Safety & Defense 11(2) (2025)
DOI https://doi.org/10.37105/sd.281

Cyborg Soldier 3.0 Towards the Dream of the Universal Soldier

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Received: 30 November 2025 | Revised: 11 December 2025
Accepted: 11 December 2025 | Available online: 30 December 2025

Abstract

The article argues for the inevitable transformation of the soldier from a tool user to an inte-grated weapon system – Soldier 3.0 – constituting a new arena in the global arms race. This evolution is driven by the convergence of four key domains (NBIC): nanotechnology, bio-technology, information technology, and cognitive science. The article cites the foundational U.S. Department of Defense report, *Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD*, **as a strategic forecast for this transformation. The analysis identifies three main areas of technological advancement: physical, cogni-tive/psychological, and sensory. These advancements constitute a key element of advantage and are fundamentally redefining the nature of future armed conflicts, dangerously blurring the line between human being and strategic asset.**

Keywords: cyborg-solider, future safety, military enhancement, solider 3.0, soldier enhancement

1. Introduction

In the annals of military history, every era is defined by breakthrough technology – from bronze to gunpowder to the atom. The present and future eras will be defined by a fundamental reconfiguration of the warrior himself, transforming them from a tool user into a living, integrated weapons system. Humanity's quest to create soldiers with superhuman abilities, once the domain of myth and legend, is becoming a technological reality in the 21st century. The concept of the "supersoldier" – understood as a soldier capable of operating beyond the limits of normal human capabilities through permanent artificial enhancements such as genetic modification or technological integration – is no longer the realm of fiction, but an evolutionary inevitability in an arms race in which the human biological form has become another battlefield.

The purpose of this article is to provide an in-depth analysis of the technological and conceptual foundations of this unprecedented transformation. It will examine how the convergence of four key scientific fields – nanotechnology, biotechnology, information technology, and cognitive science – is creating a powerful feedback loop that is driving this revolution. It will also explore the strategic visions driving this process, with particular emphasis on the groundbreaking U.S. Department of Defense report, "Cyborg Soldier 2050" (Emanuel et al., 2019) which provides the conceptual foundation for Soldier 3.0.

To fully understand the scale of these coming changes, three key areas of technological advancements were analyzed: physical enhancements (from exoskeletons that redefine strength and endurance, to next-generation pharmacology, to the revolutionary potential of genetic engineering), cognitive and psychological enhancements (anti-fatigue technologies, as well as brain-computer

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interfaces that fundamentally redefine the concept of command and control), and sensory enhancements (which aim to achieve information dominance by extending sensory perception far beyond natural human limits, enabling the creation of entirely new senses).

2. Research Methodology

The research methodology used in this article is based on qualitative analysis and synthesis of relevant literature, which gives the work a review and analytical character. The methodological foundation of the work is a critical literature review, in which strategic forecasting documents, such as the key US Department of Defense report "Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD" (Emanuel et al., 2019) constitute the conceptual axis of the analysis. This analysis is then deepened by references to specialized academic publications on human augmentation theory: from early, pre-scientific pharmacological interventions in ancient times, through institutionalized research programs during the world wars, to contemporary paradigms shaped by DARPA. This way allows for the creation of a holistic picture of the complex phenomenon at the intersection of technology, military strategy, and human evolution, aiming not only to identify key vectors of technological development but, above all, to assess their strategic implications for the future nature of armed conflict.

3. Evolution of the Enhanced Soldier Concept: From Optimization to Fusion

Analyzing the evolution of thinking about soldier augmentation is of crucial strategic importance. It allows us to understand that we are not dealing with a simple continuation of existing practices, but with a qualitative leap that redefines the human role in armed conflict. Understanding the transition from simple augmentation to full integration is crucial for assessing the scale of the upcoming changes.

To precisely describe them, it is necessary to distinguish between optimization and augmentation. Optimization, as pointed out by analysts such as Gérard de Boisboissel (2020), refers to improving performance within natural human limitations, for example, through rigorous training or diet. Augmentation, on the other hand, means exceeding these limitations through technological or biochemical interventions (Casey et al., 2024; Schulyok, 2025).

