The future of human enhancement in the military domain

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Abstract

The future of human enhancement technologies in the military domain presents transformative opportunities and complex challenges. This report explores advancements in physical and cognitive enhancements, including genetic engineering, brain-computer interfaces and pharmaceutical interventions, highlighting their potential to redefine soldier capabilities and military strategies. While these technologies promise significant advantages, such as improved resilience, situational awareness and operational efficiency, they also raise critical ethical, legal and societal concerns. The report provides a comprehensive analysis of emerging trends, technological innovations and their implications for future warfare, culminating in strategic recommendations for policymakers and military planners. By balancing innovation with ethical considerations, these advancements can be harnessed to create a resilient and adaptive military force capable of addressing the dynamic challenges of modern conflict. Currently, it seems that the EU is paying relatively little attention to human enhancement and rather considerable attention to artificial intelligence. However, these research topics are interconnected and should be considered as such to foster the positive aspects for industrial development and economic prosperity.

Introduction

The future of human enhancement in the military domain holds transformative potential, offering profound implications for national security, combat readiness and soldier capabilities, even in small countries. This report aims to explore the horizon of possibilities afforded by advancements in technology that can amplify human physical and cognitive abilities. As nations increasingly invest in military technology, understanding these enhancements' ethical, strategic and operational dimensions becomes imperative.

The primary purpose of this report is to provide a comprehensive analysis of current and future technologies in human enhancement within the mili-

tary. It seeks to identify potential applications, benefits and challenges, offering guidance to policymakers, military strategists and defence researchers. The scope of this report encompasses a wide range of technologies, including genetic engineering, cybernetic implants, pharmaceutical interventions and neurotechnology to compile **a roadmap to 2045** with potential research and development directions. A small selection of most promising technologies is examined for its current capabilities, potential military applications and associated risks. The analysis also considers the ethical and social implications for society of deploying these technologies in military settings.

In its broadest sense, human enhancement refers to the application of technologies and scientific methods to improve or expand the physical, cognitive or psychological abilities of humans. As such, it is a relatively new scientific research topic. The bibliometric research, visualised in the following figure, did show that the active research was conducted in two waves. The first wave started in 1960 and mainly concerned neuroactive drugs. The second wave, started in 2000, concerned a wide variety of different technologies.

Figure 1: Overview of the relevant information space

Source: Author's own compilation, based on Google and AIT data.

The report will focus on the second-wave innovations and is organised into several key sections, beginning in Chapter 2 with a background overview of human enhancement technologies. Subsequent sections delve into specific types of enhancements, discussing their development, implementation and the strategic advantages they may confer.

In Chapter 3, future trends and possible future innovations are portrayed, referring to possible future war scenarios. Weak signals for future trends, innovations and threats of these technologies are discussed and summarised in a roadmap to 2045 for military research opportunities, followed by an exploration of potential tactical and societal impacts of these technologies.

In Chapter 4, the report concludes with a set of recommendations aimed at navigating the future landscape of military enhancements with risk assessment and some social and ethical considerations for each core technology cluster. The reader can expect to obtain a comprehensive overview of new and upcoming potentially useful future military capabilities in the fast-evolving field of human enhancement.

Current scientific research and technologies in military use

In general, human enhancement refers to the application of science and technology to improve human performance beyond what is necessary to restore or sustain health. This includes any alteration or augmentation that increases physical or cognitive function, potentially giving individuals abilities considered superior to normal human capacities. Over time, almost all military tactics have involved some kind of performance improvement, often reflected in the military doctrine as a "game changer", with disrupting effect to win a conflict. In recent times, the amount and the effectiveness of these disruptive innovations has grown exponentially, in particular, because of the digitalisation in research. Therefore, it is the intention of this publication to draw attention to this and find solutions to the high pace of innovations in the military context, avoiding linear improvements and focussing on the non-linear yet exponential growing amount of essential military capabilities, without the overwhelming effect of overtraining.

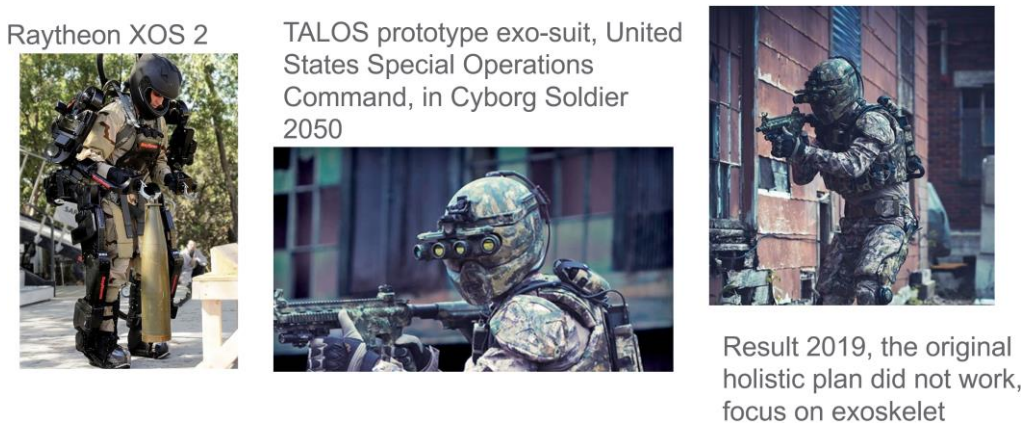
As mentioned in the document "Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD",[1] the US vision for

[1] Defense Technical Information Center: Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD, 2019, https://apps.dtic.mil/sti/pdfs/AD1083010.pdf.

human enhancement by the year 2050 discusses the potential for integrating advanced biotechnologies to augment human capabilities, enhance situational awareness and improve communication and control systems through direct neural enhancements. This future vision includes ocular, auditory and muscular enhancements, with particular emphasis on the revolutionary impact of brain-machine interfaces that could enable two-way data transfer directly with the human brain, enhancing operational effectiveness in military contexts. All concept scenarios in this document point to some sort of human performance improvements.

The following figure shows different concepts of the future military suit. None of these are in operational use yet, but it is very likely that the next-generation suit will contain new forms of protection and other features to enhance the capabilities of soldiers.

Figure 2: Future soldier body suit



Source: Different internet sources.[2] [3]

[2] Osias: Robotic Exoskeletons - SlideServe. SlideServe. July 17, 2014. https://www.slideserve.com/osias/robotic-exoskeletons.

