
# Human Performance Optimization and Enhancement

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# Imprint



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Supporting Nations & Organizations

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| Chapter 1 | DEU - GIDS |
| Chapter 2 | MilMedCOE; DEU – BODP; NZL – FLO J-7; FRA – CICDE; GBR – DCDC; SWE - FOI |
| Chapter 3 | MilMedCOE; DEU – BODP; NZL – FLO J-7; FRA – CICDE; GBR – DCDC; SWE - FOI |
| Chapter 4 | DEU - BODP |
| Chapter 5 | SWE – FOI; DEU – BODP; FIN – FDRA; ESP – INTA; NDL |
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| Chapter 7 | DEU – BODP, Bw Medical Academy; SWE - FOI |
| Chapter 8 | USA - Gorge Mason University |
| Chapter 9 | MilMedCOE; DEU – BODP, GIDS; NZL – FLO J-7; FRA – CICDE; GBR – DCDC |
| Chapter 10 | GBR – DCDC; DEU - GIDS |
| Chapter 11 | GBR – DCDC; USA - Gorge Mason University; CHE - Zurich University |
| Chapter 12 | All |

## Administrative Remarks

This document is not an academic study and does not raise an academic claim. It attempts to provide concise information compiled from various sources. For this purpose, the authors waive the requirement of formally citing references; academic standards on quoting are not applied. Yet it is recommended to consult relevant publications listed in the text for additional information in the context of the original source.

## Picture Credits

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Picture 1 Passive exoskeleton in field experiments in Germany left: Laevo (NLD), middle: Paexo Shoulder from Ottobock Industrials (DEU), right: SofTec Dorso from Bauerfeind (DEU).

Photos: German Defense Forces.

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Picture 2 AR glasses from Fraunhofer Institute FEP.

Photos: German Defense Forces.

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Photos: Finnish Defense Forces.

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# EXECUTIVE SUMMARY

## Human Performance – a Tool for Service Members

Performing human capabilities of warfighters to cope with rough and demanding situations historically has always been a progressing challenge for any armed forces. Today, with the rapid development of technology and access to applicable knowledge, we see that human performance techniques are more and more used by societies beyond elite athletes and service members and will continue to influence the future conduct of conflicts.

This project is introducing insight and knowledge of currently available technologies and methods for augmenting human performance. It is a first step in collecting information and assessment of ongoing and planned Human Performance Augmentation programs in the light of interoperability and preparedness of future conflict scenarios. However, the speed of Human Performance Modification developments and the abundant potential of dual use applications requires a much larger and continuous analysis. Ideally, that should be provided by an interdisciplinary and multinational mechanism, which would initiate guidance and best practices, facilitate interoperability and provide situation awareness on emerging threats and vulnerabilities among the MCDC partner nations.

The following five key challenges affecting the interoperability of multinational forces and civil-military interactions have been identified and the following recommendations derive from it:

**1) Common Terms of References - the foundation for interdisciplinary interoperability.** There is a wealth of terms in the domain of human performance that spread from the bio-hacker community to elite sport athletes, health and wellness industry and lastly from the military/security operators community, which created confusion when comparing them. Acknowledging that what is perceived as Human Performance Augmentation today might be normal tomorrow. This project is offering terms and definitions that should fit most of the purposes and support interoperability:

- **Human Performance Modification** (HPM): Active and passive change of an individual's level of performance. While Human Performance Modification usually focuses on optimization and enhancement, we include both Human Performance Degradation and Human Performance Restoration.

- **Human Performance Augmentation** (HPA): HPA is the application of science and technologies to temporarily or permanently improve human performance. This field can be further divided into Human Performance Optimization and Human Performance Enhancement.

- **Human Performance Optimization** (HPO): The process of applying existing and emerging science and technology to individuals allowing them to reach their biological potential.

- **Human Performance Enhancement** (HPE): The process of applying existing and emerging science and technology to individuals allowing them to exceed the biological potential of the individual.

- **Human Performance Restoration** (HPR): Return to baseline when performance has degraded below baseline. The focus here is on degradation caused by illness, injury, exhaustion, side effects, violence, or coercion.

- **Human Performance Degradation** Decrease in performance below previous levels resulting from four principal sources. It can be explained by factors such as reduced biophysical skills or capacity through [1] fatigue, exhaustion; [2] diseases, injuries; [3] system safety issues, degraded system functionality of prior optimization or enhancement; or [4] actions by hostile externally based technologies, platforms or systems.

➢ **Recommendation: Adopt a commonly recognized definition to support common understanding, comparison and interoperability.**

**2) Optimizing human performance seems to be the low hanging fruits**. While physical and cognitive training and drills are at the center of any security and armed forces to achieve a certain level of performance, methods being used so far are mostly based on conservative knowledge and standards. Meanwhile, science has revealed many aspects to improve physical and cognitive performance both of specialized (elite) and conventional forces by utilizing bio-feedback (biomonitoring), specialized nutrition strategies, individualized training and recovery methods. HPA has huge potential to increase mission success, lower risk for injuries and the survivability of any service member. However, there seems to be a reluctance to adopt new methods and tools due to potential disruptive effects on established structures, financial constraints, and unclear advantages of performance programs.

➢ **Recommendation: To conduct a meta-analysis of existing HP programs versus conventional training.**

**a. Focus on potential (short & long term) performance benefits versus the costs of implementing them. Identify low cost programs with high strategic advantages.**

**b. Analyze interoperability, needs and determination among multinational coalition partners with respect to HPM in mission challenges.**

c. **Share reviews and evaluations to assess usability and best practices among partner nations of applied HPA programs.**

d. **Assess future HPM threat environment addressing offensive and defensive issues for tactical and strategic aspects of future battle domains.**

**3) Human Performance is mostly developed in isolated programs – leading to interoperability gaps and wasted advantages for wider unit performance.** Nations have diverse HP programs, however, they usually conducted them in isolation for smaller units, even within one nation. This leads to multiple performance goals and standards which impairs interoperability among joint and combined forces/units. More importantly, sharing knowledge across partner nations beyond isolated and specialized multinational working groups seldom occurs due to several reasons such as protecting the intellectual property-IP or the fear of losing the force advantage edge.

- **Recommendation: Develop guidelines and coordination mechanism to foster sharing of best practices among partner nations and facilitate joint combined research and development projects. Ideally, this would be supported and led by the strategic leadership and conducted through operational and tactical organizations such as a Human Performance specifically dedicated "Center of Excellence", which incorporates existing national and multinational research initiatives.**

**4) HPM will change future warfare.**

HPM methods and technologies are here to stay and will be used both by allied partners and by opponents. Future conflicts will depend on HPM methods applied both for offensive operations and similarly for the protection and survivability of own forces. New skillsets, tactics, leadership and civil-military interaction will be required to compete with the rapid HPM developments. Understanding the rapid pace of development in the domain of HPM technologies will help to address emerging new threats and strategic vulnerabilities. Threats can emanate from lone actors, criminals, terrorist groups or states. Even if we chose not to develop capabilities for legal or ethical reasons we would still need to be aware of the potential of an opponent with HPM supported capabilities.

- **Recommendation: A comprehensive approach towards HPM conflict scenarios should be developed. This includes strong civil-military interaction and requires comprehensive operational doctrine and response strategies and preparing for potential hybrid whole of society scenarios.**

**5) Developing multilateral legal and ethical frameworks.**

As the growth of modern technology affords greater sophistication in future iterations and combat applications it is expected that several different nations may be in possession of advanced HPA technologies, systems and platforms which convey a distinct strategic advantage. There is also the inherent risk that global research and development work on HPA systems, technologies and platforms will continue covertly and under clandestine circumstances conveying tactical and strategic military advantages to forces adopting this set of technologies. Therefore, the explicit pursuit and adoption of both offensive and defensive principles, doctrine and operational guidance are needed to assess the conduct of future combat operations in a climate where the presence of HPA is more likely than not.

Additionally, the current legal landscape regarding HPM challenges among MCDC nations offers multiple interpretations what can be used and what not. The more ethically controversial HPA technologies are likely to prompt demands for new international law to prohibit or restrict their development and use. Defining a common legal base for the implementation of HPA technologies is essential for the societal acceptance of augmented service personnel.

- **Recommendation: First, develop specific HPM principles, doctrine and operational guidance for national service members and multinational alliances.**

- **Secondly, a whole of society approach should enable the development of legal and ethical frameworks that provide guidance beyond the military in the use of HPA science and technologies.**

# 1. Introduction

## 1.1 The Problem

While life expectancy enjoys a huge increase worldwide due to better access to health care, food, water and many other factors, recruiters of military and police services are at the same time struggling to find enough personnel that meet the enlistment fitness criteria. This gap between available performance and that required in current missions is likely to increase in future conflict scenarios. Therefore, optimizing and enhancing has always attracted the attention of armed forces to find the extra nudge that determines survival in a hostile environment and outcomes of armed confrontations, which has the related significance for adversary forces, leading to a potential "arms race" of human performance technologies.

Rapidly improving military technology requires future soldiers to take on a wider range of physical demands and cognitive tasks such as carrying much more personal loads on combat foot patrols while simultaneously handling complex and complicated technical systems to deal with new threats derived from artificial intelligence (AI), autonomous drones, information overflow and blue-red recognition (fratricide) in hyper-dynamic environments.

Some nations have already taken the challenge to cope with those future battlefield scenarios, others have less. From an Alliance or Coalition point of view this leads to significant interoperability issues that can compromise multinational mission success.

Many factors can be named causing this disparity in the adoption of human performance tools, the most prominent ones being ethical and legal issues related to the employment of technologies such as brain computer interfaces or synthetic biological enhancements. While those technologies are considered extreme and aggressive in unchartered ethical territories other programs such as exoskeletons or technically assisted physical or cognitive training by using AR/VR[1] tools face some slow implementation due to technical challenges or unconvincing cost benefit ratio.

The main issue is a lacking overview on current programs. This overview would facilitate closing the existing interoperability gaps. Yet, although almost every nation is working on the above-mentioned topics, there is no common definition of HPE/HPO. In addition, ethical or moral discussions and multinational legal guidelines are not keeping up with the dynamic in HPE/HPO developments.

[1] AR/VR – augmented reality/virtual reality

In times of rapidly changing and evolving technologies, it is necessary to develop a generic HPE/HPO concept, accompanied by an ethical, moral and legal discussion, and, finally, to produce/generate definitions, concepts, guidelines and operational frameworks accepted on a multinational level.

## 1.2 Project Aim and Objective

- A common definition and understanding of HPE/HPO topics, issues and complexity.
- A comprehensive overview of methods for optimizing and increasing performance and their applications in the military context.
- A proposed holistic view of the technological possibilities including the possible ethical and moral challenges for society as a whole and for the armed forces.

Human Performance Optimization and Enhancement are a considerable domain with many linkages to other disciplines. As there is currently no commonly agreed definition and firmly agreed technical terms, the main objective of this project is to increase the level of understanding within the MCDC partner nations to improve multinational military operations.

Furthermore, this project aims to support strategic decision making to invest into the Future of our armed forces while accepting the limitation of budget and resources. By this, armed forces would be fit to face disruptive developments.

## 1.3 Scope and Deliverables

The main outcome should facilitate future HPE/HPO concepts and guidelines for NATO/EU partner nations. The intent is to describe aspects of current and future operating environments, which require additional performance capabilities of the future soldier and military leadership.

The project aims to deliver two concrete outcomes:

- A Project Report, describing the opportunities and challenges, advantages and disadvantages, and potential legal, ethical, cultural, political, and technical implications for service members, as well as aspects of the current and future operating environment demanding improved military capabilities and proposes potential use cases.

- An Information Note, a high-level excerpt for policy and strategic decision makers. Analytical concept describing

## 1.4 Methodology and Approach

Method: The project team from CHE, DEU, ESP, FIN, FRA, GBR, NDL, NZL, SWE, USA and MilMEDCOE has commonly reviewed the study plan & scope and assessed the resources required to complete this study. After initial background research, three Study Focuses were identified:

STUDY Focus 1 – Defining Terms and Reference and the Social, Ethical, Legal Environment

- Developing a working definition for Human Performance "Optimization" and "Enhancement"
- Describing the social, legal, and ethical frameworks that influence the use of HPE/HPO for military purposes.

STUDY Focus 2 – Physical and Cognitive HPE/HPO Programs

- What kinds of HPE/HPO programs exist within MCDC partner nations and how can we ensure interoperability?
- Which programs are the new "must have" capabilities that need to be shared among MCDC partner nations?

STUDY Focus 3 – Future Operation Environment with HPO/HPE

- Science and methods influencing soldiers' and units' capabilities and requirements.
- Identifying shortfalls and risks among friendly forces and assessing capabilities in potential opposing forces.
- Do our multinational guidelines for HPO/HPE support interoperability in coalitions?

Limitations: As the main limitation for this study two challenges were identified:

- Getting required and essential HPE/HPO information and program details (sensitivity, classification)
- Involving the private technology sector and academic institutions outside of the MCDC chain of command / resources.

The intention was to identify trends based on the content of various HPO/HPE programs. A list of programs was compiled based on previous knowledge and additional information retrieved from easily accessible sources. The objective was not to conduct a systematic review as that would have taken another approach and been hampered by constraints in sharing sensitive information. In addition, an inventory was made of existing/available HPA related technologies, predominantly those in current use by the armed forces.

Based on the length of the list of identified HPA programs, it could be assumed that more open programs existed and accordingly additional information that could be accessed. Therefore, a questionnaire was compiled in an additional effort to gather more information from the MCDC participants. This collection was targeted towards data on nation, type, status, aim, content, and objectives regarding established, ongoing and planned HPA projects. The questionnaire was divided in two parts, where the first was focused on HPO and the second directed towards HPE-related programs. Areas of research for the HPO programs were separated into physical performance, recovery/sleep, nutrition, mental performance and other areas deemed important to improve. The HPE-related part addressed sensors, monitoring systems, cognitive neuroenhancement, pharmaceuticals, and genetic technologies. More information and results regarding the questionnaire can be found in the Appendix.

A questionnaire was distributed twice to all MCDC participants though the respective national/organizational coordinators. The second distribution was initiated due to lack of responses in the initial attempt. The following reasons might have be the cause for the little return:

- Difficulty to reach the appropriate contact person/person in charge of the programs.
- The questionnaire got lost in the mailboxes (the second questionnaire was sent out during the onset of the Corona pandemic).
- The concepts of HPO and HPE are not well known throughout the various organizations.
- The questionnaire primarily targeted Special Forces.
- There was an active decision not to answer the questionnaire due to secrecy (classification constraints) or unwillingness to share with the large community.

There seems to be a strong interest in sharing information on research level, which is somewhat reduced when it comes to technology with higher TRL[2]. Apart from classification for military reasons, there may be an issue regarding the industry's ability to protect their intellectual property when information is shared both nationally and on a multinational level.

Finally, four different scenarios referring to distinct stages of conflict spaced out in time going from 2020 out to 2035 were developed, each one consisting of 4-5 pages. The scenarios should tell a story about a specific situation related operation set in a defined area and time. They should be used as a tool to be able to answer questions related to HPO/HPE interoperability including civil-military challenges.

Audience

This project seeks to inform a wide audience, both inside and outside of MCDC partner nations across the defense and civil security sector. It should be relevant to policy and strategy decision makers, concept, capability and innovation development, and additionally to operational commanders and training facilities:

- National and multinational operational HQs and leadership
- J1, J2, J3-5, J7, JMed planners and capability development decision-makers
- Leadership Academies and Tactical/Operational Training Facilities

[2] TRL – technology readiness level

# 2. Multiple Terms and Definitions

One goal of the MCDC project "Human Performance Enhancement and Optimization" is the standardization of definitions. As the topic has been around for quite some time, there is a legacy, and we will find many different terms and definitions. A comparison of the existing definitions shows that they often are ambiguous, imprecise, and overlapping. This leads to the necessity to introduce distinct definitions that can be accepted by different organizations, and hence contribute to interoperability.

However, it is hard to establish a new and precise concept when there is a legacy. Some definitions have been developed with a focus on the needs of specific groups, such as the military. Such definitions are often found in publications that were initiated or commissioned by the military. These definitions are often transferable to other groups, for instance the police and rescue services, especially if they have similar operational patterns. Other definitions specifically address certain aspects to which they directly relate.

A distinction can be made between definitions that refer to the characteristic to be enhanced, such as performance, resilience, or endurance. Others address the concrete property to be enhanced, such as cognition, mental or neurological aspects. Our approach was to build on the existing concepts and define a suite of coherent definitions that would consider all aspects of changes to the human system, passive or active.

For many different purposes like international research, military interoperability and consideration of legal and ethical consequences, neutral and purpose-free definitions are essential. Furthermore, the use of terms like enhancement and optimization has to be clearly understood and internationally accepted.

## 2.1 Human Augmentation

There are many ways to augment a person, ranging from coffee in the morning, a diet with special supplements, the use of tools or sensors on the body to capture environmental factors, to brain interfaces. These substances, technologies and methods can augment a person's human capabilities or, in some cases, go beyond them. In order to clearly separate these two options, it is advisable to distinguish between optimization and enhancement. Optimization means that the human performance is increased up to the individual´s maximum, which we refer to as the biological potential.

Optimization includes all human abilities that can be improved without adding any non-human abilities. The biological potential is, thus, unique for each individual and includes both physical and cognitive aspects. Enhancement, on the other hand, involves substances and technologies that are used to achieve performance that extend beyond the inherent human abilities. Consequently, classification as optimization or enhancement solely depends on the possibility to exceed the biological potential.

Augmentation technologies and methods can be applied in various ways: non-invasive but close to the body, invasive, temporary, or permanent.

Both optimization and enhancement activities change human performance in a positive direction, and in some cases, the transition between the two can be seamless. Since the differentiation between optimization and enhancement often is difficult, especially near the biological potential, we suggest using the inclusive term Augmentation. Human Performance Augmentation thus comprises Human Performance Optimization and Human Performance Enhancement. In this note we will therefore always talk about HPA, and only use the terms HPO or HPE when they are specifically warranted.

*Baseline*

The baseline is an individual's current level of performance. It changes over the lifetime of a person as well as over a single day. Therefore, it is better to think of this baseline as a range rather than a clearly defined line. The basis of this current level of performance of a person is the so-called homeostasis. Homeostasis is the ability to maintain a relatively stable internal state that persists despite changes in the world outside. As this internal state is disturbed by external stimuli, the human has to keep and restore the balance between demand and performance.[3]

In some cases, the improvement in performance starts from a level that is below the baseline. To distinguish this type of positive performance changes from HPA, the word human performance restoration has been introduced and will be discussed in more detail in the chapter with the same name.