In this perspective, "Soldier 2.0" is an optimized individual – perfectly prepared, yet still operating within the limits of human physiology. "Soldier 3.0," on the other hand, is an individual fused with technology, whose abilities are permanently and biologically enhanced beyond the natural norm. The key difference lies in the persistence and integration of biological change. Soldier 2.0 uses tools, while Soldier 3.0 themselves becomes an integrated system. This process, termed "anthropotechnics" by Vincent Guérin (2020), refers to the deliberate use of technology to modify human capabilities, leading to the creation of a new type of combatant.

The pursuit of enhancing soldiers' combat capabilities is as old as the history of conflict. The strategic importance of early, pre-scientific methods for enhancing combat performance lay in attempting to overcome fundamental human limitations, such as fatigue and fear. The transition from intuitive use of natural substances to the first systematic medical interventions marked a key moment in the history of soldier enhancement, laying the foundation for more advanced scientific approaches in the future.

One of the earliest examples of pharmacological support on the battlefield is the use of psychoactive substances. Inca warriors chewed coca leaves to maintain alertness and combat fatigue during prolonged combat operations (Hanlon, 2011). This practice, although based on tradition rather than scientific analysis, represented an early form of biochemical intervention aimed at directly influencing a soldier's physiology to gain an advantage. The first fully scientific modification aimed at strengthening military forces was the introduction of vaccinations. Already during the American Revolutionary War (1775–1783), the US Army began vaccinating its soldiers, as a fundamental step toward protecting the military from infectious diseases and increasing its overall immunity and combat readiness (Sawin, 2016). This precedent paved the way for medicine to be viewed not only as a therapeutic tool but also as a preventative means of strengthening the soldier's body. The World Wars and the Cold War intensified and institutionalized the search for methods of enhancing soldiers on an unprecedented scale. Advances in chemistry, medicine, and engineering opened up new, previously unimaginable possibilities for modifying human capabilities. Striving for a decisive advantage, nations began investing in systematic research programs aimed at creating the soldier of a new era.

The 20th century saw the emergence of both radical, almost fantastical concepts and the mass application of pharmacology. In the 1920s, the Soviet Union, under Joseph Stalin, attempted to create a humanape hybrid – a creature impervious to pain and difficult to kill – that would become the foundation of a new, invincible army (Sawin, 2016). Although this project failed, it demonstrates the scale of early biological engineering ambitions.

World War II became a global testing ground for psychoactive substances intended to enhance combat performance. In Germany and Japan, methamphetamine was used on a massive scale (Goodle, 2020; de Boisboissel & Revue, 2020). In Germany,

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it was known under the trade name Pervitin and distributed to Wehrmacht soldiers to combat fatigue and increase aggression, which was crucial to the success of the *Blitzkrieg* doctrine. British and American forces also resorted to stimulants. Amphetamines, such as Benzedrine tablets, were widely used to keep pilots and bomber crews alert during long-duration missions. This practice continued into the Cold War. American pilots, especially during long patrol flights, were regularly given so-called "go-pills" (dextroamphetamine tablets) to combat drowsiness and maintain concentration (Bower et al., 2003).

A turning point in the history of soldier development was the establishment of the American ARPA (later DARPA – Defense Advanced Research Projects Agency). Its birth was a direct response to the geopolitical humiliation of the Soviet Sputnik launch in 1957. This event initiated a fundamental paradigm shift in thinking about military superiority. It was understood that technological dominance could not be limited solely to advanced weaponry, and the agency's mission was not to be incremental, but rather radical and groundbreaking research. Consequently, systematic investment in human potential – optimizing a soldier's cognitive, physical, and mental capabilities – was recognized as a key element of defense strategy (Kamieński, 2022). The terrorist attacks of September 11, 2001, and the protracted conflicts in Iraq and Afghanistan became a powerful catalyst for the intensification of DARPA's research on human performance. The nature of these wars, requiring soldiers to operate in extreme conditions for extended periods, highlighted human limitations. In response, DARPA launched programs such as *Continuous Assisted Performance* (CAP). These programs aimed not only at overcoming the need for sleep but also at optimizing metabolism (Sawin, 2016).

