

“NANOMANIA,” “NANOREALITY,” AND THE FUTURE OF WARFARE: POTENTIAL CONTROVERSIES OF THE MILITARY APPLICATION OF NANOTECHNOLOGIES*

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Abstract: This paper examines the controversies that may arise from the application of nanotechnological innovations to the enhancement of military capabilities in the early twenty-first century, driven by the privileging of the neoliberal version of instrumental rationality at the expense of the formative social and political effects of weaponry. The author starts from the assumption that decision-making grounded in an understanding of weapons as value-neutral instruments of foreign and defence policy—that is, reducing their utility solely to their designed/technical operational characteristics and functions—creates room for new disruptive uncertainties and risks. The analysis adopts a critical-theoretical perspective and draws upon Ulrich Beck’s concept of the risk society, Gilles Deleuze’s and Félix Guattari’s concept of desire, and Benjamin Meiches’s concept of the affective power of weapons. It addresses the most plausible controversies, all sharing a common denominator in the form of the porous boundary between civilian and military research, the dual-use nature of nanotechnologies, and the complex regulation of innovations that can be readily redirected toward destructive purposes. The author concludes that the techno-optimism of political and military decision-makers, as a driving force behind the political constitution of nanoweapons, may further undermine the processes of shaping futuristic military imagination, perceiving the level of future threats, and defining the boundaries of acceptable violence.

Keywords: *nanotechnologies, warfare, weapons, defence policy, armed forces, critical war studies*

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Nanotechnologies in the Early Twenty-First Century: “Nanomania” or Technological Reality?

Success in conducting military operations has always depended on answering the question of precisely which modes of operational employment of emerging technological advances can ensure battlefield superiority and victory, within the specific context of military strategy, logistics, and command and control (Hauard, 1999; Creveld, 2000). Alongside military practice, reflection on warfare has long fuelled the imagination of technical inventions capable of compensating for the limitations of the human body and endowing it with “superhuman” abilities. The richness of literary and cinematic production bears witness to the enduring vitality of imagining the future of warfare. For example, the highly successful Terminator film franchise portrays fictional nanotechnological achievements such as the liquid metal known as polyalloy, which enables a cyborg warrior to recover instantaneously from virtually any injury, alter its physical form to replicate an adversary’s appearance, or disperse into molecules and subsequently reassemble itself within seconds in order to evade damage from enemy attacks. Nanotechnology also serves as the foundation of the superhuman abilities possessed by the protagonists of the Marvel film series, while numerous video games feature it as a regenerative capability for injured combatants or in the form of nanosuits that provide enhanced strength, invisibility, and armour protection (e.g., *Deus Ex* and the *Mortal Kombat* and *Crysis* franchises, to mention only the most prominent examples).

Major technological breakthroughs never occur suddenly, nor are they the result of a single discovery or invention; rather, they are typically the product of cumulative advances across several scientific disciplines. This is particularly true of nanotechnology, a term that would more accurately be used in the plural because it integrates knowledge gradually accumulated in several fields of science, including chemistry, physics, and materials science. It encompasses scientific and engineering achievements related to the measurement, manipulation, and organization of matter at the atomic level, specifically on the nanometre scale (1–100 nm), that is, the manipulation of atoms, molecules, or clusters of molecules (macromolecules) in order to create new, desired structures (Andersson, 2008: 94)² Nanoscience and nanotechnologies thus embody an atomically precise way of perceiving material reality and engineering and controlling it so as to assign it a practical function (Ramsden, 2016: 1–2).

The enthusiasm for using the prefix nano- in the titles of research initiatives—which lasted from the late 1970s and early 1980s until roughly a decade ago—has since been exposed as a marketing strategy aimed at attracting investment to scientific and technological projects and start-ups through exaggerated promises by nanoscientists regarding the actual applicability of their research findings and inventions (Moriarty, 2022: xix–xxi). Once the exaggerations characteristic of advertising and media discourse are set aside, however, nanotechnologies can by no means be dismissed as a hoax. Why are they likely to shape the decades ahead? Because it has

2 A nanometer (nm) is one-billionth of a meter or one-millionth of a millimeter.

been discovered that, at the nanoscale, substances exhibit unique physical, chemical, or biological properties that differ from those of the same substances at the macroscale, while at the same time significantly improving existing production processes by enhancing material quality and reducing production costs (Ramsden, 2016: 13–14; Rogers et al., 2015: 15–16, 24–26; Altmann, 2006: 1, 3–4). The “nano factor” refers to the fact that the complex interaction between the composition and physical structure of a material may cause one of its individual properties to deviate from the expected behaviour (Hull, 2017: 17–18).