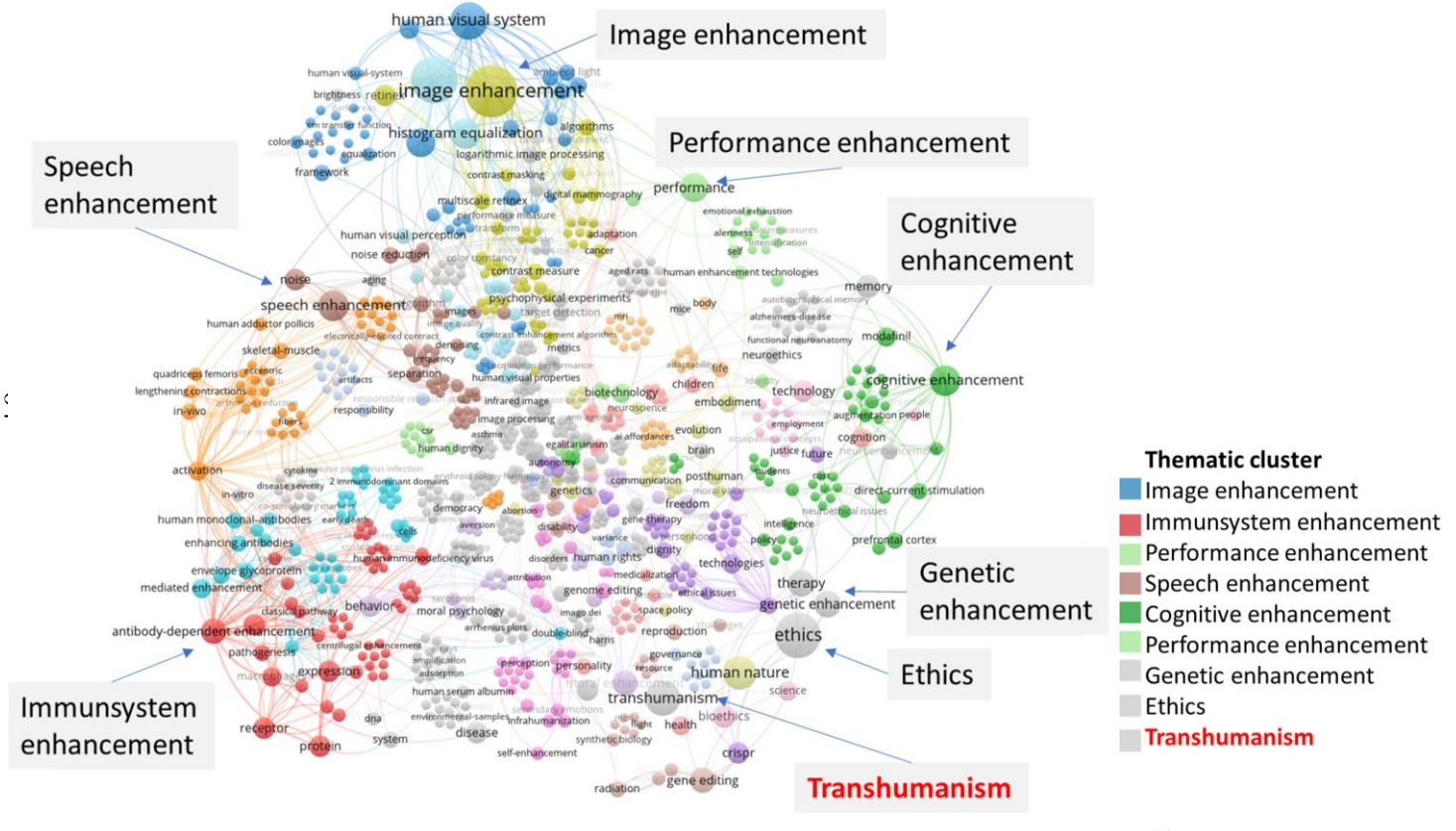
[3] Keller, Jared: The Inside Story Behind the Pentagon's Ill-fated Quest for a Real-life 'Iron Man' Suit. Task & Purpose, July 11, 2021. https://taskandpurpose.com/news/pentagon-powered-armor-iron-man-suit/.

Soldier suits are an obvious approach to new and enhanced soldier capabilities. Other military applications within the future US scenarios focus on augmenting human capabilities to improve effectiveness, resilience and survivability in complex and demanding combat environments. These enhancements range from physical and cognitive enhancements to more futuristic implementations. Physical enhancements, such as on the left-hand side of the figure, include exoskeletons designed to augment strength and endurance, allowing soldiers to carry heavier loads and maintain peak performance for longer periods. These devices can also help in reducing the risk of injury by providing additional support and reducing the strain on the body during intense physical activities. Cognitive enhancements are another critical area, involving the use of neurotechnology to improve decision-making and information processing abilities. Technologies such as brain-computer interfaces (BCIs) enable direct communication between the brain and external devices, enhancing situational awareness and enabling faster reactions to dynamic situations. Additionally, advances in biomedical technologies have led to developments in gene editing and biotechnology that could potentially enhance physical endurance, resistance to environmental stresses and recovery times for injuries. Overall, these technologies from future US scenarios are being explored with the aim of providing soldiers with a significant advantage on the battlefield, ensuring they are better prepared, more resilient and capable of performing at higher levels in the most challenging situations.

In this publication, advanced horizon-scanning methods are used to identify likely future technologies for military human enhancement and compare these with the existing future scenarios to update future expectations. An initial step towards this is the creation of a topic map, based on recent scientific publications. The results of this approach, with data from 2023 and 2024, are visualised in the following graphic, resulting in eight identified clusters.

Figure 3: See next page.

Figure 3: Topic cluster - human enhancement research



Source: Authors calculation, data WoS (Clarivate, Web of Science, https://www.webofscience.com).

The cluster "**image enhancement**" in the military refers to any type of sensor or method to improve the visualisation of information, useful for better situational awareness. It pertains to improving the quality and effectiveness of visual equipment such as night-vision goggles, thermal imaging devices, surveillance cameras and any other sensors. Thus, enhanced imaging technologies give soldiers greater situational awareness and operational capability in diverse environments, enabling clearer, more accurate identification and tracking of targets under various conditions. Usually, these sensors are outside of the human body. Cyborg Neil Harbisson, a colour-blind artist, implanted a sensor for perceiving colours beyond the natural range, allowing him to even sense, e.g., infrared light. This is not directly useful to the military, but did show that sensors could potentially be implanted, which would give them somewhat enhanced capabilities to recognise valuable radiation in a previously unrecognised spectrum. The US forecast is expecting soldiers to have human brain implants, eye implants and ear implants by 2050.[4] An overview of actual implantable sensors shows that the actual trend is to provide implants for medical purposes.[5]

Another well-known and often mentioned cluster of human enhanced capabilities is that of **immune system enhancements** (e.g. by vaccinations and bacteriophage). They are crucial in military tropic settings to protect soldiers from biological threats, including engineered pathogens. Enhancing a soldier's immune system can involve advanced vaccinations or genetic modifications aimed at creating superhuman resistance to toxins and diseases, thus maintaining readiness of forces in biologically compromised environments. It is likely that future enhancements will make more use of synthetic biology and artificial intelligence.

Another research direction involves **physical enhancements** such as exoskeletons that increase strength and load-carrying capacities, or substances

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[4] Morrison, Ryan: Cyborgsoldiers: Plan to Create Deadly 'machine Humans' by 2050 Outlined in US Military Report. Mail Online, November 29, 2019. https://www.dailymail.co.uk/sciencetech/article-7738669/US-Military-scientists-create-plan-cyborg-super-soldier-future.html.

[5] Yogev, David/ Goldberg, Tomer/Arami, Amir/ Tejman-Yarden, Shai/ Winkler, Thomas/ Maoz, Ben: Current state of the art and future directions for implantable sensors in medical technology: Clinical needs and engineering challenges. APL Bioeng. 27 September 2023, 7(3):031506. doi: 10.1063/5.0152290. PMID: 37781727; PMCID: PMC10539032.

that boost stamina and reduce fatigue. Mental performance enhancements could also be employed to improve focus, reduce stress responses and enhance decision-making speed under pressure.

Speech enhancement technologies are used to improve communication clarity in noisy or chaotic battle environments. Enhanced speech systems could include advanced communication devices that offer noise-cancellation features or even implantable devices that facilitate silent communication through sub-vocal recognition technologies, facilitating covert operations.

Cognitive enhancement is clearly highly valued in the military for roles that require high levels of cognitive function such as strategy development, real-time decision-making in combat or complex machinery operation. Techniques might include pharmacological agents to enhance alertness and cognitive processing, or neural interfacing to directly integrate devices that augment cognitive capacities as well as LLMs or other AI reasoning mechanisms. It is very likely that the reasoning mechanism will be connected to new brain-machine interfaces.

Genetic enhancement might be pursued to develop soldiers with naturally enhanced capabilities such as heightened senses, superior muscle growth and accelerated healing processes. These genetic modifications could potentially create soldiers who are better adapted to extreme conditions and capable of performing at high levels that are currently not reached by unmodified humans. However, it is a question of whether this is favourable, whether the other option would be to use machines in dangerous environments and hot zones.

