. Guido Huppertz)
4. High Energy Solid-State Laser Weapons, Ed. 1.0, 11FMV2150-22, 2011-11-30 (Fraunhofer INT, Dr. David Offenberg)
5. Automated Behaviour Analysis, Ed. 1.0, 11FMV2150-30, 2011-11-30 (Fraunhofer INT, Dipl.-Ing. Thomas Euting)
6. Biomimetic UUV, Ed. 1.0, 11FMV2150-23, 2011-09-01 (Fraunhofer INT, Dr. Martin Müller)
7. Electromagnetic Guns, Ed. 1.0, 11FMV2150-21, 2011-11-30 (Fraunhofer INT, Dipl.-Ing. Wolfgang Nätzker)
8. Small Satellites, Ed. 1.0, 11FMV2150-28, 2011-11-30 (Fraunhofer INT, Dr.-Ing. Guido Huppertz)
9. Evolutionary Robotics, Ed. 1.0, 11FMV2150-26, 2011-11-30 (Fraunhofer INT, Dr. Martin Müller)

10. Wireless UV-Communication, Ed. 1.0, 11FMV2150-25, 2011-11-30  
(Fraunhofer INT, Dipl.-Ing. Thomas Euting)

**Definitions**Military utility

Activities that efficiently and with the lowest cost in terms of lives and materiel lead to fulfilment of the mission objectives.<sup>1</sup> Future work is planned in order to further elaborate the definition.

**Method**

The method consists of four steps. It was chosen in order to be efficient and take advantage of the professional expertise of the reviewer.

Step 1: The reports were distributed among the participants of the working group, on the basis of their special interest and expertise. Each reviewer was responsible for reviewing one or two reports.

Step 2: The reviewer wrote a summary of the report and defined one (or more) tentative military technical system and put it in a possible scenario for the Swedish Armed Forces in the timeframe 2025-2030. The purpose of each scenario is to illustrate the usefulness of the technology and hence to be as convincing as possible while being in accordance with the reported technology forecast.

Step 3: Each review was discussed at a seminar. The reviewer shortly introduced the technology, presented the technical system concept and the scenario. The reviewer's role was to be an advocate of the military utility of the technology. The other participants' role was to support or criticize the concept. At the seminar a SWOT-analysis, an assessment of the technology contribution to SwAF capabilities and an assessment of the cost was made. The discussion was documented with a tape recorder.

Step 4: The result of the seminar was documented and conclusions on the military utility of the technology were drawn. The results were summarized in a Capability matrix in chapter 13.

**The working group**

The working group consisted of staff members from the Department of Military-Technology at SNDC:

Kent Andersson, Lt Col (AF), Licentiate of Technology  
Peter Bull, Docent in Military-Technology  
Lars Löfgren, junior lecturer, MSc  
Bengt Mölleryd, Licentiate of Technology

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<sup>1</sup> Åke Sivertun, Militärgeografi och GIS – delar av militärteknik, Kungliga Krigsvetenskapsakademiens Handlingar och Tidskrift, Nr 1/2012

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Stefan Silfverskiöld, Cdr (N), PhD  
Åke Sivertun, Docent

The seminars were also attended by:

Martin Bang, 1. Serg (A), MSc  
Gunnar Hult, Professor of Military-Technology  
Pernilla Foyer, Lt (AF)  
Björn Persson, MSc  
Toivo Sjöberg, Lt Col (Amphibious Corps)  
Patrik Stensson, Maj (AF), MSc  
Peter Stureson, Capt (AF), MSc

## **Metamaterial cloaking**

Ref: [1]

### **Introduction**

Metamaterials are artificially structured materials and hence can be made to exhibit properties that cannot be found in nature. In this application the objective is to design “cloaks” for objects to make them invisible in a specified part of the electromagnetic spectrum or in a part of the acoustic spectrum. There are two different approaches. Firstly, to make a design where the incident radiation or wave is deflected and guided around the object. Secondly, to make a design that completely cancels any scattering from the hidden object. The report claims that the result in both cases is the same – the passing wave connects to the initial direction of propagation and the object becomes “invisible”.

### **Identified constraints**

From analyzing the report the following constraints in design have been found:

- The design of the cloak is dependent on the shape of the object. The simplest case is a sphere. A conclusion is that it will be extremely difficult to make a complex shaped object invisible in every incident angle.
- The second approach design also requires a perfect match between the cloak properties and those of the concealed object.
- Metamaterials have to be structured on a size scale considerably smaller (typically 1/10 -1/100) than the wavelength of the incident radiation and hence:
  - It is difficult to produce a broadband design, especially using the second approach design.
  - It becomes more difficult and time consuming to produce cloaks the shorter the wavelengths are. In the visible wavelength range the structure will have to be on the nanometer scale, according to the report.

Conclusions in the 2025- 2030 timeframe:

It will be extremely difficult to make a complex shaped object invisible in every incident angle – strive towards spherically shaped designs or cylindrically shaped, if limiting the aspects of incoming waves to two dimensions.

Cloaks will probably be integrated with the object, especially if they are large and have a complicated shape.

Broadband, carpet like, cloaks can probably be produced to hide objects on the ground. When the carpet cloak is placed on the object the whole system is perceived as a flat surface.

It is more realistic to picture an application in the acoustic spectrum, or the radar spectrum, than in the visible spectrum.



**Assumptions**

The concept scenarios are based on the following assumptions.

It will be possible in the 2025-2030 timeframe to make

- Spherical, or cylindrical (2D), large objects, invisible in the acoustic spectrum
- Less complex shaped, large objects, invisible, in some perspectives, and in some narrow parts of the electromagnetic spectrum

**Suggested military use**

The following military use for metamaterial cloaks are suggested in the report:

- Protecting military platforms or sensors in operation – at least in limited wavelength spectra – from weapons targeting
  - Acoustic cloaking can be employed to hide underwater objects like submarines or naval mines from sonar
- Protecting military platforms in base from airborne radar surveillance systems
- Protection against damaging radiation, such as High Power Microwaves (HPM)

The report identified the following platforms to be of interest: undersea platforms; fighting land vehicles; logistic, command and surveillance land vehicles; unmanned vehicles; fighting naval surface platforms; logistic and naval support platforms and sea mines.

**Concept scenarios in 2030**

The following scenarios are assessed to be consistent with constraints, suggested military use and the long-term study on SwAF development;

1. Cloaked submarine
2. Cloaked mines and subsurface sensors

*Cloaked submarine***Description**

There is tension between Sweden and a neighbouring high-tech strong sea power and an invasion over the sea is imminent. Our submarines' mission is to gather intelligence on the adversary's activities and to provide early warning (FU2). The submarine is not to open fire unless fired upon.

When the submarine closes in on the adversary's assembly area they meet a red force submarine firing two high frequency, active sonar, torpedoes towards the ship. Our submarine launches countermeasures, returns fire, goes into silent mode and moves away from the position in which it was discovered turning the "invisible" side towards the red force submarine and the approaching torpedoes.

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Thanks to this manoeuvre our submarine disappears in front of the torpedoes and they miss their target.

The red force submarine is sunk and it becomes important to quickly report the events to HQ. Our submarine ascends close to the surface, raises the HF antenna having a cloak design with optimum properties in the 3-10 mm radar band. The red force sea surveillance radars do not intercept the antenna and hence our submarine is not detected and cannot be tracked when finally descending and moving away from the area.

### *SWOT-analysis*

The following strengths, weaknesses, opportunities and threats with the cloaked submarine concept scenario were identified at the seminar:

#### Strengths:

- Higher survivability due to reduced acoustic signature to active torpedoes. The cloak is probably most effective mounted on the tower since this is the weakest part of the submarine and the most probable target for the torpedoes.
- Better situational awareness in SwAF since the submarine HF antenna can be raised to transmit orders and information with a reduced threat of being detected by airborne surveillance radars. This is, however, not a big issue since the transmission, even today, would be very quick and the probability of detection would be low anyway. Orders on the long wave radio band can be received when submerged.
- Higher mission accomplishment due to reduced risk of interception, if the submarine is invisible to active sonar.

#### Weaknesses:

- An expensive construction. But, since a submarine is a high value asset the investment should be considered. Maybe the cloak can be used on carefully chosen parts of the submarine, for example to reduce scattering from critical junctions between tower and ship.
- Since the crew will not trust the cloak as the only countermeasure it is important to design other countermeasures not to reduce the value of the invisibility properties.
- Possible need for balancing speed/friction in water and cloak performance. An assessment is that time on station cannot be allowed to be reduced too much.
- Sensitive surface having impact on handling procedures in base.

#### Opportunities:

- A design preventing the submarine from being detected in the first place. This would have given the submarine in our scenario the opportunity to continue on its route and complete its mission. In this scenario the

submarine was probably detected by magnetic sensors or passive acoustic sensors. But thanks to cloaking the enemy torpedoes missed their target.

**Threats:**

- Sea tulips and other flora and fauna having impact on the intended properties.
- Development of torpedoes with multiple band active sonar
- Development of torpedoes with a passive electromagnetic sensor – not known at present

***Cloaked mines and subsurface sensors******Description***

A red side naval task group enters Swedish territorial waters with the intent to launch an amphibious operation on SÖDERTÖRN. They sweep for mines in areas with assessed higher probability of occurrence. Since Swedish mines are known to be equipped with state of the art signature sensitive sensors, ship-counters etc. the aggressor decides to use the more time consuming technique to hunt mines individually. Mine hunting vessels are sent forward using sonar systems to detect high-tech mines and Remote Operated Vessels (ROVs) to destroy them. Some of the mines are however cloaked in the acoustic wavelength spectrum and cannot be detected by the mine hunting vessel. The result is a considerable loss of ships on the red side, a slowdown of the operation and maybe even a failed amphibious operation.

***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

**Strengths:**

- Low probability of detection in a broad part of the acoustic spectrum. A mine can be designed to have favourable size and shape, from a cloaking perspective.

**Weaknesses:**

- Sensitive surface having impact on handling procedures before deployment
- Design constraints in shape due to the need for invisibility

**Opportunities:**

- Forces an opponent to use greater, and more exclusive, resources on mine sweeping

**Threats:**

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- Sea tulips and corresponding flora and fauna having impact on the intended properties

### Assessed capability impact

The proposed concepts are assessed to have impact on the SwAF capabilities listed below:

- P 503 Capability to protect objects on the ground against attack
- P 504 Capability to protect objects on and under the surface against attack
- P 505 Capability to protect C3I systems against attack

### Footprint/cost 2025 – 2030

The following list is a compilation of anticipated footprints created by the concept in use.

Item	Assessment
Acquisition cost/ System	Considerable, more expensive towards shorter wavelengths
C2 footprint	None
Logistic footprint	New procedures on how to handle ships or mines, in order to keep them clean and maintain their best performance
Doctrine/TTP	Yes, new tactics will have to be developed
Training	Training of personnel in techniques to handle ships or mines, in order to keep them clean and maintain their best performance
Facilities	New facilities needed to handle ships or mines, in order to keep them clean and maintain their best performance
R&D	Cloaking for underwater purposes will probably have to be developed in military R&D programs.

### Conclusions on military utility

Metamaterial cloaking has an uncertain potential for military utility. In the scenarios studied, the technology is assessed to possibly have a positive impact on SwAF capabilities P503-505, and especially the capability to protect subsurface objects from detection and engagement.

The review has shown that cloaking of submarines and mines in the acoustic spectrum are probably feasible in the 2025-2030 timeframe. The cylindrical shape of a submarine is suitable for cloak designs. Submarines are high value assets and could probably bear the acquisition costs involved. The benefit would be higher survivability due to reduced signature to active torpedoes. The need for cloaks must however be balanced with other paths of development and techniques for reducing the probability of detection in the first place and with the development of countermeasures. The cloak cannot be allowed to reduce the submarines' speed/or increase friction through water since this will affect time on station. Mines are of simpler shape and do not have to manoeuvre through water. Cloaked mines will be a serious threat, even to advanced amphibious operations.

Cloaking in radar wavelengths is interesting, e.g. protecting military platforms in a temporary base from airborne radar surveillance systems. Cloaking in shorter wavelength spectra is still considered to be far off into the future. The technological development in this area should be closely monitored and compared to existing, maturing techniques for countermeasures and for the development of broad spectrum active torpedoes.

## **Augmented Reality**

Ref: [2]

Other references:

- Gustafsson T., Carleberg P., Nilsson S., Svensson P., Sivertun Å. & Le Duc M. (2004) Mixed reality för tekniskt stöd. Mixed Reality for technical support. Linköping, FOI 2004, 57 p. (FOI-R--1198--SE)
- Gustafsson T., Carleberg P., Nilsson S., Svensson P., Sivertun Å. (2005) Mixed reality systems for technical maintenance and gaze-controlled interaction. (FOI-R--1695--SE), (In Swedish English abstract).

## **Introduction**

Augmented Reality (AR) is a group of technologies that are used to improve the capabilities to observe, understand and communicate spatial information, mostly in the visual domain. When for example looking at a battlefield through an appropriate technical device, the visual information can be mixed with sensor data obtained with a night vision device, Infrared (IR), radar or other sensors. It is also possible to mix the visual image with a digital map that shows where land mines or other, to the naked eye, invisible things are placed.

The technology also allows the user to share (if the system is designed in that way) his view with colleagues in order to be able to explain or ask for help to understand a complex reality. In this way AR has been suggested to provide support in logistics and to aid repairmen with instructions for how to repair complicated technical equipment (the whole repair manual can be built into the system in a compact portable computer). It is also suggested that a medical doctor

in theatre together with a specialist, at a distance, could be able to perform complicated surgery, mixing x-ray and ultrasonic diagnostic images on top of the tissues that are treated.

The technique is also referred to as Mixed Reality (MR) which is the technologies used to mix reality and “virtual” or additional information for the user. Here, two approaches are most common – namely *video see through* and *optical see through*. In the video see through both the surroundings and the additional information are presented through video images on a display. In optical see through the surroundings are presented through an optical system or a semi-transparent mirror on which additional information is superimposed. The later system is more technically challenging and therefore less common.

Dr. Klaus Ruhlig at Fraunhofer concluded that AR is a “very promising technology because of its unique integration of virtual information and real objects”.

### **Identified constraints**

Dr Ruhlig continues “However, its full potential will not be realized until several technical challenges are overcome”. In particular, a satisfactory solution to the problem of tracking, position and orientation is needed. In addition, more sophisticated display technologies, especially HMDs (Head Mounted Displays) are needed, that can present the virtual information without restricting the user too much. For example, it would be desirable to have smaller and lighter HMDs.

### **Assumptions**

The concept scenarios are based on the following assumptions. There must be an infrastructure of digital maps and other harmonized spatial data. Those data must further be possible to fuse with sensor data and automatically or manually entered intelligence data etc. There must be available digital hand books and manuals for the systems that should be repaired. There must be systems for communication where the balance between “fat” and “lean” user segment ensure that the user also have a minimum of data in his own terminal in case that the communication part of the ICT solution fails. There should be procedures to handle and ensure safe, encrypted and perhaps also secret or sensitive data in the system. Several MMI questions must also be solved to make the systems accepted by the users.

### **Suggested military use**

AR is according to the report considered to be potentially of high importance for military applications. For instance, AR can be used to supply relevant information to soldiers within the framework of network centric warfare. This can significantly enhance the situational awareness of soldiers in the battlefield which is especially of interest in urban terrain [6]. For example, mobile AR systems based on HMDs could be used to display positions of enemy forces and friendly units, as is shown in fig. 3 in the report.

In a similar way, the positions of mines or information about certain buildings could also be presented. In this sense, AR can be viewed as an important building block to achieving information superiority.