[3] The chapter Human Performance Restoration will discuss the phenomena involved in this process in more detail.

## 2.2 The Opposite of Human Performance Augmentation

A positive increase in performance could or should theoretically be accompanied by a negative decrease in performance. Thus, for the sake of completeness, we have also looked at these possibilities under the name of Human Performance Degradation.

We have identified four different types of degradation in performance from the current individual baseline:

1. Normally, the performance level of an individual decreases throughout the day. This process is intensified when the person is engaged in physical or cognitive activities. Little rest, insufficient food intake and all kinds of stress can also accelerate this process. A healthy lifestyle, regular eating and drinking, and sufficient recovery periods after strenuous phases can counteract this phenomenon. The internal processes in the body ensure that the organism recovers on its own.

2. The performance level of an individual decreases when the body is weakened by illness or injury. Diseases can have external (viruses) and internal (autoimmune reactions) origins, which can be treated with selective (medical) therapies. Injuries can be caused by physical trauma in accidents or on missions. The danger of injuries due to overstrain should also not be underestimated. Here, too, people can be helped with appropriate medical interventions and therapies. Nevertheless, it is still possible that performance cannot be fully restored.

3. HPA techniques aim to augment the performance of a person. However, their application can also have the opposite effect. It is also possible that through incorrect use, misuse or faulty technology the opposite effect - a reduction in performance - can result. It is also possible that an increase in the performance of a specific ability as a "side effect" lowers the performance in another ability.

4. The last case to be mentioned here is the targeted reduction of performance by adverse or hostile forces. On the one hand, this can be done by sabotaging or eliminating HPA techniques or by neutralizing their effects. It is also plausible that technologies and methods are developed specifically to decrease the performance of a human being.

# 3. Definitions

## 3.1 General definitions covering the HP phenomena.

In the previous paragraphs the terms HPA, HPO, HPE, HPR and HPD were introduced and will now be summarized in short and concise definitions. Common to all terms is that they consider a change in a human's performance in both the positive/increasing and negative/decreasing directions. The relation between defined terms is shown in the diagram in **Error! Reference source not found.** We have chosen the term Human Performance Modification as an umbrella term that includes all other terms. HPA covers both HPO and HPE, which are positive developments of performance, and therefore shown in green. HPR, which has no intersection with HPA, is also positive in performance development, and thus shown in green. HPD, however, does not intersect with the other terms and has negative performance development, hence represented by red color.

- **Human Performance Modification**: Active and passive change of an individual's level of performance. While Human Performance Modification usually focuses on optimization and enhancement, we include both Human Performance Degradation and Human Performance Restoration.

- **Human Performance Augmentation**: HPA is the application of science and technologies to temporarily or permanently improve human performance. This field can be further divided into Human Performance Optimization and Human Performance Enhancement.

- **Human Performance Optimization**: The process of applying existing and emerging science and technology to individuals allowing them to reach their biological potential.

- **Human Performance Enhancement**: The process of applying existing and emerging science and technology to individuals allowing them to exceed the biological potential of the individual.

- **Human Performance Restoration**. Return to baseline when performance has degraded below baseline. The focus here is on restoration from degradation caused by illness, injury, exhaustion, side effects, violence, or coercion.

- **Human Performance Degradation**. Decrease in performance below previous levels resulting from four principal sources. It can be explained by factors such as reduced biophysical skills or capacity through [1] fatigue, exhaustion; [2] diseases, injuries; [3] system

safety issues, degraded system functionality of prior optimization or enhancement; or [4] actions by hostile externally based technologies, platforms or systems.

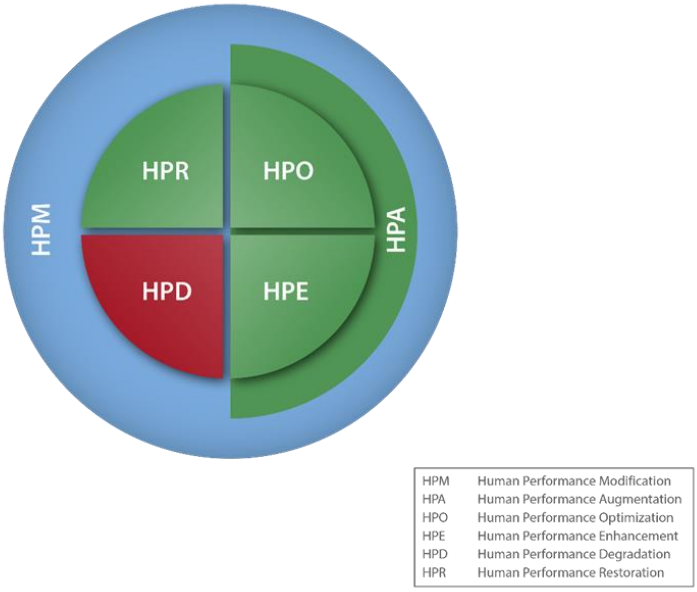



Figure 1 Relation between different notions of performances.
HPM is the umbrella term that includes all other terms. HPA includes HPO as well as HPE, which are both positive developments of the performance of an individual, therefore shown in green. HPR is also a subset of HPM but has no intersections with HPA and shows a positive performance development, therefore shown in green, too. HPD is also a subset of HPM without intersections with the other subsets and is a negative performance development, represented by the red colour.
Source: own development

The possible process to achieve HPA relies on interventions such as adapted training, appropriate diets, pharmacology, implants, prostheses, and genetic modifications. Use of equipment, even if it is not intrusive in the body, may require a cognitive modification. Hence, some nations may consider that equipment is part of HPA while others may consider equipment as out of scope. The view in this note is that equipment is closely linked to the body and thus part of HPM.

In the course of an individual's life, values such as the current physiological performance level (baseline) or the biological potential change, sometimes considerably. Figure 2 shows a standardized representation of lifetime in which the definitions of the different performance types have been inserted.

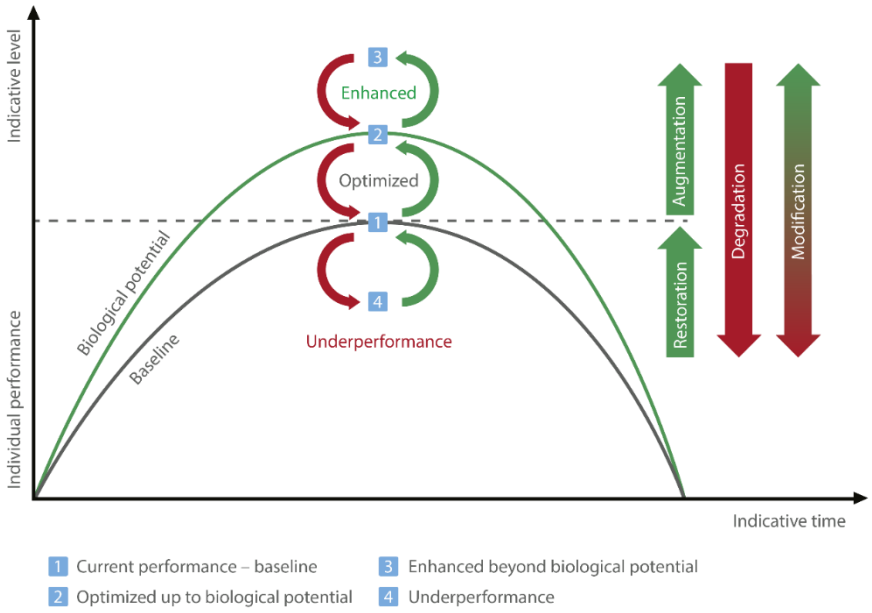



Figure 2 Individual life cycle.
Source: own development

We recognize that group or unit performance relies not only on the individual reaching the minimal standard needed for task performance but also on appropriate assessment and selection of the individual for the task and engaged leadership. How this can be applied in the military context will be discussed in chapter 11 – HPM Assessment of Future Scenarios.

# 4. History of Human Performance Augmentation Technologies in Warfare

Human Performance Augmentation is not a new topic. From the first time one of our ancestors picked up a rock to hit their prey or enemy, we have tried to reach and exceed our potential. More importantly, we have, until recently, considered aspects of performance modification such as cognitive and physical performance as separate. With improved testing and a more complete understanding of neuroscience, we understand that the two are intimately connected. This chapter reviews parts of history of human performance augmentation technologies with a special focus on warfare.

Augmentations to improve relative military performance is not a new concept; far from it, the scope of use ranged from the slingshot to increase the throwing range through the knight's armor to reduce the risk of an injury to World War 2 soldiers taking Pervitin (methamphetamine, "crystal meth") in the form of tablets in order to enhance their physical and mental performance capabilities. The traces of enhancement can be tracked back to the beginning of human conflict.

**Alcohol**

Roman legions and Greeks – **wine**
British military –- **beer, gin and brandy**
Royal Navy – rum
to stiffen resolve, to encourage, to motivate,
to enhance combat effectiveness

**Plants and Mushrooms**

Viking "berserkers" fought in a trance-like state, possibly as a result of taking agaric "magic" mushrooms and bog myrtle. Ancient Icelandic historians described them "as mad as dogs or wolves, bit their shields, and were strong as bears or wild oxen".

**Cocaine and Opium**

Pain relief provided by cocaine and opium at the cost of drug dependence and addiction
Indian Mutiny of 1857
American Civil War 1861 - 1865

**Steroids**

World War II - to help malnourished soldiers gain weight
Cold War - objection to build muscle mass and strength, quicker reaction times, greater situational awareness, sensory awareness, resistance to environmental factors such as extreme cold and heat.

**Synthetic Drugs**


Heroin - quicker in its effects than opium but more addictive
Methamine and amphetamine drugs called Pervitin
For military personnel in highly stressful, confined, or isolated conditions (fighter and bomber crews, submariners, in combat environments, such as jungle warfare)

There is also another factor: Many historical commentators, especially technologically focused Europeans, have attributed the ferocity of their opponents to a combination of primitive religious beliefs, unsophisticated cultural and social structures and a variety of artificial stimulants to increase aggression and strength and resistance to pain or serious injury. The Cheyenne Dog Soldiers, Maori people of New Zealand, Zulus of Southern Africa, Dervishes of Sudan and Pathan tribes of the North West were all described by Western forces in the 19th century as savage, courageous, unsophisticated and employing drugs of one type

or another to enhance performance. However, a more balanced appraisal would identify all of these widely diverse and distinct civilizations as having one thing in common: A distinct social and cultural identity, providing cohesion are linked with strong military and warrior cultural ethos, based upon close quarter individual combat, glorifying individual sacrifice and bravery in defense of their community.

Stimulants in combination with these attributes created fearsome warrior cultures that could overcome dreadful wounds in fight with the enemy; this is seen today in militant Jihadist groups across the Islamic world, but also amongst other religiously and ideologically motivated groups. In other words, group identity, distinct ethos, ethnic and cultural values as well as nationalism and ideologies may provide a narcotic-like effect with heightened psychological and mental faculties that which is only magnified by artificial stimulants.

The future of human enhancement will therefore be shaped by the history and the past of human development and efforts to gain clear advantages from 'warrior superiority' on the battlefields from ancient Rome, Europe, North America, through the Napoleonic Wars and World Wars, into the battlefield of the future battlefields of the 21st century.

# 5. Programs in Use

HPA is associated with many different types of technologies and scientific knowledge to improve soldier's protection, physical and cognitive performance as well as recovery. The area is overly broad; there is so much that can be done and should be done. The notion is that, working together, there will be a larger body of knowledge, chances to avoid pitfalls, possibilities to establish common interfaces as well as practices and policies to the extent possible depending on national regulations.

This section will address observed trends and aspects of interoperability together with a selection of programs and future opportunities for human augmentation that can be seen in the midterm timeframe. The overview includes examples of technologies such as internal and external devices but largely excludes the wide field of biotechnology. Some of the herein mentioned technologies are put into use and context in the chapter "HPM Assessment of Future Scenarios".

## 5.1 Trends

The overall review of the information collected on activities from MCDC participants showed that most, if not all, have some kind of HPA programs. With some exceptions, most existing technologies and programs that relate to human augmentation can be found in the area of optimization. The different programs comprise a number of technologies and applications including Telemonitoring, Smart Textiles, Exoskeletons, Augmented Reality, Virtual reality, Body heating, Power & Connectivity, Sensors, Neuroenhancement, Pharmaceuticals, Training applications, and Soldier of the Future concepts. The overview revealed that the programs were either based on commercially available products and tools or specifically developed solutions for the unique military purposes.

Unfortunately, only six nations answered the questionnaire, which means that the result is not representative of programs and activities among MCDC member nations. However, the result provides an indication of the relative interest between categories and is complementary to previously gathered information. The results indicate that HPO programs concerning physical performance and recovery/sleep are already common and established, thus presumably considered important by the participating MCDC nations.

The inventory also revealed that there is a lack of established and ongoing programs with respect to HPE topics, at least not for general use by the larger group of service personnel. Compared to the HPO programs it is clear that the HPE programs are less common but also presumably more secret/classified than HPO programs. None of the participants indicated that they had any activity related to genetic enhancement.

By looking at directions of current research and development in combination with gathered information on previous, current, and planned HPA programs, some short- and mid-term trends could be identified:

- Exploration of the exoskeletons
- Exploration of VR/AR
- Extensive interest in biosensor technology
- Development of biomonitoring systems (physiological monitoring) based on biosensors
- Opened interest into the vast area of biotechnology for augmentation purposes

Widening the search to include the concept of biotechnology reveals that in fact virtually all aspects of HPA are of interest to the participating nations. The programs range from assessment of the applicability in measuring devices to advanced combined training solutions and genetics. Together the nations have activity that cover all military arenas with R&D[4] that can be found in a wide range of TRLs.

At this point, we must recognize that one type of technology may have more than one application. In fact, VR/AR and biomonitoring systems have multiple applications. This means that we must consider the fact that there may be differences in trends depending on the application domain. Figure 3**Error! Reference source not found.** illustrates how four of the identified application domains for "Wearable monitoring system" relate to various subsystems technologies. Successful realization of such complex systems depends on development in vastly different technological areas.

[4] R&D – research and development

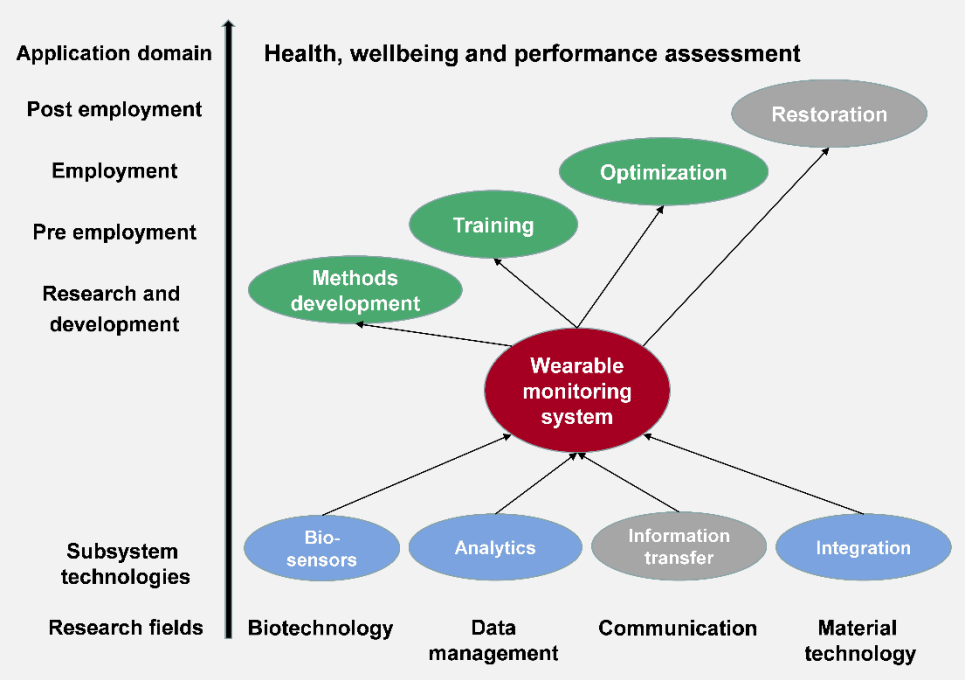



Figure 3 Illustration of the relation between technology and application domain.
Green color is associated with applications; blue color indicates technologies; and grey color shows areas that have been excluded from this note.
Source: own development

## 5.2 Aspects of Interoperability

The nature of HPA may entail clear risk of silo effect with respect to technological development and operational use. One purpose of the MCDC collaboration is to work for interoperability, which means, among other things, developing common concepts. Interoperability does not manifest by itself; on the contrary, targeted activities are needed on several levels. Figure 4 illustrates in a nutshell how national and international activities take place in parallel as the technology readiness level increases. Each step up in the pyramid requires an active measure to maintain the opportunity for interoperability at the next level.

The interoperability concept with respect to human augmentation relies on recognition of the content associated with each step and definition of activities that must take place. This involves anything from making an inventory of where we are technically, where our interest and focus lie, as well as recognizing differences in use, legislation, and acceptance between nations.

Although Figure 4 is based on a bottom up perspective, the outcome does not end with utilization. In practicality, both utilization and threat generate need for further development and the sequence starts all over.