According to predictions made a decade and a half ago by futurist James Canton, who has also been influential in political circles through his long-standing role as an adviser to the White House, nanotechnology-based products constitute one of the four principal drivers of the global innovation economy (Kanton, 2009: 104–105), with the potential to trigger a new industrial revolution carrying far-reaching implications for the design and manufacture of products. It is therefore unsurprising that nearly four thousand scientific laboratories and research and development centres, in both the public and private sectors worldwide, are currently engaged in nanotechnology research (Nanowerk, 2026). Despite considerable expectations—accompanied, admittedly, by a degree of apprehension—the commercialization of nanotechnological advances remains limited, largely to the fields of computers and mobile phones, cosmetics, and paints and coatings. Most research efforts are still at the stage of theoretical modelling and laboratory testing, while the slow pace of commercialization reflects the fact that industry adopts only those innovations that promise substantial financial returns.

Potential Directions for the Application of Nanotechnologies

Potential directions for the application of nanotechnologies were the subject of extensive scientific and professional debate as early as two decades ago (Simonis & Schilthuizen, 2006: 23–24; Altmann, 2006: 71–117), when they were also largely outlined with the aim of improving public health protection, optimizing the psychological and physical performance of individuals, producing durable, functional, and active materials, designing miniature devices and miniature power sources, and developing quantum computers.

In terms of developing military capabilities, the envisaged applications of nanotechnologies have been directed towards the creation of a self-sustaining soldier-cyborg (equipped with a “smart” uniform and microsenors for monitoring bodily functions), the protection of personnel during combat operations against kinetic, biological, and chemical enemy attacks, increased durability of materials and devices, greater precision and lethality of weapons incorporated into smaller-sized projectiles, the revolutionization of microelectronics and computer technology, the construction of microdevices (nanodrones and nanorobots), and the creation of a hybrid form of

chemical-biological weaponry (Ostojić, 2018). Nevertheless, at present, the greatest progress in nanotechnologies in terms of controlling structures at the atomic and molecular levels has been achieved in the field of materials. The enhancement of materials crucial for weapons, military equipment, and vehicles represents an area of nanotechnology application in the development of defence capabilities where practical results are expected in the short and medium term (Hilton, 2023).

The development of military applications of nanotechnologies has also focused on exploring methods for achieving radar and sonar invisibility of military aircraft, vessels, and submarines, as well as visual camouflage and the suppression of thermal and radar signatures through the use of new types of camouflage coatings (Hilton, 2022).³

Critical-Theoretical Reflections on the Design and Political Constitution of Weapons

Contemporary war theorists agree that exponential technological development is leading warfare towards a turning point, but that it also carries a disruptive impulse in the form of projected far-reaching implications for future warfare (Jordan et al., 2016: 442–443). Since foreign policy decision-makers are often susceptible to the seductive promises of introducing advanced technologies for military purposes, without a rational assessment of the political and organizational context of their application (Jordan et al., 2016: 446–447), the following analysis seeks to highlight potential controversies that the military application of nanotechnological achievements may generate in the future.

We argue that, when considering the interaction between advanced technologies and the improvement of existing as well as the design of new weapons systems, it is necessary to move beyond the framework of the traditional treatment of weapons as mere instruments for achieving foreign policy objectives—a perspective that disregards their materiality, the processes of their technical design and construction, and their affective properties. Therefore, we theoretically position our analysis within the field of critical security/war studies, relying primarily on Ulrich Beck's understanding of the risk society, Benjamin Meiches's conception of the power of weapons to shape the desire for violence, and Gilles Deleuze's and Félix Guattari's thesis of desire as a primary, affirmative, and vital force that continuously creates, connects, and produces social reality.

The common denominator of these theoretical perspectives lies in an approach that transcends the one-dimensional insistence on a state-centred epistemological paradigm by incorporating considerations of human well-being and the environment, as well as broader social and moral consequences of employing advanced weapons systems.

German sociologist Ulrich Beck developed the concept of the risk society to describe a condition in which contemporary individuals experience a sense of moving

³ I base my analysis of the controversial aspects of the military application of nanotechnology on the comprehensive overview of achievements and plans in this field to date, which I presented in my previous article published in this journal (Korać, 2024).

every day through a forest inhabited by various lurking risks. This condition stems from the fact that the current level of scientific, technological, and industrial development prevents the calculation of the social consequences generated by that very development (Beck, 1992; Beck, 2000). Alongside the production of wealth comes the production of risks, understood as systematic ways of dealing with dangers and uncertainties.