Lastly, a very special cluster in the actual publications about HE is formed by the cluster **transhumanism,** in which proponents are claiming to produce a new species, which is better and more capable than humans. This is likely the most radical approach to HE. In a military context, this can essentially be seen as creating a new soldier for strategic advantages through biotechnological superiority, including controversial technologies such as genetic improvements. The concept pushes for the development of "super soldiers" who are extensively enhanced through a combination of biotechnologies, artificial intelligence and information technologies. This could lead to fundamental changes in the conduct of warfare, where enhanced soldiers might display abilities that blur the lines between human and machine capabilities.

All of these enhancements not only promise to increase effectiveness and survivability in combat situations but also pose complex ethical and legal challenges, as *the line between soldier and weapon becomes increasingly blurred*. The implications for international law, warfare ethics and the nature of conflict itself are profound and require careful consideration as these technologies evolve, which will be discussed in Chapter 4.

The next argumentative step will, however, be to go into the two most promising examples of human enhancement in more detail:

- physical enhancements with pharmaceuticals and
- cognitive enhancements with artificial intelligence, sensors and computation power, either in a human body, externally or in combination.

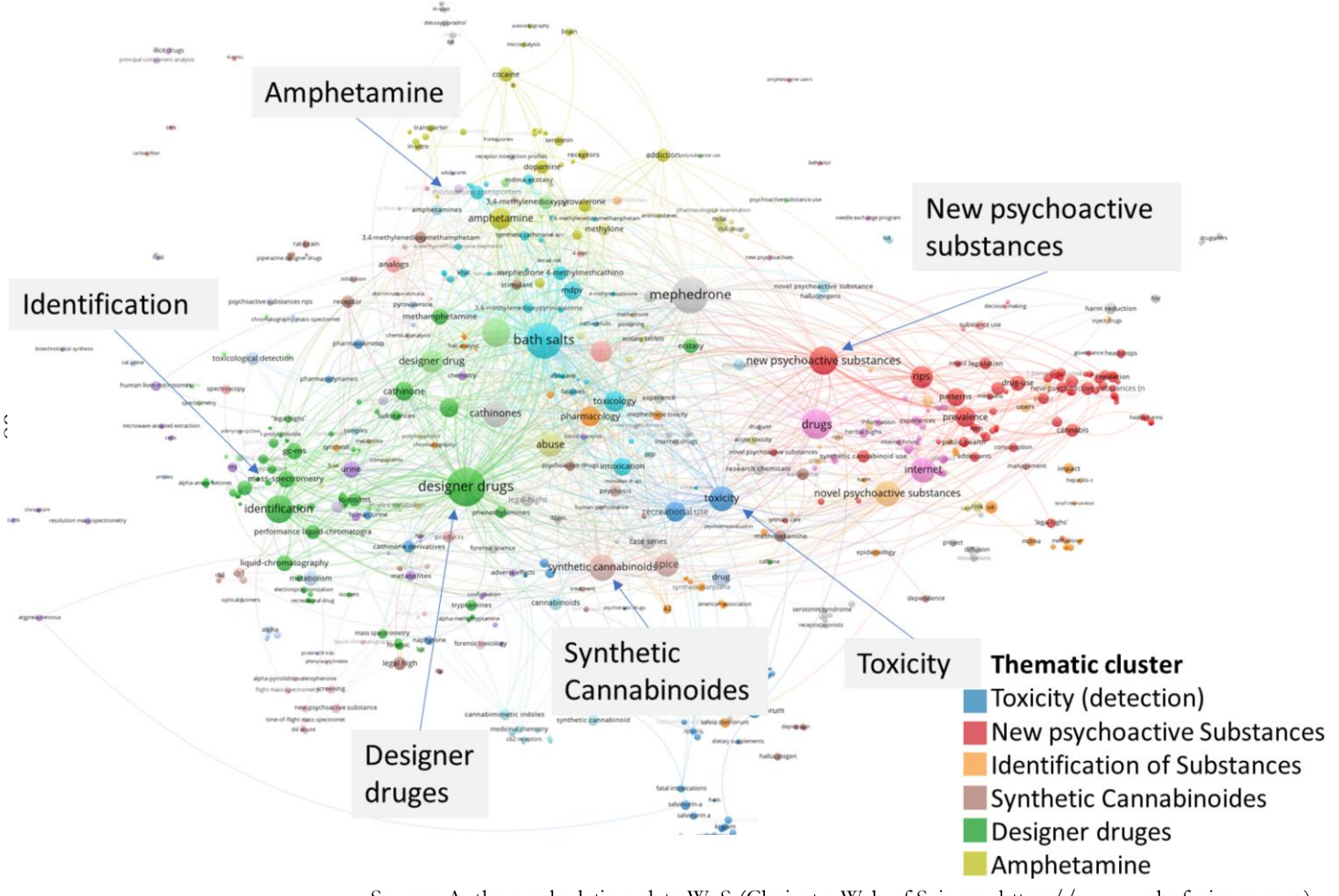
The following excurses will present detailed research topic maps with examples of technology innovations, which are particularly relevant to military use.

Excurse: Pharmaceutical enhancements

The military relevance of human enhancement technologies related to toxicity detection and the identification and use of new psychoactive substances, synthetic cannabinoids, designer drugs and amphetamines is significant in several aspects. Enhancing the ability of military personnel to detect and identify toxic substances within the environment is essential to survival in combat and reconnaissance missions. Technologies that can quickly and accurately determine the presence of chemical agents can be lifesaving. This capability is essential not only for immediate threat responses but also for long-term health monitoring in potentially contaminated areas.

Furthermore, the use of new psychoactive substances, synthetic cannabinoids, designer drugs and amphetamines can impact military operations. These substances can be engineered to enhance alertness, reduce fatigue and increase endurance among soldiers, potentially giving them an edge in prolonged engagements. However, the use of such substances also raises ethical, legal and health concerns that must be carefully managed. The identification of these substances is crucial for enforcing bans, monitoring usage and understanding their effects on human performance and decision-making in military settings.

Figure 4: Topic map of psychoactive substances

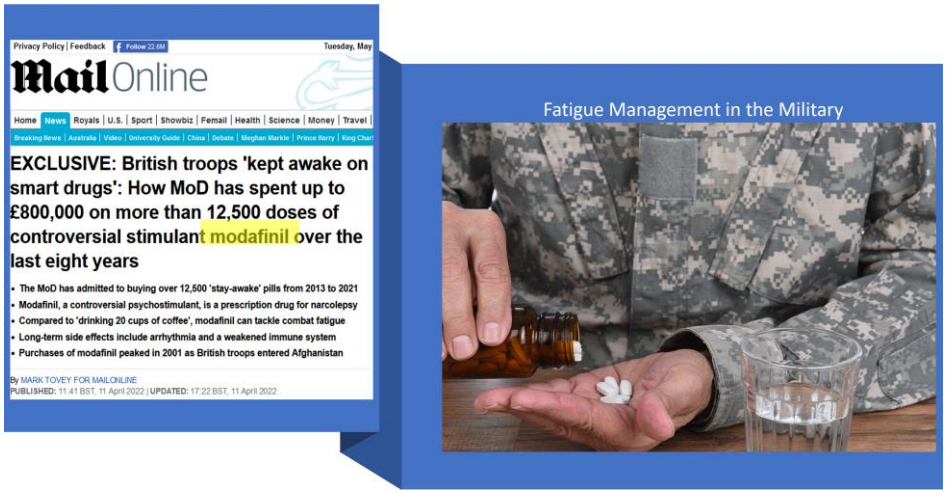


Source: Authors calculation, data WoS (Clarivate, Web of Science, https://www.webofscience.com).