Another possible military application could be the assembly of complex machinery or structures like communication systems [1, 3]. In this case, instructions can be easier to understand if they are available, not as usual manuals, but as information superimposed on the actual equipment, for example visualized by computer animations. In a similar way, the maintenance and repair of complex objects like vehicles and airplanes can be facilitated by giving instructions and presenting blueprints and manuals on top of the structures.

### **Concept scenarios in 2030**

Scenarios suggested for judgment of the relevance of the AR technology are (N.B. these are only a few examples of many plausible scenarios in this area):

1. Information for driver in combat vehicles (all arenas)
2. Support to dismounted soldiers in urban environments
3. Support in military logistics
4. Medical support

#### *Information support for driver in combat vehicle*

##### ***Description***

The driver of combat vehicles of all kinds doesn't have sufficient view in all directions, especially not in the rear direction. If it was possible to add information about enemy vehicles, blue forces and recommendations for the best choice of paths with respect to location of land mines etc., AR would augment survivability and mission accomplishment. Today the driver of fighting vehicles has to raise his head through the manhole in order to get a better overview of the situation. This is of course a dangerous habit as the position not only is unprotected for the driver but it also leaves the whole vehicle more vulnerable to attacks and influences of different kinds, e.g. CBRN threats.

The problem with absence of sight when the vehicle is moving backwards has in some cases been solved in a way that the mechanics added a civil rear observation camera (made for busses or trucks) and added an extra monitor to handle. By adding a number of cameras around the vehicle together with the possibilities to record also in IR and night vision modes would remove potential problems in handling different devices for navigation and night goggles for firing. If additional information about own and enemy forces is added this will also aid the decision making process for the soldiers and ease the burden of too much information (information overflow) through several information devices.

The need to coordinate head and eye movements for the coordination of surrounding image and additional information will be quite easy through different approaches with accelerometers attached to the helmet or a pattern of light diodes

in the ceiling that keep track of the head movements. Also eye movements are possible to track in real time for control of focus and for eye gazed interaction with the system. In Gustafsson et al (2004, 2005) this was described and tested but further development is perhaps necessary to fine tune the equipment.

### ***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

#### Strengths:

- The technology is reasonably mature and simple
- Combination of navigation, blue force tracking and targeting simplifies and enhances the operation
- It can be used also for maintenance and other purposes
- The need for the technology is expressed in several services and arms

#### Weaknesses:

- There must be coordination between different areas of responsibilities in the material procurement
- There must be harmonisation work between different providers of technologies for sensors, night vision systems, navigation and weapon systems.
- The technology has to be enhanced with respect to “simulator sickness” and performance
- Redundant functionality must exist in case the system is damaged or malfunctions

Our judgment is that such a system should not only give one service to the driver but include sensor-data fusion together with navigational aid and perhaps other functions. However, there is a need for emergency systems that makes it possible to drive and navigate also if the AR system fails. Traditional navigational skills must be enhanced by training with back-up systems.

#### Opportunities:

- Augmented reality through head mounted displays could with proper training and adjustment of the working procedures give a better operational picture and understanding
- Situational awareness of own forces as well as enemy forces will give better decisions
- Logs of training can be used for debriefing and discussions about the tactical behaviour



- AR could be used for virtual training of weapon systems that in other cases would need huge areas and safety arrangements
- AR can be used for repair and maintenance as instructions and manuals can be carried in a small, easy to use computer.
- AR can be used for distance guidance by experts that can observe for example technical or medical problems and propose proper actions.
- AR can be used to document a difficult situation and the documentation could be used as evidence for legal action.

**Threats:**

- All technical devices depend on an infrastructure to work (electricity, spare parts, backups etc).
- A balance between reliability and performance must be found to provide system performance that is good enough for the task and the time required.
- The system must be flexible to allow changes in instructions and performance to meet new threats and technologies in the future.
- The system must further be designed with a balance of need for bandwidth for communication and born data.
- Risk for manipulation of information.
- Consequences of not introducing the system.

***Support to soldiers in urban environment******Description***

Several sources stress the problems when fighting in urban areas and there are several suggestions for how to provide real time updated information as well as detailed information about the sewage system, tunnels and information about snipers on roofs and in buildings. Navigation in urban areas can be difficult, especially if the roads are narrow and irregular and the land marks – that could be used for navigation – are few or difficult to see. An AR system seems to be able to fulfil several of these needs. There are systems for inertial navigation together with systems for recognition with help of point clouds that give the needed redundancy to the system.

***SWOT- analysis*****Strengths:**

- Different groups or patrols could coordinate their actions in a much more sophisticated way.
- Risks could be avoided or eliminated to a higher degree.
- Local capture of intelligence in exchange for satellite or UAV observations

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- Exchange of observations and verification of suspicious objects or situations

### Weaknesses:

- The system is perhaps too heavy for every soldier to carry
- The risk that higher officers start to command subordinate level

### Opportunities:

- New form of mission command where different patrols and groups can share the same operational picture and coordinate their activities and support each other in difficult situations.
- By smart positioning one group can see “around corners” for another group which could reduce risk of casualties.
- The risk that the higher officers start to command at low levels is a question of training.
- If only the commander or his deputy is equipped with the system this could perhaps be bearable.

### Threats:

- Technical systems might fail, therefore training and education is needed in order to understand the strengths and possible weaknesses of the system.

*Support in Military Logistics Technical services.*

### ***Description***

Military equipment becomes increasingly sophisticated and difficult to maintain and repair. In best cases also the quality is improved implicating that the need for maintenance personnel will decrease. For instance, the Volvo dumper on which the Archer artillery is installed has a Meantime Between Failure (MBF) rate that is so good that Volvo has centralized the support function in order to be able to maintain their competence in the diagnosis and repair of rare problems. By introducing expert systems for repair, or by adding a digital maintenance manual with instructions how to dismount and replace spare parts, the access to the equipment and the safety in operations could possibly increase.

### ***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

### Strengths:

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- In many cases regular maintenance such as check of oil level, small adjustments etc. are crucial for the functionality and life expectancy of a vehicle or other equipment. By facilitating maintenance and introducing expert systems, the functionality and availability of the equipment and their military usefulness will increase.

### Weaknesses:

- The question is whether a formalized knowledge based system can replace personal experience.
- Here comparisons with civilian systems for technical support could be investigated in order to see the extent to which trivial problems could be solved through the automated system leaving more time to concentrate on more tricky problems.

### Opportunities:

- As the military forces are reduced and the number of specific pieces of systems is suspected to be much lower than earlier, the capabilities and function of these will increase in importance in the future.

### Threats:

- The documentation and maintenance manual of a JAS fighter is heavier than the whole airplane. If someone destroys the computer or hard disk it is still easier to have a backup somewhere than a new set of documentation in paper format.
- Unauthorized downloading or copying of documentation can be avoided with systems to encrypt data. To develop this in cooperation with experts on maintenance and AR is necessary in order to find suitable solutions to this potential problem.

*Support in Military Logistics Medical services.*

### **Description**

Military medical services are an area where expert help could be crucial. Civilian experiences from telemedicine are promising. This need is especially vital when front line medical care in remote places is performed by only one general surgeon that must perform life saving interventions. Also such a system could be very useful in hospitals where several operations are going on in parallel and colleagues have to ask for a second opinion in difficult cases.. An AR system allows someone from outside to take part in the diagnosis and decision making without entering into the operating theatre and without rigorous sterilization routines.

***SWOT-analysis*****Strengths:**

- Medical services are not only important in order to keep up the fighting spirit but further to keep the ability to act.
- If diagnosis and treatment can be more efficient and more accurate, the chance of saving lives increases.
- Magnetic Resonance (MR) and other equipment that are needed to make qualified diagnosis in trauma can be used more efficient.
- The few specialists that are available to make diagnoses with help of such equipment can be used more efficiently as built in functions for automated diagnosis can be used to identify difficult cases where extensive experience and wisdom have to be consulted.

**Weaknesses:**

- Some cases have been reported where physicians that are used to analogue x-ray images have a problem judging a digital image. As digital x-ray and other images can be stretched and enhanced, the risk for misjudgement increases. As it takes several decades to train a physician in image diagnosis there will be a period when there are two different cultures working in parallel.

**Opportunities:**

- In the future most physicians will work in a digital environment. The possibility to use different diagnostic images together with support from knowledge based systems and telemedicine will probably become standard procedure.

**Threats:**

- If the military forces do not invest and plan for procedures that take advantage of new technologies such as AR there will be fewer doctors and medical staff available that can do their job without this support.

**Assessed capability impact**

The proposed concepts are assessed to have impact on the SwAF capabilities listed below:

- C 102 Capability to command on operational level
- C 103 Capability to command on tactical level
- C 105 Capability to maintain communications
- E 213 Capability to affect targets in urban terrain

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- I 301 Capability to obtain and deliver geographical information
- I 302-303 Capability to obtain and deliver oceanographic and meteorological information
- I 304 Capability for ranging and transfer of target information
- I 305 Capability to establish a common operational picture
- I 306 Capability to support commander on tactical level with intelligence prior to decision
- I 307 Capability to support commander on operational level with intelligence prior to decision
- I 309 -313 Capability for HUMINT, IMINT, SIGINT, MASINT and RADINT
- S 708 Capability for technical support and repair in Area of Operations
- S710-711 Capability for initial medical care (Role 1) and medical care (Role 2 E)

The Capabilities of AR could be divided into three different areas; Navigational tools, Training and for Military Logistics.

As Navigational tool the technology has potential to in the same display provide

- Sight all around a vehicle,
- Driving guidance
- Transponder and sensor fusion
- Blue force tracking

Impact assessment in case of enemy use;  
Faster operations also in dark and difficult sight conditions and unknown areas like our backyard. Information advantage

Training;

- Possibility to train systems without destruction
- Less need for large test and training sites

Impact assessment in case of enemy use;  
Better trained soldiers, less mistakes more difficult to beat

Military logistics;

- Repair and maintenance with portable repairbook and perhaps external expert help
- Medical aid including mix with x-ray or MR images.
- Expert help on distance

Impact assessment in case of enemy use;  
Better access to equipment. Faster repair Better and more adequate medical service

The enemy have less problem with distance to their origin of sources

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

<b>Item</b>	<b>Assessment</b>
Acquisition cost/ System	Low if commercial components are used in a suitable rugged system
C2 footprint	Could involve the procedures used now
Logistic footprint	Small and light weight systems. Require small amount of electricity
Doctrine/TTP	Could result in different tactical behaviour
Training	Same system could be used in training mode
Facilities	Huge potential for other use
R&D	Medium needs

**Conclusions on military utility**

Augmented Reality has a significant potential for military utility. In the scenarios studied, AR is assessed to have a positive impact on several SwAF capabilities, especially for C2 and intelligence.

For soldiers, the head mounted display system could be a burden and perhaps also restrict their mobility and fighting ability. For drivers of vehicles including pilots and navigators at sea, the system is believed to have a great potential. The technology could be implemented in the near future based on information obtained from other projects, including former MR/AR projects run by FMV.

In urban terrain the situation is perhaps different as the requirements are different than for regular fighting in more open terrain. The question mark regarding the possibility of providing every soldier with an AR system is still there but for the officer or his deputy this system could be of great value. The possibility of adding sensor information in wavelengths other than visible light allows markers in colours or objects visible only in IR, UV or other spectral bands to be displayed. This way the potential problem of mismatch between VR and RR (Real Reality) will be reduced.

Regarding logistic use of AR we all agree that the potential must be great. Perhaps this application, together with the use in vehicles, is the most promising.

Medical use of AR systems is expected to be widely introduced in civilian medical care according to all identified advantages, which will most certainly also have an impact on military medical care.

The challenge will be to coordinate the use of such a commonly useful technology within several activities in the Military Forces while avoiding introducing several stovepipes for every service instead of a modularly built system that can be used in most of the above situations.

Today, AR is mature technology, applicable in many different branches. There are examples where AR is applied with great success, e.g. Head-Up-Displays (HUD). The technology has proven its value. However, there are well known drawbacks to the technology such as weaknesses regarding models, increased weight for dismounted soldiers, power consumption etc. There is also a risk that personnel will have problems solving their tasks when AR systems fail, not being used to fighting without supporting systems.

## **Nano Air Vehicles**

Ref: [3]

### **Introduction**

Nano Air Vehicles (NAV) are defined in the report as air vehicles weighing less than 20 g and having a wing span of less than 15 cm. Another way to define them is also presented. Using an aerodynamic coefficient called the Reynolds number, which uses the relation between the cord of the wing, the velocity of the airflow across the wing, the density of the air, and the viscosity of the air, NAV has a Reynolds number of less than 10 000. Usually, regular aircraft encounter Reynolds numbers above 500 000.

Their main use is stated to be in restricted areas where the interference of wind and rain is limited, such as inside a house that is either standing or has fallen down.

Because of their limited size the smaller ones (<100 mm wingspan) utilize flapping wings and the larger ones (> 100 mm wingspan) utilize rotary wings (helicopters). Fixed wings and a propeller are argued not to be sufficiently efficient for NAV.

The potential benefits with NAVs would, according to the report, be: low weight, low cost, low signatures, new capabilities and low risk for hazards.

### **Identified constraints**

The following technological advantages and disadvantages have been identified by the reviewer:

*Advantages*

- Low weight
- Low cost
- Low signatures
- New capabilities
- Low hazard potential

*Disadvantages*

- Very limited payload
- Limited transmission range
- Short range
- Short endurance
- Sensitivity to weather

The constraints identified are mainly coupled to miniaturization of parts such as wing actuators on flapping wing NAV, processors and RAM to control the NAV, sensors, radio transmission equipment, and power cells.

Development of software, processors and RAM that are capable of giving the NAV a sufficient level of autonomy is believed to be a large obstacle.

Scaling laws imply that a very small flying vehicle such as a NAV requires very little energy to fly. However, few current systems are capable of staying in the air for a period longer than 15 minutes<sup>23</sup>, which is too short to be of any practical use in military applications.

**Assumptions**

The concept scenarios are based on the following assumptions:

- Miniaturization of sub-systems such as cameras, radars, IR-sensors and actuators has reached an adequate level
- Stability problems coupled to small flapping wing aircraft have been solved

**Suggested military use**

It is argued in the report that due to the low cost and low weight of NAVs, soldiers will more or less get their own NAV. Considering that today's soldiers have to carry almost their own weight in uniform, protective clothing, personal weapon, ammunition, and supplies, it is quite unlikely that they can be equipped with NAV's unless other equipment is discarded. The NAV's inherent sensitivity to weather will also render it useless outdoors.

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<sup>2</sup> ProxDynamics ([www.proxdynamics.com](http://www.proxdynamics.com)), claims a demonstrated 25 minute endurance for their PD-100

<sup>3</sup> Aerovironment ([www.aerovironment.com](http://www.aerovironment.com)), claims an 8 minute flight time for their Nano Hummingbird



It is far more likely that a platoon of soldiers might be equipped with a few NAVs when they are sent on a mission that requires that capability. Such missions can be search and rescue in fully or partially collapsed buildings, indoor surveillance and special operations where it is imperative to know what a building looks like inside and where the opposition is located before entering.

**Concept scenarios in 2030**

An NAV can be used to have a peek around the corner and access areas that are difficult to get to. Since they are small they can either fly around for as long as the power cells last or they can fly to a certain location, land there and keep watch.

1. Search and rescue missions in damaged buildings
2. Surveillance and intelligence gathering inside buildings and in confined spaces
3. Mapping out enemy buildings and forces during special forces missions
4. Temporary relay station for communication inside buildings, tunnels and other places where radio coverage is limited and difficult

*Search and rescue mission*

In a peace-enforcement mission a building has been hit by mistake. It has partially collapsed and there are possibly several people trapped inside it. Sending personnel into the building is deemed too dangerous, because the building is unstable and threatens to fully collapse.