According to Beck, contemporary society is dominated by risks arising from human decisions and characterized by structural threats to the survival of civilization, as they are global in terms of their potential harmful effects, frequently beyond the scope of human perception and everyday experience, and require specialized knowledge. This means that they are difficult to measure reliably and precisely, which consequently stimulates intense political debates over optimal institutional solutions (Beck, 1992: 19–50, 155–156). Unlike their ancestors, modern individuals are highly aware of the existence of risks and therefore clearly demand that authorities respond effectively to threats. This leads Beck to conclude that cultural perception and definition are what actually constitute risk; that is, “risk” and the “public definition of risk” are one and the same thing (Beck, 2000: 213).

In this respect, Beck’s argument is particularly important: uncertainties and potential insecurities associated with new technological achievements should not be treated merely as issues belonging to the domain of engineering and scientific expertise, but rather as public questions concerning legal and moral responsibility, as well as public participation in debates and decision-making regarding who benefits, who bears the risks, and how uncertainty should be governed.

Deleuze and Guattari advocated a philosophical-psychological concept of desire as a set of creative and motivational forces that construct a social field composed of people and objects, within which individuals’ responses to various combinations of possibilities offered by their relationship with those objects are subsequently shaped and directed (Deleuze & Guattari, 2004 [1972], 1–8). Desire, as a psychological condition responsible for connecting people and objects, actively constitutes reality (agency), while through reciprocal feedback it also transforms human beings as subjects—creating an altered social field.

For example, when an individual adopts the use of a new technology, both the individual and the technological device are gradually transformed as parts of the same mutually constituted relationship and flows in which they continuously participate. The device is not merely an object of passive use; rather, it reciprocally shapes the user by encouraging reflection on new ways of employing it and by linking them with established interests and objectives.

Viewed within the social field of warfare, the two theorists argue that a feedback relationship gradually emerges between humans and weapons through desire as an active force, within which people begin, through affective states, to imagine and politically consider unintended (originally unplanned) ways of using a particular weapon (Deleuze & Guattari, 1987: 395–403). The affective power of weapons, based on their designed capacity to destroy people and objects, is evident even in the very act of possessing them, which triggers emotional reactions such as fear. This demonstrates

that threat is a by-product of the latent potential of destructive power (Deleuze & Guattari, 1987: 399–400).

Potential new (unintended and unrealized) modes of weapon use generate contingent reactions among users, thereby indirectly expanding and transforming imagination in the planning and projection of military force.

Following Deleuze's and Guattari's reflections, Benjamin Meiches develops the argument that the material dimension, design, and structural characteristics of weapons should always be understood as a feedback mechanism embedded within the broader interaction between humans and objects. Meiches argues that this interaction represents a series of affective encounters that produce desire, and that the inherent power of weapons shapes the desire for violence; in other words, the diversity of relationships between humans and weapons generates an emotionally grounded affective power capable of making acts of violence not only legitimate but also desirable (Meiches, 2017: 7–10).

This is what Meiches refers to as the phenomenon of the “weaponization of politics”, describing a social condition in which weapons not only coexist with humans but also become objects of concern and essential features of political life (Meiches, 2017: 2). Weapons understood in this manner encourage securitization as a process of discursively constructing threats through the development of new weapons systems with enhanced destructive capabilities. These capabilities subsequently stimulate the emergence of new fantasies and forms of desire, which together create space for violent social conditions (Meiches, 2017: 15–16).

The Utility of Nanotechnological Achievements for Military Purposes: Identifying Potential Controversies

Half a century after the Japanese scientist Norio Taniguchi first coined the term “nanotechnology,” sensationalist media reports continue to reflect both the possibilities and uncertainties surrounding this promising avenue of scientific and technological development in the twenty-first century. The utility of nanotechnological achievements should be examined within the context of the question of how to simultaneously achieve two fundamentally important objectives: preserving scientific freedom for innovations and research beneficial for civilian purposes, while ensuring reliable control over the conditions of their potential military repurposing. As with any dual-use technology, legitimate applications of nanotechnological achievements can easily be redirected towards harmful purposes, or undesirable outcomes may emerge as a result of irresponsible or morally misguided choices of action.

The perspective of “nanomania” should in fact come as no surprise, as it represents a logical outgrowth of the positivist paradigm upon which the entire intellectual framework of modernity and the accompanying model of socio-economic organization of nation-states have been constructed under conditions of successive industrial revolutions. This perspective is based on the belief that objective scientific results make it possible to predict the direction of human action and that, on the basis of such predictions, bureaucratic and disciplinary procedures can be applied in order to control

its unforeseen and therefore undesirable consequences (Rosenberg, 2005: 95–97). Horkheimer and Adorno (Max Horkheimer, Theodor Adorno) referred to such practice as the triumph of instrumental rationality, criticizing the elevation of the principle of utility to the level of the primary criterion of reasoning oriented exclusively towards self-preservation rather than towards the pursuit of truth and ultimate purpose (Horkheimer & Adorno, 1974).