The future trends in human enhancement technologies related to toxicity detection and new psychoactive substances are likely to focus on integration, miniaturisation and increased sophistication. As technology advances, we can expect to see more portable and user-friendly drugs capable of providing a customised range of possible improvements, without strong side effects. These drugs will likely support humans in collaborating or even incorporate advanced sensors and artificial intelligence to provide immediate, accurate analyses, enabling military personnel to make quick decisions in the field.

In some specific situations the US military recommends the use of modafinil to treat "sleep work shift disorder". "The use of modafinil as a 'cognitive enhancer' in healthy subjects has been suggested in the literature; however, the precise benefits and risks associated with this use remain uncertain".[6]

Figure 5: Human enhancement with smart drugs



Sources: different internet sources and scientific reports[7] [8] [9]

[6] Greenblatt, Karl/ Adams, Ninos: Modafinil. StatPearls - NCBI Bookshelf. February 6, 2023. https://www.ncbi.nlm.nih.gov/books/NBK531476/.

[7] Bendak S and Rashid HSJ (2020) Fatigue in aviation: A systematic review of the literature. International Journal of Industrial Ergonomics 76. https://doi.org/10.1016/j.ergon.2020.102928.

[8] Wingelaar-Jagt YQ, Wingelaar TT, Riedel WJ and Ramaekers JG (2022) Subjective Effects of Modafinil in Military Fighter Pilots During Deployment. Aerospace Medicine and Human Performance 93(10), 739-745. https://doi.org/10.3357/amhp.6072.2022.

[9] https://www.banyantreatmentcenter.com/2022/11/29/modafinil-military-use-mvir/.

In the area of psychoactive substances, research might expand into developing substances that can be safely used to enhance cognitive and physical abilities, such as concentration, reaction times and resilience to stress. However, ethical considerations will drive the development of guidelines on the use and control of these substances, with an emphasis on safety and the reversibility of effects.

Lastly, as synthetic biology and chemical synthesis technology evolve, there will be a concurrent need for improved regulatory and detection methods to keep pace with the rapid development of new compounds. Military and civilian sectors will likely collaborate more closely to harness these technologies, ensuring that advances in enhancement technologies meet broader societal needs while maintaining national security.

The intersection of technology, medicine and ethics will increasingly shape the discourse and direction of pharmaceutical enhancement technologies in the military sphere. However, the most important question remains unanswered in several publications: why would a pharmaceutically enhanced soldier be necessary when it is possible to send autonomous robots?

Excurse: Cognitive enhancement

Cognitive enhancement refers to the application of various techniques or substances to improve mental functions, such as memory, attention, creativity and intelligence, beyond typical human capabilities, either internal to the human body, externally or in combination. This can involve the use of pharmaceuticals, brain stimulation technologies, neurofeedback or cognitive training exercises, as well as artificial intelligence, human-machine interfaces and any other IT infrastructure, designed to boost cognitive performance and overall brain function. The goal of cognitive enhancement is to enhance mental processes, potentially leading to better decision-making, problem-solving and learning abilities.

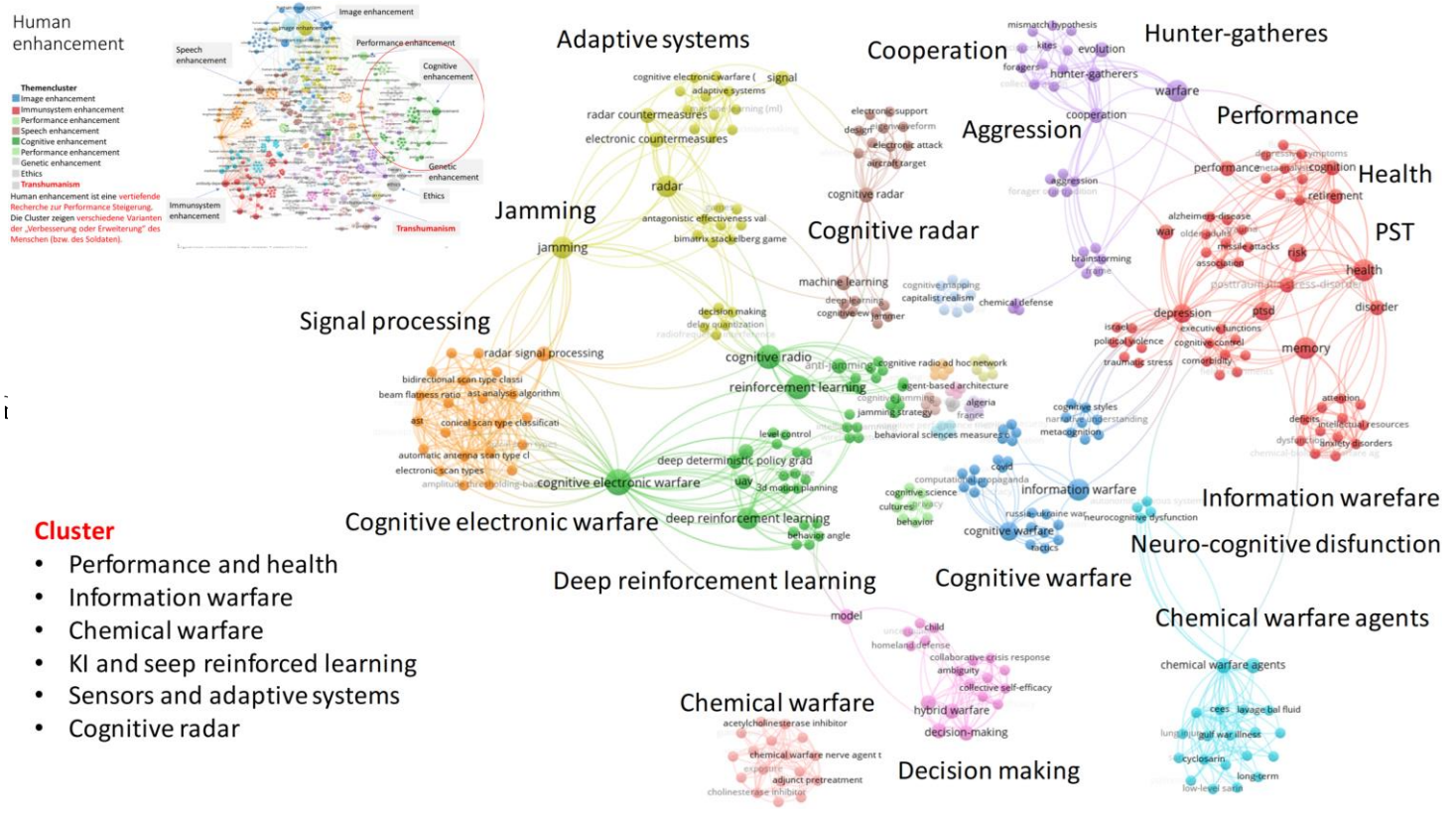
Based on this, cognitive warfare strategies target the mind and behaviour of individuals and the culture of societies to influence perceptions, beliefs and actions within the cognitive enhancement infrastructure. In this context, human enhancement plays a crucial role by augmenting cognitive and psycho-

logical capabilities to gain an advantage or render an advantage of the adversary harmless.

The following figure shows clusters of scientific research concerning recent (2023-2024) human enhancement research topics correlated to cognitive warfare and thus going further into specific details than the previous, more general introduction on human enhancement.

Figure 6: See next page.

Figure 6: The role of human enhancement in cognitive warfare



Source: Authors calculation, data WoS (Clarivate, Web of Science, https://www.webofscience.com).