A small swarm of NAV's is sent into the building. Each NAV is equipped with a set of sensors and communication equipment. Stereo-video and LIDAR are used to navigate inside the building and thermal IR is used to scan for hot objects that can be people, but also signs of fire. A small microphone and speaker are also fitted in order for the rescue personnel to talk with people trapped inside the building.

Some distance into the building, the strength of the signal between the NAVs and the control station outside reaches its limit. One NAV lands at a suitable spot, turns off its sensors and enters into a communications relay station mode. The swarm of NAVs divides into two groups that enter deeper into the building in different directions. As each group of NAVs reaches the limit of the communication range they leave one NAV behind as a communications relay. The relay stations can also be used as sentries to look for displacement in the building.

After a while some of the NAVs have located trapped people, they land close to their head and enable the rescue personnel to talk with the trapped people. Some other NAVs have located hotspots and identified that at least one of them, with a high degree of probability, is a small fire.

During entry of the building some NAVs became trapped. As they detected this, they signalled the rest of the NAV network and entered a sentry/relay mode.

**SWOT-analysis:**Strengths:

- Ability to get to otherwise inaccessible places
- Can reduce risk for rescue personnel

Weaknesses:

- Limited range of system and sub-systems
- Sensitive to weather conditions

Opportunities:

- Increased support for situation awareness

Threats:

- Dependency on automated systems

**Assessed capability impact**

A NAV is assessed to contribute to the following capabilities as listed in the armed forces development plan, FMUP 2012.

- C 105 Capability to maintain communications
- I 301 Capability to obtain and deliver geographical information
- I 304 Capability for ranging and transfer of target information
- I310 Capability for image acquisition
- I311 and I 313 Capability for SIGINT and RADINT
- I318 Capability for CBRN-related acquisition

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by a NAV system in use.

<b>Item</b>	<b>Assessment</b>
Acquisition cost/ System	Relatively low, per unit
C2 footprint	Limited, requires a small cell to interpret the gathered information
Logistic footprint	Some, each unit is small and cheap, but requires recharging
Doctrine/TTP	Doctrines no, TTP requires update to make as much use of NAVs as possible

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Training	Yes, handling of system and interpretation of gathered intelligence. Support
Facilities	Simulation equipment, urban combat training facilities, control equipment and operator console
R&D	Yes, simple systems are commercially available. More advanced systems of some utility require development. Development is needed in order to be able to define relevant requirements on procured systems.

### Conclusions on military utility

Nano Air Vehicles have a significant potential for military utility. In the scenarios studied they have been assessed to contribute to a large range of capabilities, primarily intelligence. The limited radio communication range will reduce a NAV's utility as a surveillance and intelligence-gathering platform in a confined space. Using several NAVs that can constitute an ad-hoc wireless network can possibly reduce this limitation. It will, however, increase the requirements on energy sources in order to relay communication.

Their lifecycle cost has been assessed to be low, since development in this area is commercially driven, bringing down acquisition costs. FAA has decided to allow NAVs in controlled air space from 2015, which is expected to lead to a rise in civilian use of NAVs. The technology is relatively mature even though there are obstacles concerning suitable materials used to build them, energy efficient propulsion systems as well as miniaturized microprocessors and software to control them.

### High Energy Solid-State Laser Weapons

Ref: [4]

#### Introduction

Directed-energy weapons use energy instead of kinetic or explosive projectiles to affect targets. In the case of laser weapons, the energy comes in the form of laser radiation. Depending on the radiation power, one can differentiate between two classes of laser weapon systems:

- Laser weapons with lower power (less than 1 kilowatt) can be used to dazzle humans, but especially to jam optical sensors. Such systems have already been in use for several years.
- Laser weapon systems with higher power (up to megawatts), intended to damage or to destroy sensors, rockets, artillery, mortar or aircraft have not been employed routinely so far.

Two well-known examples of experimental chemical laser weapon systems are the Tactical High Energy Laser (THEL) and the Airborne Laser (ABL). In both cases, huge amounts of potentially toxic and flammable chemicals are consumed per laser shot. Therefore, such weapon systems depend on a permanent supply with special fuels. Furthermore, the chemical reactions produce vast amounts of toxic and aggressive exhausts that are harmful for humans and the environment, and that amplifies the system's infrared signature.

To date there is no laser technology other than chemical lasers which can produce high power in the megawatt range. With the recent progress in the development of electrically powered solid-state lasers (SSL), operational laser weapon systems seem to be feasible within the next ten years. Solid-state lasers are logistically simpler and easier to handle than chemical lasers, because they are powered electrically without needing special fuels or producing exhausts. In the last few years, solid-state lasers have reached continuous power of tens of kilowatts and a SSL system has in 2009 demonstrated a continuous laser beam of 100 kW. Modern solid-state lasers use electrically driven laser diodes as a light source for pumping and can reach electric-optical efficiencies up to 30 %.

**Identified constraints**

From analyzing the report the following constraints in design have been found:

- The prime challenge in the development of high-energy solid-state lasers is the cooling of the gain medium. This is the reason why no MW SSL laser has yet been built. The waste heat can only be removed via the surface of the gain medium causing gradients of temperature, mechanical stress and index of refraction, leading to lower laser beam quality and mechanical instability of the laser medium.
- For efficient waste heat dissipation an increase in the surface to volume ratio is needed. However, for crystalline laser media the production process limits the maximum size of the crystals. By sintering ceramic nano-powders at high temperatures and high pressures, ceramic gain media of almost arbitrary shape and size can be produced. Therefore, in the next few years ceramic gain media is expected to replace crystalline and glass-like gain media for high-energy laser systems.
- Adaptive optics is used to improve performance of laser beams by pre-shaping the beam so it creates an intense focal spot on the target surface. The atmospheric turbulence between laser weapon and target has to be measured and the output beam must be shaped. Due to the fast relative motion, this pre-shaping needs to be readjusted in millisecond time intervals.
- The interaction of the laser beam with the air, which is heated by absorbing a fraction of the laser radiation, causes an expansion of the beam diameter, and hence, a reduction of the beam intensity on the target, so called thermal blooming. Without the compensation of these atmospheric effects by adaptive optics, laser weapons do not produce sufficiently high

intensities on the targets, and are unable to be used to defeat far distant targets at all.

- It is not possible to produce laser beams with a power of more than 100 kW using a single solid-state gain medium. In order to produce high-energy laser beams with SSL, beams of several separate laser sources must be combined. Here again, adaptive optics play an important role for generating homogeneous beams that remain collimated over long distances.
- High-energy SSL are still in an early stage of development. In addition, the technology of high-energy SSL is more complex than that of chemical lasers due to the elaborate powerful cooling systems.
- The energy supply for mobile HEL weapons is still an unsolved technological problem.
- Only under favourable atmospheric conditions can high-energy lasers have a full effect on far distant targets.

#### Conclusions in the 2025- 2030 timeframe:

- HEL weapons based on SSSL technology have several advantages compared to conventional C-RAM systems (counter rocket, artillery, and mortar) and anti-aircraft missiles.
- SSL have a potential as automatic close-in weapon systems or air defence systems, being more precise and more agile with much lower operational cost per shot.
- SSL are more compact than chemical laser which could allow for the development of mobile HEL weapon systems installed not only on ships and large aircraft, but also in military ground vehicles or fighter jets.
- Furthermore, there are also several disadvantageous aspects of laser weapons, such as limited deployability under adverse environmental conditions and the fact that they are subject to comparatively simple countermeasures against their effect.
- HEL weapons are, due to their limited deployability, not expected to replace conventional weapon systems and their actual future relevance is considered lower than often suggested.
- SSL do not offer fundamentally new capabilities compared to existing weapon systems.

#### Assumptions

The concept scenarios are based on the following assumptions. The technological maturity of SSL in 2030 is assumed to enable use of SSL as automatic close-in weapon system for ship defence, being more precise and more agile with much lower operational cost per shot than HEL and without environmental hazards.

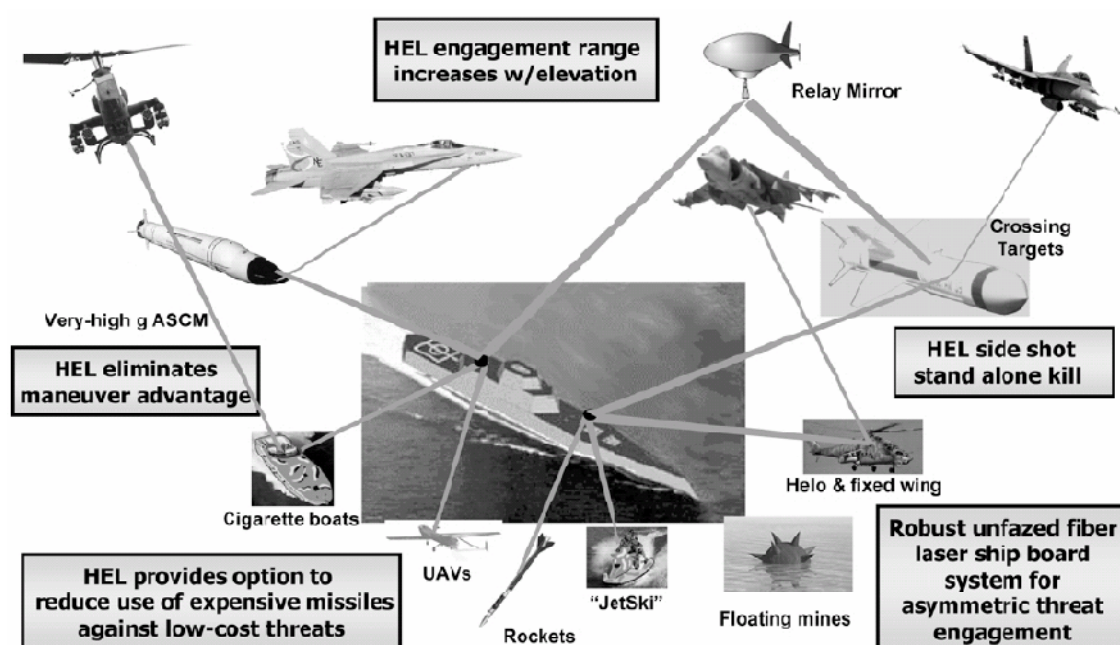
#### Suggested military use

The following military use for solid-state lasers are suggested in the report:

- Shipboard self defence
- Aircraft defence (DIRCM)<sup>4</sup>
- Base camp protection
- Intercepting cruise missiles from airborne platforms
- Intercepting ballistic missiles as a part of ground based air defence (GBAD)<sup>5</sup>
- Destruction of optical sensors or unmanned aerial vehicles (UAVs)
- Defence against asymmetric threats, such as speed boats

### Concept scenarios in 2030

#### *Ship defence*



The tension around the gas pipeline close to Gotland has increased. Sweden has indications of pre-deployed military installations such as sonar systems and underwater weapon system on the fundamentals of the pipeline and has therefore sent a diplomatic note to the opponent demanding the immediate removal of these installations that are seen as a direct military provocation against Swedish vital interests.

A Visby class corvette on a routine mission east of Gotland has just got a plot on its radar of an unidentified surface ship on its radar heading straight on. A minute later the ESM system determines that the emitters are originating from an approaching cruiser. Suddenly the ESM operator warns that he has an emitter

<sup>4</sup> This military use is not mentioned in the Fraunhofer report.

<sup>5</sup> This military use is not mentioned in the Fraunhofer report.

from the seeker of a surface to surface missile in the same direction. All systems are set at highest alert. The electronic warfare officer activates the active radar jammer in order to pull-off the missile, but he soon reports that the jammer has no effect on the missile, which probably has turned over to infra-red seeker mode.

The EW officer then activates the solid-state laser ship defence system. First theIRST (infra-red search and track) system is directed towards the threat bearing and immediately finds the heated nose cone of the missile. The fast optical pointing and tracking system allows for extremely precise, highly agile and rapid targeting and activates the solid-state laser weapon system that sends out a pre-shaped laser beam that creates an intense focal spot on the missile nose cone. After 2 seconds of illumination the approaching missile explodes. The fast optical tracking system finds a new threat and immediately locks over to a second approaching missile which also effectively is taken care of by the laser weapon system.

A few minutes later a surface laying mine is observed and the solid-state laser weapon system is again activated and the laser beam burns a hole in the surface of the target which explodes at a safe distance.

Two hours later a combined attack is initiated by a hostile UAV and a speed boat that are approaching. The solid-state laser weapons system easily engages the identified threats.

### ***Description***

The Visby class corvette has a solid-state laser weapon system with an output laser effect of 200 kW. The output laser beam consists of 14 combined beams from diode-pumped slab laser modules with a power of 15 kW each. The system is equipped with adaptive optics in order to compensate for atmospheric effects.

### ***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats with the solid-state laser weapon system concept scenario were identified at the seminar:

#### **Strengths:**

- The system has a potential to counteract against the hostile multiple seeker missile when the radar jammer is found to be ineffective against the threat when the missile turns into IR-seeker mode.
- The system can, due to the fast optical pointing and tracking system immediately re-engage multiple incoming missile threats.
- The system can also efficiently engage surface laying mines.
- Low cost per shot
- “Deep magazine”
- Small environmental and health problems compared to chemical laser weapon systems.

- Multi-purpose system that engages threats in the air (missiles, UAVs), on the surface (small fast boats, mines)
- Graded response
- Less lethal weapon

**Weaknesses:**

- The adversary may have countermeasures (e.g. highly reflective surface with good temperature dissipation properties or active laser protection systems) for their missiles.
- Atmospheric effects “blur” the laser beam which reduces the effect and range if adaptive optics could not be developed in time

**Opportunities:**

- Silent weapon
- Swedish defence industry might have a potential to develop the FOI laser protection technology demonstrators (self activated, non-linear protection)

**Threats:**

- Technologies for of SSL weapon systems takes longer time to develop
- Developed SSL weapon systems are not available for our off-the-shelf purchase.
- Our adversary gets SSL weapons before us or develops countermeasures that make our SSL system ineffective.

**Assessed capability impact**

The proposed concept is assessed to have impact on the SwAF capabilities listed below:

- P 504 Capability to protect objects on and under the surface against attack
- E 201 Capability to affect targets on the surface
- E 204 Capability to affect targets in the air

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

Item	Assessment
Acquisition cost/ System	High
C2 footprint	No, integration in EW console possible
Logistic footprint	Positive impact on logistics since no need for ammunition. The need for electrical power is generally not a problem for



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	ground based and sea born platforms. Need for maintenance personnel.
Doctrine/TTP	Doctrines need to be in accordance with the Protocol on Blinding Laser Weapons (protocol IV to the 1980 UN Convention). Specific regulations for use and safety are needed.
Training	Need for new education and training of maintenance personnel.
Facilities	Need for new education and training facilities, test equipment and simulators. Threat libraries for EO equipment needed.
R&D	Yes, since research in EW and equipment not commercially available due to secrecy. Jamming algorithms need to be developed.

### Conclusions on military utility

High Energy Solid State Laser weapons have a significant potential for military utility. In the scenarios studied the technology is assessed to have a positive impact on SwAF capabilities to engage targets on surface and in the air. The technology can be used to protect a vessel on the surface and thereby increase survivability. Laser based self defence systems are needed in order to deal with advanced missiles with modern IR-seeker that can discriminate flares.

The development of SSL in the given timeframe is expected to lower cost per shot and avoid environmental problems with use of chemical lasers. Neighbouring military powers are expected to use laser weapons in the future. Therefore the SwAF should monitor the development of laser weapons technology and develop and purchase adequate countermeasures.