Proponents of critical reflections on the ontology of violence argue that an object is transformed into a weapon through the combination of its physical properties with the social context, and that only in their interaction do they create the potential for domination through threat and/or the production of death and bodily destruction directed at other human beings (Bousquet et al., 2017). In this sense, Horkheimer's and Adorno's warning regarding the destructive dominance of instrumental rationality also encompasses the assessment of an object's utility based on the purposeful materialization of human will through rational decision-making processes aimed at exploiting the possibilities of its design for violent actions.

Since they have developed under the influence of a realist worldview of international relations, military techno-fetishism and the commercial utilitarianism of the military-industrial sector in post-industrial societies have historically tended to prevail easily, in the justification of foreign policy decisions, over ethically grounded normative requirements concerning the proportional use of armed force and the distinction between legitimate military targets and civilians or non-military objects. Consequently, anticipated improvements in defence capabilities and enhanced protection of personnel are themselves questionable, as they do not necessarily exclude the emergence of uncertainties related to the proliferation of nanoweapons, the initiation of a new arms race (Nichols, 2017), and their immediate and long-term effects on human health.

The very dual-use nature of nanotechnology complicates its international and national regulatory frameworks and effective oversight, since the boundary between civilian and military applications is often highly porous or difficult to identify. For example, scientific and technological achievements and technical solutions developed at the nanoscale in medicine, electronics, or materials science can subsequently be easily adapted to military requirements. Although nanotechnology applications originate in civilian research institutions and the corporate sector, converging technologies—including nanotechnology, biotechnology, information technology, and cognitive science—have transformative implications for both civilian and military sectors. This overlap makes the monitoring and control of military applications considerably more difficult (Roco & Bainbridge, 2002).

Seumas Miller and Michael J. Selgelid draw attention to the existence of the so-called dual-use dilemma, which arises from the fact that the results of the same scientific research may sometimes have the potential to be used simultaneously for both harmful and beneficial purposes. This creates tensions between the need for continuous innovation and efforts to prevent misuse (Miller & Selgelid, 2007). This is fundamentally an ethical dilemma because the development of nanotechnologies represents a step towards enhancing national defence capabilities as a public good; however, when considered in the context of their potential to cause harm to the health

and lives of innocent people, these technologies simultaneously become a source of insecurity and structural violence.

The field of ethical risks emerges along the axis of the dual-use dilemma, particularly when certain types of research must be declared impermissible or when restrictions on the dissemination of scientific findings become necessary due to significant and far-reaching risks to health and security (Miller & Selgelid, 2007: 542–548). This ethical dilemma is indirectly linked to the individual responsibility of researchers because of potential actions by malicious researchers or third parties who could use published scientific results as a step towards their own findings, subsequently applying them for immoral purposes. The dilemma also enters the domain of political and administrative responsibility, since it is necessary to find a delicate balance between the principle of transparency in scientific research and the objectives and requirements of national security. Such a balance must ensure that excessive restrictions do not hinder innovation, while insufficient oversight does not enable the dissemination of specialized knowledge necessary for designing nanoweapon systems (Miller & Selgelid, 2007: 549–554).

Beyond corporate utilitarian calculations, which are often contrary to public interests, the inherent lack of transparency in the development of military capabilities easily encourages suspicion, accompanied by anxiety, regarding the social acceptability of risks attributed to the utility of future weapons systems. This concern is also present within scientific and professional communities due to the potential for permanent damage to human health and the environment caused by contamination with nanoparticles released during combat operations.

Nanoparticles can penetrate the human body through natural biological barriers and interact with cells in entirely new and unpredictable ways. The problem lies in the fact that toxicological knowledge regarding artificially created nanoparticles remains limited, which significantly complicates the assessment of the actual scale of various security risks (Service, 2004). Current knowledge accumulated in the field of neurotoxicology indicates the limited effectiveness of natural protective mechanisms against the penetration of nanomaterials into the human brain, enabling the intentional vector-based transfer of these substances from the external environment into cerebral space (Bencsik et al., 2018).

Since neurons readily assimilate nanoparticles, nanomaterials already possess the capacity to induce inflammation within the nervous system, oxidative stress, neuronal cell death, disruption of the production of various neuroactive chemicals, and alterations in the network properties of the brain (DeFranco et al., 2019: 52–53). Military personnel involved in the production, handling, or deployment of nanomaterials may therefore face exposure risks that are still not fully understood.