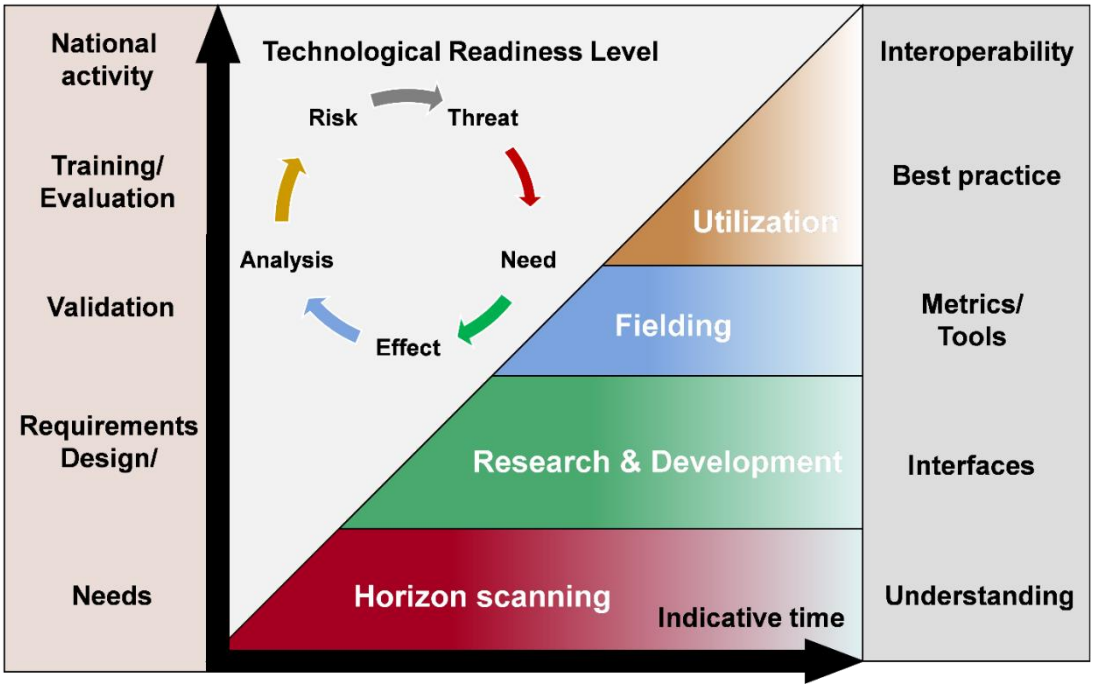



Figure 4 Framework for establishment of an operational augmentation concept.
The circular inset illustrates the continuous need for capability development with respect to defense materiel.
Source: own development

In the context of HPA, there are many different opportunities and possible directions for interoperability. Starting at the lowest level and working the way upwards:

- Questions for the first level are "what is the next thing and what should we concentrate on?". The lowest level pertains to common understanding based on shared knowledge and assessments of emerging technologies and future potential for HPA utilization. The effort is facilitated by established common definitions such as stated in section 3 of this note.

- The second level deals with those "hard" requirements that are a prerequisite for realization of interoperability and have to be built into the systems. Typically, this level stresses the need for common interfaces that enable compatibility, such as physical and electrical standards. This need has been addressed by multiple NATO efforts, EDA and other initiatives. For instance, specific programs have been looking at standardization

of soldier systems (STASS, GOSSRA) which has many parallels to the wearables that are in discussion for HPA. Standards and recommendations developed within MCDC could support interoperability.

- The third level focuses on "how to do things". For instance, the versatility in MCDC participating organizations and defense forces with respect to materiel, education and training means that it is difficult to compare results and experiences. The goal is to identify common metrics and tools for assessment of augmentation effect. Part of that is to share methods and work towards building a larger common body of knowledge.

- The highest level deals with "how well does it actually work and what are the issues?". At this stage, there are experiences from operational usage and the goal is to share lessons learned and define best practices. Interoperability on this level depends on established agreements and policies between the participating organizations.

This project has initiated work aimed at identifying the various forms of interoperability that apply to HPA development and use. An important part of the continuing effort is to determine the level of ambition per technology area and application. There is also a need for a way to manage and administer the body of knowledge that is being built up over time.

# 6. Overview of HPA Technologies and Programs in the Military

The concept of HPA is not new, it is essential to personal, family, unit, and organizational success. The objectives of HPA programs should include efforts to: optimize mental and physical resilience of the service personnel, reduce injury and illness or promote more rapid recovery, provide information and knowledge transfer from laboratory to line, improve the human system contribution to mission success, and improve human systems' ability to accomplish the mission. Today's HPO programs are primarily directed towards training opportunities, professionalization, and analysis methods while HPE programs focus on exoskeletons. This chapter describes technologies and programs that match the identified trends.

Training and operational circumstances affect individuals differently. The expectation is that sleep, nutrition needs, mental/physical training (fitness) and stress could be managed on an individual level using biomonitoring systems. The aim is to provide a wearable sensor system that is usable for training and operational scenarios to monitor physiological and mental status. The ability to control the effects on an individual level enables high priority on prevention. These types of monitoring systems could be used to support casualty alerts, triage and medical care. However, the initial goal has been to provide operational support to individuals and their leaders.

## 6.1 Exoskeletons

Another interesting field is the use of exoskeletons (external structures) that can reduce the impacts of carrying heavy loads and add extra strength and endurance. Exoskeletons include both passive and active (powered) systems as well as robotic gloves. Although the military started out with exploring the usage and advantages with active exoskeletons, the interest has now shifted towards the passive types of exoskeletons. While active skeletons, capable of providing extra force, are mostly still in the R&D phase, the passive ones are more technologically mature and easier to apply in the field (see **Error! Reference source not found.**).

Picture 1 Passive exoskeleton in field experiments in Germany left: Laevo (NLD), middle: Paexo Shoulder from Ottobock Industrials (DEU), right: SofTec Dorso from Bauerfeind (DEU).
Photo: German Defense Forces.

Power consumption rate creates a limitation for active skeletons. Currently, they have a place in short duration missions with certain use cases such as specific tasks that require heavy lifting and repetitive movements (e.g. logistics). However, there are expectations that future technological advances, e.g. in battery technology, will extend their usability.

ATREC (Assessment in Real Time of the Stress in Combatants) is a system developed for the Spanish MoD by Alcalá University between 2011 and 2013. The final product was a smart textile (textrode-enabled measurement) able to differentiate among four states (cognitive activity, emotional activity, physical activity and neutral baseline) in real time while the user was dealing with typical military activities.

Although initially measures of skin galvanic response, environmental and peripheral temperature, cardiac biopotential and thoracic impedance were studied, the final wearable garment uses a set of parameters (more than two hundred) obtained from cardiac biopotential and thoracic impedance measures.

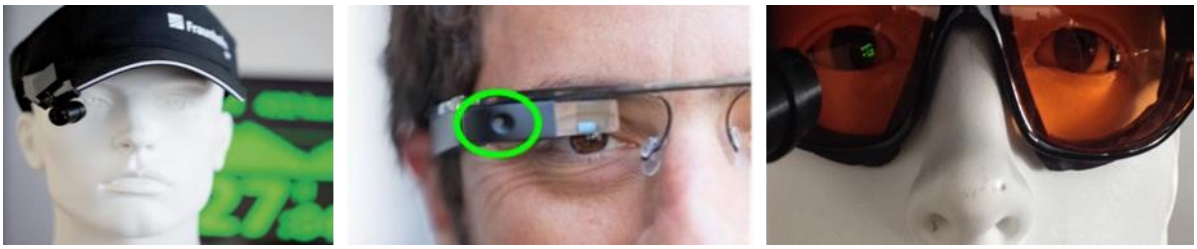
The system algorithm was implemented using artificial intelligence and was tested by soldiers and policemen, even bomb disposal experts, in a real environment. Once the final prototype was finished, it was tested in a real situation but analyzing the data offline. This situation consisted in studying several advanced training pilots' sessions where they solved emergency situations in helicopter simulators. As a result, we proved that the system could detect the pilots' implication in the problem to solve. Although it is necessary to continue working on this device developing different algorithms in order to adapt it to different situations, ensuring the generalization and the validity and the reliability of the results, it is possible detecting, in real time, the mental involvement in real environments.

New technologies are adding complex challenges to the operational environment. There are a lot of studies related to stress and high mental workload, but it is necessary to consider the opposite state, that is, "an insufficient" motivation and attention to solve unexpected situations. When a system notifies an alert, the operators have to know how to deal with the sudden situation, but the automation of new technologies can elicit operator boredom, and finally an incorrect performance. ATREC system was able detect low mental activity.

## 6.2 Augmented Reality / Virtual Reality

Augmented Reality is a technology that can be used to readily present information to the soldiers on the battlefield. AR is based on symbology that is overlaid on the battlefield view in real-time. Dedicated symbology is used to highlight vital information such as threats, intent, orders, call-signs, high risk areas, and special points of interest. Suggested actions, as determined by built-in AI, may further aid the soldier/commander in the decision-making process. The information could originate from various sources such as an UAV/UGV[5], members of own unit, different command levels, and medical staff. The result is expected to be an information advantage in the battlefield, provided that the information can be presented to the user without increasing the cognitive workload. Virtual Reality is a technology that presents an all virtual environment, thus creating an immersive sense of being in another place and situation.

Military AR and Virtual Reality applications can, largely, be based on commercial products. For instance, DreamGlass from Dreamworld was tested in the German project "AR in operation". They also found that HoloLens from Microsoft was suitable for briefing and debriefing applications. On the other hand, the German project "AR and VR technologies" was using in-house developed prototypes (see **Error! Reference source not found.**).



Picture 2 AR glasses from Fraunhofer Institute FEP.
Photo: German Defense Forces.

[5] UAV/UGV – unmanned aerial vehicle/unmanned ground vehicle

AR-based presentation offers additional possibilities for enhanced situational awareness. For instance, an AR system equipped with eye gaze technology could provide feedback on the user's eye point of gaze in relation to enemy position in a 360° surrounded field, thus indicating areas the operator should be focusing. Opportunities and varieties of use are very wide and under further development. In addition to operational applications, AR and VR are for instance used for education, familiarization, training, briefing and debriefing.

## 6.3 Biomonitoring and sensing

The development of physiological monitoring systems (sensors, transfer, analysis, feedback) has been triggered by sport and health trends. Today, the commercial market provides an abundance of low-cost data collection gadgets such as sports watches, all of which have been enabled through miniaturization of technology and connectivity. From a comfort and usability point of view, wrist based monitors offer an advantage over chest belts. However, the functionality and accuracy may not reach the necessary level. For instance, NATO panel HFM 260[6] reported that the test of a Swiss wrist -based heart rate (HR) device based on PPG-technology produced inaccurate HR readings for some individuals. Although limited in functionality, COTS systems can, for instance, serve as a first step in keeping track of individual progress in fitness.

More capable monitoring systems (e.g. ZEPHYR® Performance System and Equivital by Hidalgo Ltd) can often record various types of biodata including heart rate, body temperature, breathing frequency and oxygen saturation. However, there are caveats; most commercial monitoring systems are not sufficient for neither research nor military needs. Typically, a military environment places demanding requirements on:

- reliability and data quality,
- comfort and ergonomics (usability)
- offline/online data collection,
- access to security measures,
- robustness, and

[6] Buller, M., Bitterle, J., Delves, S. K., Veenstra, B. J., Roos, L., Beeler, N., & Wyss, T. (2016). Validity of wrist based heart rate monitors for the physiological assessment of Swiss Army recruits. In: 13th Annual International Body Sensor Networks Conference (BSN 2016) (p. 49).

- handling of authorization (accessibility) and integrity.

A difficulty is the ability to obtain reliable and accurate data under the often harsh and varying conditions in the field environment. For instance, there has been a significant technological development effort with focus on wearable EEG monitoring solutions. Efficient noise reduction and advanced data analysis methods are warranted for credible and useful status assessment indices. Together, these particular needs have led to national approaches and efforts to develop bespoke biomonitoring systems.

Physiological monitoring has many potential applications for the military where real-time health and performance status of individual soldiers can provide actionable information to the individual, leaders, and medical personnel. Actionable information relevant to military applications is needed and can be derived through development of physiologically based algorithms and iterative testing with soldiers in realistic field environments. One example is the Ambulant Registration of Military Operational Readiness (ARMOR) that is being developed by the Royal Netherlands Army in collaboration with partners. It is an integrated multi-sensor system aimed at measuring physical workload, performance, and soldier health status. Recorded parameters include gait speed, distance, step frequency, activity class, heart rate, core temperature, energy expenditure, and sleep duration.

Biomonitoring systems can be integrated into Smart Textiles (new materials for protection, lighting, heating, cooling, adaptive camouflage, energy harvesting, and sensors). For example, the German Bundeswehr specialized Smart Textiles based system (the MobPhysioLab®), with integrated human biomonitoring sensors, was tested under military field conditions. This monitoring system, shown in **Error! Reference source not found.**, is a R&D prototype for monitoring skin temperature, oxygen saturation, humidity, respiration, and heart rate. The biosensor system transfers suitable biodata for military purposes and can be used to analyze physiological strain index and wound parameters.

Picture 3 MobPhysioLab Systems. Photo: German Defense Forces

In a threat situation, the optimization of casualty care decisions is facilitated by monitoring parameters related to injuries. The requirements for the digitalization of the medical evacuation chain using human biomonitoring data was analyzed in the Human Performance Enhancement: Smart Textiles and Augmented Reality project (HPE-STAR). It was important to determine who needs which information. Further experiments to visualize human biomonitoring information for medical and unit leaders will be the next step. Human biomonitoring data should also support the rescue of fellow soldiers, because the first hour after a casualty event is the most important for survival of the injured soldier. All results from

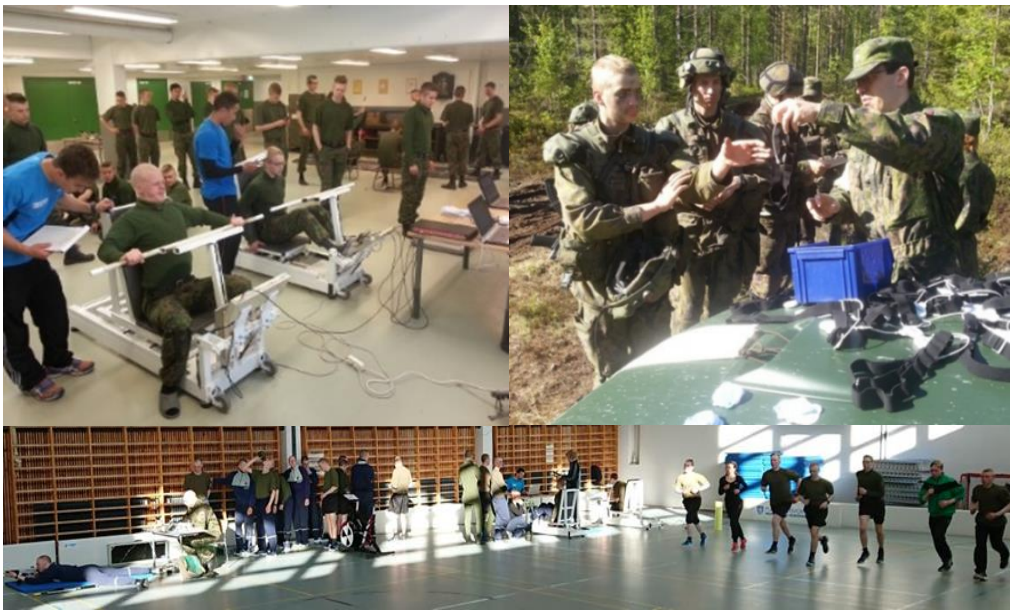
the project will be transferred to the NATO architecture framework to promote interoperability. Furthermore, a data protection and IT security concept will be developed with experts to facilitate implementation.

Other efforts include combinations of several types of technology used by the monitoring system. One such wearable military sensor system is the REAL TIME PHYSIOLOGICAL STATUS MONITORING (RT-PSM) project led by USARIEM (United States Army Research Institute of Environmental Medicine). The project analyzed uses cases for monitoring of thermal strain and workload management, alertness and neurocognitive status assessments, physical fatigue management and avoidance, early detection and pre-clinical mitigation of musculoskeletal injury, and hydration and metabolic fuel management in soldiers. This is in line with the German CD&E-project HPE-STAR.

## 6.4 Training

Training is the oldest and most popular approach to increase performance. However, advances in understanding the physiology of strength building, endurance, metabolism, and neuropathways can contribute to the optimization of a person in ways that show extraordinary results in comparison to "classic" training methods. For example, the Tactical Human Optimization Rapid Rehabilitation and Recondition (THOR3) program used by the US Special Operations Command (SOCOM) has developed an approach to increase combat performance, prevent injuries, improve health and longevity and facilitate rapid return to duty. The program differs from other fitness programs in that it applies a holistic approach to improving physical and mental performance. The training of an individual unit include besides strength and conditioning also physical therapy, diet, teaching of expertise and supervision of cognitive specialists.

The Finnish Defense Forces have developed the Training 2020 concept to adjust the structure of the training system in order to increase effectiveness and efficiency of conscript training. Human performance optimization is a key element of the Training 2020 concept, which has two main programs: Soldiers' Mind and Soldiers' Body. Both programs are aimed to be progressive training programs throughout conscript service. Soldiers' Mind has core training elements such as self-confidence, group cohesion, recognition and control of combat stress, reinforcement of morale and the will to fight and win, restoration of psychological fitness after demanding experiences, ethics of war & ethics in war. The goal of Soldiers' Body program is to develop aerobic endurance, power, and strength of the conscripts to meet the physical performance demands set for their task. The core elements for Soldiers' Body are: integrating training into military activities, periodization of physical training, nutrition, hydration & sleep, balance between training and recovery, task-specific physical requirements, knowledge about enhancing physical condition in the following reserve years. The background for both Mind and Body is based on the theory of human performance



Picture 4 Collection of HPO-related activities in Finland.
Photo: Finnish Defense Forces.

optimization, mental and physical training of tactical occupations, and the practices and theory for mental and physical training from different sports, see **Error! Reference source not found.**.

Another holistic approach to training is provided by "Conflict Kinetics", an US private enterprise, using new methods called Synthetic Training, which differs fundamentally from classic simulation shooting ranges. The training focus is on four key human elements: eyes, mind, central nervous system and body. During the training each of these elements is tracked and new abilities are developed via feedback, which gives the trainees an important improvement in reaction time (seeing, deciding, acting) and confidence in shooting performance under hostile conditions. Our visit to Conflict Kinetics had a remarkable training effect and improved shooting accuracy after just one day of training and, more importantly, gave us an understanding of the training potential of cognitive and physical mastery for skills need by warfighters.

It seems that mental fitness and toughness are factors that determine the success rate to fulfil elite military training requirements. Therefore, new programs address specific stress triggers that naturally occur in the volatile, uncertain, complex, ambiguous (VUCA) environment. It is becoming popular in the armed forces to train the mind to combat acute and chronic stress, which has been linked to mental degradation and as a potential cause of depression, vulnerability to post traumatic stress disease and impaired cerebral functions. SEAL Fit is a program that serves not only SEAL candidates to successfully undergo the harsh US Navy

SEAL training but is open to civilians as well. Through breathing techniques, mindfulness, and physical training impulses the trainees are to be empowered to go beyond their own limits.