## Automated Behaviour Analysis

### Introduction

More than 50 % of the human behaviour takes place by means other than verbal. Automated Behaviour Analysis comprises methods to analyse behaviour in an automatic way using technology, cameras with supporting computer systems, etc. The report divides the methods into three categories.

1. Analysis of the behaviour of people during interpersonal interactions. For detecting and sorting of unintended micro expressions.
2. Analysis of the behaviour of people in the public. For detecting and sorting of suspicious persons in public areas.

3. Analysis of the behaviour of groups and within groups. For assessing groups of people, e.g. in order to detect riots.

**Identified constraints**

None of the technologies are ready. Nonetheless systems are operational in the USA, in Israel and India. In India the system is claimed to have helped in 'solving' several crimes.

The report also mentions problems with false alarms regarding suspicious behaviour, especially at airports where many travellers behave strangely for many reasons without being security issues.

**Assumptions**

The concept scenarios are based on the following assumptions.

None of the technologies are ready. Nonetheless systems are operating in USA, Israel and India. This could indicate that systems can be developed although the technology in the systems is not yet mature.

**Suggested military use**

Main areas for Automated Behaviour Analysis will probably be within public security. The military use of this kind of technology will probably be for related kinds of security tasks, i.e. in connection to entrance to military bases or in the vicinity of military bases. These kind of system can complement other security measures with automated security.

**Concept scenarios in 2030***Description*

At a Swedish camp, there is a threat of infiltrators of different kinds. At the same time the traffic to and from the base is considerable. A few hundred meters outside the base there is a small city containing approximately 500.000 persons. Automated Behaviour Analysis can be used in order to enhance the security in the base supporting the monitoring of people accessing the base.

To enhance the overall security in the entrance of the camp and in the surroundings, technology for Automated Behaviour Analysis is set up. Technology for mobile Automated Behaviour Analysis is also used on vehicles belonging to the base in order to perform mobile security screening of gatherings of people, giving security personnel early warning to prepare for possible break out of riots.

*SWOT-analysis*

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

**Strengths:**

- Can give enough time for security personnel to act.
- Can be used for filtering flows of people
- Part of a security screening

**Weaknesses:**

- Can give a false sense of security if threat object is adapting to measures.
- High camera resolution required
- False positives
- Does not detect terrorists by proxy
- Accuracy of database

**Opportunities:**

- Automated security screening of public places or security screened areas; airports, railway stations etc. can unburden staff.
- With increased computing power, including more efficient and adaptive algorithms etc., the system can give better accuracy, fewer false positives and better knowledge development.

**Threats:**

- Changed attack pattern or modus operandi for terrorists etc.
- Manipulation of the system

**Assessed capability impact**

The proposed concepts are assessed to have impact on the SwAF capabilities listed below:

- I 305 Capability to establish a common operational picture
- I 307 Capability to support commander on operational level with intelligence prior to decision
- I310 Capability for image acquisition
- P 503 Capability to protect objects on the ground against attack

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

Item	Assessment
Acquisition cost/ System	Not to high, since systems exist today. Manual security screening systems could be supplemented
C2 footprint	High, a lot of information is gathered, needs information management

Logistic footprint	Networks have to be built, new equipment has to be acquired and maintained
Doctrine/TTP	New TTPs
Training	High for C2
Facilities	High for C2
R&D	Market driven

### Conclusions on military utility

In the scenarios studied the technology is assessed to have negligible potential for military utility. However, it could be of some relevance to SwAF capabilities for increased security screening and surveillance. The primary utility of the technology will probably be in international activities and to a lesser extent for increased base security in Sweden.

Generally the main use for this kind of technology will probably be for civilian use in public spaces and close to high value areas like airports, important buildings and other similar objects.

The main difference between these kinds of automated system and manned systems already in use all over the world is the automation. With skilled staff manning surveillance stations and technology, the same tasks can already be solved today. It is a matter of manning and protection since personnel can be removed from immediate threat if security screening is done close to high value objects in high threat environments, i.e. "dull and dangerous" tasks.

### Biomimetic Unmanned Underwater Vehicles (UUV)

Ref: [6]

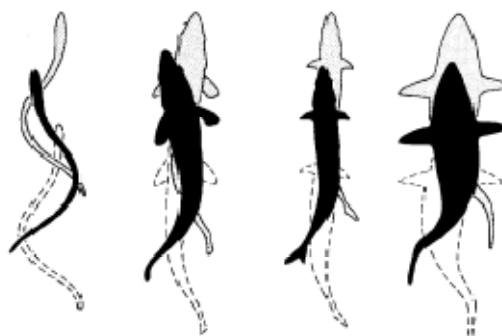


Figure 1: Fin propulsion of fish. From undulating (left) to oscillating motion (right). Source: C. C. Lindsey, "Form, function and locomotory habits in fish", in Fish Physiology Vol. VII Locomotion

**Introduction**

The report focuses on autonomous underwater vehicles (AUVs) with design and functionality mimicking real biological systems, such as fish, crabs, turtles or jellyfish, etc. The technology used to mimic the effective fin propulsion, i.e. the swimming motion, of marine biological systems is of foremost interest. It has the potential to be much more efficient than traditional propeller propulsion and promises good stability and low acoustic emissions. There is potential to reach a velocity of ten body lengths per second and to make changes in direction almost instantly. If the snakelike motion can be copied, it will also be possible to make an AUV that can crawl up on land in coastal regions for reconnaissance missions.

This kind of design, however, needs new types of actuators. Today most actuators have to transform a rotating motion into an oscillation to be able to satisfy the demand. The new type need to be less complex and create a force in the way that real muscles do. So far artificial muscles operate pneumatically or hydraulically. There are however reports on promising technologies with electro active polymers or shape memory alloys.

**Identified constraints**

From analyzing the report the following constraints in design have been found:

- Advanced automation and learning systems for adaptability of AUVs are far off
- Fatigue in polymers

Conclusions in the 2025- 2030 timeframe:

More complex tasks in environments not known beforehand will still need remote control. Simpler, well specified tasks will be possible with AUVs. Already there are prototypes for patrolling harbour areas monitoring water quality etc. These prototypes go out on patrol for hours and return to station for power charging and reporting. In this timeframe the propulsion is likely to become more efficient and more difficult to separate from real biological systems. With more efficient propulsion systems the payload weight may increase. With the development in other technologies like miniaturization, communication, sensors and computers the AUV may well be an able node in a sensor communication network. To be used inconspicuously the AUV will have to adhere to the biological life in the area. Changing missions will need a change in disguise.

**Assumptions**

The concept scenarios are based on the following assumptions.

- Fin propulsion with artificial muscles can be made to work, and with low acoustic emission.
- Of course, to make a really useful AUV there is a need for development of other adjacent technologies such as autonomous robotics, miniaturization,

underwater sensors, underwater communication and powerful energy supplies or energy harvesting.

**Suggested military use**

The following military use for biomimetic AUVs are suggested in the report:

In general:

- Covert surveillance
- Inconspicuous reconnaissance missions, in the sea or amphibious in coastal regions
- Operation in harmful or dangerous environments

The following specific tasks are suggested:

- Harbour area reconnaissance
- Inconspicuous nautical mapping
- Floating swarm jellyfish-like robots creating a network of communicating sensors over large areas
- Inconspicuous delivery of explosives

**Concept scenarios in 2030**

The following scenario is assessed to be consistent with constraints, suggested military use and the long-term study on SwAF development;

*Biomimetic recce cod***Description**

The Swedish navy has the task of monitoring the gas pipelines going through the Baltic Sea east of Gotland. The instructions are to keep a low profile in order not to escalate the tension in the region. There are, however, suspicions that the pipeline is used as platform for hostile military intelligence purposes towards Sweden.

The navy uses biomimetic recce cod, of about two meter length, swimming in small shoals along the pipeline. The cod are equipped with passive sensors in the acoustic and visual spectra and are programmed to swim in patterns difficult to separate from those of real cod. On active sonar there is no way to separate them from real fish. The recce patrols can be initiated from any ship sailing across the Baltic. The Navy sometimes uses fishing boats or other commercial ships. When the run is completed, after eight to ten hours (280-360 km), the cod have a rendezvous with a submarine or another fishing boat at a predetermined point. The videos and acoustic recordings are reviewed at headquarters.

The cods are recharged, reprogrammed, equipped with other sensors and used for other missions, perhaps routinely monitoring underwater military plants or routes in the Swedish archipelago.

***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats with the biomimetic reconnaissance cod concept scenario were identified at the seminar:

**Strengths:**

- No risk for personnel<sup>6</sup>
- Covert/camouflaged reconnaissance under water
  - Fishlike motion
  - Low acoustic emission
- Useful in deep waters and in environments that are harmful to divers<sup>6</sup>, i.e. dirty, dull and dangerous missions.
- Efficient propulsion, speed/endurance

**Weaknesses:**

- Have to blend in with other biological systems in the area or at least appear as a fish on sonar.
- Some acoustic emission not consistent with fish
- Energy consumption
- Need time to prepare, need specific tasks and a pre-programmed map of the environment

**Opportunities:**

- Modular payload

**Threats:**

- Sensitive sonar systems picking up the weak, but artificial, sound of propulsion
- Fishing nets
- The use of fishing boats in this scenario is questionable

**Assessed capability impact**

The proposed concepts are assessed to have impact on the SwAF capabilities listed below:

- I 302 Capability to obtain and deliver oceanographic information
- I 310 Capability for image acquisition
- I 312 Capability for MASINT acquisition

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

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<sup>6</sup> In relation to already existing systems the UUVs are not unlike other technologies.

Item	Assessment
Acquisition cost/ System	Not too high, based on the fact that a French working prototype costs about 200 000 Euro.
C2 footprint	Some C2 and evaluation facilities have to be built
Logistic footprint	A new complex system to support
Doctrine/TTP	TTPs have to be developed
Training	Personnel have to be trained, moderate impact
Facilities	Some C2 and evaluation facilities have to be built
R&D	Monitor development

### Conclusions on military utility

The military utility of biomimetic UUVs is mostly dependent on the development of advanced automation and learning systems. Biomimetic UUVs could be used for covert surveillance and inconspicuous naval reconnaissance missions at sea or in amphibious missions. As of now, we assess existing technologies as being preferable due to lower cost and less complexity. The performance of UUV's needed for SwAF capabilities are assessed to be far off into the future. Simpler systems could however be used by potential adversaries for monitoring our own base areas and hence the development should be monitored from a protection point of view.

## Electro Magnetic Guns

Ref: [7]

### Introduction

Electromagnetic guns utilize forces generated from electrical power to accelerate a projectile. There are three main design principles discussed in the article: electro-thermal chemical gun, rail gun and coil gun. The first utilizes electrical power to ignite a regular powder cartridge in order to achieve a more controlled combustion with higher energy levels. The other two utilize electrical power to accelerate a projectile along a barrel.

The odd man out in this collection of electromagnetic guns is the electro-thermal chemical (ETC) gun. It works as any regular gun, with the exception that the combustion of the propellant is controlled and enhanced by means of adding electro-thermal energy. Controlling the combustion of the propellant can possibly increase the muzzle energy without increasing the peak pressure inside the gun barrel.



A rail gun consists of two electrically conducting rails, an armature that short circuits the two rails and propels the projectile along the rails, and a pulse generating network that powers the gun. The armature is accelerated along the two rails when an electrical pulse is sent through the first rail, the armature and the second rail.

A coil gun, or Gauss gun, consists of several coils of electrical leads mounted in series along a barrel and a pulse forming network that powers the gun. A projectile is propelled along the barrel by magnetic forces generated by the electrical coils when an electrical pulse charges them. A control system charges the coils in sequence as the projectile travels along the barrel.

A somewhat curious, but important, feature of rail guns is their limited recoil force. This makes it possible to have very powerful guns mounted on relatively light platforms.

To achieve muzzle energies in the order of 20 MJ requires a pulse forming network capable of delivering electrical pulses with energy of 60 MJ, or 20 GW. Such high energies put very high demands on the pulse-forming network that delivers the power to the gun. Currently there are three different principles to store and deliver the power required by the guns. One principle is high-performance capacitors, another is superconducting coils, and the last is a combination of fast revolving flywheels and alternators called a compulsator. One important common feature of these three principles of making pulse-forming networks is that they are heavy and require a lot of space. Therefore the positive effects of the low recoil of rail guns are limited by the requirements of the large and heavy pulse-forming networks.

### **Identified constraints**

The first attempts to make electromagnetic guns were made around the turn of the 20<sup>th</sup> century. Still, a hundred years later, there are needs for further development before they can be used in the field.

One large obstacle that is common for all three types of electromagnetic guns is the pulse-forming network. It is large, heavy and requires a relatively long time to recharge before another shot can be released.

The main obstacle for rail guns is material technology. Plasma is generated in the contact surface between the rails and the armature. This erodes the rails and limits the multi-shot capability of the guns.

Coil guns require accurate power delivery to each coil in order to propel the projectile as efficiently as possible. High-power electronics are still unable to handle the very high voltages and currents required.

The following technological advantages and disadvantages have been identified by the reviewer:

*Advantages*

- No explosives or propellants required, which limits vulnerability
- Capability to generate very high muzzle energies
- Limited recoil forces on rail guns
- Pulse forming network can be placed some distance away from the gun making it easier to mount the gun on e.g. a ship

*Disadvantages*

- Complex, large, and heavy power-forming networks
- Power-forming networks store large amounts of energy which can make them vulnerable to damage from e.g. projectiles and shrapnel
- Large amount of electrical power is required

A limitation that is not due to the electromagnetic guns themselves, but rather their possibility to generate very high muzzle velocities, is air friction. The friction between air and a projectile travelling at hypersonic velocity is significant enough to generate plasma at the tip of the projectile. This plasma will erode the projectile unless materials capable of withstanding such high temperatures are used.

**Assumptions**

The concept scenarios are based on the following assumptions:

- Development of pulse-forming networks has reached an adequate level
- Materials that can handle the extreme currents and temperatures have been made available
- High power electronics that can handle the currents required with adequate precision

**Suggested military use**

An electro-thermal chemical gun can be used to increase the muzzle velocity of existing guns, provided that the increase in muzzle energy can be achieved without increasing peak pressure inside the gun barrel. Rail and coil guns can, in theory, be used as any other gun is used in military contexts.

The following applications are mentioned in the report:

- Long range naval gun
- Long range artillery gun
- Rapid fire close in weapons systems
- Main battle tank gun
- Mortars
- Aircraft guns

- Launching satellites into low orbit

**Concept scenarios in 2030**

There is an important difference between electro-thermal chemical guns on one hand, and rail and coil guns on the other. The ETC gun utilizes electric power to increase precision and power in a regular propellant cartridge. Rail and coil guns utilize electric power to propel the projectiles. Therefore the concept scenarios will differ significantly between ETC and rail/coil guns.

*Main battle tank ETC-gun***Description**

The gun on a Leopard 2 main battle tank has been updated to fire rounds that are initiated using an electro-thermal chemical igniter. The breach of the gun has been changed with one that accepts the updated igniter, and a pulse-forming network capable of delivering pulses of about 100 kJ has been added to the tower. In addition an extra 100 kW alternator has been fitted to the existing power pack in order to power the pulse-forming network. The alternator is capable of recharging the pulse-forming network in about two seconds.

The muzzle velocity of the updated gun has become less dependent on temperature, air pressure, and humidity. Therefore the precision of the gun has improved and the deviation between calculated point of impact and actual impact has been reduced.