The greatest security risk in the context of the (mis)use of nanoparticles and nanodevices for destructive purposes stems from the complexity of detecting and locating them once they begin operating in the natural environment and within human organisms. Nanoparticles possess high aggregation capacity and environmental reactivity, meaning that they can easily accumulate in ecosystems and consequently cause un-

predictable ecological damage and adverse health effects once they enter the human body through the skin, nose, respiratory system, or digestion (Hamdan, 2023).

The danger is evident because these are invisible particles whose chemical composition, in most cases, does not differ from that of components naturally present in the surrounding environment (Hull, 2017: 19). Consequently, forensic detection of nanoparticles and successful decontamination remain questionable, which is particularly troubling when combined with uncertainties regarding whether—in the worst-case scenario where a nanotechnological product escapes human control—its effects could be halted simply by “switching it off” (Hull, 2017: 20).

The potential application of nanotechnology in the combat employment of chemical and biological weapons would be especially controversial, since delivery systems for nano-enabled biological and chemical agents could increase the effectiveness of such harmful substances while simultaneously making their detection in the environment more difficult. This also creates the danger of blurring the boundary between legitimate scientific research and the development of prohibited weapons (Tucker, 2012). For example, advances in synthetic genomics may facilitate the production of customized DNA molecules as key components of urgently needed medicines, but they may also enable the creation of lethal viral agents for biological warfare (Lentzos & Silver, 2012; Epstein, 2012).

The possibility of employing artificial-intelligence-guided nanobots, devices invisible to the human eye, for intelligence gathering, covert combat operations, and undetected penetration into the human body represents a significant source of risk associated with future nanoweapon systems (Altmann, 2006: 4–6). Nanotechnology enables the construction of extremely small sensors and monitoring devices capable of collecting extensive and diverse battlefield intelligence more effectively and almost imperceptibly.

The use of microsensors would open possibilities for surveillance and monitoring of both military personnel and civilian populations in conflict zones, thereby undermining the right to privacy and increasing the likelihood of abuse. Practices based on integrating nanotechnology into surveillance devices would fundamentally transform existing understandings and normative regulation of the right to privacy, as they would enable continuous, decentralized, and invisible data collection (Van Den Hoven & Vermaas, 2007). The problem is that nanotechnologies deprive individuals of the ability to perceive and understand that they are being monitored or surveilled, thereby undermining generally accepted principles of consent and bodily autonomy (Ganascia, 2011: 687–688).

A serious intrusion into bodily autonomy could occur on another level as well—the creation of a self-sustaining soldier-cyborg. The development of various implants designed to enhance physical and cognitive performance, “smart” uniforms, and microsensors for monitoring health conditions (bodily functions) and the external environment in which soldiers operate ultimately aims to increase combat effectiveness and the probability of survival. However, the traditional nature of social relations established within military hierarchies and the ethos of the military profession could create an organizational culture and environment in which soldiers would accept invasive

medical and engineering procedures for transition into cyborgs under a form of institutional pressure rather than voluntarily, without autonomous decision-making based on detailed information regarding all long-term health implications (Mehlman et al., 2013; Van Den Hoven & Vermaas, 2007: 288–289).

Some authors, such as Keiper and Del Monte (Keiper, 2007; Del Monte, 2017: 178), place the level of risk posed by the apocalyptic consequences of nanoweapons on a par with dark scenarios associated with nuclear or biological weapons, because they perceive a threat to the survival of the human species. Technopessimistic reflections on nanotechnology are not new. Already in his 1986 popular science book *Engines of Creation: The Coming Era of Nanotechnology*, Eric Drexler predicted that manipulating matter at the atomic-molecular level could either transform the world around us or destroy it (Drexler, 1986: 14, 172–174).

Since Drexler's bleak predictions are today considered outdated, it is useful to examine Del Monte's two major arguments (Del Monte, 2017: 178) for drawing an analogy with nuclear apocalypse. First, effective control over sophisticated nanoweapons may exceed human intellectual capacities, including the ability to predict ultimate outcomes and consequently make decisions regarding the possible use of such weapons. Second, Del Monte expresses a robo-apocalyptic concern that allowing future superintelligent computers to design nanoweapon systems, with the aim of simplifying industrial processes and reducing production costs, could remove the human factor from the chain of command (Del Monte, 2017: 178).