## 6.5 Nutrition

The Netherlands wishes to look into combining acceptable nutrition supplements with standard food and other performance augmenting interventions to temporally boost/optimize/enhance mental, cognitive and physical performance for specific tasks of specific military branches. Nutrition supplements refer to tolerable doses of off-the-shelf nutraceuticals such as tyronsine, creatine, dietary polyamines, beta-analine, and catechin (flavanols). Standard food includes fruits, vegetables, whole grains, proteins, healthy fats and sugars, while other performance augmenting interventions focus on sleep, exercise, off-the-shelf electro/magnetic stimulation.

## 6.6 Future Outlook of HPA Technologies in the Military Context

Innovation and technological development in various areas are expected to be crucial for extensive progress of human augmentation. Advances in the fields of neuroscience, genetics, biomedical engineering and diagnostics, computer and information technology, materials and energy technology, and communication are imperative for the area of human augmentation at large.

Technological progress in the area of HPA is not expected to be linear. On the contrary, development may be fast in some areas, such as computing and miniaturization of electronics, while progress is slower for instance when the challenge is to work against the laws of physics. Irrespective of rate of progress, the largest potential is expected to be found in the combination and integration of HPA technologies and methods. Data, analytics and connectivity are expected to be paramount for advances into the HPE realm including such technologies as prosthetics and robotics, advanced biomonitoring, implantable and sensory enhancement.

It will continue to be important to take all aspects into account that can influence the performance of soldiers such as family, organization, and environment. Modern individualized methods for physical training and nutrition can make a difference in human performance for service personnel now and in the future.

## 6.7 Pharmaceuticals

Pharmaceuticals have the potential to enhance human capacity in a number of different ways. Examples of effects include improvement in physical performance (e.g. increased muscle mass and speed), cognitive performance (e.g. memory, alertness, mood). However, as

addressed in the background chapter, the chemical substances that are involved often cause unwanted side effects. For instance, cognitive functions are not separated in nicely delimited brain regions with unique receptors. Instead, the chemical compounds used in pharmaceuticals have the ability to affect multiple brain functions at the same time. The result is not necessarily an overall improvement; rather it has been shown that an increased effect in one area may be accompanied by a degradation of other functions. In addition, pharmaceuticals have been developed for the treatment of people with already degraded functions, which means that there is less knowledge about effects and efficiency in healthy individuals.

Cognitive enhancing drugs (also called "smart drugs") include stimulants such as methylphenidate, for improvement of concentration alertness and focus, and modafinil which can be used to prolong wakefulness. There has long been stigma around the medical utilization of psychedelic drugs. However, substances such as LSD (Lysergic acid diethylamide) and MDMA (Methylenedioxy-methamphetamine) are now being researched for therapeutic applications, based on low doses. Future development and usability of pharmaceuticals rely on the ability to precisely control dosage based on individual needs, specific targeting using nanotechnology, further understanding of neural chemistry, and screening for potential new drug candidates.

## 6.8 Sensory Enhancement and Communication

Sensory enhancement is the collective concept for a number of different approaches. This includes ways to provide new types of information, fuse, or augment information, convey information through other "channels" or modify the senses per se. The near-term efforts are looking into extending the human sensory range or acuity by means of wearables.

It's possible to artificially increase the range by converting one type of information into another. Extended senses are achieved by translating frequencies beyond the human spectral range into e.g. hearable sound or visual information. This enables, for example, penetrating vision ("see-through walls"), sensing of vibrations and airborne chemicals ("artificial nose"), and detection of magnetic variations. A combination of different types of displays provides more information to the user since different modalities use their own channels of processing.

There is a large interest in applications for contact lenses with embedded electronics. These so-called smart contact lenses are in direct contact with the eye with the intention to provide biosensing capability (tear fluid biomarkers) or vision enhancement. One example is the start-up company Mojo vision that has demonstrated a lens with a NanoLED display capable of generating a pixel density of 14,000 ppi in monochrome in green (2019). The aim is to integrate an image sensor, a radio, and a motion sensor for proper overlay and stabilization.

The initial use is targeted towards individuals with impaired vision, but the final goal will be next generation high-resolution AR applications with eye tracking capability.

As military operations often take place in adverse noisy environments, effective communication becomes a performance and safety issue. Verbal communication without noise interference is necessary at voice-guided applications. An example is a device that can provide clear two-way acoustic communication through a unit placed in the mouth. This wireless and hands-free device, called SoundBite, was initially developed as an aid for hearing loss but has since then been tailored for military use.

## 6.9 Language Translation

Translation programs can eliminate language deficits today and in the future. The main difference to former/first translation programs is that today and in the future programs will no longer translate single words, but rather focus on the semantics of sentences. Standard translations by Google Translate are already used by half a billion people per month, and the number of words looked up daily amounts to 140 billion and will continue to grow in the future. However, translations will not only increase in quantity, but also their quality will improve gradually, and they will become almost perfect through the use of AI. Likewise, spelling mistakes, grammatical errors or colloquial language are no longer a problem for AI today.

Today, neural networks are not only able to recognize words or texts, but can also display translations in images or videos on an ad hoc basis. The latter application in particular is advantageous for helmet integration. In the future, a soldier can have ad hoc translations of posters, inscriptions or documents translated into his helmet display using translation memory. However, a connection to the translation server is always required. Currently, there is no alternative that includes a local strong AI translation tool. AI translation systems not only need to be fed with test data, but also need to be trained further. This is where linguistic changes, homonyms, technical terminology, dialects, new words or even changes in the meaning of words present challenges. Only through pattern recognition of bilingual texts can AI master the challenges mentioned above. However, a certified translation can never be done by an AI system, but will always require a human being.

## 6.10 Implantable Biosensors

The application of implantable systems (Implantables) to enhance physiological or mental performance could in future represent a possibility to optimize physiological abilities in soldiers. Implantable miniaturized devices are currently used primarily in the medical treatment of diseases or disabilities. The following systems represent the ones that are mainly used: Deep brain stimulation with modern brain implants to treat neuropsychiatric disorders

by remotely sending electrical impulses to stimulate specific areas of the grey matter, cochlea implants, cardiac pacemaker / defibrillator / cardiac monitoring to monitor heart rate and rhythm disorders, drug delivery systems, gastric stimulator, sensors for controlling prostheses, artificial joints etc.

Implantable systems for use in healthy individuals are under development. A Swiss research institute has developed a subcutaneously implantable chip which includes sensors to determine lactate, glucose, and ATP (adenosine triphosphate). The battery can be charged through the skin. Other implantable microchips can have password or lock functions. These implantable devices, which have no medical curative relationship, are often used in the so-called biohacker scene.

A literature search in Pubmed using the search terms "implantable", "sensor" and "military" has shown that no publications in this field were found. No official programs about the use of Implantables in the military for HPE are known today. Although the use of implantable systems to increase performance in healthy individuals for military purposes would be technically feasible in the future, there is currently no indication of specific military medical research and development on Implantables for military purposes. In addition to the potential damage to health, such as the risk of infection, damage to anatomical structures, the risk of bleeding, etc., there are also various legal questions related to the potential use of implants in healthy soldiers.

## 6.11 Smart Textiles with Multifunction Capabilities

Nowadays, there are some COTS (commercials off the shelf) that generate heat from electricity (socks, vest, jacket, insoles, gloves). Besides that, modular attachable heating elements can be used. Especially heated layer materials, which can easily be integrated into other clothing, are of interest. Currently, the heating duration is too short for military needs because of high energy consumption. This is likely to be changed in the future with more potent battery sources arising. Another way to heat up, not only for military personnel, are phase change materials, which passively heat clothing using crystallization heat when there is a transition from liquid to solid. The disadvantage is that this effect is used up at some point and has no further functionality but adds an additional weight burden to the soldier himself.

Auxetic materials or phase change materials can be used for passive cooling as well. Auxetic materials expand when heated and thus allow heat to be dissipated. These materials are light and can be integrated into textiles. The main pathway for cooling soldiers is the fast evaporation of sweat. This can be achieved by different means like active of passive cooling systems. Furthermore, passive cooling can also be created by textiles that generate cooling energy from water and body heat. With an active cooling system, air flows through the textile.

Instead of ambient air, it is better to use dry air, as the cooling effect is limited or contrary at high temperatures and in case of humidity.

It is expected that in the future heating and cooling systems can be combine in order to modify heat transfer. It is also foreseen that an active self-regulating suit will exist someday that gets its information through body worn sensors. Heating or cooling actuators will then regulate the body temperature. Furthermore, new materials will exist that combine warming and cooling properties.

### 6.12 Personalization (In-Theater Supervision and Capability Development)

Each person has different individual capabilities, which can be optimized through personalized training. Personalized training takes into account four aspects that are combined with each other: adaptive training, tailored nutrition, sleep and recovery.

Circumstances in the operational environment and stressful tasks expose the individual to special and in some cases unique needs in terms of nutrition. Underconsumption of allotted food, which is a real risk in field conditions, leads to degradation of muscles, lower endurance and impaired cognitive abilities. Causes of underconsumption can be lack of appetite, time pressure, lack of water or that the food is perceived as unnecessarily heavy to carry. By adapting nutrition, sufficient intake of foods can be ensured irrespective of the prevailing situation. One example of technology is an "eat-on-the-move ration" which allows continuous intake of nutrition.

Personalization of nutrition is about ensuring adequate and favorable nutritional intake based on current individual needs. Properly adapted nutrition enhances performance by acting as a source of energy, increasing the availability of otherwise limited substances, reducing metabolic by-products and facilitating recovery. Tailored nutrition helps to counteract deficiencies due to inadequate diet and to restore impaired performance resulting from long-term efforts. Potentially, fully individualized diets could be created through 3D-printed foods.

Today, access to detailed information on bodily levels of nutrients, chemicals and different biomarkers requires blood work. For instance, the analysis can provide information on levels of essential vitamins and minerals, free amino acids, hormonal levels, to name a few. The increasing market for self-tests is expected to serve as an incentive for industry to further invest in development of user-near devices. If more advanced and miniaturized technology were to become available, it would be possible for individuals to perform their own self-tests. The result could be used to adjust food and supplement intake for optimized healing, muscle gain, muscle retention based on the individual's own needs. It might also be possible to use readily available information for assessment of behavioral factors.

With the use of various sensors, it is becoming increasingly easy to measure physical and cognitive parameters. Advanced biomonitoring of an individual's psychological state would make it possible to conduct early (and effective) behavioral interventions. This, however, requires data on the particular individual as well as large quantities of general behavioral data to be able to make accurate predictions. In the near future, technology based on advanced algorithms may facilitate training routines that are tailored to the individual's biological limitation as well as capable of adapting to previous experience and progress. In combination with e.g. machine learning, the activities of individuals can be customized to achieve the best possible results.

## 6.13 Human Machine Teaming

A current trend is to explore what it would mean to bring more autonomy to the battlefield. Human Machine Teaming (HMT), sometimes interchangeably called Human Autonomy Teaming (HAT) or Manned Unmanned-Teaming (MUM-T), refers to the ability to use advanced weapons and war equipment (such as UAVs, UGVs or robots) as part of a team, which would normally consist of human actors. The human-machine teams are partly subject to the same dependencies as a human-human team, which includes cooperation, integration of abilities and knowledge, as well as complementary areas of responsibilities. The foundation of a good team builds on communication (knowing how and when to communicate), team coordination (shared mental models, mutual performance monitoring, assistive behavior and adaptability, and leadership), and cooperation (team orientation and mutual trust). New types of communication and interfaces are needed. For instance, it has been suggested to use gestures for interaction and control interaction to engage with partially autonomous actors.

## 6.14 Neural Interfaces

Advances in wearable sensors, as described above, have allowed a better understanding of cognitive function in addition to physiological state. This has contributed to a new field of research called neuroergonomics, which involves the study of the brain in real life, outside the laboratory setting. Developments in artificial intelligence and machine learning have also created an environment where systems can decode brain activity in real time; this combination of technologies is essential for improved human-machine teaming. Current work in this area is in its infancy, but funded military programs have investigated the use of brain signatures to facilitate target detection, to understand and support multisensory processing, and to improve decision-making. Neural interfaces of this sort allow brain signatures which the operator may not be overtly aware of to be incorporated into the system, in the case of target detection operators are able to scan images of land for targets in milliseconds, in the case of decision-making systems are capable of reliably assessing human decision accuracy and discarding inaccurate decisions.

Information about brain state and cognitive function can be inferred from many physiological outputs such as heart rate, eye movement and pupil dilation, respiration, and electromyography in addition to more direct brain recording by electroencephalography and functional near-infra-red spectroscopy. To this end the recent Royal Society iHuman report refers to neural interfaces, which incorporate the whole area of wearable and implantable sensors. This is a better description of the state of the art than the more traditional term "brain-computer interfaces".

In the clinical world there is evidence of implants being used to restore function in patients with brain injuries or diseases, however regulation is necessarily strict because surgery can result in death or further brain damage. In animal models brain implants have been used to both record brain activity and to interact with the brain and create brain-brain or brain-robot connections. Implanted technologies provide a direct link with specific neurons in the brain, whereas wearables require a signal to pass through hair, skin, bone and fluid which necessarily attenuates the signal and makes localization of activity very difficult. However, it is unlikely that brain surgery would be conducted on healthy humans unless there is a significant reduction in the attendant risks of death and brain damage.

External technologies, which can stimulate the brain by passing an electrical or magnetic current over areas of the skull, are a growing area of interest. There is some evidence that fine motor function can be enhanced in athletes and musicians and in some cases cognitive functions can be altered. However to-date there is very little reliable evidence for consistent improvement in broader cognitive performance, many experiments are not well controlled, and it can be the case that stimulation creates differing effects in the same participants across blocks in an experiment. While this area is of interest to the military, it is essential that good-quality research is conducted in order to investigate this area further.

While neural interfaces and human-machine teaming are promising areas for human augmentation, a significant amount of research is required in order to understand what baseline neural signatures look like in military personnel across their many and varied tasks before work can begin on how to augment their cognitive performance and measure the degree of augmentation.

### 6.15 Tele-existence

Tele-existence is based on the combination of telepresence and teleoperation. The concept means that the user has the experience of being in another location combined with the opportunity to physically interact with the (remote) environment. The physical interaction is created by having an equipment (avatar) that is capable of conveying environmental information and acting on control commands from the operator. The avatar (robot) is equipped with sensors that allow the operator to see and hear what is happening in real-time. The

operator's precise movements are transmitted in real time and replicated by the physical avatar in six degrees of freedom. Haptic feedback facilitates grip and feeling for the force that needs to be applied for lifting and handling of objects.

The system allows good situational awareness and creates an opportunity for the operator to act and (in principle) carry out tasks in the same way as in the case of real physical presence. This capability means that the service personnel is given the ability to operate in environments that would otherwise be inaccessible or unadvisable. Consequently, operation in the real physical environment is enabled while the user stays out of harm's way.

To some extent telepresence and teleoperation already exist in the battlefield. However, fully developed solutions based on human avatars still have a long way to go. There are technical challenges in the form of power need, reliability, mobility, speed and bandwidth needed for maximum usability. Accessibility and endurance depend on the environment.

## 6.16 Conclusion

Optimization programs follow a holistic approach which includes body, mind, social, and ethical performance. Successful HPO programs depend on many factors, including biological, physical, psychological, cultural, and social ones, all of which interact. Well-planned HPO programs will give service personnel knowledge, skills, and access to emerging technologies to improve and preserve the capabilities needed to execute mission essential tasks. A personalized approach to performance optimization should be emphasized when improving enhanced operational readiness of soldiers.

There is a wide range of programs with major focus on HPO, although some HPE programs are being established. Unfortunately, information on these projects was not available or detailed enough to draw conclusion about the "must have capabilities". It is assumed that many programs contain sensible information, which prevent them from being shared in the large MCDC community.

Most technologies in use (fielded) can be found in the HPO realm, while HPE technologies are still immature or restricted in use. The technologies described will find applications in different areas where the timeframe for realization will depend on numerous factors. For instance, the expectation is that the largest potential will be found in a combination of techniques. Although biological and genetic engineering are not part of current military programs, there should be awareness of new aspects and developments. We need to understand what may be feasible in the future.

Programs with focus on wearable biosensors and physiological status monitoring are already part of many research projects run by the various participators in MCDC. The analysis of collected biodata is both a data quality problem and a big data problem that today requires

bespoke systems. Further development is warranted to find sensor (monitoring) systems that are sufficient for military requirements in the field with respect to signal transduction, artefacts, built-in quality assessment, and security.

The history part of this note touched on the detrimental consequences that can arise when interventions are used in an improper manner. At the same time, it is important to seize the potential of already present as well as emerging remedies. Thus, effects and side effects of performance enhancing drugs must be studied to get the answers to the questions what, when and how much/long stimulants can be used to enhance service personnel performance without harming the individual.

Interoperability relies on common understanding and standards, information flow, interaction principles, strategies, system safety and logistics – aspects that are necessary for efficient collaboration. For example, different views and legislation regarding the use of potent drugs may generate an interoperability issue. It is therefore necessary to use and develop concepts that are inclusive but at the same time as diverse as deemed necessary. According to our survey, there are no multinational initiatives that aim to increase the interoperability of combined or joint operations. Instead, the focus clearly is on isolated individual/small units.

## 6.17 Recommendations

This program provides insight and knowledge regarding available technologies and methods for HPA. It became a first step in the collection of information and the assessment of ongoing and planned HPA programs. A new MCDC cycle on this topic should facilitate an opportunity to take advantage of the collected material and further process the insights. The next effort should therefore include:

- Shared in-depth reviews and evaluations of the material in order to assess the best way forward, including analysis of effects, usability, and best practices with respect to technologies and programs.

- In-depth analysis of interoperability needs and determination of clear ambition per technology area and application.

- An exhaustive comparative analysis of the future HPA threat environment. The assessment must outline the offensive and defensive issues involved with due regard for tactical and strategic aspects of future battle domains where HPA will be deployed and used either on behalf of own forces or against them.

Although there was a strong interest in sharing information between MCDC participants, there seems to be some hesitation on the national level. This should be discussed on the appropriate executive level in order to find a solution and actions.

It is necessary to determine the aims for interoperability in the context of HPA while taking into account constraints in the form of national laws and regulations. The present HPO/HPE project is a step towards addressing and identifying those essential actions. However, the complexity of the task will require another cycle to develop a concept for interoperability in the context of HPA.

There is a need for a common structure that can manage and administer the body of knowledge that is being built up over time. On that account, it is proposed to start a discussion on how an organization of the center-of-excellence type could support further development of technology and science for HPA. Furthermore, such a common structure could take on the responsibility of collecting, coordinating, and disseminating information about HPA projects and results for MCDC participants in order to facilitate interoperability and lessons learned.