**SWOT-analysis**

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

Strengths:

- Increased precision
- Slight increase in range
- Reduced risk for accidental shots
- No explosives or propellants required, which limits vulnerability
- Capability to generate very high muzzle energies
- Limited recoil forces on rail guns
- Pulse forming network can be placed some distance away from the gun making it easier to mount the gun on e.g. a ship

Weaknesses:

- One more system that can fail
- Increased weight due to pulse-forming network and uprated alternator
- Power-forming networks store large amounts of energy which can make them vulnerable to damages from e.g. projectiles and shrapnel
- Large amount of electrical power is required

**Opportunities:**

- Slight increase in range
- A first development step towards rail or coil gun

**Threats:**

- Uncontrolled release of stored energy in the pulse-forming network

***Main battle tank rail gun******Description***

For demonstration purposes a Leopard 2 main battle tank has been equipped with a 10 MJ rail gun. The gun is capable of launching apfsds<sup>7</sup> projectiles at muzzle velocities of up to 2 000 m/s.

A pulse-forming network capable of delivering pulses of 30 MJ has been mated with a capacitor bank consisting of 500 kg grapheme capacitors. The capacitors are capable of delivering 150 MJ, making it possible to release a maximum of 5 shots before recharging<sup>8</sup>. Due to limitations in the design of the capacitors the capacitor bank can be recharged in about one minute. The engine on the Leopard 2 has been uprated to about 2 MW and fitted with an alternator capable of delivering 1 MW<sup>9</sup>. Charging an empty capacitor bank with 1 MW takes about two and a half minutes. In order for the alternator to develop 1 MW it needs about 1.3 MW from the main engine. Therefore, the tank has only limited capability to manoeuvre while charging the capacitors at full power.

***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats were identified at the seminar:

**Strengths:**

- Reduced recoil which might facilitate reduced weight of turret and turret mount
- Increased precision due to reduced recoil
- No need for propellant which reduces vulnerability
- Reduced weight of ammunition
- Reduced logistic footprint due to lighter ammunition
- Difficult to shoot down incoming fire

**Weaknesses:**

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<sup>7</sup> Armor Piercing Fin Stabilized Discarding Sabot

<sup>8</sup> <http://physicsworld.com/cws/article/news/2010/nov/26/graphene-supercapacitor-breaks-storage-record>

<sup>9</sup> Mobile generators delivering 1.1 MW and weighing 4500 kg are currently commercially available (<http://www.turbinemarine.com/generators.html>).

- Increased requirement on power-plant
- Increased logistic footprint due to increased fuel consumption
- Volume requirement of pulse-forming networks
- Increased weight of pulse-forming network
- Recharging time of pulse-forming network
- Cooling requirement of barrel
- Health risks from ozone

Opportunities:

- Possibility to increase rate of fire

Threats:

- Short circuit in power-forming network
- Development of sufficiently durable rail material
- Development of power-forming networks

**Assessed capability impact**

Electromagnetic guns are believed to contribute to the following capabilities as listed in the armed forces development plan, FMUP 2012.

- E 201 Capability to affect targets on the surface
- E 203 Capability to affect targets on the ground
- E 204 Capability to affect targets in the air
- E 207 Capability to affect the adversary in depth in the Area of Operations
- E 215 Capability for detaining field engineering
- E 216 Capability to support combat on the ground
- P 503 Capability to protect targets on the surface against attack
- P 504 Capability to protect objects on and under the surface against attack

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by electromagnetic guns in use.

Item	Assessment
Acquisition cost/ System	High, these are advanced and expensive systems
C2 footprint	No more than other gun systems
Logistic footprint	Reduce the need for propellant, but increase the need for fuel

## Report

Date  
14 September, 2012

Enclosure 1  
72/2012

46 (75)

Doctrine/TTP	Some to take into account the possible long range of these guns
Training	Similar to other gun systems, personnel capable of repairing high-power electric systems
Facilities	High-power electric systems require new facilities
R&D	Yes, these systems have just reached demonstrator level

### Conclusions on military utility

The electro-thermal chemical (ETC) gun seems to be a first step towards a fully electrical gun such as the rail-gun or the coil-gun. The fully electrical guns have been a work in progress for some decades and there are still remaining challenges both concerning electrical power supply and design materials. When, or if, they will be operational is difficult to say.

All the types of guns described in the report are, even though functioning prototypes were made in the late 20<sup>th</sup> century, still in relatively early phases of development. There are still some difficult hurdles to cross before fully operational guns can be used in a military context. BAE Systems have developed a 32 MJ rail gun for lab purposes. The Office of Naval Research does not, in the press release, specify whether the 32 MJ refers to muzzle energy or input energy.

Judging from the limited number of references to coil guns in the report, coil guns have not reached the level of maturity rail guns have.

Electro-thermal chemical guns should be easier to implement, partially because they do not need as high energies as rail or coil guns and partially because they should be able to utilize existing gun barrels and platforms with limited redesign. They do require a pulse-forming network, but with significantly lower energies than those driving rail and coil guns. The report covers two basically different weapons systems; one where a high-energy electrical discharge is used to increase the control on a chemical propellant, and another where electrical power is used to propel a projectile.

Both systems require added electrical energy, which currently is not available in a tank. The introduction of the all-electric vehicle will change this, but when that will happen is not clear. The technology needed for the all-electric vehicle is available, and has been shown to work by e.g. BAE Systems Hägglunds with their SEP armoured vehicle. Customers, however, do not yet seem to be ready for these vehicles.

## **Small satellites**

Ref: [8]

### **Introduction**

Mini- or microsatellites exhibit significantly less weight and volume compared to conventional satellites. They are not an evolutionary branch originating from the big satellites; instead they represent a separate philosophy of system design and development. Whereas for big satellites the primary layout design criterion is their absolute capacity and technical reliability, for small satellites the design goal is utilizing miniturization and plug and play avionics while maintaining as much capacity as possible compared to conventional satellites thus creating a cost-effective realisation.

In order to achieve a capacity that is better than with scaled down traditional satellite technology, small satellites are usually placed in relatively low orbits. Consequently they exhibit lower in-orbit service lifetime. Due to their considerably lower production time and costs however they might serve as an attractive alternative or supplement for a number of space applications, provided the respective payload can be integrated in the satellite.

Small satellites usually fly in lower altitudes of the Low Earth Orbit (LEO), between 200 and 800 km. They are categorised according to their weight. Picosatellites between 0.1 and 1 kg, nanosatellites between 1 and 10 kg, microsatellites from 10 to 100 kg and minisatellites from 100 kg to 500 kg.

The report also claims that this new class of satellites constitute a “Paradigm Change” based on the miniaturisation trend of consumer electronic components for communication, cameras, computers, memory, communication etc.

Use of commercial off-the-shelf products (COTS hardware) is suggested to meet the high costs in traditional satellite development. The lower technical and physical life time of such smaller and cheaper satellites could be motivated with the fast development of new technologies that makes the traditional systems outdated before the end of their technical lifespan.

The technology is proven and even so called Femtosatellites with a size of 10 x 10 x 10 cm and a weight of ca 1 kilogram have been launched. The modular CubeSat-units could also be coupled to form a bigger nanosatellite if the functions needs that. Such satellites can be launched with very small rockets and perhaps also from aircraft – that reduces the size and power of the rocket.

The report identifies the following advantages to traditional satellites:

- lower production costs
- lower start costs
- lower integration complexity
- shorter development period

- higher technology dynamics
- more start opportunities
- lower signature
- lower target area

**Identified constraints**

In order to assess small satellites, they need to be placed in the right context. Fast jets, civilian aircraft, UAS, helicopters and satellites are all different platforms using same sensor principles with similar designs. Comparisons must therefore start from the platform perspective. Satellite fly envelopes are decided by the Keplerian laws.

There is very little discussion in the report about small satellites and their feasibility for different functions. In order to reduce the satellite mass and volume without reducing performance in the same order, technology development will face some challenges. Some of these are already investigated through the USAF and US Navy TacSat program regarding small satellites with a mass between 100 and 400 kg, but for micro- and nanosatellites there still remains some uncertainties.

There is a need for a comparison between different platforms and different sensor mission profiles which would show how and to which extent small satellites could be a complement to other platforms including traditional satellites. This comparison has not been made within the Fraunhofer study and did not fit within the schedule of this report. It is however highly recommended in future assessments of military utility.

Some complementary remarks are added below.

**Radio communication.** Micro satellites could perhaps work as relay platforms for radio communication. Questions remain about bandwidth and the need of several satellites in orbit to maintain capacity. Geostationary satellites that have a fixed position are easier to position but as they are at high altitude the size must be bigger and the construction more robust. For other envelopes than GEO, there is a need for a larger number of satellites in order to achieve continuous coverage or they must fly at higher altitudes. This is the case regardless of the size of the satellite. Today, the Iridium system operates with 60-80 satellites in MEO-envelopes. The facilities at the ground segment are the same for both large and small satellites and they can handle, in principle, all envelopes unless they are too close to the geographical poles, where the GEO-envelope becomes difficult to access. As a comparison, geostationary satellites are limited to cover approximately 40% of the surface of the Earth from their position in the envelope/orbit.

*A nanosatellite in geostationary envelope with today's antenna technology is not very useful, therefore they must fly envelopes that are at lower altitudes and thus they must fly in clusters. In order to provide continuous coverage for*



*communication an unreasonably large amount of satellites is needed. Therefore, nanosatellites can only be used for transmitting information that is not minute or second critical. This has been shown by simulations made by the SwAF Space study.*

*On the other hand, nanosatellites provide global coverage over time. The military utility thus depends on the mission objectives and not on the size of the satellite or the technology that is being used.*

**Television or broadband** satellites also require more electric power than today's smallsats can produce. The large distance from the geostationary orbit together with the dispersion of the signal strength makes it difficult to replace large satellites with small for telecom broadcasting.

**Image generating**<sup>10</sup> satellites require quite long "telescope" optics to be able to take pictures of the ground with reasonable spatial resolution.

**Multi- and hyperspectral**<sup>11</sup> sensors also require energy to receive and to transmit satellite scenes to the earth. Normally these scenes are downloaded when the satellite passes download-centers like ESRANGE in Kiruna because the satellite will be in reach for the huge receiving antenna when passing above the arctic circle.

**Infrared sensors**<sup>12</sup> require cooling to be really sensitive. One way to achieve this is to have the platform at high altitude but then the energy from the observed surfaces will be too low due to the distance. Cooling of sensors requires either some gas or other energy dependent methods.

**Radar and other active sensors**<sup>13</sup> require high power to generate the signal and to receive and analyse the return. The receiving segment is especially important if the satellite uses SAR (Synthetic Aperture Radar technology) to obtain higher spatial resolution of the observed areas. Existing systems are huge in volume and have sophisticated energy systems (nuclear power supply). They are used to build up elevation databases and maps over the whole world with focus on the most important areas from a strategic and economic point of view. If micro SAR satellites were to be technically and operationally possible to construct and launch, their use could be to update existing data bases for change detection. This, however, requires that the format of data and the ontological structure of the scenes are harmonised and that methods for analysis and fusion with other data is developed.

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<sup>10</sup> (Surrey Satellite Technology, Eves S., 2008)  
(USASMDC/ARSTRAT)

<sup>11</sup> (TacSat-3 to demonstrate rapid delivery of imagery, 2009)  
(Wikipedia, 2012)

<sup>12</sup> (Surrey Satellite Technology, Eves S., 2008)

<sup>13</sup> (Peter Fox, 2008)

This discussion reveals a general problem with the term “small satellites”. A 500 kg satellite is not much smaller than contemporary conventional reconnaissance satellites thus the payload size and performance as well as launch cost is in the same order of magnitude<sup>14</sup>. But a 50 kg satellite implicates such differences in the mentioned parameters that new technological challenges occur. The report does not separate its analysis by these size differences but is in fact rather focusing on nano- and microsatellites than minisatellites.

### **Assumptions**

The concept scenarios are based on the following assumptions, in the timeframe 2025-2030:

- The technology to produce small devices that combine optical and other sensors, computation, encryption and communication will probably be enhanced during coming decades – i.e. we assume necessary minituarisation is feasible.
- Launch services for small satellites will be developed and available. This is a reasonable assumption since there is both a governmental and commercial interest in developing this area.

### **Suggested military use**

The report suggested using the satellites also for civilian applications. A scenario is presented where national space organisations or research institutions launch distributed satellite systems with 50 to 100 small satellites until the middle of the decade. Earth observation minisatellites are expected to achieve a ground based optical resolution of 0.6 meters (but the radiometric resolution is not mentioned). This is a spatial capacity formerly associated with military spy satellites. The formal requirement for spatial resolution for strategic imagery intelligence in Sweden is  $< 0.5 \text{ m}$ <sup>15</sup>, however, for operational and tactical levels and for other uses of satellite imagery this figure is larger<sup>16</sup>. Also the price for satellite imagery is forecasted to decrease, from about 20 \$/km<sup>2</sup> in the past to about 0.15 \$/km<sup>2</sup>.

When it comes to communication or data services, a comparison is made with the laser based communication technologies developed for UAVs. These allow for extreme data rates, and are forecasted to be available also for microsatellites soon. Space weather and atmospheric research is another area where small satellites can be used for special investigations and where the costs for traditional satellites are too high. A last example is the removal of space debris. The cost is mentioned as an obstacle and here the military use to also destroy active satellites could be suspected.

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<sup>14</sup> A typical mass is 700-800 kg.

<sup>15</sup> (Försvarmakten, 2010)

<sup>16</sup> (Risen, 2012) (Andersson C. R., 2009)

In a recent masters thesis at the Swedish National Defence College (Rasmus Nordström (2012)), the usefulness of micro satellites was discussed. The purpose of the paper was to examine how microsatellites could be used to support operational capabilities in both national and international scenarios. To enable this, several different types of capability are needed. Some of these are based on C4, intelligence and information. Remote sensing can be done by space services and has been studied by the Swedish Armed Forces during the last ten years. The conclusion is that space services are needed. Technology development in miniaturization techniques in recent years has led to the possibility of using microsatellites for remote sensing. The SwAF is now able to implement the desired space services as a result of much lower costs compared to traditional larger satellites.

The thesis stresses the value of an improved operational capability in the coverage of the whole world. Several of the response capabilities that are connected with C4 and ISTAR are enhanced by the use of microsatellite systems both in national scenarios and in international operations (Rasmus Nordström 2012). It is, however, important to note that this requires much greater organisational and educational efforts than the SwAF has today.

### **Concept scenarios in 2030**

#### *Small ISR satellites*

##### ***Description***

The political situation in middle and northern Africa is deteriorating due to conflicting interests in the natural resources of the region. There has been a shift in political leadership in several states resulting in a more radical policy, hostile to western influence. During this transition, conflicts between different ethnic groups have led to violence and destabilization. The fighting has resulted in poor production in agriculture, fishing and local trade. People have started to migrate towards more stable areas. This in turn has led to consequences for the European countries north of the Mediterranean, whose military and police resources are already strained due to an influx of refugees via the sea. In a number of African countries, emigrants and refugees clash with the local population. Regimes in several of these states react by using military violence, further deteriorating the political and humanitarian situation.

Meanwhile in Europe there is once again a growing tension between western European countries and Russia, leading to an increase in military activity in the Baltic Sea region.

In order to stabilize neighbouring areas and to establish control over the refugee situation, the UN calls on the European Union to act. The EU is asked to increase surveillance over the Mediterranean Sea and the coastal areas towards the Atlantic Ocean and to deploy a battlegroup into one of the African states where the

situation is most acute. The operation is planned as a *Time-limited military action*, similar to the former mission in Libya.