The identified clusters include internal as well as external solutions. However, the mind-blowing advances in artificial general intelligence (AGI) and artificial superintelligence (ASI) are not yet incorporated.

Biometric monitoring, through wearable technology and health analytics, tracks physiological and cognitive states to provide real-time feedback and optimise performance. This monitoring helps predict and mitigate cognitive decline or mental fatigue. Educational and cognitive training programmes, using advanced pedagogical techniques and cognitive exercises, accelerate learning, improve retention and enhance specific cognitive skills such as memory, attention and problem-solving.

Neuroenhancements, such as pharmaceuticals, neurostimulation techniques and genetic modifications, can improve cognitive functions like memory, focus and learning abilities. For instance, nootropics can enhance cognitive performance, while transcranial magnetic stimulation or transcranial direct current stimulation can boost mood and cognitive abilities. Potential future applications of genetic technologies, such as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), might also offer ways to enhance cognitive capacities.

Brain-computer interfaces (BCIs) allow direct communication between the brain and external devices, enhancing the control over technology and cognitive processes. These interfaces can improve decision-making speed and accuracy, situational awareness and strategic planning. Augmented reality (AR) and virtual reality (VR) are also valuable in cognitive warfare, providing immersive training environments to enhance cognitive and psychological preparedness. Additionally, AR interfaces can overlay real-time data and intelligence, improving situational awareness and decision-making.

Data-driven personalisation through psychographic profiling and targeted messaging uses big data and analytics to understand and predict behaviours, creating more effective influence operations. Personalised messages and information campaigns can sway opinions and behaviours based on detailed profiles.

Cybernetic enhancements, such as devices that improve sensory perception and motor functions, can enhance operational capabilities. Behavioural

and psychological techniques, including cognitive behavioural strategies, mindfulness and stress reduction practices, improve mental resilience, focus, emotional regulation and stress management, thus enhancing cognitive performance.

Artificial intelligence (AI) and machine learning contribute significantly to cognitive enhancement in warfare. AI tools assist in processing large amounts of data, improving decision-making processes and providing insights through cognitive assistants. These technologies can enhance memory and suggest strategies based on data analysis.

Social and behavioural engineering in cognitive warfare involves sophisticated use of social media and other platforms to shape perceptions and influence public opinion. Crafting and disseminating narratives that align with strategic objectives leverage storytelling to influence thought and behaviour. These elements of human enhancement, when combined, can significantly improve the cognitive capabilities of individuals involved in cognitive warfare, enhancing their effectiveness in conducting and defending against such operations. However, the ethical implications and potential risks associated with these enhancements, particularly regarding autonomy and consent, are significant considerations in their deployment.

To answer the question about new military capabilities, it is helpful to look into the concept of cognitive warfare in detail, which is a rather new concept, most likely introduced by the PLA of China. In 1999, Qiao Liang published a book titled "Unrestricted Warfare: China's Master Plan to Destroy America",[10] which could be seen as the first manual concerning cognitive warfare, later analysed and improved by the NATO publication "Cognitive Warfare, a Battle for the Brain".[11]

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[10] Liang, Qiao/ Xiangsui, Wang: Unrestricted Warfare: China's Master Plan to Destroy America. Free Download, Borrow, and Streaming: Internet Archive. Internet Archive. 1999. https://archive.org/details/unrestricted-warfare/page/n3/mode/2up.

[11] du Cluzel, Francois: Cognitive Warfare, a Battle for the Brain, 2020, https://www.sto.nato.int/publications/STO%20Meeting%20Proceedings/STO-MP-HFM-334/$MP-HFM-334-KN3.pdf.

Figure 7: Search interest in cognitive warfare

Source: Authors compilation, search interest data from Google Trends and correlated book cover.[12] [13]

The Chinese book emphasises the shift from conventional warfare to more diverse and integrated forms of conflict, where the boundaries between war and peace, military and non-military actions, are increasingly blurred, causing intense cognitive challenges that future commanders will face. It suggests using all available means – military and non-military, violent and non-violent – to achieve strategic objectives, highlighting the importance of innovation and adaptability in modern conflict. In terms of military implications and future trends, "Unrestricted Warfare" underscores the need for nations to develop capabilities in cyber warfare, economic manipulation and psychological operations. It also points to the importance of human enhancement

[12] Unrestricted Warfare (Chinese Edition 1999) – Softcover, Wang Xiangsui; Qiao Liang.

[13] Manual for "cognitive warfare" of the PLA, https://archive.org/details/unrestricted-warfare/page/n5/mode/2up.

technologies, suggesting that future conflicts will require enhanced cognitive and physical abilities to effectively manage and counter multifaceted threats.

The US publication focuses on the "militarization of Neuroscience and Technology" but refers to the more holistic approach of the PLA.

Both approaches recognise the importance of the brain and foster a comprehensive and flexible approach to warfare, integrating technological advancements and unconventional methods to disrupt and outmanoeuvre traditional military powers. This perspective on warfare suggests a future where conflicts are pervasive, leveraging all aspects of society and technology to achieve national objectives, and where cognitive capabilities are the most important military resource, either supportive or destructive. Recent AI models show typical cognitive capabilities, including not only information management but also creativity and problem-solving capability.

Future trends and innovations

This chapter explores how current scientific research and technology advancements could shape future war scenarios, highlighting the potential of emerging technologies and their impact on military operations. It discusses weak signals indicating future trends, innovations and threats, providing a roadmap for military research opportunities leading up to 2045.

Starting with the current landscape of future warfare scenarios, based on the interdependence of disruptive military innovations and corresponding changes in military doctrines reflected in the composition of military domains, it delves into the interdependence of warfare scenarios, disruptive innovation and domain concepts. Each of these domains is briefly analysed for their disruptive effect on military tactics with reference to their current capabilities, potential military applications and associated risks. This comprehensive overview sets the stage for understanding how human enhancements could transform military operations and soldier capabilities.

Following this, the chapter about predictions for the next decade investigates possible future innovations, considering how these technologies might evolve and be integrated into military strategies. It looks at hypothetical war scenarios where enhanced soldiers might play a crucial role, analysing the