# 7. Human Performance Restoration

## 7.1 Restoration

Restoration is understood as the process of bringing the body (of a person whose performance level has fallen below the baseline) back to the baseline level through appropriate measures. The focus here is on restoration from previous degradation caused by illness, injury, side effects of HPA interventions, violence or threats. The restoration measures, or interventions, always come from the Medical Service spectrum. The aims of the measures are, where possible, to restore all physical and cognitive abilities as fully as possible, so that the person can return to the level of his/her performance baseline before the HPD event. Where this is not possible due to excessive damage, the aim is to find the best possible replacement or compensation in the form of e.g. prostheses. It is even possible that by using the latest (prosthetic) technology, the person will exceed the previous level of his/her performance baseline, at least in the performance range supported by the prostheses. In this case, the transition between HPR and HPO is somewhat blurred.

In many cases, HPA applications originate from therapies and methods that have been used in HPR treatments of various medical diseases and mental conditions. The idea behind this was that if an intervention is found to have performance-enhancing effects at disabled or ill individuals, it could potentially be used to improve healthy individuals as well. This means that the same intervention can serve as HPR or HPA, depending on the individual. Decisive for the classification is the performance starting point of the respective individual and the primary aim of the treatment, therapy versus augmentation.

## 7.2 Recovery and Supercompensation

There are a number of natural HPD processes that occur when the body has been exposed to various types of loads. Those processes can be summarized under the term recovery and should clearly be separated from the concept of HPR as we define it in this study. Loads refer to physical, psychological and cognitive strains, such as stress, fatigue, exhaustion and lack of nutrition. In order to understand how these factors affect the body, we need to take a closer look at our baseline, the actual performance level of an individual.

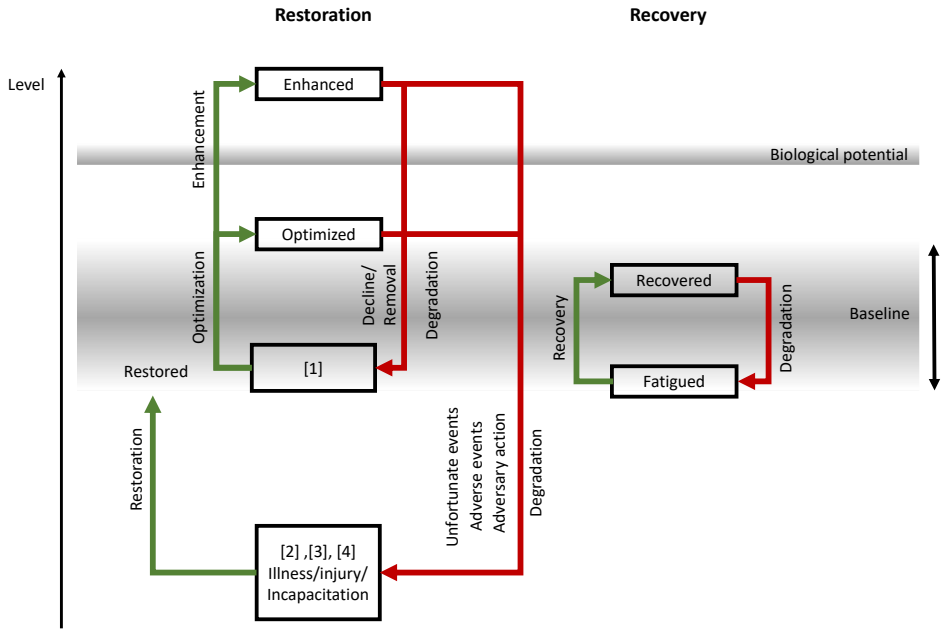



Figure 5 The sources behind degradation consist of: [1] fatigue, exhaustion, [2] disease, injury, [3] system safety issues, degraded system functionality, or [4] actions by hostile externally based technologies, platforms or systems.
Source: own development.

In Figure 5 the baseline is not shown as a precise level but rather as an area without distinct boundaries. The reason for this illustration is the fact that our performance is subject to constant fluctuations. External and internal factors such as time of day and hormone status, influence each other and require constant adjustment. As described earlier the baseline can be described from a physiological point of view as homeostasis - the fluid balance between the organism and its environment. If this balance is disturbed by extra external stimuli such as mentioned above, the organism tries to restore the balance between the resulting demands and performance. Intensity and duration of the strain influence the need for recovery.

The different structures and systems in the body take different lengths of time to recover. This means, for example, that the electrolyte balance recovers from strenuous training within a few hours, whereas the muscles may need up to 8 days to do the same (see Figure 6).

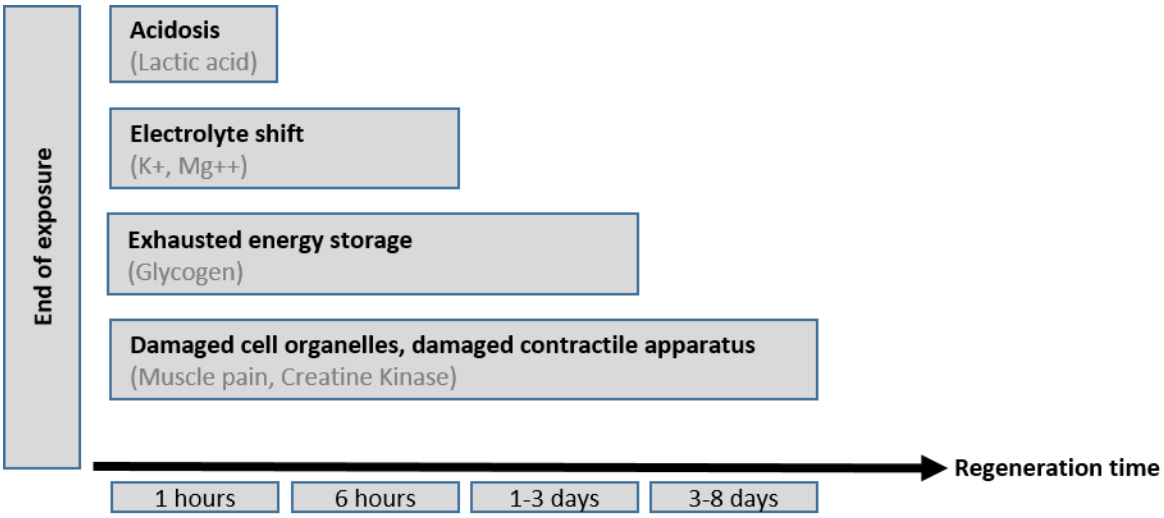



Figure 6 Supercompensation of different organs and systems.
Modified according to Weineck J (2000). Optimal training. Nuremberg: Spitta.

In order to be better adapted to future challenges, the body takes advantage of the principle of over-adaptation (also called hypercompensation or supercompensation). This means that the body will react to the strain by improving the performance beyond the initial level, which can be noticed after the recovery phase. For a limited period of time, functions and structures are adapted (see Figure 7). This adaptation mechanism is the basis for every training success and thus also for HPO. For a lasting success, it is important to use the knowledge on phases of supercompensation in training to achieve a more permanent increase in performance. In our picture of the interrelationships within HPA, this process means that the baseline shifts upwards. In a maximally optimized individual, this means that his/her baseline equals the maximum biological potential.

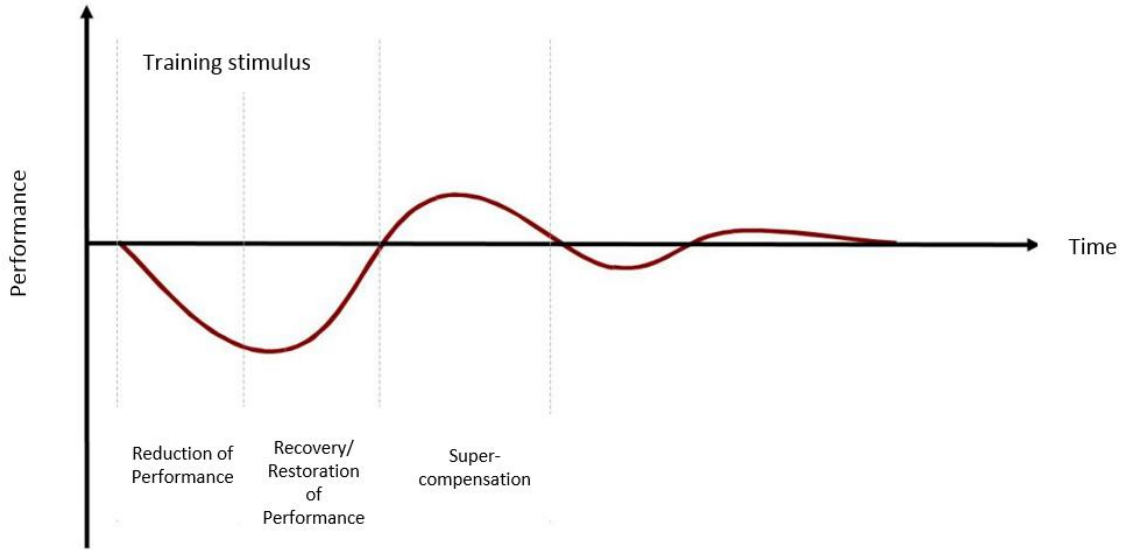



Figure 7 Adoption of functions and structures over time.
Source: own development.

## 7.3 Conclusion

The performance of an individual varies continuously and is in a fluid balance between the organism and its environment. If this balance is disturbed by external stress, the body has natural mechanisms to counteract. These balancing mechanisms take different lengths of time and can be summarized under the term recovery. Through the principle of supercompensation, the body also ensures adaptation to future challenges, which enables the desired performance increase in HPO.

If the body is damaged by HPD to such an extent that injuries occur, we no longer speak of recovery, but of HPR, when we try to correct these damages. Such injuries can be caused by diseases or accidents, events in mission, HPA side effects, adversary actions, but also by excessive stress factors[7].

HPR interventions always have a medical background. Many HPA applications originate from interventions that have been used in connection with HPR treatments of sick people.

[7] Factors such as exhaustion or fatigue, which should actually be counted under recovery if they are so pronounced that they cause pathological changes in the body that require medical treatment.

# 8. Human Performance Degradation by Adversary Actions

As triggers for degradation in performance from the current baseline of an individual, we distinguish four different triggers: [1] reduced physical and psychological performance through fatigue, exhaustion, stress, lack of nutrition; [2] reduced physical and psychological performance through diseases and injuries; [3] every optimization or enhancement method can also have adverse effects; or [4] reduced physical and psychological performance through adversary actions.

## 8.1 Military Risks Associated with HPD

HPA technologies, systems and platforms are designed to increase soldier performance in a variety of conflict scenarios and enable augmented forces to leverage their enhanced and optimized human performance systems towards retaining a combat edge and technical force superiority in contested situations. Risks of HPD - must be included in any serious comparative assessment of MNF conflict scenarios versus opposing forces. Forces aligned against MNF troops benefitting from HPA confront a variety of risks such as:

- Opposing forces possessing intelligence identifying MNF HPA weaknesses
- Opposing forces possessing countermeasures to nullify MNF HPA
- Opposing forces retaining equivalent or superior HPA to offset MNF forces
- MNF HP augmented forces discover unknown vulnerabilities in their own HPA functionality

Degradation of HPA, i.e. HPD, among MNF troops is a vital aspect of deployment decisions. Intelligence and reliable updated threat information which evaluates MNF vs opposing forces in terms of their respective HPA inventories is vital. In recognition that contending forces may exhibit an imbalance in HPA MNF commanders should determine the nature and extent of the threat posed by opposing forces. This emerging threat is based on several factors which contain the risk that friendly MNF HP systems may suffer from:

- Exploitable data and tasking information to HP forces accessible by opposing forces
- Unknown, or known, vulnerabilities in MNF HP systems exploitable by enemy forces
- Enemy intelligence leverage about MNF HP systems affording them combat advantage

- Hidden HP system weaknesses/vulnerabilities degrading MNF HP system performance

As such, a comprehensive meta-assessment of both friendly and enemy HP systems' capabilities and weaknesses before armed confrontation is essential. An analysis, which depicts the comparative HP systems' capabilities of MNF and enemy forces for each presumptive conflict scenario is equally essential. Any intelligence collected and analyzed about enemy HPA should guide operational testing and exercising of friendly MNF forces. In addition, failure to accurately gauge the HP tactical vulnerabilities and operational capabilities of enemy forces can undermine MNF tactical and strategic capabilities in divergent combat scenarios. Discerning HP combat advantages possessed by opposing forces, which create combat imbalances is likewise crucial.

HPD must be understood in terms of its reciprocal characteristics. The comparative HP capabilities and vulnerabilities of MNF and enemy forces are essential. Research is needed to grasp the full spectrum of neural, physical, psychological and combat augmentation technologies considered valid for combat use. Additionally, HP countermeasures and systems vulnerabilities should be well understood. Likewise acquiring validated intelligence about both the offensive and defensive technologies which enemy forces possess and which can either overcome, deflect or impair friendly HP systems is essential. Elimination or alteration of combat leverage and strategic imbalance is based partially on accurate assessments of countermeasures, HP system combat reliability, and overcoming combat situations where opposing forces retain a technological edge enabling them to prevail. Further research is needed to isolate and explore these diverse issues before establishing operational doctrine about deploying HP systems. In summary, the full set of combat dimensions from both an offensive and defensive standpoint must be evaluated and its inherent risks discerned. HP degradation issues and dynamics must be assessed and evaluated on a regular and recurring basis to eliminate or reduce risks that opposing forces will exhibit robust countermeasures to nullify or weaken any friendly HP systems or platforms owned by MNF commanders. Exploitable weaknesses and vulnerabilities in MNF HP systems must be identified and remediated as soon as possible after their discovery.

## 8.2 Countermeasures and Vulnerabilities

Comparative evaluation of friendly and enemy countermeasures for deployed HPA systems and platforms prior to armed conflict is essential in devising courses of action and operational strategy for MNF commanders. Enemy HPA blind spots or intelligence gaps can impair situational awareness of MNF commanders which can be further eroded by incomplete or flawed intelligence about enemy HPA systems. There is also the risk of unjustified or misplaced reliance by MNF commanders on incomplete data that their own countermeasures against enemy HP technologies are adequate and will prevail in all conflict scenarios. Finally, there is also a compelling argument about MNF decisions to inject or apply HP augmented

systems if ambiguous or ill-defined concepts of ROE[8] –especially among and within any forces rejecting HP – create uncertainties about using HP systems in armed conflicts.

MNF commanders must possess valid reliable intelligence about enemy HPA systems, capabilities and weaknesses. Disposition of enemy HPA is crucial in formulating appropriate strategy and operational tactics. MNF commanders must have available countermeasures to remedy known vulnerabilities of their own HP systems as well as having suitable countermeasures to offset any superior enemy HP systems deployed against them. Along with that is the important and frank assessment of MNF and enemy vulnerabilities in their respective HP systems which can be exploited in conflict scenarios.

Special care should be extended to grasping the tactical capabilities of enemy forces to employ non-kinetic neural degradation technologies which aim to nullify cognitive functions and exploit neural vulnerabilities such as perception, reasoning, speech, memory and balance. Technologies necessary to detect cognitively disruptive and neurally targeted emanations and deflect or defend against its insidious effects will be essential defensive elements in future MNF conflict situations. These non-kinetic technologies exist apart from HP systems and could adversely affect MNF leadership or impair and disrupt MNF troops and their combat communications.

## 8.3 Conclusion

MNF commanders must weigh the risks they may encounter opposing forces with three possible HP battle arrays. Some will be non-existent; others may display equivalent systems others may actually be superior to available MNF HP technology. Given these situations flexibility in deploying engineered and tailored countermeasures to nullify or weaken any HP systems which opposing forces may possess or utilize is vital. This implies the value of informed strategic warning to gauge the capabilities of opposing forces before armed conflict ensues. This creates a burden on intelligence agencies to identify, gauge and characterize the HP capabilities [including countermeasures] which enemy forces may possess and deploy in the specific combat scenario to be faced. MNF commanders must know their capabilities and weaknesses.

The resulting operational risks influencing the situational assessment, common operational picture, and overall correlation of opposing forces can be impaired or flawed if available intelligence does not provide timely strategic and tactical warning. Likewise, situational assessment and a common operational picture of the threshold battlefield could be impaired. Intelligence risk issues which address the deployed capabilities of opposing forces and their

[8] Rules Of Engagement

inherent vulnerabilities will become essential in planning future operations where the risks of confronting enemy HP systems is considered likely.

# 9. Ethical and Social Aspects of Human Performance Modification

One of the most important societal implications of modification technologies will be equality of access for everyone in society. There may be specific social and religious groups who feel strongly about such technologies and recommend that their members do not engage with them, this could affect military recruitment into certain roles. If technologies are used by the general public cost may also be an issue, in which case they could cause an increase in economic inequality. This could particularly affect school children if the systems are deployed to better engage them with learning and assessment technologies. It is possible that children from more affluent backgrounds could be more familiar and comfortable with the systems due to having them at home, this would also be an issue for military selection and recruitment.

Individual differences mean that it is currently easier to record brain signatures from some people than others, this may be solved by technology improvements over time, but it may remain an issue and could also apply to other modification technologies where some people are more suitable for modification than others due to their physical body or mental preconditions. This could lead to a situation where people cannot perform some jobs (in safety-critical environments for example) because it is not possible to apply or record modifications accurately.

In a situation of economic inequality, it may be that less affluent members of society feel that they have no choice but to submit to modifications in their everyday working lives because they need to earn money. In the military this could also be the case if promotion is based on progression through roles which are predicated on modifications.

Another major issue to be considered is privacy, the idea of the military being able to monitor internal states such as concentration, trust and accuracy of decision making will make many people uncomfortable. Additionally, the secure storage of masses of personal data from multiple sensors will require oversight and regulation.

Human performance modification technologies will necessarily lead to discussions around agency, and what it is to be human. Modification technologies may raise challenges for attributing legal responsibility when actions or speech have been executed/facilitated by a device that enhances, augments, or otherwise alters human decision making

Changes to ways of working will bring about issues regarding duty of care and corporate responsibility. One of the first issues to be considered is that of ongoing support for augmented personnel. Additionally, there will be a need to weigh up whether the benefits of invasive enhancements outweigh risks from tissue damage or infection. In these cases, the technology is not reversible.