The conceptual foundation for Soldier 3.0 is a 2019 report by a US Department of Defense research group titled *Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD* (Emanuel et al., 2019). This document, developed by a team led by Peter Emanuel, is not a manifesto but a strategic forecast that identifies four key areas in which human-machine fusion could become a reality by the mid-21st century.

- Vision Augmentation: Forecasts predict the development of ocular implants that would replace or complement the natural eye. Such a soldier could perceive the battlefield in various light spectra (e.g., infrared), identify targets with unprecedented precision, and transmit visual data directly to the tactical network.
- Programmable Muscle Control: The concept involves the creation of an optogenetic suit or subcutaneous sensor network that could stimulate and control muscle groups. This would allow for increased strength and endurance, as well as optimized motor responses in combat situations.
- Hearing amplification: Next-generation hearing implants could not only protect against acoustic trauma but also enable the perception of sounds at frequencies inaudible to the human ear. Furthermore, the report's authors predict the possibility of covert, subliminal communication between unit members.
- Direct neural amplification: This is the most revolutionary area, involving the use of brain-computer interfaces (BCIs). These would allow soldiers to directly mentally control advanced combat systems, such as drone swarms or autonomous weapons, as well as receive and process data at speeds impossible with traditional interfaces.

The realization of this vision, while distant, is not merely the realm of fantasy. It depends on the development of specific, existing technologies, which are becoming increasingly advanced with each passing year.

4. The Arsenal of Enhancement: A Review of Contemporary Technologies

Currently, the development of enhancement technologies is not limited to a single field but encompasses a broad spectrum of interventions, from next-generation pharmacology to genetic engineering and direct human/machine fusion. This multifaceted advancement aims to create an integrated combat system in which human and technological components become inextricably linked, realizing the vision of full technointegration. The foundation of this revolution is the concept of NBIC convergence, defined in the early 21st century in the report *Converging Technologies for Improving Human Performance* (2002). This term is an acronym for four key, interconnected fields:

- Nanotechnology (the manipulation of matter at the atomic and molecular level);
- Biotechnology (including genetic engineering);
- Information technology (computing power, artificial intelligence, and communication).
- Cognitive science (the study of the brain and cognition).

This synergy creates a powerful feedback loop: nanotechnology provides the tools to manipulate biology at the molecular level, information technology offers the computational power to model and guide these processes, and cognitive science provides the blueprints for integrating these new capabilities into the human brain. The combination of these four fields creates a powerful platform for fundamental innovation, enabling the design of interventions that simultaneously impact matter, biological systems, information flow, and mental function. The paradigm shift after Sputnik and 9/11, theoretically underpinned by the NBIC concept, irreversibly transformed the soldier from a weaponwielding combatant into a modifiable and optimized component of the weapon system itself.

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4.1 Physical Enhancement

The strategic importance of physical advantage on the battlefield is undeniable. Strength, endurance, and resistance to the rigors of combat are fundamental attributes that determine a soldier's effectiveness and ability to survive. Modern technologies offer unprecedented opportunities to enhance these traits, allowing soldiers to operate at a higher level of physical fitness (Mehlman, 2019; Baker, 2025).

One of the most recognizable symbols of physical enhancement is the exoskeleton. Its evolution perfectly illustrates technological advances in this field (Jansen, 2001; Richardson, 2004). Early attempts, such as the Hardiman project by General Electric in collaboration with the US Army in the 1960s, resulted in the creation of a gigantic, unwieldy machine. Although pioneering, this exoskeleton was completely impractical on the battlefield, and its uncontrolled movements posed a lethal threat to the operator (Erden, 2024).