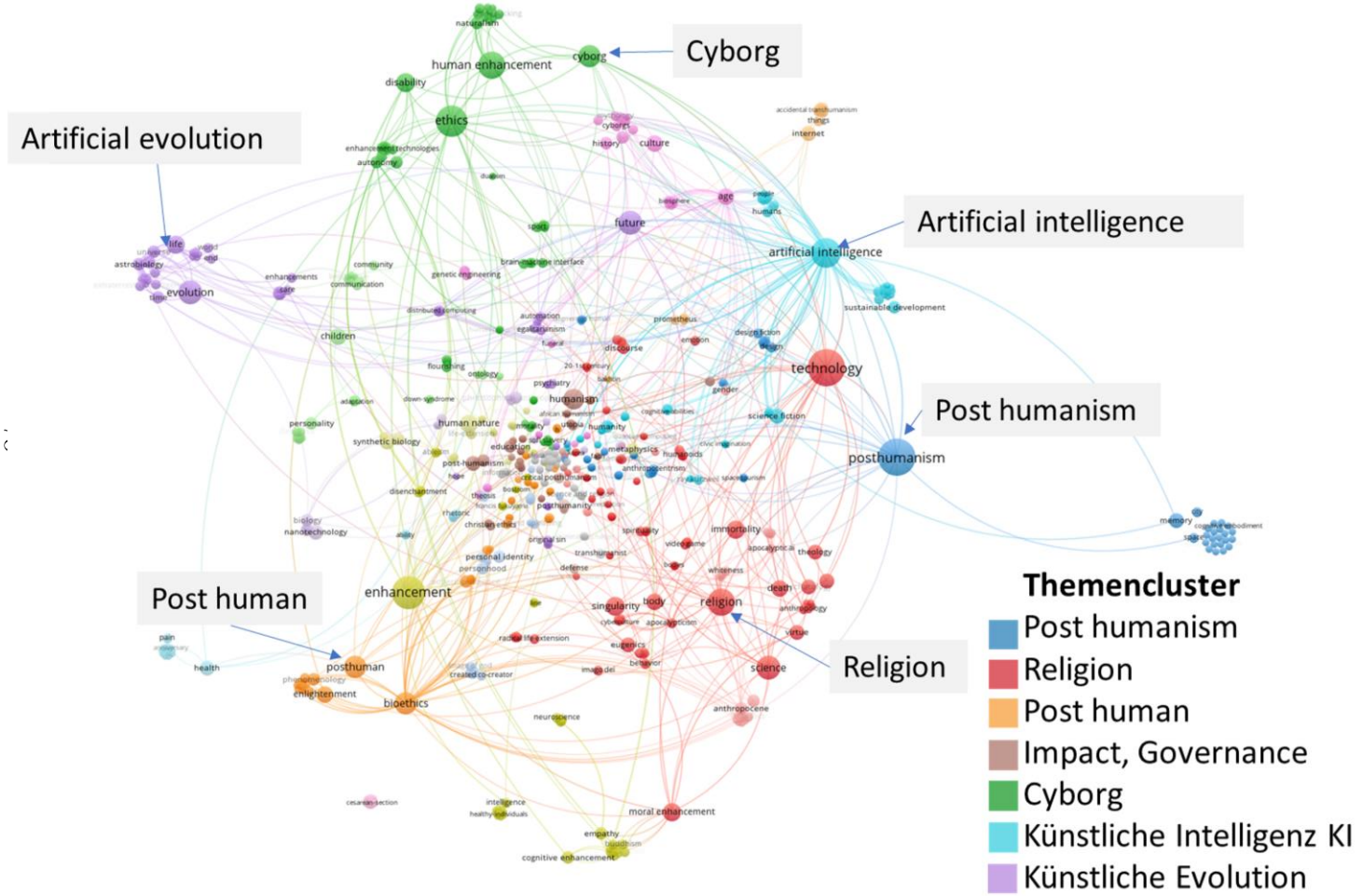
tactical advantages and societal impacts of deploying such technologies. The discussion also includes several explorations of the ethical and social implications, such as the blurring line between soldier and weapon, and the potential challenges in international law and warfare ethics.

Lastly, the chapter presents a summarised roadmap to 2045, outlining research opportunities and strategic directions for military enhancements. This roadmap is designed to guide policymakers, military strategists and defence researchers in navigating the complex landscape of future military human enhancement technologies. It emphasises the importance of staying ahead of technological advancements to maintain national security and combat readiness.

Transhumanism, a movement that advocates enhancing human capabilities through technology, intersects with military concerns in several ways. At its core, transhumanism explores the potential for humans to transcend their biological limitations, which naturally extends to military applications where enhanced physical and cognitive abilities can provide significant advantages.

Figure 8: See next page.

Figure 8: Transhumanism



Source: Authors calculation, data WoS (Clarivate, Web of Science, https://www.webofscience.com).

One of the central themes within transhumanism is the concept of posthumanism, which envisions a future where humans have evolved beyond their current physical and mental forms, possibly through genetic engineering or cybernetic enhancements. This entails profound implications for military forces, as soldiers could potentially be augmented with superior strength, endurance or intelligence, redefining the capabilities and strategies of the armed forces.

Religion also plays a role in the discourse surrounding transhumanism, as the latter challenges traditional beliefs about the sanctity and purpose of human life. In military contexts, these enhancements could lead to ethical and moral dilemmas regarding the treatment of enhanced soldiers and their role within the traditional frameworks of military ethics and laws of war.

The theme of cyborgs, or cybernetic organisms, is particularly pertinent. By directly integrating technology into the human body, such as through implanted devices that enhance sensory capabilities or cognitive processes, soldiers could operate more effectively in diverse and challenging environments. This not only shifts the tactical dynamics on the battlefield but also raises questions about the governance and regulation of such technologies, including international laws and norms.

Artificial intelligence (AI) is another significant element of transhumanism with military relevance. AI can augment human decision-making processes, provide sophisticated analyses of complex scenarios or autonomously operate systems and machinery, which are all critical in modern warfare. However, this integration of AI raises concerns about control, accountability and ethical use in military settings.

AI is necessary to address the increasing complexity on the battlefield. Drones can attack at any time and in any place, making it increasingly difficult for human agents to keep track of the situation.

Figure 9: The complexity of future warfare

Source: Authors compilation with pictures from youtobe videos demonstrating drone swarms[14] [15] and a youtube video showing Neuralink's First Patient.[16]

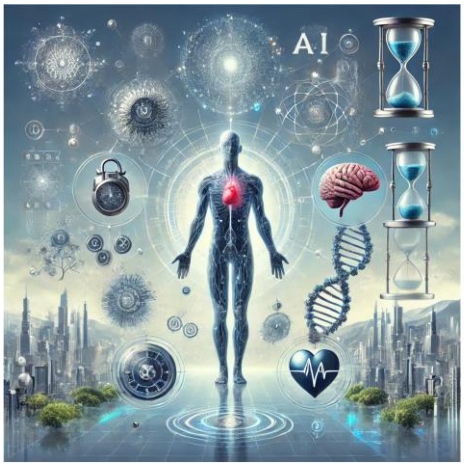
Lastly, the concept of artificial evolution touches on the deliberate genetic or mechanical enhancement of humans to better adapt to future environments and challenges. In a military context, this could mean creating soldiers tailored to specific tasks or environments, a controversial prospect that touches upon issues of bioethics, inequality and the potential misuse of technology.

Overall, the exploration of transhumanism within the military sphere involves a complex interplay of technology, ethics, governance and human potential, driving both opportunity and profound caution in the evolution of military capabilities. To the most extend, it was resulting from the perception of the Silicon Valley Tech Community, which did experience "successful hegemony in the global information space". It seems that the capability to get data from billions of people, literally looking into the brains of billions of customers and managing services with billions of customers did leave their tracks.

[14] https://www.youtube.com/watch?v=rPul9WKQ6oQ
[15] https://www.youtube.com/watch?v=y0KNhSejkOI
[16] https://www.youtube.com/watch?v=5SrpYZum4Nk

The following figure shows some of the as of yet not fully realised trends, with the possibility to enhance human species in a way, not possible today.

Figure 10: Transhumanism – Research and innovation or religion?



Not yet fully realized trends

- Cybernetic tattoos and skin sensors
- Symbiotic relationship with artificial intelligence
- Genetic manipulation for the development of a new humanoid species
- Mind uploading
- Digital immortality vs cryonics
- Nanotechnology sensors
- Biomechanics
- Neuro-enhancement
- Life extension and anti-aging technologies
- Virtual reality vs augmented reality

Source: Authors compilation, picture generated with Dall-E 2, by making use of the not yet fully realized trends.

The trends represent a fascinating exploration of emerging possibilities in science, technology and human evolution. Cybernetic tattoos and skin sensors point towards a future where the human body integrates seamlessly with technology, providing real-time data and interaction capabilities. A symbiotic relationship with artificial intelligence envisions humans and AI working closely together, potentially merging capabilities to enhance decision-making and creativity. Genetic manipulation, meanwhile, aims at developing entirely new humanoid species, pushing the boundaries of biology and ethics (due to ethical limitations, cell experiments are either not possible or not fully documented).