Ethical dimensions of HPM must extend to consideration of appropriate defensive and

deterrent measures designed to protect the civilian population, Alliance leadership, soldiers and deployed human systems which may be vulnerable to hostile enemy HPM technologies, systems or platforms to nullify or deflect unethical applications of HPM technology for combat purposes. Justifiable defensive measures precluding harm to friendly forces is a bedrock value found in the globally accepted right of self-defense found in Article 51 of the UN Charter.

A final aspect of performance modification technologies which requires consideration is the acceptance of military personnel in society both during service and after their retirement. There may be a distrust of personnel who are modified beyond biological baseline, and there is a duty of care issue around personnel who may find their enhancements intrusive to everyday life.

## 9.1 Minimization of Harm

Minimization of harm to personnel is always one of the most important factors when assessing new equipment, augmentation technologies should be no different and their use requires consideration and regulation. Even something as innocuous as caffeine to enable personnel to stay awake can affect their ability to rest if the situation changes, meaning that they will be at more risk later due to fatigue. There will no doubt be situations where use of performance augmentations will be of greater use to the unit as a whole rather than to individual personnel, but policy and doctrine must consider how decisions about benefit to the whole versus harm to the individual should be managed. It is possible that an adversary will not share these ethical concerns, in which case policy and doctrine must also support decision makers in countering an enemy who uses in our eyes un-ethical performance Augmentation. This situation may have the potential to affect the mental wellbeing of allied personnel.

Augmentation in one area may lead to degradation of performance in another area. The human body is a complex system made of compromise. We can achieve an increase in one kind of Performance, like strength, but will probably have a decrease in another kind of Performance, like endurance. In the situation requiring endurance, the person will experience degraded performance.

If personnel come to rely on augmentations, they may be adversely affected if such augmentations are removed or fail. This could be caused by damage to or withdrawal of the augmentation in an operational setting, or by removal of the augmentation when personnel leave the military.

## 9.2 Fairness

In the military and also in industry, the question of fairness arises when considering the individual on the one hand during service / working hours, in which the person him/herself and the employer both benefit from performance modification and after work as a private person. If it is a question of reversible technologies, the individual can go home after work as an unmodified person. If, on the other hand, it is a question of irreversible technologies (e.g. implantable), people may remain superior to their fellow human beings even after work has ended. This can lead to conflicts in civil life or in leisure activities, e.g. during sports. Debates of envy are conceivable as well as negative effects on cohesion and morality in society.

The last two aspects (cohesion and morale) also play an important role in teams. It still has to be examined whether and how they change in mixed (modified and unmodified) teams.

## 9.3 Necessity & Proportionality

When considering necessity and proportionality, one could also quote the parable of the crossroads with the easy and difficult path. HPE is often touted as the perfect solution to many problems - an easy way that alleviates or eliminates many problems, but also possibly brings with it new problems that are not yet foreseeable today. HPO might be a better alternative in some cases, but more difficult to achieve, e.g. with more training or changes to previous routines and behaviors.

On the other side, the adoption of a HPE solution depends on the risk and the situation. Side effects not acceptable for the long term may become acceptable in a particular situation where human life is endangered. Ejection into a hostile zone may lead to an acceptability of the solution, as the risk of death/being captured is bigger than the side effects. Maybe in these situations, military needs should override personal rights. Conflict with a high risk of attrition may also lead to different considerations compared to the principles defined for low intensity conflict.

Since the decision-making for the use of HPO or HPE takes place at leadership level, the leadership must be informed neutrally and comprehensively. In addition to the always topical aspects of financing and precise situations the most important question should always be whether it is necessary to modify the human being on a massive scale (irreversibility, HPE) or if there are alternatives with less strong interventions in the individual (reversibility, HPO, HPE) or equipment.

## 9.4 Maintenance of Dignity

It is possible that augmentation technologies could be controlled by automated systems or by decision makers from a distance. This would lead to a situation where personnel would in fact be used as "equipment". There will be a need for careful consideration, regulation and accountability of such technologies and their use; personnel could feel dehumanized in such situations, and there will be a fear that remotely controlled augmentations could be hacked.

The presence of an augmentation, even if controlled by the user, may lead to them being seen as "less than human" or "cyborg" by fellow personnel and by society at large. If decision makers and senior officers are enhanced this could affect the chain of command and willingness of junior personnel to obey orders.

The question of the perception of augmented persons also arises. It is to be feared that an augmented person could appear "less than human". In this case, it is unclear whether the Geneva Convention applies and how these persons should be treated according to the Geneva Convention (see also paragraph "Medical Treatment or Maintenance"?).

There would need to be serious consideration of what it is to be human, and what autonomy means before such technologies could be used by the military. The question of consent is important because personnel are recruited at a relatively young age and it is possible that they will consent to augmentations in their 20s which will have significant effects on their mental and physical health in their 40s, and which their 40-year-old selves would not have consented to.

In addition, in Western armies the soldier is always seen as a citizen in uniform, i.e. as an individual who also has a right to a private, civilian side of life. However, under certain circumstances, enhancement techniques cannot be taken off, as one does with a uniform. Are "enhanced soldiers" allowed to use their special abilities in civilian life or how can the boundaries be drawn? Here one also encounters moral, ethical aspects. While the doped athlete is frowned upon in the civil sector, HPA explicitly achieves exactly this aspect of increased performance through training methods, performance-enhancing substances or implants.

## 9.5 Responsibility

Rules of Engagement differ slightly across international militaries but there is generally an agreement that decisions must be made by a human operator (for example whether to fire on a target), and that the person responsible for that decision retains a degree of situational autonomy even beyond the chain of command.

Performance modification technologies will require significant regulation and doctrinal consideration because they could remove direct responsibility and autonomy from an operator. It is possible that the timed delivery of interventions (such as pharmaceuticals) could be triggered by senior decision makers or by monitoring equipment; this would raise ethical issues around responsibility for any mistakes made by the modified individual such as friendly fire incidents. This method is diametrically opposed to the current rights of the individual in Western Europe. Nevertheless, Western allies will be confronted with the fact that opposing armies consider these legal aspects to be irrelevant.

Implants and wearables which could be triggered externally could also be vulnerable to hacking so security is a significant issue.

The part of responsibility of the command in implementing the HPM should also be investigated due to the possible difficulty to ensure free consent by the respective soldier. This responsibility may have some legal implications especially when the modification is invasive to the body (implants, prosthesis, DNA modification, …) or may be considered as eugenics practice. While HPR solutions are legal, the applicability to military in good health may be far from being legal.

If performance modification technologies are permanent there is the question of who is responsible for the actions of individual military personnel outside of operations. Modifications which enhance aggression or strength could lead to a typical drunken brawl or domestic incident ending in civilian deaths. Similarly, war crimes investigations would need to consider whether any performance modifications could have removed autonomy from individuals.

## 9.6 Medical Treatment or Maintenance?

If, as in this study, technical equipment is also assumed to be a modification possibility, questions concerning the international Law of Armed Conflict[9] (LOAC) could arise in conflict situations. According to the LOAC, wounded persons must be collected and cared for, whether friend or foe. The attack of medical personnel, equipment and facilities is prohibited. From this constellation two unclear situations arise: I) How should medical personnel provide care especially to pharmacologically enhanced enemies who do not exhibit the usually expected medical behavior or respond to commonly used therapies? II) Do medical personnel who provide care to a person enhanced with technical equipment (non-invasive or invasive)

[9] The Law of Armed Conflict (LOAC) is a set of generalized rules that apply to any armed conflict. The LOAC principles are based on a variety of international laws and rules, the most prominent of which are the Geneva and Hague Conventions.

still fall under the LOAC when the care consists in "repairing" the HPA technology itself or involves the interface between man and machine? Will we need mechanics on the battlefield in the future who work together with medical personnel or will medical personnel need further training in this field? These questions become more and more urgent the more the interface between man and machine evolves.

## 9.7 Acceptance

Each use of enhancement modification methods and technologies through individuals requires acceptance by the user. As acceptance is one of the drivers for future development and future use of HPO/HPE we have to be aware that acceptance is not self-evident. Perhaps in the future we have on the one hand people advocating the technologies, others tolerating them and others consistently rejecting them. Individual acceptance is the key for the implementation of HPO/HPE in a society. The challenge for society is to strike a balance between channeling scientific curiosity, the common good and weakening distrust of new technologies and equipment to create an atmosphere that is at least tolerant of HPO/HPE.

A particular challenge would arise if a majority of the population viewed the use of HPO /HPE as cheating. So far we only have these discussions about doping in sports. However, these might then also extend to education, work, security bodies and even the military. Other reasons for rejecting HPO/HPE could be religious in nature or the hypermoralization of Western societies currently being observed.

Societies will have to find answers to the questions for themselves who is entitled to optimization and enhancement modification technologies, whether there is even an ethical obligation to access these technologies or whether it is all the responsibility of the individual. The general acceptance of the population as mentioned before, legal aspects and the political framework of a state are decisive for these answers and depend on each other. They will have a main impact on the acceptance aspect in the military itself and society's view of its own enhanced military.

It is essential to develop a uniform legal framework for the use of HPM methods within the Western value-based military alliance. While the basic moral questions remain to be answered mutually, differences in details still exist. Nevertheless, an agreement not only on basic but also more sophisticated and concrete actions in HPA is theoretically possible and also militarily necessary, because otherwise joint operations couldn't be carried out as efficiently as it could be theoretically possible. However, the starting point is a diverse one: "All European armed forces already have codes of conduct and these are deeply rooted in each nation's history and military traditions. Trying to merge all these codes together into a meaningful single code, in a way that was more than an exercise in reaching the lowest common denominator, has proved to be difficult. That difficulty was further complicated first

by the discovery that many of the key words, such as patrie, honour, human dignity and duty mean slightly different things to different nations." (Air Commodore (Ret) John Thomas, President of the International Society for Military Ethics in Europe, Euro-ISME, in: Enhancing Soldiers - An European Ethical Approach)

## 9.8 Ethic – Acceptance – Law

We have to bear in mind that every single rule and law in Western societies is based on ethics. The abilities and limits of rules and laws have always a flexible but mandatory ethical question whether a military action is legal and legitimate. There is no single military engagement thinkable without these preconditions. In addition, in Western armies the soldier is always seen as a citizen in uniform, i.e. as an individual who also has a right to a private, civilian side of life. In the end, the three dimensions of ethics, acceptance within the society and legal obligations are inseparably linked.

## 10. Legal Aspects of HPA

Understanding the legal aspects of HPA technologies will become more and more challenging as the integration between technologies and humans deepens. The legal considerations of HPA technologies range from the individual up to organization level and cover national to international perspectives. It raises many questions regarding legal responsibility here and now, but the complexity will increase as the legal perspective must adjust and adopt as HPA technologies will fundamentally change society in future. The first and most obvious question is whether an augmented person still is considered a human being in the eyes of society? Is there a point when humans are no longer accountable for their actions because of effects of augmentations? The term "cyborg" reflects the idea that humans no longer merely use machines – instead machines are integrated into humans and provide any type of assistance in our lives for increased benefit and wellbeing. The future may require that humans and HPA technologies are legally distinguished.

As the legal protection of a combatant is an important aspect of HPM, defense has new and specific questions to address. For instance, does an augmented soldier who is captured have the same protection under the Geneva Convention as an ordinary soldier, and does the augmented status alter treatment in any way? Looking into the future the question arises if an augmented person even can be classified as a biological weapon?

The existing legal framework can give some guidance on these questions. International law that affects HPA can be divided into two categories, the first is commonly known as International Humanitarian Law (IHL) (or LOAC) and the second is composed of international agreements related to biomedical research. Under IHL, the main instruments of interest are: the Hague Conventions (1899 and 1907), the Geneva Conventions (1949) and the additional protocols of 1977, the Biological and Toxin Weapons Convention (1972), the Conventional Weapons Convention (1980), the Chemical Weapons Convention (1993) and the Rome Statute of the International Criminal Court (1998). International biomedical research laws include the Nuremberg Code (1947), the Declaration of Geneva (1948) and the Declaration of Helsinki (1964).

One reference to the need to carry out legal reviews of new weapons, means and methods of warfare is found in international treaties: In Article 36 of the Additional Protocol I of 1977 to the Geneva Conventions, which states: "In the study, development, acquisition or adoption of a new weapon, means or method of warfare, a High Contracting Party is under an obligation to determine whether its employment would, in some or all circumstances, be prohibited by this Protocol or by any other rule of international law applicable to the High Contracting Party."

The aim of Article 36 is to prevent the use of weapons that would violate international law in all circumstances and to impose restrictions on the use of weapons and methods that would

violate international law in some circumstances by determining their lawfulness before they are developed, acquired or otherwise incorporated into a state's arsenal. Does this apply to the development of HPA technologies? The defining point is if the service member can be considered to be or become a weapon in him/herself.

A SIPRI (Stockholm International Peace Research Institute) report presents the importance of, and challenges associated with, reviewing the legality of weapons, means and methods of warfare that are based on three emerging fields of technology: cyberwarfare technologies, artificial intelligence and robotics, and human enhancement. The report finds that despite their technical and operational differences, the military applications derived from these technology areas raise similar challenges as far as the conduct of Article 36 reviews is concerned. The report suggests targeted research in several areas, one of them being on human augmentation with the specific aim to answer the question: "At what point does an enhanced soldier cease to be a human being and become a mere weapon for the purpose of an Article 36 review?"

Specific to the military is the chain of command and the legal right to use orders to control activities of subordinates. That poses the question whether a service member can be ordered to be augmented without consent. Consent in the military is necessarily different to consent in wider society due to the unique relationship between subordinate personnel and their superior. It could be difficult for military personnel to give sufficient and informed consent voluntarily due to a tendency to follow orders and prioritize the greater good over their own individual interest. Could a soldier's refusal to undergo an invasive augmentation – possibly because of known risks of injurious side effects – be a defense to a charge of disobedience to a lawful order? Would such an augmentation against the soldier's will – motivated perhaps by a desire to protect him/herself or his/her colleagues, or to improve the combat effectiveness of the unit – be a violation of human rights? These questions have been raised in discussions around vaccination prior to deployment.

Another legal perspective is who will have the responsibility for maintaining the augmentation technology over the individual's lifetime? A smart prosthetic limb that is replacing a missing leg or arm lost in combat will have to be continuously updated/upgraded to be able to function on the same level as the natural limb even after the service has been completed. There are both the security and the safety aspects of the device; security updates so it cannot be hacked and safety to ensure intended performance without risks for the user and surroundings. Potential solutions include manufacturer insurance involving check-ups and upgrades as needed, the military support system for those who are still in service, or provision by society through the national health care system. The legal parameters need to be defined for a lifetime perspective to ensure performance, safety and security. They will be one of the most important factors in the decision on what technologies to develop and put into operational use.

## 10.1 Conclusion

Defining a common legal base for the implementation of HPA technologies is essential for the societal acceptance of augmented service personnel. This legal aspect is the basis of the political ability to use such techniques on the battlefield in the future – as every military action has to be approved politically and accepted societally.

Whilst the military application of some human augmentation technologies might be legally unproblematic, other technologies raise a large number of complex legal issues across a wide range of legal fields. The more ethically controversial HPA technologies are likely to prompt demands for new international law to prohibit or restrict their development and use. Defense should invest in the development of legal and ethical frameworks that anticipate the use of future HPA science and technologies.

# 11. HPM Assessment of Future Scenarios

The chosen method is to work with scenarios based on development trends in the military. As a specific timeframe is not defined for the future operating environment, four scenarios have been created from 2020 to 2035 to explore and showcase assessed technological development in the HPM area for the next 15 years. The main outcome should facilitate future HPM concepts and guidelines for NATO/EU partner nations. The intent is to describe aspects of current and future operating environments, which require additional performance capabilities of the future soldiers and military leadership.

The level of complexity and intensity of the operations as well as different climates and environments have been used to make it possible to draw conclusions from different types of operations ranging from special forces operations to warfighting with conventional forces.

- Scenario 1: Multinational Special Forces operation 2020
- Scenario 2: Grey zone – Hybrid warfare urban operation 2025
- Scenario 3: Multinational stabilizing operation 2030
- Scenario 4: Coalition warfighting operation 2035

The scenarios should be seen as a tool to facilitate discussions and to draw conclusions in important areas regarding future development. The scenarios should support the creation of multinational guidelines and SOPs in the areas of:

- **Policy.** Legal and ethical concerns utilizing HPM technologies will certainly find a place in national and international policy.
- **Organization.** Ideally, the results would be considered in operational and capability development HQs.
- **Materiel.** The identified value added of HPM in Future Operational Environments would have an impact on the acquisition of future materials either for personal use or broader use in training/educational settings.
- **Training.** The scenarios should provide recommendations to develop and invest in specific training programs, ideally, multinational.
- **Interoperability.** The main objective of this project is to generate a minimum level of interoperability among multinational partners to empower their tactical and operational mission.

## 11.1 Scenario 1 - Multinational Special Forces (SF) operation 2020

"Got it! Positive identification of objective - Send! Even with all the technologically advanced systems that support us it gives some comfort to know that not everything can be achieved by machines. In the end we need to have boots on the grounds and that's why we are here. It's essential for the Intel community, especially when it comes down to identifying specific individuals working for certain organizations and who they are cooperating with.

We have been on the task now for 60 hours and it's time to extract, should be a piece of cake. The new pills we took before going in are amazing. No problem to stay awake and alert for 72 hours and the only side effect is that we must sleep it off when we're back at base. One of the biggest risks getting out of here is that we a carry a lot of gear and it is easy to stumble on the rocky and treacherous ground and injure yourself. The passive exoskeletons really help with supporting the heavy loads we carry and also stabilize and protect our joints. Another risk is that we will be discovered by just anyone that happens to be out and about and that they will raise the alarm. It's an unfamiliar environment for us and we fully recognize that, as an example, if we get too close to a herd of sheep they can get uneasy and the shepherds are very good at reading the mood of their animals and start to look for the reason. Our AR supported glasses are invaluable in giving us improved situational awareness to support our decisions. Night-time it's almost magical and really gives us the edge time to leave, I just did a final check on my teams stats, they are all OK but Johnsson and Schröder were amber on hydration, so I ordered them to drink before we leave. We have a 10-hour hike ahead of us."

Multinational strategic SF operation in a mountainous country within an ongoing NATO operation. It includes participants from four different nations with varied approaches to HPM. The operation is led by multinational SF command supported by strategic resources and is assessed to take 72 hours. Coordination of such a complex operation will demand a good command and control network with reliable communications. The vital part of the operation will be conducted during night-time. Extreme weather variations with hot dry days and cold nights. This is also a region of maximum physical stress due to altitude, arduous terrain and combat loads.