The contemporary vision, presented in the *Cyborg Soldier 2050* report (Emanuel et at., 2019) is much more advanced and integrated with the human body. It envisions the creation of an exosystem equipped with sensors monitoring the soldier's physiology and a network of implanted sensors and microdevices that use light to stimulate muscle activity (photostimulation). Such a system could not only enhance strength but, if necessary, even take control of limb movements, enabling the performance of tasks beyond natural human capabilities. An example of such a solution is the ONYX system developed by Lockheed Martin. It analyzes the user's leg movements and delivers a pulse to support knee function at the appropriate moments. This significantly reduces the load on the lower limbs, increases endurance, and allows for significantly more repetitions of exercises, such as weighted squats (Ma, 2025; Luna et al. 2025). Power requirements remain one of the main technical challenges in exoskeleton development. Analyses show that knee and hip joints can require up to 600 W and 120 W of power, respectively, during simple movements, placing significant demands on power systems. During dynamic movements such as walking or running, peak angular velocities in the joints can be up to three times higher, further complicating the design of power systems and actuators (Łaszczyca, 2018; Ma, 2025). Future versions of these systems may blur the line between wearable tool and integral body part. They are envisioned to be integrated with the body through subcutaneously implanted sensors and optogenetic muscle stimulation using light. Artificial intelligence-based predictive algorithms will be crucial for controlling such complex movements, enabling intuitive and smooth control of the armor, which will become a soldier's second, more powerful skin.

Prosthetic technology is advancing in parallel. Modern prosthetics not only restore lost functionality but often surpass it. Thanks to advanced sensors, they can provide sensory feedback, giving the user a sense of touch and allowing for precise manipulation of objects (Deniss & Kleffner, 2016).

Pharmacological interventions have long been used to improve soldiers' physical performance. Current research focuses on substances that can provide an advantage during critical moments in combat. The US Air Force officially uses drugs such as Modafinil and Dexedrine to ensure pilots can perform long-duration missions without losing focus (Taraska, 2017; Goodley, 2020; Walsh et al. 2023). Captagon, a cheap amphetamine-based stimulant, is also known, used by ISIS fighters to suppress fear and increase endurance. Programs like *Metabolic Dominance*, funded by DARPA, aim to create a pill that would allow soldiers to maintain peak physical and cognitive performance for 3 to 5 days without the need for calories (Taraska, 2017, Walsh et al. 2023). This capability would fundamentally change special operations logistics, freeing small units from the constraints of traditional supply lines during short, intense missions.

The most revolutionary, though still largely hypothetical, method of physical modification is genetic engineering. CRISPR/Cas9 technology opens the prospect of precisely editing the genome of soldiers to permanently enhance their biological characteristics (Greene, 2018). Its potential extends beyond treating diseases and includes the ability to “enhance” traits such as intelligence, muscular strength, and resistance to pain and stress (Lindenberg, 2018; Taraska, 2018). Although human research is ethically restricted, successful genetic modifications in animals point to real possibilities for military applications. For example, dogs with double the muscle mass, created in Chinese laboratories, could be used in police and military services (Lindenberg, 2018). This technology could also be used in genetic modification – research on unique tardigrade proteins could be used to create genetic safeguards for soldiers, protecting their DNA from ionizing radiation, which is crucial in the context of a potential nuclear conflict (de Boisboissel et al., 2020). The concept of a genetically modified soldier has already entered strategic discourse. In 2017, Vladimir Putin stated that a soldier “will soon be able to fight without fear, compassion, regret, or pain,” (Guérin, 2020, p. 57) illustrating how seriously these prospects are taken at the highest levels of government.

Besides physical strength, mental agility is playing an increasingly important role on the modern battlefield, and it has become another key area of interest for enhancement technologies.