Strategic cooperation with other states has given Sweden access to services from one constellation with SAR- satellite systems and one constellation with optical sensor satellite systems. The availability of these services is, however, limited and tied to other ongoing missions. Some intelligence on agricultural conditions, movement of refugees and the presence of heavier weapon systems is obtained. To supplement this intelligence with mission specific information, Sweden agrees with another state to launch a new constellation of small satellites. The new constellation is to support the EU mission with surveillance over the Mediterranean Sea and refugees, while at the same time collecting data for intelligence and planning of the battlegroup mission.

The new constellation of small satellites is configured in accordance with the specific interests of the two cooperating states, common interests and their respective analytic capabilities. Mutual information exchange is contracted. The agreed configuration is made up of optical sensor satellite systems, SAR-sensor satellite systems and SIGINT-sensor satellite systems (Electronic Order of Battle). The service lifetime is estimated to be no longer than three years. Esrange has, in virtue of its experience, knowledge and suitable geographical location for communication with satellites in polar orbit, developed into a central actor. Hence, Sweden can contribute with the ground segment.

Most of the satellites in the new constellation are designed in accordance with the 6U and 4U CubeSat bus standard (typically 30 x 20 x 10 cm<sup>3</sup> and 20 x 20 x 20 cm<sup>3</sup> respectively). In 2025 Plug and play architecture allows design and construction within two weeks of decision, provided components are kept in store. During development, suitable launch services are booked with commercial launching companies or space agencies. The first satellites can be launched at the end of the two week period.

The constellation is configured as follows, in order to best solve the tasks at hand.

- Four satellites with optical sensors. One of which is placed at higher altitude for greater coverage and three are placed at lower altitude for focused retrieval of information. The planes of the orbits are chosen to facilitate command and frequent visits to the - areas of interest (AOI).
- Four satellites with Syntetic Aperture Radar sensors providing high resolution radar pictures of AOI.
- Four satellites with SIGINT-sensors providing EOB-information (Electronic Order of Battle) from AOI.
- Orbit altitudes are chosen between 350 and 450 km.
- A ground segment with two polar stations are used for rapid tasks and data downloading. The main bulk of tasking is made through small rugged user segments similar to the ROVER stations used today for close air support<sup>17</sup>.
- Revisiting frequency in the interval three to five hours can be expected.

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<sup>17</sup> (USASMDC/ARSTRAT)

- After three years the orbits will have degraded and the satellites burn in the earth outer atmosphere.

SwAF first rough estimate of the cost for the mission is presented as follows. Each satellite costs approximately one million<sup>18</sup> kr, i.e. 30 miljon kr in total. The launch is 500kkkr/kg x 20kg/sat x 12 satellites, i.e. 120 million kr in total. The Esrange information management and maintenance of the satellites cost 3500 kr<sup>19</sup>/passage x 4/day x 12 sats x 365 days x 3 years, i.e. 184 million kr in total. Thus, the total estimate of the mission cost over three years is 300 million kr, to be shared between Sweden and the partner state.

For comparison, the cost for the Swedish contribution to the UN-mandated multinational coalition operation in Libya during 2011 was 315 million kr<sup>20</sup>.

### ***SWOT-analysis***

#### Strengths:

- The operation does not violate the territorial integrity of any state and hence it does not require a mandate from UN or EU.
- The configuration gives global coverage over time, thus providing information from other areas of interest, such as the Baltic region in the proposed scenario.
- The effort produces intelligence of great military and political value to Sweden.
- The constellation of small satellites, built with mass market technology, yields lower costs per square km monitored land area as compared to traditional satellites.
- Standardized technology, and hence readily available components and simple integration, permit a relatively short time interval between decision and launch.
- In the proposed scenario there are a relatively high number of satellites. With such a configuration, orbits can be chosen to optimise the revisiting frequency to certain areas of interest for the operation.
- High availability and control when compared to traditional satellites, usually controlled by other actors.
- No personnel in the area of operation yields low risk.
- If conventional forces are deployed for a time-limited-military-action, the satellites can be used in collaboration with other systems such as fast jets and unmanned systems.
- The configuration in the scenario provides conditions for bistatic radar surveillance, thus reducing the effect of stealth technology.

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<sup>18</sup> 6-8 miljon kr 2012

<sup>19</sup> 2012 the cost is 500 dollar/passages – it is expected to decrease with volume

<sup>20</sup> <http://www.regeringen.se/sb/d/14969/a/171151>, Updated 2011-08-24, read 2012-09-11

- The low elevation orbits of the satellites means lower risk of collisions with space debris and lower risk of damage caused by solar wind charged particles, as compared to satellites in higher orbits.
- After use, these satellites will burn in the earth's atmosphere and will therefore not increase space debris.

**Weaknesses:**

- Several involved actors/states could cause contradictory requirements.
- There are payload limitations in the launch.
- SwAF will be dependent on other actors for launch services.
- The small size of the satellites will not permit flexibility in tasking between tactical and strategic levels.
- The small satellite size and low elevation orbits will not permit information from all spectral bands, e.g. imaging IR.
- The coverage is not continuous.
- As the satellites transmit information in a network and to the ground segment, an adversary can use SIGINT and adapt tactics.
- Large amounts of data require large resources for analysis and information management.

**Opportunities:**

- Constellations of small satellites, such as in the proposed scenario, could be used to balance tasks otherwise performed by tactical or strategic air surveillance, manned or unmanned.
- Future development could lead to an increase in available launch services and lower costs.
- The main part of the budget is for ground segment command and control of the satellites. An increase in the number of satellites handled by Esrange might have a positive impact on cost per passage – maybe even “package deals” for SwAF is foreseeable. This is otherwise a part of the process where efficiency-enhancing measures could yield significant pay off.
- Miniaturised technology and plug and play avionics are probably useful in other areas of military materiel development. There could be spin off-effects.

**Threats:**

- Space could become internationally regulated, affecting the possibility of quickly launching satellite constellations.
- Collisions and developments in anti-satellite weapons might prevent use of the lower elevation orbits.

**Assessed capability impact**

Small satellites are believed to contribute to the following capabilities as listed in the armed forces development plan, FMUP 2012.

- C 105 Capability to maintain communications
- I 301 Capability to obtain and deliver geographical information<sup>21</sup>
- I 304 Capability for ranging and transfer of target information
- I 310 Capability for IMINT
- I 311 Capability for SIGINT
- I 313 Capability for RADINT
- I 318 Capability for CBRN-related acquisition
- Anti satellite capability
- Flexible access to the space arena

### Footprint/cost 2025 – 2030

The following list is a compilation of anticipated footprints created by the concept in use.

Item	Assessment
Acquisition cost/ System	Unclear cost/benefit relation. Small satellites in this scenario are used as a valuable complement to air reconnaissance and surveillance. In our very rough estimate of costs the scenario constellation over three years is comparable to SwAF contribution to the seven months operation in Libya.  Significantly lower cost per satellite in comparison to traditional satellite systems.
C2 footprint	This cost is not negligible. However, systems to receive, integrate and analyze remote sensing data must be developed in any scenario. Information management is resource consuming, regardless of future scenario and technology.
Logistic footprint	Could be integrated in existing C3 systems. Need launch services and adaption of ground segment.
Doctrine/TTP	A Space doctrine must be developed – needed in any future scenario.

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<sup>21</sup> Network of Excellence GMOSS – Final Activity Report. Project No. SNE3-CT-2003-503699. Project acronym. GMOSS. Project title. Global Monitoring for Security and Stability Instrument Network of Excellence Aeronautics and Space Date of preparation: 2008-04-09 Project coordinator name: Dr. Hans-Joachim Lotz-Iwen DLR.

Training	Needed on strategic and operational level.
Facilities	Need launch services and adaption of ground segment.
R&D	SwAF should fund and monitor R&D in this area in order to be a competent acquirer and user.

**Conclusions on military utility**

The military utility of small satellites is disputed within our working group, despite an assessed contribution to several of the SwAF capabilities. The main reason for this is that there seems to be other alternatives which provide the desired capabilities, at a lower cost. Communications with and maintenance of the satellites in orbit, as well as the information management of the satellite constellation, still drives cost. Furthermore, the realisability and performance of small productionline manufactured nanosatellites still remains uncertain. Since there is a great interest in the technology area and several programmes are ongoing the knowledgebase is assessed to be significantly better in a five year period. Neither big satellites nor other platforms such as UAVs, SIGINT or reconnaissance aircraft is likely to become obsolete, even if all the technical challenges of miniaturisation are overcome. However, the scenario has shown that there are benefits to the military utility not met by other resources, e.g. the capability to perform surveillance and reconnaissance in operational areas globally without risking violation of the territorial integrity of other states or the lives of military personnel.

We suggest further work to evaluate the military utility of micro satellites and existing relevant platforms in a matrix, where the platforms, the sensors and the operational needs are evaluated in different situations. The purpose would be to guide the optimisation of the mix of platforms for SwAF desired capabilities.



## Evolutionary Robotics

Ref: [9]

### Introduction

Evolutionary Robotics (ER) is an imaginative and metaphorical title for a quite futuristic technology subject. The description of ER in the report seems to focus more on the evolutionary principles (whether achieved characteristics can be replicated or inherited by a subsequent generation or if evolution is better characterized by a process of continuous and steady variation, basically haphazardly, where the fittest survives to bring its characteristics to the next generation), than the advancement and development pattern of robotics and the founding technology itself. Of course it is imaginative to compare the technical development process with evolution through naturally occurring variation and selection. When it come to robotics we can imagine the process both ways as an intellectual process, finding the best solution and applying this or some kind of experimentation that happens to create a better solution, depending on the level of observation and perspective (a designer likes to see characteristics inherited or transferred to the next generation while a more experimental attitude will see the variations, serendipitously as the basis for change).

### Definition of Advanced Robotics (AR)

In order to review Evolutionary Robotics we have to reduce and limit Evolutionary Robotics to advanced robotics (AR) with some smartness and intelligence, which in this case is a degree and capability of adaptation (still within a range, which can be broader than usual, of alternatives and unforeseen variations in the context and environment which still have to be defined), in the direction of a certain learning\_capacity and autonomy (acting with lack of communication and intelligent support from outside). It is then a question of what faculties might be commanded by an advanced robot. Of course movement and manipulation of physical objects are prime capabilities.. But it can also be analytical and intellectual sensing of other sorts.

Anyhow, there may be a certain convergence of technologies that makes many of these characteristics possible to develop and mature in an evolutionary process, into autonomous and intelligent systems. We do not need to see one single “final solution” of this development as some kind of humanoids, “dogoids” (for this, see below) etc. The sheer and proper imagination of capable robots and their usefulness is absolutely satisfying and sufficient as a goal (capable robots means an autonomy and a capability of adaptation and learning). We should not avoid an ethical discussion of developing “too capable” robots either (in popular culture these creatures are often illustrated by over-human capable and invincible robots that overtake, they just need some power to run).

It should be stressed that AR is a technology that recently has been and is being developed and supported in many places in the world, in European countries, the US and Japan to mention the most important places. The development is civilian

to a great extent, with special military and cross military-civilian (emergency situations, laboratory) interest as well. The application areas are traditionally industrial/manufacturing (manipulation) but increasingly social and service oriented (for example in home care of elderly and prosthesis).

In short, the report takes a somewhat special view – a more philosophical than technological view on the developing process when it come to specific capabilities and potential use of robotics, evolutionary or advanced more generally. Summarizing, the report makes an assumption, with which we can generally agree, that there is as much of an enormous potential for military as there is civilian applications of advanced robotics. The report is, however, thin on the specific technologies, the various technological functions, and how and when they can be implemented, integrated and designed into a system. The report does not explicitly project or forecast when and how these functions and uses can come about. There is no specific vision presented in the report of the exact characteristics of an advanced or evolutionary robot. Neither road maps nor technological trajectories along which development can go are presented.

Some of the following characteristics and assessment of characteristics are based on the imagination of the reviewer, and his knowledge and intuitive expectations of robotics development rather than the actual report.

We have no very qualified opinion about the “method” of evolution (design of robots) that the report proposes, although an experimental attitude and approach to robotics development is quite reasonable from a general point of view.

### **Identified constraints**

From analyzing the report the following constraints in design have been found:

- Energy supply limited for longer operations. Autonomous robots must have their own energy supply system (using solar or biofuels input?).
- Locomotion critical (unpaved routes and cross barriers have to be conquered). Moving around in unknown territory is a challenge. A library of territories can be downloaded to be available for particular missions. An intelligent system might develop new algorithms for exploring unknown territories. Micromotors and hydraulics are critical technologies.
- Complex and sophisticated control and movement system needed but easily can fail. Maybe the evolutionary or experimental approach here is appropriate; developing a variety of approaches and designs, where the fittest survive (which ones we do not know from the beginning). Heuristic programming and neural networks a possible solution.
- Probably difficult to harden the system without losing functionality (but intelligence is probably lighter to carry than physical protection and robustness). The lifespan of a system is critical for economic use. Resisting heat, cold, radiation, kinetic energy, data infection and so on are

vital (due lethality is the other side). Self-repair and mending are also important capabilities for viability.

- A broader use and use in dangerous environments require cost per unit to be reduced radically. Mass use or a well designed modularized system (combinations of standardized units for different purposes and contexts) is necessary.
- Intended applications and specialization fields must be clearly stated. The cost factor is discouraging for more than rather special and in statistical terms unusual applications. A certain standardisation or typification of solutions for specific applications (intelligence, recognition) might help, and hopefully reduce effective cost per operation.
- We foresee that an advanced robot has mostly or purely defensive or supporting functions. Can we foresee use of robots for offensive situations (special robot operations?). Systems are lacking (some) operational intelligence for self-defence (the aggression factor may be absent as an alternative to a pre-programmed response to offensive action).

Still, for the foreseeable future, it will depend on external intelligence (for control and downloading of memory, specific problem solving). An advanced robot must have some tutoring to grow up!

### **Assumptions**

The concept scenarios are based on the following assumptions.

- Emerging multi-factor intelligence (identification and adaptation to a variation of conditions, contexts and environments) is on its way. New methods of control, possibly intelligent, are programming through neural networks, heuristic methods and so on.
- Visual interpretation and intelligent pattern recognition usable for surveillance soon, if not already for special situations.
- Sensors are being developed for many situations (chemical nose, image analysis, visual recognition, analysis of electromagnetic activity, vibration and sound analysis etc). Senses for chemicals and substance recognition instruments soon applicable. Objective environmental screening and analysis (humans are subjective).
- Can substitute human labour in difficult as dangerous environments, saves blood (life and injuries), sweat (toil) and tears (more force).
- Tactical behaviour from robots possible (hiding, low signature design through surfaces and shape as innocent creatures).
- Manipulation of heavy and large objects is possible.
- Possible joint or partly joint (civilian – military) development of robotics (platform technology in particular) in regard to the very broad application

spectrum that is possible (rescue and emergency systems or space missions, to name a few).

- Significant for the development of the area is the Stanford Robotic Operating System (ROS), a common platform for robotics developers.

The most extreme applications of advanced robotics we presently know are space missions exploring other planets. An intelligent robot can manage a micro-environment on a planet or a space object that is not very well known. Its purpose is to investigate the ground and the environment and the particular intelligence may be in navigation, identifying (including prospecting) and investigating the characteristics of the object and place (with no communication and correspondence with human operators and intelligence on earth).

### **Suggested military use**

Advanced robotics systems might be autonomous, if not durable within a substantially long time frame. They can hopefully operate when robust, in reasonably low danger environments. The systems might be used for limited or well targeted intelligence operations and explorative situations. Hypothetically they might also become operative as labour in explicit counter enforcement environments in special operations, rescue and surveillance – but this is debatable. For some applications, e.g. when saving human lives is urgent, the systems might be useful and welcome. Relying on robots in the most dangerous situations, e.g. combat, is questionable because advanced robotics lack protection and also because of rules and regulations. Advanced robotics thus can be equipped with the most sophisticated sensors and analyzing systems, superseding humans in all capacities (but relatively “cheaper” than loss of human life). The system can have a low signal profile, lower than humans, who make noise and become fatigued by a heavy mission load (as someone said these systems also do not stop or behave irrationally because of fear). Advanced robotics can be used for advanced intelligence in unknown territories which are considered to be very sensitive, complex and dangerous.