*Technologies available:*

Nutrition optimized to the individual operator.
AR supported protective goggles to present Common Operational Picture (COP) daytime and in Night Vision Goggles (NVG).
Passive exoskeletons to support heavy loads and reduce risk of injuries.
Physiological status monitoring with uploading capabilities to mission command.
Pharmaceuticals allow troops to stay awake for 72 hours.

Pharmaceuticals to enhance cognitive capabilities by 20% for improved battlefield awareness and quicker reactions and improved decision-making.

*Opponents*

Highly motivated units with clan structure leadership, low technology. Very good knowledge of the operational environment, unlimited intelligence sources through a well-developed social network. Support from state sponsor with access to an information network with global reach.

Conclusions

In this scenario it is possible to have a differentiated approach depending on what level of HPM integration the nation aspires to. Adjustments of friendly force use of HPM methods and technologies will depend on reliable intelligence about extent of HPM displayed by opposing forces. Using enhanced troops equipped with augmented technologies should exhibit a combat edge and prevail. The extent to which normal asymmetric opposing force (OPFOR) tactics respond in kind is unknown but engagements involving enhanced forces should reveal whether enhanced soldiers retain combat advantage and prevail. Limited use of pharmaceuticals and unpowered exoskeletons to assigned SF should provide a superior combat edge.

Recommendations

**Policy.** Each nation must decide on the criteria and eventual certification of its forces for HPM options including possibility of a tiered system which delineates the capacity training and augmentation they will accept as a condition for multinational SF deployment. Participating nations need to be informed and understand the different national approaches to HPM. Therefore, it is in the utmost interest of any nation to ensure interoperability among multinational units for mission success. Ultimate decisions on specific application of various HPM technologies by Defense leadership regarding their SF personnel should be based upon authorized medical, psychological and ongoing R&D factors. Confirmed parallel participation by multilateral SF forces with other enhanced forces will be jointly agreed and implemented by appropriate unit commanders.

Each nation needs to decide on how to handle personal data provided by body-worn sensors. There need to be guidelines on who will have access to the information from the individual operator. It is a question of safety, security and personal integrity that needs to be defined.

**Organization.** Introduce HPM as a factor in SF command that will support differentiation in ambition concerning human optimization/enhancement. One uppermost level includes forces

allowed to use both technologies, on the next level below that only optimization technologies are authorized and enabled and on the lowest level it will be just normal unoptimized/unenhanced forces.

Create a list of optimization requirements based on scenario requirements and specify levels of optimization needed. Let the participating nations state their operational constraints and goals and then certify themselves for the level of preparedness they are expected to fulfill. The decision on what level each nation wants to engage will be based on ethics and their view of HPM.

Clarify the assignable cost for each participating command element based on the specific operational level chosen by their organization.

**Materiel.** Create a common organization for research and development of technologies and equipment for the SOF units. SOF commanders should identify special medical support expected to back up any optimized forces. Net costs for each contributor force associated with each optimization level should be identified. Create a common validating and procurement organization for acquiring equipment for SOF units.

**Training.** It is necessary to have SF units trained for operations in an environment where they can encounter an enhanced opponent. Overall training will take place when the nations are still in a peacetime status and mindset. Relationships between medical support staff and SF personnel will be reinforced through specialized training. Non-augmented forces will undermine familiarization training for operations where they will function alongside augmented forces. Exercising together will create an understanding and acceptance for different levels of capabilities and at the same time create a foundation for what needs to be available for the unit and mitigate shortcomings.

The military will have to talk about the necessity to be able to train with capabilities that can be controversial such as the use of pharmaceuticals. SF units need to train continuously to be able to operate under a variety of conflict scenarios today in order to have the needed edge.

**Interoperability.** The level of interoperability between participating nations will determine the success ofthis multinational operation.

## 11.2 Scenario 2 Grey-zone - Hybrid warfare 2025

"Those farsighted people who understood the importance of interoperability of different organizations that have a task in a situation where no-one really knows what's happening in our society should be commended. That we actually have a common Operation Center where we can share information, intelligence and situation development in real time is a game changer.

Yesterday I was sent out with my EOD team to the site for the big explosion. I was impressed with how everything was coordinated and led both from the Operation Centre and on the actual site. The big exoskeletons the rescue service used made a real difference when we had to get to trapped people. After the first booby trap went off, we were called in and as it was a high building with many stairs and rubble, we used our avatars. The third door we opened just blew out the whole apartment, we lost the avatar, but the operator was safe outside the house. This slowed us down as we had to through the walls to get to the rest of the apartments. We found another device on the top floor that we could dismantle. What sort of people are doing this? Is it anarchists or is it state sponsored?

That we have had the opportunity to train together really makes a difference, we know what capabilities the other organizations bring in and when we trust each other of doing their part it's so much easier.

We remain vigilant and keenly aware that whoever is behind this may have enabling detection technology which identifies us in non-permissive situations. We have to be diligent with using our eye protection as we are continuously targeted with blinding lasers. It is especially concerning that they are able to use drone swarms as we then can be attacked from all directions. They also use acoustic pulse that gives you a splitting headache that lingers on for hours after the attack. We lack confidence we have adequate countermeasures to negate their combat leverage as we have problems to identify who they are. Are we dealing with social unrest here or are we fighting a war?"

Starting as coordinated social unrest in suburbs around a European capital where evidence of internal and external influence to encourage unrest is ambiguous at best, selected economic activities are compromised. There is a popular notion that social and civic destabilization will enable a firm crackdown by authority to prevent further civic erosion and spread into the capital. Inflammatory events on social media supported by religious and political statements. Impact on whole society and infrastructure is gradual but pernicious. Using proxies to set the stage, burning cars, vandalism, shootings and attacks on police stations. Sabotage against electric grid and freshwater plants. A pattern emerges that the actions are coordinated to target respected institutions and undermine public confidence in selected assets in society to create distrust and chaos. A wide array of contradictory information and speculations are delivered

by media. There is suspicion that the events are state sponsored or could provide a prelude to a coup or could be the initial phase of a military operation. How is the division line defined where responsibility goes from the police to the military? The operation environment is urban with a rich infrastructure.

*Technologies available*

Nutrition optimized to the individual police, rescue service and Defence personnel.
AR supported protective goggles to present COP based on social assessment of situation.
Key personnel such as firemen and certain police in specific roles equipped with powered exoskeletons.
Physiological status monitoring with uploading capabilities to unit level.
Pharmaceuticals for use with co-located coordinated civilian/military command personnel to enhance cognitive capabilities and speed up decision making.
Tele-existence technologies for police/military Explosive Ordnance Disposal (EOD) units, also used in advanced remote surgery by experts performing surgery from central hospitals. Smart textile with automatic wound therapeutic function.

*Opponents.*

Highly motivated units which operate in cell structure. Loyalties and partisan divisions among host nation military can potentially be exploited by the neighboring nation to increase civil chaos and undermine prospects of peaceful resolution. Regular use of proxies is the way how they can gain mass, economic support from state sponsor. Access to an information network with global reach to establish their narrative. Drugs enhancement is used by a wide range of terrorists and insurgents, the aim being to gain advantage due to pharmaceutical enhancement, improving strength, endurance, attention spans, ability to go without sleep, deal with pain, inure the individual to violence, or committing acts of great savagery.

Conclusions

Urban focused unrest which pits rival ethnic groups in conflict places the host government in a dilemma to either repress the dissidents or eventually succumb to their demands. Risks of power sharing with dissident groups supported by a neighboring nation create conditions for a coup or shift in government unless host government can satisfy or moderate dissident demands. Personnel with improved strength, agility, endurance, enhanced cognitive capabilities and ability to coordinate technology through human-machine interfaces. This would mean that resources can go a lot farther, because they have greater resilience and responsiveness, but also be integrated and coordinated in ways that maximize results at a higher operational tempo. AI-assisted intelligence collation models, should be able to sift vast

amounts of data/information and prioritize responses. Controlling and/or dictating the "battle of the narrative" across multiple domains to gain dominance at the earliest stage will be of crucial advantage.

The regime in power retains the right of engagement and use of force when it appears a borderline riot or insurrection is taking place. Non-lethal force would be the rule and non-kinetic disabling technologies could be used to subdue the crowd.

In this scenario it will be crucial to reach interoperability between civilian and military resources concerning HPM methods and technologies. From lowest levels of firefighters – medical personnel – police – soldiers all the way up into the common national crisis response command. Everyone needs to know what capabilities the other part brings into the operation and what impact it will have on the operation.

Recommendations

**Policy.** Mixed military/civilian urban conflict situations will require coordination, balance, and cooperative framework for police/military operations with appropriate political leadership governing deployment of these combined elements under specified legal and ethical rules. HPM technologies will be optional for police/military personnel under express authority of civilian leadership in advance of their needs in an urban conflict situation.

**Organization.** Ideally, integrated and coordinated resources and elements among police and military forces will report to a senior civilian official and operate cooperatively and jointly as directed and resourced by the host government.

Urban insertion of Multinational Nation Force (MNF) troops which are alien to the host country must subordinate their operational commands to the host nation senior military official unless prior joint arrangements have been agreed.

Weapons, tactics and special operations, including use of HPM, are determined by civilian authorities under advice offered from police and military leaders. Redundant command and control systems will be needed to ensure mission accomplishment.

**Materiel.** The acquisition of effective technologies, autonomous and other conventional items available to the police and the military in urban conflict situations should be protected against catastrophic failure, hacking or disablement. Redundant systems are preferred to support and sustain value added HPM technologies for future complex urban conflicts. Include adoption of systems which can disable or disorient urban troublemakers temporarily and permit police to reinforce stability and order.

**Training.** Training of police and military forces should include a variety of urban conflict scenarios where mixtures of conventional, autonomous and HPM methods and technologies are employed to accomplish the mission of social stability and civil control. Exercises would feature situations where senior civilian leaders can make decisions and authorize certain operations which reflect the full spectrum of calibrated responses to urban conflict.

**Interoperability.** Fully complimentary and compatible systems between police and military forces adaptable to urban conflict situations. They should be deployed under mission command of civilian leadership. Common SOP and ROE along with appropriate peace enforcement policies should guide joint and cooperative police/military leadership operations.

## 11.3 Scenario 3 Multinational Stabilizing Operation – Joint Expeditionary Force – Africa 2030

"I am so happy we have our cooling suits, otherwise we would have been toasted in this blistering heat. These long days with all the training really take a toll on your strength. Unfortunately, the training together with our partners is not proceeding at the pace we have anticipated even though we have personal equipment for instantaneous translation. We don't seem to have a common view of what goals we should reach. In some way the fundamentals of being a soldier are not shared and we have problems to explain certain procedures and activities we need to have in common to be able to operate together. There also seems to be a lack of common ethical and legal foundations for the use of HA methods and technologies in the operation. All soldiers from different nations need to have the same views and understanding of HA, so they all can take advantage of the technologies. Our tradition is to train as you fight – that means to use the Advantage Pills when we train so we know on an individual level how they will affect our capabilities. There are already rumors that some of the Nations in the Force regard us as cyborgs with magical powers, that can be fun as long as we are on the same side, but what happens if that rumor reaches our opponents? Will that make us a legitimate target as we are not regarded as humans anymore?

One positive factor is that the MNB have the latest in advanced combat medical care systems. Ranging from wound healing function in our battle dresses to advanced remote surgery capabilities here at Battalion Aid Station performed by specialists from hospitals at home. It will increase our chances of survival drastically if things get rough."

Stabilizing operation with UN mandate in Western Africa in the Sahel region. Tribal and Christian citizens have been terrorized in recent weeks by Islamic militant attackers. NATO thereafter authorized and airlifted a reinforced Multi-National infantry Brigade (MNB) to help stabilize the borders and ensure continued security in the area. UN peacekeepers, along with a contingent of Organization for African Unity (OAU) troops have deployed into the area.

The operational environment is characterized by extreme heat, scorching sun, jungle growth and obstructions, urban squalor, disease, sandy soil and limited infrastructure. MNB forces are equipped and provided with limited advanced HPM technologies which have not been distributed or shared with other NATO expeditionary force elements.

*Technologies available for MNB*

Nutrition optimized to the individual service member.
AR supported protective goggles to present COP daytime and in NVG.
Key personnel in fire support roles use powered exoskeletons to improve firepower.

Smart textile with cooling function and physiological status monitoring, information uploaded to company level.
Pharmaceuticals to enhance cognitive capabilities by 40% for improved battlefield awareness and quicker reactions and improved decision making.
Direct translation in conversations via microphone and loudspeakers in helmet,
Force consists of 30% unmanned vehicles such as 4-wheeled all terrain weapon platforms, robot drones, and logistic vehicles.
Smart textile with automatic wound healing function
The human-machine interface is tailored to be intuitive for humans.

*Opponents*

Highly motivated units with clan structure leadership. Average level of technology with some state-of-the-art capabilities provided by undefined sponsor nations. Very good knowledge of the operation environment, unlimited intelligence sources through a well-developed social network. Support from state sponsor with access to an information network with global reach. Highly capable cyber units that can affect the whole Area Of Responsibility (AOR) and beyond into our base areas including home nations.

Conclusion

In this scenario it will be possible or even desirable to operate with different levels of HPM methods and technologies within the Force. In this way it will be possible for each nation and /or organization to set the level of development without any constrains that everyone should participate in the development. One thing that will be essential is information on what capabilities certain technologies provide so that rumors and accidents can be avoided.

Insertion of MNF forces where not only border integrity but also regime integrity is in jeopardy will require extensive prior joint agreement on troop deployment, ROE and tactical disposition.

Recommendations

**Policy.** In complex scenarios where a mix of OAU, UN and multinational forces for stabilization operations are required there will be dilemmas about command and control and intelligence sharing apart from issues where HPM technologies may be considered. Depending on the totality of political factors involved HPM technologies may be invoked, deferred or adopted in very diverse forms. Operational, cultural, legal and ethical concerns involving HPM technologies will certainly require leadership and guidance from NATO, multinational forces, the UN and OAU. This will determine the size, shape, equipment,

deployment and disposition of the force. Participating nations will agree to arrangements with the host nation for the use, type, disposition and location of HPM technologies.

**Organization.** Operational commanders heading multinational force will designate and deploy selected HPM technologies where appropriate and retain anonymous data collection and operational management custodianship of such technologies.

**Materiel.** Medical augmentation for multilateral forces will be tiered to support selected optimized operations. Participating nations among multinational forces will identify actual and potential HPM operational systems in advance of each mission-integration with UN and OAU forces.

**Training.** Tiered training for diverse units ranging from normal unoptimized operations to selected optimized operations will require adjustments in content and emphasis to suit differences among UN, OAU and multilateral forces. The adaptive training would be adjusted for specific mission tasking apart from any SF force elements. Multilateral forces which elect to optimize their forces will demonstrate their special capabilities to familiarize UN and OAU forces with their inherent operational differences. Training would include cultural, tribal and environmental factors affecting the behavior of opposing forces.

**Interoperability.** Designated force mission assignments would be isolated and distinct among UN, OAU and multilateral forces based on political and HPM issues. Tiered forces with differential interoperability based on selected HPM systems are identified for relevant UN and OAU commanders as part of economy of force structure for the mission.

## 11.4 Scenario 4 Coalition Warfighting Operation – Eastern Europe 2035

"Here we go again; the alarm is sounding loudly in my ears. I had really hoped they had got enough from the last whipping we gave them. I check the levels in my exosuit: power, ammo, EW, comms, CBRN shield – suit OK! Self-assessment: pulse, blood pressure, temperature, nutrition, hydration, stress levels – OK, battle ready! All info goes to my Log/HR manager in the company command post. The battlespace AR system in my visor is feeding me information from our drone swarm that is patrolling our outer perimeter. It is not possible to discover anything using normal vision as the enemy is using adaptive camouflage but when you shift to RADAR/LIDAR mode it is obvious what is going on. In the obscured parts between the ruins in the city you can see the enemy UGVs and Technicals crawling towards us. This is going to be a tough one, I pop one of my Advantage Pills to increase my cognitive capabilities to ensure I will be able to adapt to the intense battle situations.

From previous engagements with our opponents, we know they are on drugs that give them improved strength and stamina and at the same time reduce their fear and cautiousness. It seems the effect of us hitting them will not be immediate as some of their pain receptors probably are blocked. This has the side effect that it has created an enemy less emphatic operating on the border of LOAC. We call them Dronbies as they appear to be a mix of drones and zombies. They don't scare us, but we will definitely not get into close combat with them, we try to take them out at a distance where our advantages in quicker target acquisition and ranged weapons will give us the upper hand.

We are so fortunate to have such a skilled commander, the best one in the force, she always makes the right decisions at the right time and is always able to outsmart our enemies. The AI supported decision making system is state of the art. A lot depends on her making the right calls in a timely way. Yes, here comes the delivery from our supporting Navy units. Our strategic cyber command takes out their electronic shields for better EMP effects on the communications interface between their commanders and autonomous units. That is something our opponents have never been able to do against us; we have the best protected interface and can use that to our advantage. Now it will be easier for us to pick them off one by one."

Major Joint operation against a peer enemy. After a long period of escalation and probing the Coalition standing forces in Eastern Europe are attacked. Both sides are utilizing available resources but have so far refrained from using nuclear weapons and cyber-attacks have only been used in the affected region, not on a global scale. The unspoken understanding on both sides is that the conflict should be contained as a regional conflict to avoid escalation into a global crisis. Coalition forces have moved their delaying and defensive actions into urban areas to force the enemy to commit more resources. The operational environment is a mix of urban/suburban. The weather condition is worst possible for January in Eastern Europe with

temperatures below freezing and continued strong winds combined with sleet and snow. Fighting in a truly three-dimensional landscape would be formidable even without hyper connectivity, drones and robots controlled by interfaced controllers, exoskeleton-wearing troops, able to breach buildings, maneuver across formidable obstacles, controlling drones, supplying a comprehensive picture of the battlespace and miniature robots, working in tunnels and sewers combined with an enhanced individual soldier, could make this a truly formidable undertaking for any army. If we then add in a peer enemy, with the ability to sustain operations at high tempo and we could see a scale of conflict and urban combat that we have not witnessed in a long time.