Furthermore, concerns regarding the future use of nanotechnology in fully autonomous weapons systems equipped with artificial general intelligence (AGI) stem from anticipating intelligent killing machines that would allegedly be unable to effectively perform combat tasks while simultaneously distinguishing between combatants and civilians and respecting the principle of proportionality in the use of force (Sparrow, 2007). The deployment of enormous numbers of miniature weapons systems on the battlefield would represent a genuine nightmare for command structures. The gap between human mental and intellectual capacities to process massive amounts of data within a short timeframe and rapidly make correct decisions in a complex and dynamic combat environment could fundamentally limit commanders' ability to exploit the projected performance of military devices incorporating nanotechnologies.

What Do Potential Controversies Entail: Problems of the Political Constitution of Nanoweapons from the Perspective of Critical Theory

In analysing plausible controversies surrounding the social constitution of nanoweapon systems, Beck's theoretical perspective of the risk society is useful because it brings to the forefront the question of whether the military application of nanotechnologies can simultaneously be made safe (for users, civilians, and the environment) and effective (for military and political leadership). It appears that the thesis of risk pro-

duction as a substantial feature of the contemporary age validates concerns regarding the realistic possibility of creating new forms of military power with long-term consequences that are currently difficult to predict, describe in detail, and fully comprehend.

Eric Drexler and Dennis Pamlin warn that the application of nanotechnologies for strengthening military capabilities could become an unpredictable disruptive factor in the event of the development of advanced conventional weapons systems that can be easily mass-produced and deployed operationally on the battlefield, as well as through the introduction of various types of portable microdevices (sensors, computers, electromechanical systems) based on surveillance and the more controlled application of force (Drexler & Pamlin, 2013: 64–65). These two authors argue that military history is replete with examples in which large-scale technological changes caused erroneous decisions by military planners and decision-makers, manifested in the overestimation or underestimation of the effectiveness of new technological inventions, existing and emerging military capabilities of adversary states, and slow institutional responses of political decision-makers to new information regarding technological achievements.

Beck's concept of the risk society, applied to the consideration of potential controversies surrounding the military use of nanotechnologies, represents a valuable epistemological instrument because it appropriately connects numerous uncertainties regarding the long-term consequences of such use with uncertainties that may arise from the decision-making processes of foreign policy-makers, military planners, and commanders due to distortions of cognitive capacities. The assessment of the future cumulative effects of already achieved and planned nanotechnological breakthroughs that may be exploited for military purposes is therefore subject to numerous variables and consequently remains unreliable as a foundation for rational decision-making.

The very process of cognitive and normative assessment of possible consequences of technological development enters the domain of evaluating the future and the psychology of risk perception, thereby contradicting strict methodological requirements for acquiring knowledge necessary for prudent political decision-making regarding risk mitigation and the assessment of the social acceptability of technological inventions (Radinković, 2022: 98–109). Evaluating the probability of adverse outcomes resulting from the military application of nanotechnologies represents a necessary step towards mature political decision-making in the field of defence policy and military capability development, particularly with regard to areas in which revolutionary advances and rapid acceleration of nanotechnological breakthroughs are already anticipated.

The enormous investments directed every year towards nanotechnology research and innovation, driven by expectations of substantial profits, seem to indicate a high probability that responsible approaches may be neglected in pursuit of maximizing the performance of nanomaterials and nanodevices. The complex interaction of beneficial and harmful consequences that may arise from the (mis)use of scientific knowledge and technological achievements in the case of nanotechnologies can hardly be clearly predicted at present, primarily due to the absence of open dialogue between independent researchers, engineers, and technologists on the one hand, and foreign policy decision-makers and military planners on the other.

The most dangerous unknown concerns the outcome of the inevitable convergence of multiple advanced technologies of the Fourth Industrial Revolution and their application in designing a new generation of weapons systems. The application of the fruits of technological progress is closely connected with their market and utility; therefore, it is essential to take into account the lack of technical understanding of their limitations and social implications. This once again confirms the validity of Beck's argument that modes of using new technological achievements as sources of insecurity must not be treated as merely technical issues.

The question of military applications of nanotechnologies should always be considered within the framework of generally accepted democratic procedures, in such a way that the engineering and scientific factual basis serves as a foundation for informed debate and high-quality decision-making regarding plausible outcomes of such applications, particularly those that could produce unintended harm. One of the most important reasons for this is the tendency of political decision-makers to embrace unfounded techno-optimism, as it can easily be transformed through marketing manipulation into attractive electoral promises.

This is perhaps best illustrated by the fact that the famous American concept of the Revolution in Military Affairs underwent serious criticism in academic and professional circles (see: Collins & Futter, 2015), and that during the last two decades, in an attempt to mitigate the original techno-optimism, the term "revolution" was removed from official terminology in favour of the phrase "military transformation."