Mind uploading and the quest for digital immortality introduce the prospect of transferring human consciousness to a digital medium, contrasting with cryonics, which focuses on preserving biological bodies. Nanotechnology sensors and biomechanical systems promise advanced monitoring and enhancement of human health and abilities, while neuroenhancement seeks to augment cognitive and neurological functions. Life extension and anti-ageing

technologies continue to push the limits of the human lifespan, challenging traditional concepts of ageing. Lastly, the interplay between virtual reality and augmented reality redefines how we experience and interact with the digital world, offering immersive and transformative applications across many aspects of life. These trends collectively showcase humanity's relentless pursuit of innovation, reshaping the boundaries of existence and interaction.

Predictions for the next decade

In strategic planning and foresight, weak signals and knowledge of emerging trends are essential elements used in creating roadmaps because they provide a structured means to anticipate future environments and prepare for potential changes. Roadmaps are visual and strategic tools that outline the path from the current state to a desired future state, incorporating milestones and timelines. The following "knowledge elements" are identified for useful military human enhancement technologies:

Anticipation of future trends and changes: by integrating weak signals and trends into roadmaps, organisations can visualise potential futures and the emergence of new technologies or market shifts. This helps in understanding how these factors might impact their operations, enabling them to strategize effectively. Identifying weak signals early on allows for a proactive response to emerging opportunities or threats, rather than a reactive one.

Guided decision-making (context information on most relevant innovations): including these elements in roadmaps aids decision-makers in prioritising resources, such as time, money and manpower, based on anticipated changes. It helps in aligning strategic objectives with the expected evolution of the market or technology landscape, ensuring that the organisation remains relevant and competitive.

Enhanced innovation (detecting root cause innovations): roadmaps that incorporate knowledge of emerging trends and weak signals foster an environment conducive to innovation. They encourage organisations to explore new ideas and technologies before they become mainstream, potentially securing a first-mover advantage on the market. This forward-thinking approach is crucial for staying ahead in rapidly changing industries.

Risk management (threat identification): by acknowledging and planning for possible future disruptions indicated by weak signals, roadmaps help organisations mitigate risks. Preparing for multiple scenarios allows them to develop contingency plans, reducing the impact of negative events and ensuring business continuity.

Weak signals are early indications of potential trends, trend changes, threats, innovations and disruptive events that might significantly influence the future. In the context of foresight, identifying and interpreting these weak signals is crucial for anticipating changes and making informed decisions. In addition, weak signals are often overlooked due to their subtlety, ambiguity or the obscurity of their sources. They can emerge from various areas, including technological advancements, social shifts, economic fluctuations or environmental changes. For example, a novel application of an existing technology in a new field might initially appear irrelevant or unviable but could eventually lead to significant industry disruptions.

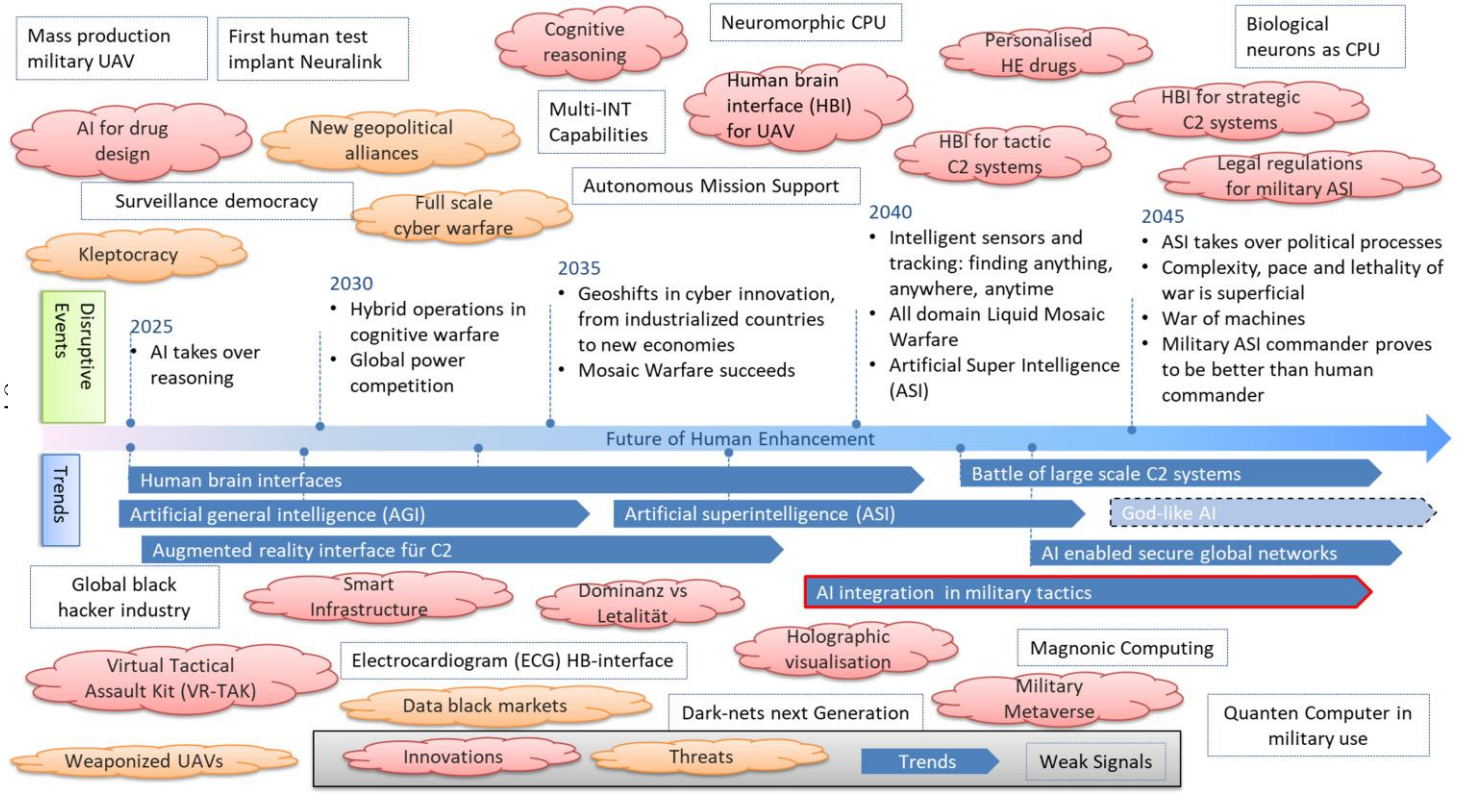
The challenge in working with weak signals lies in their interpretation and the ability to distinguish between noise and genuine emergent issues. Analysts often rely on systematic scanning of a wide range of sources, from academic publications and patents to social media and beyond, to capture these signals. The next step involves connecting seemingly disparate pieces of information to construct plausible scenarios concerning the future.

Recognising weak signals requires a mindset open to new information and alternative perspectives. It also demands continuous learning and adaptation, as the relevance and impact of weak signals can evolve over time. Effective use of weak signals in foresight can provide organisations and policymakers with a strategic advantage, allowing them to prepare for and shape future developments rather than to merely react to them. This proactive approach is essential for navigating the complexities of an increasingly unpredictable world.

The following roadmap was generated with CATALYST[17] data from AIT.

[17] CATALYST (Collaborative Trend Analytics System), AIT, 2024.

Figure 11: Conceptual road map for the global future of military human enhancement



Source: Authors compilation.

The image depicts a comprehensive roadmap for military human enhancement, illustrating various trends, innovations, threats and weak signals projected up to the year 2045. The timeline is marked with significant milestones and anticipated developments in human enhancement technologies and their integration into military operations.

At the top, the timeline is segmented by years, starting from 2025 and extending to 2045. Key developments and future predictions are marked along this timeline. For instance, by 2025, artificial intelligence (AI) is expected to take over reasoning tasks, and mass production of military unmanned aerial vehicles (UAVs) is anticipated. Around this period, Neuralink will conduct its first human test implant, signifying advancements in brain-machine interfaces.