### **Conceptual scenarios in 2030**

#### *Scenario Dog Patrol*

#### ***Description of three possible scenarios***

In managerial terms we might compare AR to managing advanced UGV/UAV operations or perhaps more adequately as a dog patrol. An advanced robot might be compared to an “advanced” dog (with more faculties than ordinary dogs, such as manipulation of objects, extra senses and superior learning, recognition, communication etc).

An AR can be used in rescue operations, e.g. the Fukushima disaster, hostile or emergency situations for surveillance and intelligence, as well as physical operations. The purpose is to identify the damage, inspect existing or potential failures, find, identify and even help victims, as well as repairing or restarting

certain broken installations or critical parts thereof. It is, in military managerial terms, to be compared with UGV/UAV operations. The complexity of tasks depends on the sophistication of the robots and their “intelligence” (all kinds of faculty). The robots can easily reprogram themselves and learn how to behave in a new environment.

A second possible scenario is advanced intelligence in an unknown territory and environment. This might be used on expeditionary operations abroad. The purpose of the robot is to discover conditions (thus needing a lot of smart analytics), identify potential problems, natural or military in character depending on the situation, and prepare solutions. This means proposing elements of strategic behaviour and possibly also tactics for the next step of operations. A presupposition is that the robot cannot for some reason communicate online with or become instructed by the human operators “at home”.

A third possible scenario could be called the combat robots. This scenario implies that the robot is equipped with weapons of one sort or another. Who is the enemy? Kinetics is probably sufficient. This scenario is not further explored.

Of these three scenarios we have selected the first “Dog patrol” in the further analysis.

### ***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats with an AR system concept scenario according to “Dog patrol” can be identified:

#### **Strengths:**

- Convergence of a range of technologies that make advanced (functionally integrated) but still small robots possible and useful/effective for a range of missions and tasks appears to be within sight. A lot of miniaturization (even into the nano scale) is needed but is rapidly developing. These different faculties are not well specified in the report but we can adhere to the overall assessment.

#### **Weaknesses:**

- A range of quite differing technologies has to be integrated into a system. Quite complex constructive design and assembly. Manipulators are critical but modern (micro)technology may make them quite useable.
- Cost factor prohibitive for advanced robots (still hopefully “cheaper” than humans). A human per se is not a substitute for AR; the human “robot” worker or soldier must be equipped with a quite substantial number of accessories for sensors, communication and so forth) which from a complexity point of view implies the true robot alternative more equal or better.
- Complex control theory and programming (autonomy or self-correcting behaviour difficult in more complex situations). New neural networks and

heuristic programming etc may achieve great advances. Functions such as self-repair and mending are also important.

- Difficult to get AR to understand the context and to act correctly in difficult complex situations (the learning function is limited) – but if we limit AR to more narrow situations and fields, this learning constraint can be sufficient (for example just recognizing types of mines within a certain range when demining)

#### Opportunities:

- “Simpler” (but to some extent autonomous and even “intelligent”) robots are already here and the further development of each faculty into ever more advanced robots is easy to foresee.

#### Threats:

- The ethical and regulatory aspects are a great challenge.
- Should there be some robot regulation (like we have for breeding domestic animals)? Must there be administrative or other constraints in autonomy and learning capabilities as well as the degrees of freedom robots can handle and practice? A kind of “speed limit” or throttle limitation that must not be overrun?

#### **Assessed capability impact**

AR can tentatively contribute to the following capabilities as listed in the armed forces developed plan, FMUP 2012.

- E 203 Capability to affect targets on the ground
- E 213 Capability to affect targets in urban terrain
- E 216 Capability to support combat on the ground
- I 301 Capability to obtain and deliver geographical information
- I 304 Capability for ranging and transfer of target information
- I 306 Capability to support commander on tactical level with intelligence prior to decision
- M 401 Capability for mine counter-measures
- M 403 Capability for explosive ordnance disposal (EOD)
- S 712 Capability for MEDEVAC
- S 715 Capability for SAR

#### **Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

Item	Assessment
Acquisition cost/	Expensive, depending on the degree of sophistication and

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System	complexity with regards to functionalities to perform. System integration complex. A well thought through program for modularization and standardization is needed to bring down general costs for difficult to predict applications.
C2 footprint	Control function critical.
Logistic footprint	Basic logistic functions needed with corresponding maintenance/repair.
Doctrine/TTP	Needs special operational rules and regulation including doctrine. It is managerially comparable with UGV/UAV operations.
Training	“Team” (robot and operator) training needed.
Facilities	Room for repair and maintenance and facility for programming and task scheduling (off-site)
R&D	Presently large basic research activities for civilian applications (mostly industrial) can be available and applied to military/military-civilian tasks (robots for rescue operations etc). Sweden has a strong general robotics research and development record. The Swedish automotive/locomotive industry is a good base for robotics development.

### Conclusion on military utility

Evolutionary Robotics, here restricted to the sub-domain of advanced robotics, has uncertain potential for military utility within the period. In the scenarios studied the technology is assessed to have a positive impact on a broad range of SwAF capabilities. The area is large and inconsistent, comprising sub-areas that are assessed to have significant potential, but also those that are believed to have negligible potential or where technological obstacles might retard the development.

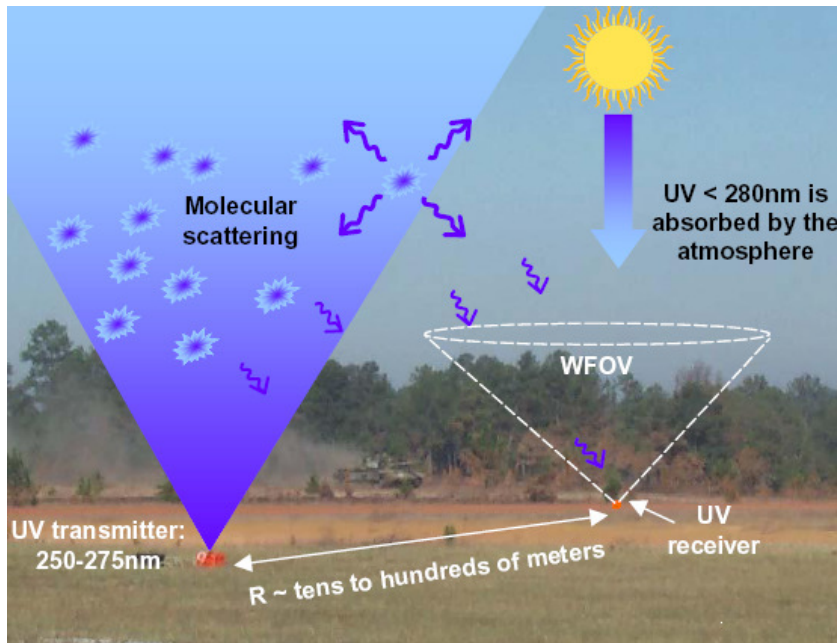
### UV-Communication

Ref: [10]

#### Introduction

Wireless UV-Communication is a technology for optical communication purposes in the wavelength region between 200 nm and 280 nm (the so called Solar-Blind-Region, where the solar radiation is nearly completely absorbed by the earth's ozone layer). Beside the communication in line-of-sight (LOS) it offers the possibility for communication in non-line-of-sight scenarios (NLOS) and also

offers a low noise background. The optical domain provides high bandwidths and therefore principally high transmission rates.



**Fig. 2: Non-Line-of-Sight ultraviolet communication.** The interaction between the ultraviolet radiation in the Solar-Blind-Region and the molecules and aerosols in the lower atmospheric layer leads to a strong scattering of the radiation, which enables a non-line-of-sight link between transmitter and receiver. Furthermore, the communication is not affected by solar background noise due to absorption in the atmosphere.

In general wireless UV-Communication is well suited for scenarios, where no line-of-sight between receiver and transmitter exists or a permanent line-of-sight cannot be guaranteed. This situation can be found in urban terrain, where currently RF-based communication dominates.

Another application area for wireless UV-Communication is the so called quasi-LOS link, which is a link where a line-of-sight between transmitter and receiver exists, but it is minimally or temporarily affected. Examples for quasi-LOS links are communication links in forested or vegetated environments.

The increase in aerosol concentration results in an increase of scattering. Thus, unlike for conventional optical channels, a decrease in visible range may result in enhanced UV-Communication.

### Identified constraints

From analyzing the report the following constraints in design have been found:

- Development of low-cost, low-power transmitters and receivers.



- Photomultipliers (PMT) that can serve as receivers are available, but these are generally fragile, somewhat bulky, costly and require a high voltage.
- Avalanche Photodiodes (APD) might be well suited but are currently unavailable in the Solar-Blind-Region. However, research is actively ongoing in this field.
- Compared to RF-based communication and established optical communication, wireless UV-Communication, LOS and NLOS, is far away from being a mature technology. Despite the progresses made, wireless UV-Communication remains in its infancy.
- Research in the area of Wireless UV-communication is almost exclusively performed by the military sector. Therefore, a limited contribution to the development is expected from the civilian market.
- Theoretical understanding of UV-Communication, especially NLOS-communication, is a crucial prerequisite for widespread applications of the technology.

#### Conclusions in the 2025- 2030 timeframe:

- Wireless UV-Communication is not expected to replace RF-based and established optical communication, but will add to both in specific scenarios.
- Wireless UV-Communication is currently (2012) in the stage of research and development. Due to recent progress concerning appropriate components like receivers and transmitters, practicable systems could be expected in the mid-term, i.e. within the next 10 years.
- LOS Freespace com, NLOS com in urban terrain, NLOS and LOS com at Quasi LOS links, NLOS com in networks with randomly deployed nodes is expected to reach TRL 9 by 2025.
- LOS subsea com and NLOS indoor networking is expected to reach TRL 7-9 by 2025.

#### Assumptions

The concept scenarios are based on the following assumptions.

Due to strong absorption and attenuation in the atmosphere, wireless UV-Communication signals are very difficult to detect and jam.

Wireless UV-Communication has a low probability of interception/low probability of detection (LPI/LPD). It is therefore very desirable in the military domain, especially in tactical operations and in the context of Network Centric Warfare.

#### Suggested military use

The following military uses for wireless UV-Communication are suggested in the report:

- squad radios at tactical level as an addition to RF-based communication

- urban terrain non-line-of-sight communication
- as a complement to established mobile phone networks in urban terrain
- mobile ad-hoc networks (MANETS)
- quasi-LOS link in forested or vegetated environments
- quasi-randomly deployed network nodes for distributed sensor networks
- subsea communication for nodes of underwater sensor networks to monitor subsea oil and gas installations for leak-detection, pollution-control, security and development
- wireless interconnection of indoor IT systems
- communication method when an RF jammer is jamming the RF triggered fuse of an IED which makes RF-based communication impossible
- UV-based communication between ground-based platforms and UAVs

### Concept scenarios in 2030

#### *Urban Communication*

##### **Description**

A Swedish MOT in an international mission has got orders to secure a block in a city where troublemakers are believed to hide after an assault on a UN relief convoy. The troublemakers are to be found and captured.

The region has no wireless communication network and currently the city is subjected to RF jamming of the opposing forces communication. Due to the urban terrain with buildings preventing LOS optical communication, the only possibility for the MOT to communicate during the mission is by non-line-of-sight wireless UV-Communication. The strong scattering of the ultraviolet radiation in the Solar-Blind-Region provides a mechanism for a non-line-of-sight-communication (NLOS communication).

If the transmitter and receiver beams overlap each other, a communication channel can be established even if the transmitter and receiver are not in line-of-sight.



**Figure 1.** When the transmitting and receiving beams are overlapping, UV-Communication is possible.

***SWOT-analysis***

The following strengths, weaknesses, opportunities and threats with the UV-communication concept scenario were identified at the seminar:

**Strengths:**

- Can be used as a **complement** to traditional RF communication, while friendly jamming inhibits own use of RF.
- Low probability of interception and therefore low risk of jamming.
- Only military development restricts opponents' access to the technology.
- Broad bandwidth facilitates good situational awareness.
- If the position of UAV is known, narrow FOV communication is possible, which increases robustness against jamming.

**Weaknesses:**

- Only military development drives costs up.
- If high cost, only one UV-Com system/squad.
- Exposure limits usability and output power.

**Opportunities:**

- Covert communication possible for Special Forces ops.
- Augmented quality of UV-Communication using UAVs as relay station in urban terrain.
- UV-Communication of sensor data from UAV to ground troops.
- If small size and low weight is achieved, gives better ergonomics.

**Threats:**

- Commercial development and availability of jammers might be a threat.
- Conventional RF communication development reduces need for and benefits of UV-Com.
- Technological development concerning high voltage components not successful.
- Theoretical understanding not achieved, hampers development of military applications.

**Assessed capability impact**

UV-Communication is believed to contribute to the following capabilities as listed in the armed forces development plan, FMUP 2012.

C103 support C2 on tactical level

C105 to uphold communications

**Footprint/cost 2025 – 2030**

The following list is a compilation of anticipated footprints created by the concept in use.

Cost	Assessed impact
Acquisition cost/system	
C2 footprint	Software module development
Logistic footprint	Two more gadgets, batteries
Doctrin/TTP	Will there be a UC-Com convention prohibiting use?
Training	Easy to learn to use
Facilities/Infrastructure	New pay-load decreases endurance
R&D	Needed, (not invented here)
Availability	ITAR constraints

**Conclusions on military utility**

UV-Communication has uncertain potential for military utility within the period. In the scenarios studied, the technology is assessed to have a positive impact on SwAF capability to maintain communications. The theoretical understanding of the area is low. It is uncertain if systems can be realized in the time frame. However, if commercial applications are developed, the prospect of military applications might change. In that case UV-Communication could be a complement to RF-Communication but it not foreseen to replace it.

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### Capability matrix

From reviewing the Fraunhofer reports and their respective technologies we have concluded that a number of capabilities listed in the SwAF development plan can be complemented, or even significantly improved. The matrix below gives an overview of the impact of the different technologies.

	Metamaterial Cloaking	Augmented Reality	Nano Air Vehicles	Solid-State Laser Weapons	Analysis	Biomimetic UAV	Electromagnetic Gun	Small Satellites	Evolutionary Robotics	Wireless UV-Communication
C 102		x								
C 103		x								x
C 105		x	x					x		x
E 201				x			x			
E 203							x		x	
E 204				x			x			
E 207							x			
E 213		x							x	
E 215							x			
E 216							x		x	
I 301		x	x					x	x	
I 302		x				x				
I 303		x								
I 304		x	x					x	x	
I 305		x			x					
I 306		x							x	
I 307		x			x					
I 309		x								
I 310		x	x		x	x		x		
I 311		x	x					x		
I 312		x				x				
I 313		x						x		
I 318			x					x		

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		Metamaterial Cloaking	Augmented Reality	Nano Air Vehicles	Solid-State Laser Weapons	Analysis	Biomimetic UAV	Electromagnetic Gun	Small Satellites	Evolutionary Robotics	Wireless UV-Communication
M 401										x	
M 402										x	
M 403										x	
P 503	x					x		x			
P 504	x				x			x			
P 505	x										
S 710		x								x	
S 711		x									
S 712										x	
S 715										x	

## Reflections on the method

Our evaluation of the method used shows that there is a risk that the assessment is biased by the participating experts' presumptions and experiences from their own field of research. The scenarios that were chosen do not cover all possible aspects of the technology and their possible contribution to operational capabilities. It should be stressed that we have assessed the ten technologies' military utility in the presented scenarios, not the technology itself. The chosen definition of military utility clearly affects the result of the study. The definition is believed to be good enough for this report, but could be further elaborated in the future.