4.2. Cognitive and Psychological Enhancements

While physical enhancements address the fragility of biological media, cognitive enhancements target the most critical bottleneck: the limited processing speed and bandwidth of the human mind. Information overload, the need for rapid decision-making

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under stress, and prolonged sleep-deprived operations have made humans the “weakest link” in the combat system from a physiological and cognitive perspective (de Boisboissel et al., 2020; Deniss & Kleffner, 2016). Cognitive and psychological enhancement technologies aim to address these limitations and strengthen soldiers' mental resilience (Clarke et al. 2018; Klerx, 2025). In this context, enhanced cognitive abilities – faster data analysis, better memory, and increased concentration – become a key strategic resource.

Pharmacology plays a key role in combating fatigue and maintaining alertness during long-duration missions. The most well-known example of a modern psychostimulant is Modafinil, a wakefulness-promoting substance used by military doctors to ensure soldiers can function despite sleep deprivation (Bakx et al., 2023; Schulyok, 2025). However, some research programs aim not only to stimulate but also to fundamentally alter the body's sleep requirements. The previously mentioned DARPA *Continuous Assisted Performance* program from 2002 aimed not so much at promoting wakefulness but at reducing the need for sleep itself. Its ambition was to enable soldiers to perform at peak physical and cognitive performance for seven days straight (de Boisboissel et al., 2020).

Transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS) are non-invasive methods for modulating neural activity. In the military context, their greatest potential lies in accelerating learning (Guérin, 2020). Stimulating specific brain regions can strengthen the neural pathways responsible for so-called “muscle memory,” drastically reducing the time required to master complex motor skills such as shooting, operating complex equipment, or piloting. This allows for faster and more effective training of soldiers and optimizes their performance in tasks requiring the highest precision (Clarke et al. 2018; Oller et al. 2025).

The brain-computer interface (BCI) represents a technological frontier that, once crossed, will forever change the face of warfare. By enabling direct communication between the human mind and digital weapons systems, BCI revolutionizes the concept of command and control, making thought the ultimate weapon. Projects like DARPA's *Silent Talk* aim to enable silent, telepathic communication between soldiers and the control of machines, such as swarms of drones, simply by thought (Taraska, 2018; Klerx, 2025). The military need for this technology is urgent. DARPA officials argue that in a world where soldiers must interact with swarms of autonomous drones and advanced artificial intelligence systems, “a computer mouse and keyboard are no longer sufficient” (Emanuel et al., 2019; Clarke & Knudson, 2019). Traditional control methods are becoming too slow and inefficient, creating a dangerous delay between intent and action. In response to this challenge, DARPA also launched the N3 (Next-Generation Nonsurgical Neurotechnology) program. Its goal is to create a bidirectional, precise interface that would not require invasive brain surgery. Instead of implanting electrodes into brain tissue, the N3 program is exploring a range of innovative methods, such as optogenetics, ultrasound, magnetic fields, and sensors introduced into the bloodstream and embedded in the brain's blood vessels (Kiszka, 2018; Baker, 2025). The next, even more revolutionary step in evolution is the concept of the brain-to-brain interface (BBI). Such a system would enable “telepathic” communication between soldiers, allowing for the silent transmission of complex commands, tactical data, or sensory images directly from the mind of one unit member to the mind of another (Taraska, 2018; Luna et al. 2025). Such technology could overturn traditional command hierarchies, leading to the emergence of decentralized, swarm-like tactical units.

BCI technology ultimately blurs the line between human and machine. Its implementation will lead to the birth of a new entity on the battlefield – a soldier whose consciousness is augmented by the computing power of machines, and whose will can be exercised at the speed of thought.

An equally intensively explored area is “emotion engineering” on the battlefield. Stress is one of the main factors reducing combat effectiveness. Research in this area focuses on two approaches. The first involves pharmacological implants that control the release of stress-reducing substances (Taraska, 2017; de Boisboissel et al., 2020, Goodley, 2020). Medicaments such as Propranolol are being studied for their ability to suppress fear and prevent the formation of traumatic memories (Taraska, 2017; Goodley, 2020; Luna et al. 2025). The second, more advanced approach involves the creation of systems that monitor neural activity in real time. When the first signs of anxiety or panic are detected, the system automatically modulates neuronal activity to restore mental balance and prevent the development of post-traumatic stress disorder (PTSD).