By 2030, hybrid operations in cognitive warfare and global power competition are highlighted, indicating a shift in military strategies influenced by cognitive enhancement technologies. Additionally, there is mention of surveillance democracy and the rise of new geopolitical alliances, reflecting broader sociopolitical impacts.

Moving towards 2035, significant trends include geoshifts in cyber innovation from industrialised countries to new economies, and the success of Mosaic Warfare. Innovations such as Multi-INT capabilities and autonomous mission support are expected to emerge, enhancing operational efficiency and decision-making in military contexts.

The timeline further projects into 2040 and 2045, with advancements in intelligent sensors and tracking technologies that allow for precise, real-time situational awareness. These technologies will support all-domain liquid Mosaic Warfare and the advent of artificial superintelligence (ASI). By 2045, it is anticipated that ASI will surpass human commanders in political and military decision-making, leading to a new era where the complexity, pace and lethality of war are dramatically increased.

The roadmap also identifies various technological and tactical integrations. Human brain interfaces (HBI) for UAVs and other command and control systems are noted, along with AI-enabled secure global networks. These in-

tegrations will facilitate seamless coordination and enhanced operational capabilities.

Several innovations are highlighted, such as augmented reality interfaces for command and control, holographic visualisation, smart infrastructure and neuromorphic CPUs. These technologies are expected to revolutionise military operations and strategy.

Threats such as weaponised UAVs, data black markets and the rise of dark nets are identified, emphasising the need for robust security measures. Additionally, the roadmap points out weak signals such as magnonic computing and biological neurons as CPUs, indicating emerging technologies that could impact future military capabilities.

Overall, the roadmap presents a detailed and forward-looking view of how human enhancement technologies and associated advancements are poised to transform military operations, strategies and global power dynamics over the next two decades.

Conclusion and recommendations

The evolution of human enhancement technologies represents a pivotal shift in military capability planning, with profound implications for future warfare. As nations confront increasingly complex and multifaceted security challenges, the integration of advanced physical, cognitive and technological augmentations promises to redefine the boundaries of human performance in military operations. These advancements not only aim to enhance individual soldier capabilities but also transform strategic planning by introducing a new paradigm of human-machine collaboration, biotechnological augmentation and cognitive warfare.

The intersection of innovation and military planning necessitates a nuanced understanding of both the opportunities and risks inherent in these technologies. On the one hand, enhanced physical endurance, cognitive agility and real-time decision-making enabled by brain-computer interfaces, genetic modifications and pharmaceutical innovations could provide unparalleled advantages on the battlefield. On the other hand, the ethical, legal and soci-

etal implications of these advancements pose significant challenges, particularly as the lines between human soldiers and automated systems blur.

Strategic capability planning must navigate this dual imperative by fostering a proactive approach to technology integration while addressing critical issues of governance, regulation and ethical deployment. This involves anticipating the long-term impact of enhancements on the nature of warfare, ensuring that innovations align with international norms, and safeguarding human dignity amidst rapid technological change. The roadmap for military human enhancement must therefore balance the pursuit of operational superiority with the responsibility to uphold ethical principles, foster global stability and prepare for a future where human potential and technological innovation coexist harmoniously.

In conclusion, human enhancement technologies are not merely tools to improve military efficiency but catalysts for reimagining the role of soldiers, the conduct of warfare and the relationship between humanity and technology. By embracing a forward-looking and ethically grounded approach, military planners can harness these innovations to build a resilient and adaptive force capable of meeting the demands of an unpredictable and interconnected world. The success of this endeavour will depend not only on the sophistication of the technologies themselves but also on the wisdom with which they are deployed.

Strategic recommendations for policymakers and capability planners within the realm of military human enhancement technologies must balance innovation, operational necessity and ethical responsibility. Therefore, the following recommendations attempt to guide the integration of human enhancement technologies into military strategy while addressing the broader societal, legal and ethical implications of their use.

Embrace a holistic approach to capability planning: policymakers and capability planners should adopt an integrated perspective that considers the full spectrum of human enhancement technologies, including genetic engineering, pharmaceutical interventions, brain-computer interfaces and exoskeletons. This requires a multidisciplinary approach that bridges military strategy, biomedical research, cognitive science and artificial intelligence to ensure cohesive planning and deployment. Capability planning should be informed by

both immediate operational needs and long-term strategic objectives, ensuring the development of technologies that enhance military effectiveness while remaining adaptable to evolving threats.

Establish clear ethical and legal frameworks: human enhancement technologies challenge existing ethical norms and legal frameworks, particularly regarding autonomy, privacy and the implications of creating **"augmented" soldiers**. Policymakers must work to establish robust ethical guidelines and international norms that govern the research, deployment and use of these technologies. These frameworks should prioritise transparency, informed consent and the reversibility of enhancements to safeguard human dignity and rights. Additionally, clear legal protocols must address liability issues, particularly in scenarios where enhanced soldiers are deployed alongside autonomous systems.

Invest in resilience and risk mitigation: while human enhancement technologies promise significant operational advantages, they also introduce risks, including the dependency on fragile technologies, cybersecurity vulnerabilities and the potential for adversaries to exploit or reverse-engineer similar capabilities. Capability planners should prioritise investments in resilience, such as developing redundant systems, ensuring interoperability between human and machine systems and implementing robust cybersecurity measures. Policymakers must also consider contingency planning for scenarios where these technologies may be rendered ineffective or compromised.

Foster international collaboration and norm-setting: given the global nature of technological innovation, international collaboration is essential to manage the proliferation and use of human enhancement technologies in military contexts. Policymakers should engage with allied nations, international organisations and private-sector stakeholders to establish shared norms, promote transparency and prevent the misuse of these technologies. Collaboration can also facilitate the exchange of best practices, accelerate innovation and ensure that military advancements align with broader societal values.

Promote dual-use innovation for broader societal benefit: many human enhancement technologies have applications beyond the military, including in healthcare, disaster response and public safety. Policymakers should encourage dual-use innovation by supporting research that benefits both military and civilian sectors. This approach not only maximises the return on investment but also

fosters public acceptance of these technologies by demonstrating their potential to improve quality of life and address societal challenges.

Prioritise education and training for enhanced soldiers: the successful integration of human enhancement technologies into military operations depends on the ability of personnel to effectively utilise these capabilities. Policymakers should ensure that training programmes are developed to address the unique demands of operating enhanced systems, emphasising both technical proficiency and ethical decision-making. Education should also extend to leaders and planners, equipping them with an understanding of the strategic implications of these technologies to make informed decisions about their use.

Maintain a balance between human and machine capabilities: as military operations become increasingly reliant on **human-machine collaboration**, policymakers must strike a balance between leveraging technological advancements and preserving the unique strengths of human soldiers. Capability planners should focus on integrating enhancements that augment, rather than replace, human capabilities, ensuring that the role of the soldier remains central to military operations. This balance is critical to maintain operational flexibility and ensure that the military can adapt to diverse and dynamic combat environments.

Monitor and address societal implications: the deployment of human enhancement technologies within the military will inevitably influence broader societal perceptions of these advancements. Policymakers must actively monitor public sentiment, address concerns about inequality or misuse and engage in transparent communication about the purpose and limitations of these technologies. Building trust and ensuring public accountability will be essential to sustaining long-term support for military innovation.

By adhering to these recommendations, policymakers and capability planners can navigate the complex landscape of military human enhancement technologies, ensuring their responsible development and deployment in ways that strengthen national security while upholding ethical standards and societal values. Currently, it seems that the EU is paying relatively little attention to human enhancement whilst it pays considerable attention to artificial intelligence. However, these research topics are interconnected and should be considered as such to foster the positive aspects for industrial development and economic prosperity.

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