The greatest value of the method used is its simplicity, cost effectiveness and the trade off that it promotes learning within the working group. The composition of the working group and the methodology used is believed to provide for a broad and balanced coverage of the technologies under study.

## Bilaga 1 – FM insatsförmågor (SwAF list of capabilities)

Referens: FMUP, Underbilaga 1.4, 2011-02-04, HKV 23 320:52470

### Insatsförmåga (IF)

Specifik verksamhet för vilken resurser (förband med personal och materiel) anskaffats och tränats i syfte att uppnå en efterfrågad effekt som varierar beroende på scenario och ambitionsnivå. En eller flera insatsförmågor bidrar till att lösa en försvarsuppgift.

Insatsförmågorna behövs i varierande grad för att lösa en eller flera försvarsuppgifter och kan beskrivas utan direkt koppling till försvarsuppgifter och deluppgifter. Valet av vilka insatsförmågor som är aktuella i en given situation varierar beroende på givna styrningar och aktuella förutsättningar (exempelvis scenarier) vid en specifik situation. Förmågor som alla förband i varierande utsträckning har för "eget bruk", exempelvis egenskydd i olika former, är inte föremål för specifik insatsförmåga eller en notering i sammanställningen av förband relaterade till insatsförmågor. Utgångspunkten för insatsförmågorna har varit underlag från Försvarsmaktens doktriner, underlag från EU samt i förekommande fall styrningar från regeringen.

Olika former av klimat, terrängtyper och infrastruktur kan normalt relateras till de flesta insatsförmågor varför det inte skapas specifika insatsförmågor för dessa ändamål. Vilka klimat, terrängtyper etc som gäller som underlag för utveckling av förband kan t.ex. återfinnas i FMUP och operativa ramvillkor. Vid behov kan de även uttryckas i ambitionsnivån för respektive insatsförmåga. Vad gäller amfibisk och urban miljö är dessa ur ett TI-perspektiv viktiga för Försvarsmakten då de omfattar områden med särskild karaktär, varför dessa miljöer återfinns som insatsförmågor.

Hur resurserna används för att bidra till insatsförmågorna och för att lösa angivna försvarsuppgifter styrs av de förutsättningar som gäller vid en specifik tidpunkt. Som utgångsläge är det dock möjligt att göra en grunduppsättning (se nedan) där det anges på vilket sätt resurser skulle kunna bidra.

Insatsförmågor används även som utgångspunkt för en förmågebaserad avvägning genom att de prioriteras relaterat till ett antal scenarier och ambitionssätts utifrån vad som krävs för att lösa Försvarsmaktens uppgifter.

### Insatsförmågor

Specifik verksamhet för vilken resurser (förband med personal och materiel) anskaffats och tränats i syfte att uppnå en efterfrågad effekt som varierar beroende på scenario och ambitionsnivå. En eller flera insatsförmågor bidrar till att lösa en försvarsuppgift. Insatsförmågorna är fördelade på kategorier där de i första hand bedöms höra hemma.

C – C4, E – Engagement, I – ISTAR, M – Movement, P – Protection, S – Support (d.v.s. kategorierna är desamma som MD s.k. grundläggande förmågor, red. anm.)

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Kategori	IF nummer	Insatsförmåga	Beskrivning
C	101	Förmåga att leda på militärstrategisk nivå	Förmåga att på militärstrategisk nivå planera, leda och utvärdera operationer, såväl nationellt som internationellt och med civila aktörer.
C	102	Förmåga att leda på ope-	Förmåga att planera, leda och utvärdera gemensamma
Kategori	IF nummer	Insatsförmåga	Beskrivning
		rativ nivå	operationer som sker på land, till sjöss, i luften och i informationsarenan, såväl nationellt som internationellt och med civila aktörer.
C	103	Förmåga att leda på taktisk nivå	Förmåga att planera, leda och utvärdera taktisk verksamhet och operationer som sker på land, till sjöss, i luften eller i informationsarenan såväl nationellt som internationellt och med civila aktörer.
C	104	Används ej	
C	105	Förmåga att upprätthålla samband	Förmåga att upprätta, vidmakthålla och administrera bl.a. data- och telekommunikation för säkert utbyte av nödvändig information inom och mellan samtliga ledningsnivåer och aktuella civila aktörer, såväl nationellt som internationellt.
C	106	Används ej	
C	107	Förmåga att genomföra informationstjänst	Förmåga att informera egna förband samt nationella och internationella aktörer.
E	201	Förmåga att påverka mål på havsytan	Förmåga att t.ex. förstöra, neutralisera, nedtrycka eller störa mål på havsytan.
E	202	Förmåga att påverka mål under ytan	Förmåga att t.ex. förstöra, neutralisera, nedtrycka eller störa mål under havsytan.
E	203	Förmåga att påverka mål på marken	Förmåga att t.ex. förstöra, neutralisera, nedtrycka eller störa mål på marken.
E	204	Förmåga att påverka mål i luften	Förmåga att t.ex. förstöra, neutralisera, nedtrycka eller störa mål i luften.
E	205	Förmåga att påverka motståndaren i informationsarenan	Förmågan att t.ex. förstöra, neutralisera, nedtrycka eller störa motståndaren i informationsarenan.
E	206	Används ej	
E	207	Förmåga att påverka motståndaren på djupet av operationsområdet	Förmågan att förstöra, neutralisera, nedtrycka eller störa mål, på stora avstånd från egna och samverkande styrkor.
E	208	Förmåga att nedhålla eller nedkämpa luftvärn (SEAD/DEAD)	Förmåga att påverka motståndarens luftförsvarssystem.
E	209	Förmåga till dator- och nätverkskrigföring	Förmåga att utnyttja datorer och nätverk av datorer för offensiva och defensiva aktiviteter.
E	210	Förmåga att genomföra elektronisk attack	Förmåga att utnyttja det elektromagnetiska spektrumet för att bekämpa, förvanska eller exploatera motparters inhämtning, bearbetning eller delgivning av information.
E	211	Förmåga att påverka motståndarens beslutsfattare, soldater och opinioner i operationsområdet	Förmåga att påverka motståndarens beslutsfattare, soldater och opinioner i operationsområdet syftande till att förstärka attityder hos målgruppen som är gynnsamma för operationen, främst genom psykologiska operationer.
E	212	Förmåga att påverka mål i amfibisk miljö	Förmåga att genomföra insatser i grunda vatten, skärgård, större floder och floddeltan och där ingående mediaövergångar mellan vattenområde och land.
E	213	Förmåga att påverka mål i urban miljö	Förmåga att genomföra insatser i urban miljö, med små ytor och en blandning av egna, civila och motståndarens



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Kategori	IF nummer	Insatsförmåga	Beskrivning
			enheter samt med stora krav på målidentifiering och graderad verkan.
E	214	Förmåga att genomföra specialoperationer	Förmåga att med särskilt uttagna, organiserade, tränade och utrustade styrkor genomföra operationer med militär-strategisk effekt.
E	215	Förmåga till fördröjande fältarbeten	Förmåga att förändra terräng och infrastruktur för att begränsa annan parts rörlighet och handlingsfrihet.
E	216	Förmåga att understödja strid på marken	Förmåga att på avstånd förstöra, neutralisera, nedtrycka eller störa mål t.ex. i nära anslutning till egna och sam-verkande styrkor.
I	301	Förmåga att skapa och delge geografisk informa-tion	Förmåga att skapa och delge geografisk information inklusive sjökort.
I	302	Förmåga att skapa och delge oceanografisk in-formation	Förmåga att skapa och delge oceanografisk information i form av prognoser eller motsvarande.
I	303	Förmåga att skapa och delge meteorologisk in-formation	Förmåga att skapa och delge meteorologisk information i form av prognoser eller motsvarande.
I	304	Förmåga till inmätning och överföring av målin-formation	Förmåga till inmätning och överföring av målinformation till annat förband.
I	305	Förmåga att upprätta ge-me nsam lägesbild	Förmåga att upprätta och distribuera operativ lägesbild som underlag för beslut.
I	306	Förmåga att stödja taktisk chef med underrättelser som underlag för beslut	Förmåga till planering, analys, bearbetning och delgiv-ning av underrättelser som beslutsunderlag för beslutsfat-tare på taktisk nivå.
I	307	Förmåga att stödja opera-tiv chef med underrättel-ser som underlag för beslut	Förmåga till planering, analys, bearbetning och delgiv-ning av underrättelser som beslutsunderlag för beslutsfat-tare på operativ nivå.
I	308	Förmåga att stödja ÖB med stab med underrättel-ser som underlag för beslut	Förmåga till planering, analys, bearbetning och delgiv-ning av underrättelser som beslutsunderlag för beslutsfat-tare på militärstrategisk nivå.
I	309	Förmåga till personbase-rad inhämtning (HU-MINT)	Underrättelser från bearbetning av information inhämtad genom mänskliga källor.
I	310	Förmåga till bildalstrande inhämtning (IMINT)	Underrättelser från bearbetning av information inhämtad genom bildalstrande sensorer.
I	311	Förmåga till signalspa-ning (SIGINT)	Underrättelser från bearbetning av information från spa-ning i det elektromagnetiska spektrumet.
I	312	Förmåga till inhämtning för att erhålla identitet och signaturer (MASINT)	Underrättelser från bearbetning av information rörande främmande objekts karaktäristika främst utgående ifrån utsänd/-a eller reflekterad/-e energi, signaler eller ämnen.
I	313	Förmåga till radarunder-rättelser (RADINT)	Förmåga att ur radarunderrättelser utvinna underrättelser på strategisk, operativ samt taktisk nivå
I	314	Används ej	

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Kategori	IF nummer	Insatsförmåga	Beskrivning
I	315	Förmåga till inhämtning via öppna källor (OSINT)	Underrättelser från bearbetning av information från öppna källor, både sådana som är publikt tillgängliga (radio, tv, press etc) och sådana som har begränsad spridning (kommerciella databaser etc).
I	316	Förmåga till medicin-underrättelsetjänst (MEDUND)	Förmåga att insamla, lagra och analysera information, inklusive utbyte med andra länder, och därigenom identifiera medicinska och miljörelaterade hot och risker.
I	317	Förmåga till teknisk underrättelsetjänst (TECHINT)	Underrättelser rörande främmande materiel, dess utveckling och prestanda, vilken har eller kan få militär användning/tillämpning.
I	318	Förmåga till inhämtning av CBRN-relaterad information	Förmåga att inhämta CBRN-relaterad information från olika källor för vidare bearbetning och delgivning. Omfattar att kunna indikera, analysera och rapportera inträffade och potentiella CBRN-händelser, inklusive ROTA.
M	401	Förmåga till landminröjning	Förmåga att lokalisera, markera, identifiera och röja landminor.
M	402	Förmåga till sjöminröjning	Förmåga att lokalisera, markera, identifiera och röja sjöminor.
M	403	Förmåga att desarmera bomber och röja ammunition	Förmåga att lokalisera, identifiera och oskadliggöra oexploderad ammunition samt IED ( <i>Improvised Explosive Devices</i> ).
M	404	Förmåga till fältarbeten för rörlighet	Förmåga att förändra terräng och infrastruktur för att bibehålla eller öka vår rörlighet och handlingsfrihet.
M	405	Förmåga till landstigning	Förmåga att etablera enheter från sjön på en fientlig eller potentiellt fientlig strand.
M	406	Förmåga till luftlandsättning	Förmåga till insats omedelbart efter tilltransport luftvägen eller efter fallskärmsfällning.
M	407	Förmåga att genomföra transporter till och från ett operationsområde	Förmåga att transportera personal, materiel eller förnödenheter från eget och samarbetspartners område till ett operationsområde eller mellan operationsområden.
M	408	Förmåga att genomföra transporter inom ett operationsområde	Förmåga att transportera personal, materiel eller förnödenheter inom ett operationsområde.
P	501	Förmåga till fältarbeten för överlevnad	Förmåga att förändra terräng och infrastruktur för att förbättra våra förbands eller systems verkan, uthållighet och överlevnad.
P	502	Förmåga att skydda objekt i luften mot angrepp	Förmåga att skydda objekt eller egna förband i luften mot angrepp.
P	503	Förmåga att skydda objekt på marken mot angrepp	Förmåga att skydda objekt, infrastruktur eller egna förband på marken mot angrepp.
P	504	Förmåga att skydda objekt på och under havsytan mot angrepp	Förmåga att skydda objekt, infrastruktur eller egna förband på och under havsytan mot angrepp.
P	505	Förmåga att skydda lednings- och informationssystem mot angrepp	Förmåga att skydda lednings- och informationssystem mot angrepp.
P	506	Förmåga att genomföra	Förmåga att skydda och evakuera nyckelpersoner till

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Kategori	IF nummer	Insatsförmåga	Beskrivning
		personskydd	säker plats.
P	507	Används ej	
P	508	Används ej	
P	509	Används ej	
P	510	Används ej	
P	511	Används ej	
P	512	Förmåga till sanering efter CBRN-händelser	Förmåga att reducera kontaminering av personal, materiel och i förekommande fall omgivande miljö.
P	513	Förmåga att genomföra eskort till sjöss	Förmåga att eskortera objekt, såväl militära som civila, till sjöss.
P	514	Förmåga att genomföra eskort i luften	Förmåga att eskortera objekt, såväl militära som civila, i luften.
P	515	Förmåga att genomföra eskort på land	Förmåga att eskortera objekt, såväl militära som civila, på land.
S	701	Förmåga att upprätta mottagnings- och omlastningsområden	Förmåga att upprätta och upprätthålla omlastningsområden för att ta emot och omlasta förband, personal och materiel samt genomföra eller stödja RSOM.
S	702	Förmåga till förhandslagring av förbandsmateriel och -förmödenheter	Förmåga till förhandslagring av förbandsmateriel- och -förmödenheter i anslutning till tänkt operationsområde.
S	703	Förmåga till beredskaps-hållning av förbandsmateriel och -förmödenheter	Förmåga till nationell beredskapshållning av förbandsmateriel och -förmödenheter för insatsorganisationen.
S	704	Förmåga till hantering och lagerhållning av förmödenheter	Förmåga till hantering och lagerhållning av förmödenheter i operationsområdet.
S	705	Förmåga till lufttankning	Förmåga att lufttanka annan enhet.
S	706	Förmåga att genomföra bunkring och förråds-komplettering till sjöss (RAS)	Förmåga att till sjöss förse andra enheter med förmödenheter.
S	707	Förmåga till förmödenhetsförsörjning i operationsområdet	Förmåga att i insatsområdet eller från ett basområde försörja förband med förmödenheter.
S	708	Förmåga att genomföra teknisk tjänst i operationsområdet	Förmåga att i insatsområdet eller från ett basområde kunna genomföra materielunderhåll och tekniskt systemstöd av förbandens materiel.
S	709	Förmåga till förebyggande hälso- och sjukvård (prevention)	Förmåga att vidta förebyggande åtgärder (prevention).
S	710	Förmåga att omhänderta skadade och sjuka på förbandsbunden nivå (Role 1)	Förmåga till kamrathjälp och omhändertagande på nivå sjuksköterska samt förmåga till omhändertagande på nivå läkare enligt Försvarshälsans principer.
S	711	Förmåga att omhänderta skadade och sjuka på högre nivåer, upp till nivå	Förmåga till kirurgi, intensivvård och medicinsk vård.