Cognitive enhancements focus on information processing, but the acquisition of information itself is equally important, which is the domain of sensory enhancements.

4.3 Sensory Enhancements

The goal of sensory enhancements is to provide soldiers with an information advantage by expanding their perceptual abilities beyond their natural human limits. Enhanced perception of the environment is crucial for building situational awareness and responding more quickly to threats (Emanuel et al. 2019). These solutions augment human senses, ensuring information dominance on the battlefield. They include night vision implants, advanced hearing aids that filter noise and amplify key sounds, and heads-up displays (HUDs) that overlay tactical data onto the field of view (Schulyok, 2025).

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Vision is the most important sense on the battlefield, which is why technologies to enhance it are being intensively developed. Key concepts include applying data streams directly to a soldier's retina, providing constant access to tactical information, maps, and sensor data without the need to look away from the surroundings. A key area of research is the development of artificial retinas. Initially designed to restore sight to the blind, this technology has the potential to surpass the capabilities of the natural eye. Innovative implants, constructed from perovskite nanotubes, feature a significantly higher density of photoreceptors and a faster response time. This means that a soldier equipped with such a prosthesis could see more and more precisely. Furthermore, replacing perovskite with materials sensitive to other light bands would open the door to perception in the infrared and ultraviolet, which would constitute a huge tactical advantage (Radovan, 2023). Infrared perception (which has been successfully tested in experiments on rats implanted with electrodes stimulating the visual cortex with signals from an infrared detector) and the use of devices such as David Eagleman's VEST – a vest that converts data (e.g. from the stock market or drone sensors) into vibrations felt on the skin, allowing the brain to learn to interpret them as a new, additional sense – are the subject of intensive work (Dawson, 2024).

Research on hearing enhancements focuses on two main goals: protecting hearing in noisy battlefield environments (e.g., from the noise of gunfire and explosions) and enhancing communication. Advanced systems can filter noise and amplify key sounds, such as voice commands or the sounds of approaching enemies (Emanuel et al., 2019).

A breakthrough technology in this field is sensory substitution, which converts data (e.g., audio, digital) into stimuli perceived by another sense. Examples include the VEST or Buzz armband, which translate battlefield data into complex vibration patterns felt on the skin. The strategic value of this technology lies in creating a non-competing sensory channel. This allows soldiers to process key information – e.g., drone data, fire direction, or threat alerts – using their sense of touch, without overloading the crucial visual and auditory channels. This allows the soldier to maintain full situational awareness of his immediate surroundings, which is crucial for survival and effectiveness in combat (Roco et al., 2013; Radovan, 2023).

The most futuristic concept, but one already being explored, is the creation of entirely new senses that allow the perception of phenomena inaccessible to natural human receptors. Pioneers in this field include cyborg artists such as Neil Harbisson, who can “hear” colors thanks to an antenna implanted in his skull, and Manel De Aguas, who uses an implant to sense changes in atmospheric pressure. Judit Parés is joining them in developing an implant that allows her to sense nearby electromagnetic fields (Maślona, 2020). These technologies open up the prospect of equipping soldiers with the ability to perceive previously invisible phenomena, which could revolutionize threat detection and navigation (Maślona, 2020).

5. Conclusions

The pursuit of the enhanced soldier is no longer the exclusive domain of research laboratories; it has become a key element in a new, global arms race. History provides clear inspiration. The concept of the “enhanced soldier” has definitively left the realm of science fiction, becoming a strategic imperative that shapes defense doctrines and fuels multibillion-dollar research investments by global powers. The journey toward Soldier 3.0 is an irreversible process that fundamentally redefines not only the battlefield. This journey places humanity at a critical juncture, where the battlefield becomes the ultimate laboratory for the future of the species, and the line between strategic asset and human being threatens to disappear entirely.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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