Maintaining the ability to effectively project military power in the international arena is closely linked to successfully identifying the utility of new weapons systems, that is, to their skilful integration into strategic and doctrinal planning frameworks (Horowitz, 2010). Consequently, quality decision-making in defence policy is hindered by the lack of clear forecasts regarding what nanotechnologies may enable in the medium and long term, as well as by the accompanying secrecy regime surrounding military projects, which prevents establishing a balance between actual technological and engineering achievements and media exaggerations regarding what might be achievable (Simpson & Sparrow, 2014: 96).

The possibility of highly effective and covert weapon systems with unprecedented destructive capabilities raises concerns regarding the destabilization of global security and the stimulation of a new arms modernization race among major powers such as the United States, China, and Russia, which have already integrated nanotechnology into their defence research programmes.

Viewed through the lens of Beck's concept of the risk society, the successful tactical and operational employment of nanotechnology-based weapons systems would undoubtedly open a new field of global insecurities and uncertainties, particularly through the emergence of new structural inequalities caused by asymmetric possession of this emerging technology. Thus, the dominance of the global core over the global periphery—historically conditioned by the accumulation of social wealth primarily in post-industrial societies at the expense of less developed ones—would extend existing inequalities into the domain of military technology. Security risks would there-

by increasingly shift towards countries of the global periphery, which would be unable to finance even partial or temporary symmetry with technologically more advanced armed forces.

Nanotechnologies have become politicized in the early twenty-first century and have consequently been constituted as an important component of military plans and military-technological development projects of leading international actors (Kosal, 2014; Dong et al., 2016). The political constitution of new weapons systems and military equipment based on advanced technologies once again brings into focus the epistemological validity of critical-theoretical reflections on the interaction between humans and weapons as a feedback relationship, in which design, material characteristics, and functional properties transformed into destructive power stimulate the elaboration of imaginative scenarios regarding practical use in specific military operations.

Expectations regarding the incorporation of nanotechnologies into military capabilities are directed towards securing unprecedented long-term strategic advantages over competitors, which would subsequently materialize either in maintaining the status of a global hegemon or in successfully challenging it. The problem emerges from the inability to achieve nanotechnological superiority in a linear manner and within a short timeframe. Therefore, the otherwise lengthy process of achieving operational reliability of new weapons systems may be shortened if military-political interests in rapidly introducing new technologies outweigh strict requirements for testing.

Under such circumstances, Meiches's thesis becomes particularly relevant: weapons can reciprocally condition the prioritization of certain directions of planning and action within the process of (foreign) policy decision-making. Following Deleuze's and Guattari's reflections, it appears that the increased destructive power of nanoweapons could stimulate a desire for violence, primarily among political and military leaders, by creating psychological conditions in which the inclination to achieve foreign policy objectives through violent means becomes an acceptable, and even desirable, position.

Achieving sufficiently rapid innovation would provide an advantage over competitors in the international arena, thereby lowering the threshold for initiating war—it would make military campaigns cheaper and more efficient. The affective orientation towards the practice of armed violence would subsequently become reinforced within public opinion, contributing to the establishment of broader social consensus and then being formulated and confirmed through legitimate democratic procedures, which would make such violence more probable and acceptable within the political community by invoking legality.

Meiches's argument that weapons constitute an active force which, through affects and fears, shapes human behaviour and creates conditions for violence can be interpreted in another dimension when applied to nanotechnology-equipped military capabilities. The very possession of an advanced weapons system can generate fear among adversaries and exert pressure on their societies through perceptions of threat and uncertainty. The emotional and affective dimension of perceiving and subsequently discursively constructing the destructive power of nanoweapons means

that such weapons exert influence even before their actual use, due to the awareness that they are designed to destroy in arbitrary and unpredictable ways.

In other words, the introduction of advanced technology leads to a transformation of the modes and directions of action not only of users but also of those who may become potential targets (i.e., adversaries). Thus, combat systems incorporating nanotechnologies may acquire, through altered modes of employment, initially unintended operational functions; for example, they may serve as instruments of mere deterrence without being operationally used on the battlefield.

Drawing upon Deleuze's and Guattari's claim that reflection on the technical characteristics of nanoweapons encourages foreign policy decision-makers and military planners to contextualize new modes of use within state interests and objectives, it appears that this also opens new possibilities in the production of knowledge. The production of official knowledge regarding defence policy and military campaigns may enter the field of controversy if the utility of advanced technologies is expressed through manipulation of the discursive meanings attributed to advanced weapons systems.