*Technologies available*

Nutrition optimized to the individual service member.
AR supported protective goggles to present COP daytime and in NVG.
Key personnel such as front-line infantry soldiers use powered exoskeletons to improve firepower and protection.
Smart textile with heating function and physiological status monitoring, information uploaded to company level.
Pharmaceuticals to enhance cognitive capabilities by 20% for improved battlefield awareness and quicker reactions and improved decision making.
Smart textile with automatic wound healing function.
Force consists of 50% unmanned vehicles such as 4-wheeled/tracked all terrain weapon platforms and logistic vehicles. Drones appear in self-adjusting swarms.
The human-machine interface is supported by AI and tailored to be intuitive for humans.

*Opponents*

Highly motivated modern units with battlegroup organization. Strong Anti-Access, Area Denial (A2AD) capabilities likely derived from use of AI, cyber, drone intel and HPM upgrades where overall capabilities may be ambiguous. Opposing force consists of a mix of up to 30% unmanned units. An assessment of the opponent's investments in R&D in the HPM area yields that commanders and soldiers are believed to be augmented to gain advantages.

Conclusion

In this scenario it will be absolutely essential to reach interoperability in the areas of HPM methods and technologies with all participating Nations in the coalition to be able to defeat a peer opponent that will use HA to gain military advantages.

Human Machine Teaming (HMT) units have the potential to take the soldier out of harm's way and replace him with machines. To be able to control the machines an intuitive, secure interface will be a key factor to exploit. HA combined with AI will be key for realizing HMT. The focus on future soldiers will be going from body to mind. From soldiers handling their own weapons in the frontline to soldiers managing machine weapon systems with vastly bigger firepower from secure positions beside the combat zone.

Delegation of authority to MNF commanders for tactical deployments of enhanced troops in selected campaigns is essential and more broadly enhanced troop upgrades appear warranted as there is vague intelligence about the nature and extent of enhanced OPFOR units. The extent to which enhancement in both sides offsets or creates a tactical advantage will require development of phased deployment of enhanced/vs unenhanced forces. Instances where OPFOR is obviously enhanced will require matching enhanced capabilities and exhibiting counter measures necessary to dilute or mitigate OPFOR presumptive capabilities.

Recommendations

**Policy.** Multinational forces must adopt operational doctrine and systems strategies which entail explicit use of all available HPM technologies, recognizing OPFOR will likely have equivalent technologies. Current investment, research, and engineering work designed to maximize HPM supported systems operations and platform integration for use by ordinary forces. Innovative diversity of engineering and science to foster technology alignment and cutting edge HPM supported systems within and among multinational forces is needed to foster widest possible civilian and military technical innovation within multilateral members to create and devise future HPM supported operational systems. Open innovation standards should be adopted by multilateral organizations.

Setting operational limits, doctrinal principles and international guidelines for development and deployment of modern HPM supported systems is essential to define the scope of future conflict. This would entail legal and ethical considerations as well as distinctions among kinetic and non-kinetic systems and platforms. Devising a compatible communications plan which depicts instances where HPM may be required is important. HPM supported systems development includes interchangeable medically adaptive systems. Policy ought to include nullification and force protection measures to neutralize any hostile OPFOR HPM technology or render them unusable. Task intelligence experts to classify the type and complexity of OPFOR enhancements with scientific and technical defensive options and effective neutralization countermeasures.

**Organization.** Identify the various HPM supported systems, engineering options and enablers which best fit the operational, defensive, deterrent and mission needs of multilateral commanders and their troops**.** Validate candidate HPM supported systems for differential and

appropriate operational missions distinguishing proven systems from systems in their earliest stages of development.

**Materiel**. Equipping multilateral forces with appropriate HPM supported systems and platforms to align with different missions and operations as appropriate. Selected HPM supported systems adapted to different combat missions and operations will be identified and scaled to fit future mission tasking adapted for soldiers through commanders. Interoperable software and hardware are essential to operate, control and govern HPM supported systems.

**Training.** Operational training adjusted to fit various applications of HPM based on variations in mission tasks will be conducted along with exercises to determine value and utility of HPM systems and platforms in diverse scenarios. Functional differentiation, and operational requirements where possible should define ultimate adoption of various HPM supported systems. Train as you fight.

**Interoperability**. Define and communicate common algorithmic language which, along with human-machine interface nodes and governance systems enables continuous connectivity between commanders and soldiers within the designated HPM supported system. Protected 5G communications will be needed to insulate and integrate multinational forces against enemy/hostile forces where their own HPM supported systems exist in hostile operations.

11.5 Overall Conclusion from Scenarios.

- Development of HPM capabilities will significantly impact future warfare. HPM methods and technologies are very diverse and have implications for many aspects of Defense activities. They can be applied before, during or after an activity and will affect and change the way how we conduct.
- Recruiting to get the individual with the right potential and capabilities,
- Individual education and training,
- Unit training and exercises,
- Preparation for deployment and action,
- Monitoring and controlling operations,
- Sharing information and cooperation in multinational operations,
- Medical treatment in front line,

- Recovery and rehabilitation of wounded service personnel.
- For Defense personnel the potential benefits of HA methods and technologies can support:
    - Improved attention, vigilance and memory
    - Increased perception and situational awareness
    - Enhanced decision-making
    - More efficient learning
    - Increased strength, speed and endurance
    - Enhanced sensory functions and range
    - Improved health and wellbeing
    - Fast recovery from injuries and wounds
    - Enhanced resilience and perseverance

HA has the potential to make it easier and safer for Defense personnel to perform their tasks. The outcome is increased probability of mission success in combination with lower risk of injuries, wounds and post operation stress effects.

The introduction of HPM methods and technologies in Defense will differentiate between the participating nations in a coalition based on R&D capabilities, economic resources and acceptance in the society of HPM development. An ethical and legal framework will be crucial to create a common understanding and view of HPM potential benefits and threats.

Interoperability in Joint Multinational Operations. Defense needs to initialize discussions about HPM in coalitions with partners to help develop policies and practices that will support interoperability. The purpose will be to minimize frictions and create a common support system for introduced methods and technologies. It should be possible to participate in a multinational operation with different national ambitions concerning HPM.

We must understand and address threats connected with HPM methods and technologies or risk creating strategic vulnerability. Threats can emanate from lone actors, criminals, terrorist groups or states. Even if we chose to not develop capabilities because of legal or ethical reason

we still would have to be aware of the potential of an opponent with HPM supported capabilities. There will be HPM vulnerabilities, and we need to have the knowledge how to exploit them.

Multinational forces should develop operational doctrine and systems strategies which entail explicit use of all available HPM methods and technologies in different scenarios.

- We have developed and applied HPM methods and technologies and so have our opponents. The outcome will be depending on who will have the best and strongest HPM and the best ways to apply it in offensive operations and at the same time protect their own capabilities.

- We have not developed and applied HPM methods and technologies, but our opponent has. The outcome will depend on whether we will be able to explore vulnerabilities connected with HPM and turn the advantage of having HPM into a disadvantage.

- We have developed and applied HPM methods and technologies, but our opponent has not. The outcome will depend on whether we will be able to explore offensive advantages connected with HPM and at the same time protect our own critical capabilities.

## 12. Summary and Conclusion

This project collected and analyzed knowledge of currently available technologies and methods for augmenting human performance and provided 4 potential scenarios how those methods might possibly be used in the near future. The main focus was to assess ongoing and planned HPA programs affecting the interoperability and preparedness of multinational coalition forces.

The main findings, conclusion and recommendations are:

1) To use commonly agreed terms of reference and definitions. We have developed a set of definitions for the ones most frequently used such as Modification, Augmentation, Optimization, Enhancement, Restoration and Degradation.

2) Currently, the benefits of Human Performance Optimization programs have the biggest potential to be implemented to improve the performance and survivability of the service members. However, further cost-benefit studies should be conducted to facilitate decision-making.

3) Across MCDC member nations, one phenomenon is significantly apparent: all HPA programs are conducted in isolation – leading to multinational interoperability gaps and wasted advantages for wider unit performance even within one nation. The recommendation is fundamentally clear: Develop common guidelines and coordination mechanisms to encourage the sharing of best practices and to facilitate joint combined research.

4) HPM will change the future of warfare including the impact on civil-military interaction. This would require a comprehensive approach for joint threat assessments and mitigation for potential hybrid whole-of-society scenarios.

5) Legal and ethical guidance have difficulty coping with the speed of current developments in HPM technologies. Specifically, the global quest for HPA advantages will continue and in the worst case in clandestine for dual use and offensive purposes. The need for HPM principles, doctrine and operational guidance is evident. That must be done as a whole-of-society approach by developing the necessary legal and ethical frameworks.

Ideally, this would be supported and led by the strategic leadership and conducted through operational and tactical organizations such as a specifically dedicated “Center of Excellence”, which incorporates existing national and multinational research initiatives.

# Appendix

Questionnaire

Definition provided to the recipient of the questionnaire:

- HPO is addressing the process of applying knowledge, skills, and emerging technologies to individuals allowing them to reach their biological potential to execute essential tasks (see Table 1).
- HPE is addressing the use of pharmaceuticals, devices, cognitive enhancement and emerging technologies to individuals allowing them to increase their biological potential beyond the border of physiological maximum to execute essential tasks (see Table 2).

The result in number of programs is presented in Figure 8 and Figure 9.

Table 1. Questions asked in the HPO part of the questionnaire.

| **Category** | **Question to be answered by Yes, No or Planned for** |
|---|---|
| Physical performance: | • Do you have established programs which target sustainable and peak physical performance?<br>• Do you have ongoing or planned studies which explore methods of optimizing physical performance? |
| Recovery/Sleep | • Do you have established programs which have positive effects on recovery/sleep?<br>• Do you have ongoing or planned studies which explore methods of optimizing recovery/sleep? |
| Nutrition | • Do you have established nutrition programs designed to improve recovery, mental and physical performance?<br>• Do you have ongoing or planned studies which explore the effects of nutrition on human performance optimization? |
| Mental Performance | • Do you have established programs which have positive effects on mental performance?<br>• Do you have ongoing or planned studies which explore methods of optimizing mental performance? |
| Other areas, apart from previous categories | • Do you have established programs for increasing HPO which are not in the four categories? Which topic?<br>• Do you have ongoing or planned studies which explore methods of optimizing human performance and which are not in the four categories? |

Table 2. Questions asked in the HPE part of the questionnaire.

| | |
|---|---|
| Technical Performance 1: Detection Systems | E.g. sensor technique and telemonitoring.<br>• Do you have established programs which have positive effects on physical performance using sensor technique and telemonitoring?<br>• Do you have ongoing or planned studies which explore methods of using sensor technique and telemonitoring? |
| Technical Performance 2: Support Systems | E.g. exoskeleton, augmented reality systems, weapon enhancement, cybernetic enhancement.<br>• Do you have established programs which have positive effects on technical performance as described above?<br>• Do you have ongoing or planned studies which explore methods of optimizing physical performance? |
| Genetic Enhancement Technologies | • Do you have established programs which have positive effects on genetic enhancement technologies?<br>• Do you have ongoing or planned studies which explore methods of genetic enhancement technologies? |
| Cognitive Neuro-enhancement Techniques and Technology | E.g. transcranial magnetic stimulation<br>• Do you have established programs which have positive effects on cognitive neuroenhancement techniques and technology?<br>• Do you have ongoing or planned studies which explore methods of cognitive neuroenhancement techniques and technology? |
| Pharmaceuticals | • Do you have established programs which have positive effects on the use of pharmaceuticals?<br>• Do you have ongoing or planned studies which explore methods of the use of pharmaceuticals? |

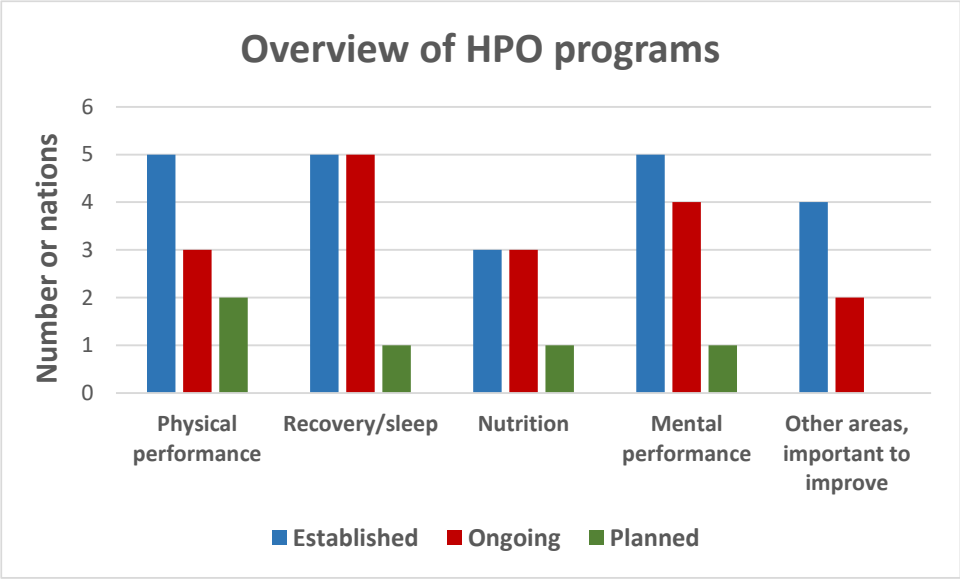



Figure 8 Summary of HPO activity within responding nations, n=6.
Source: own development

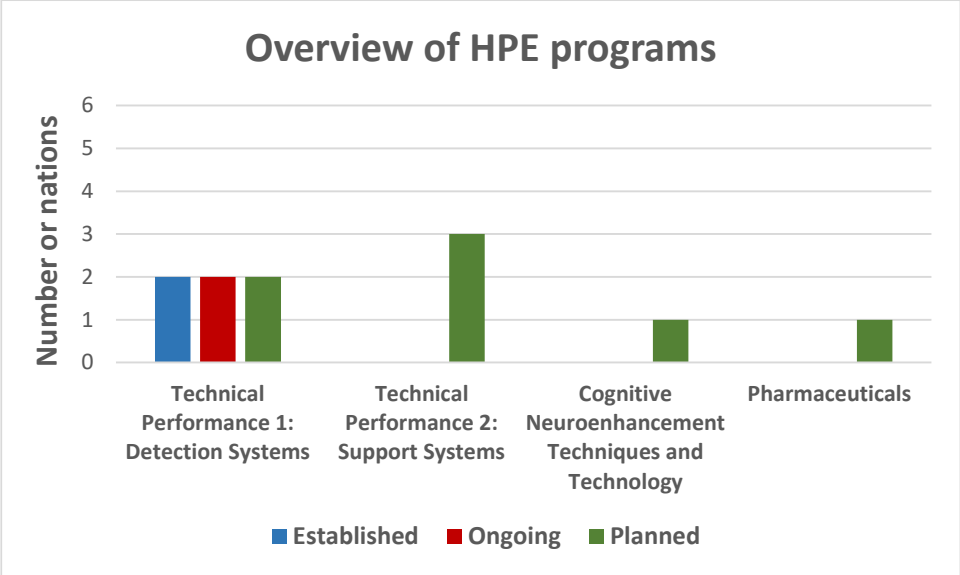



Figure 9 Summary of HPE activity within responding nations, n=6.
Source: own development

# GLOSSARY

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| A2AD | Anti-Access, Area Denial |
| AI | Artificial Intelligence |
| AOR | Area Of Responsibility |
| AR | Augmented Reality |
| ARMOR | Ambulant Registration of Military Operational Readiness |
| ATP | Adenosine Triphosphate |
| ATREC | Assessment in Real Time of the Stress in Combatants |
| BODP | Bundeswehr Office for Defense Planning |
| Bw | Bundeswehr, German Armed Forces |
| CBRN | Chemical, Biological, Radiological and Nuclear |
| CD&E | Concept, Development and Experimentation |
| CHE | Switzerland |
| CICDE | Centre interarmées de concepts, de doctrines et d'expérimentations |
| COP | Common Operational Picture |
| COTS | Commercial of the shelf |

| | |
|---|---|
| DCDC | Development, Concepts and Doctrine Centre |
| DEU | Germany |
| EDA | European Defense Agency |
| EEG | Electroencephalography |
| EMP | Electromagnetic pulse |
| EOD | Explosive Ordnance Disposal |
| ESP | Spain |
| EU | European Union |
| FDRA | Finish Defense Research Agency |
| FIN | Finland |
| FOI | Swedish Defense Research Agency |
| FRA | France |
| GBR | Great Britain |
| GIDS | German Institute for Defence and Strategic Studies |
| GOSSRA | Generic Open Soldier System Reference Architecture |
| HAT | Human Autonomy Teaming |
| HFM | Human Factors and Medicine |
| HMT | Human Machine Teaming |
| HP | Human Performance |

| | |
|---|---|
| HPA | Human Performance Augmentation |
| HPD | Human Performance Degradation |
| HPE | Human Performance Enhancement |
| HPE-STAR | Human Performance Enhancement – Smart Textiles and Augmented Reality |
| HPM | Human Performance Modification |
| HPO | Human Performance Optimization |
| HPR | Human Performance Restoration |
| HQ | Headquarters |
| HR | Heart Rate |
| IHL | International Humanitarian Law |
| INTA | National Institute for Aerospace Technology |
| LOAC | Law of Armed Conflict |
| LSD | Lysergic Acid Diethylamide |
| MCDC | Multinational Capability Development Campaign |
| MDMA | Methylenedioxy-Methamphetamine |
| MilMEDCOE | Centre of Excellence for Military Medicine |
| MNB | Multi-National infantry Brigade |
| MNF | Multinational Forces |
| MoD | Ministry of Defense |

| | |
|---|---|
| MUM-T | Manned Unmanned-Teaming |
| NATO | Northern Atlantic Treaty Organization |
| NDL | Netherlands |
| NVG | Night Vision Goggles |
| NZL | New Zealand |
| OAU | Organization for African Unity |
| OPFOR | Opposing Force |
| R&D | Research and Development |
| ROE | Rules of Engagement |
| RT-PSM | Real Time Physiological Status Monitoring |
| SF | Special Forces |
| SIPRI Institute | Stockholm International Peace Research |
| SOCOM | US Special Operations Command |
| SOF | Special Operation Forces |
| SOP | Standard Operating Procedure |
| SWE | Sweden |
| THOR3 | Tactical Human Optimization Rapid Rehabilitation and Recondition |
| TRL | Technology Readiness Level |
| UAV | Unmanned Aerial Vehicle |

| | |
|---|---|
| UGV | Unmanned Ground Vehicle |
| UN | United Nations |
| USA | United States of America |
| USARIEM | United States Army Research Institute of Environmental Medicine |
| VR | Virtual Reality |
| VUCA | Volatile, Uncertain, Complex, Ambiguous |

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