For example, development projects aimed at creating soldier-cyborgs may, from a critical-theoretical perspective, be interpreted as attempts to make the biology of the American soldier superior through discursive practices and to reconstruct the symbolism of imperial invulnerability. A discursively constructed and media-mediated representation of the soldier-cyborg as "invulnerable" and "unstoppable"—as a human being who, despite enemy action, "resurrects" and returns to the battlefield—could potentially have a demoralizing effect on enemy combatants (particularly those technologically disadvantaged), especially if battlefield practice were to verify such representation as reflecting the reality of warfare in the twenty-first century.

The analysed potential controversies of the military application of nanotechnologies demonstrate that technological progress is not unidirectional and therefore must not be instrumentalized and justified solely through measurements of efficiency and operational advantages in the context of improving defence capabilities. The military application of nanotechnologies draws us into a deep "forest" in which various uncertainties lurk: every assessment of the utility of advanced weapons systems should also incorporate the perspective of preserving the well-being of soldiers, civilians, and the environment.

Neoliberal insistence on the validity of the logic of instrumental reason opens space for overestimating the utility of nanotechnological achievements and, consequently, for the accelerated introduction of insufficiently tested solutions based on the alleged superiority of engineering expertise and driven by strong commercial pressures—while information regarding long-term harmful consequences is pushed out of public debate and democratic decision-making processes.

The techno-optimism of political and military elites, as a driving force behind the political and social constitution of nanoweapons, may become a dangerous factor in the complex and unpredictable process of shaping futuristic military imagination, perceiving the level of future threats, and defining the boundaries of acceptable violence.

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S u m m a r y

This paper examines the controversies that may arise from the application of nanotechnology innovations in the enhancement of military capabilities in the early twenty-first century, based on the prioritization of a neoliberal version of instrumental rationality over the formative social and political effects of weapons. Nanotechnologies are conceptualized as a heterogeneous field of scientific and engineering practices concerned with the manipulation of matter at the atomic and molecular levels. The paper starts from the assumption that decision-making grounded in the understanding of weapons as value-neutral instruments of foreign and defence policy, namely in reducing their utility solely to designed technical operational properties and functions, creates space for new disruptive uncertainties and risks. The central argument is that the improvement of defence capabilities cannot be reduced solely to the role of technological innovations, since the utility of any new weapon system or military capability is mediated by the quality of (foreign) policy decisions, existing military strategies and doctrines, military organizational culture, as well as the functioning of logistics and command structures.

The analysis adopts a critical-theoretical perspective and relies on Ulrich Beck's concept of the risk society, Gilles Deleuze and Félix Guattari's concept of desire, and Benjamin Meiches' notion of the affective power of weapons. It examines the most plausible controversies arising from the common denominator of porous boundaries between civilian and military research, the dual-use nature of nanotechnologies, and the complexity of regulating innovations whose technical characteristics can be rapidly redirected toward destructive purposes. In the short and medium term, the most likely military applications include lighter and more durable materials, enhanced pro-

tection of personnel and platforms, advanced camouflage technologies, miniaturized sensors, portable energy sources, improved communication systems, and potentially robotic devices at the micro- or nanoscale.

The analysis demonstrates that the most important potential controversies surrounding the future military application of nanotechnological solutions are associated with the dual-use dilemma of nanotechnology (civilian and military), blurred boundaries between civilian and military research, and difficulties in establishing effective regulatory mechanisms for controlling innovations whose technical features can be quickly adapted for destructive purposes. Particular attention is devoted to risks arising from nanoparticle toxicity, long-term environmental contamination, invasive methods of creating enhanced or cyborg soldiers, surveillance systems based on miniature devices, autonomous weapon systems, and the possible destabilization of global security through the emergence of a new arms race.

The paper also emphasizes that the secrecy surrounding military research, combined with commercial pressures for accelerated innovation, may weaken democratic oversight of the defence sector and responsible foreign policy-making. It concludes that the military application of nanotechnologies cannot be assessed exclusively through the prism of efficiency and operational advantages. Although nanotechnologies promise significant improvements in defence capabilities, they simultaneously generate a range of uncertainties concerning the security of soldiers, civilians, and the environment. A particular concern is the neoliberal reliance on the logic of instrumental reason, as it creates conditions for overestimating the utility of nanotechnological achievements and for the accelerated introduction of insufficiently tested solutions. Such an approach, based on the presumed superiority of engineering expertise and driven by strong commercial pressures, may result in the exclusion of information about long-term harmful consequences from public debate and democratic decision-making processes.

Therefore, techno-optimism among political and military elites, as a driving force behind the political and social construction of nano-weapons, may become a dangerous factor in the complex and highly unpredictable process of shaping future military imaginaries, assessing emerging threats, and defining the boundaries of acceptable violence.

Keywords: *nanotechnologies, warfare, weapons, defence policy, armed forces, critical war studies*

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