

RESEARCH ARTICLE

The more-than-human biopolitics of swarming – complexity, emergence, and control in military robotics

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Abstract

Military robotic swarming is expected to herald a disruptive change in warfare. This article analyses how both the technoscientific promises and problematizations of robotic swarming in the military relate to transformations in the way wars are cognized and conducted by liberal societies. This analysis will be conducted through the lens of a more-than-human biopolitics. Firstly, the paper traces how a new understanding of life, established by complexity sciences, has enabled entanglements and translations between different forms of life and how these have informed the military imaginaries and design principles of military swarming. Secondly, the problematization of robotic swarms as potentially running out of human control is re-interpreted in terms of this re-conceptualizing and appropriation of a more-than-human life. The central argument here is that a biomimetic robotic swarm not only inherits the desired properties of a natural swarm but also its inherent risks. Thirdly, it is analysed how military approaches to the government of robotic swarms and their dangerousness move to a less centralized and less direct form of Command and Control (C2), aiming to maximize the benefits of swarming while minimizing its risks. The article concludes by discussing how this new C2 paradigm of governing at the ‘edge of chaos’ points us to the need to rethink the legal ordering of swarming.

Keywords: biopolitics; command and control; complexity sciences; more-than-human; robotic swarming

Introduction

Among military strategists, defence organizations, and arms manufacturers around the world, there is a growing interest in robotic swarming. Until 2021, at least eleven states had announced military swarm research & development (R&D) programmes.¹ The technoscientific promise driving these endeavours is to apply the principles of life to its destruction. Based on the mimicking of the ability of natural swarms to self-organize, to work collectively towards a common goal, to quickly adapt to changing conditions, and to perform tasks that a single entity would not be capable of, robotic swarms of uncrewed, networked, ‘autonomous’ air, land, or (under)water vehicles are seen as the key to superiority in future wars.² They would bring ‘greater mass, coordination, intelligence, and speed to the battlefield, enhancing the ability of warfighters to gain a decisive advantage

¹Zachary Kallenborn, ‘The Plague Beckons: On the Proliferation of Drone Swarms’, in Rajeswari P. Rajagopalan and Sameer Patil (eds), *Future Warfare and Critical Technologies: Evolving Tactics and Strategies* (New Delhi: ORF and Global Policy Journal, 2024), pp. 12–22.

²While it is possible to differentiate among multiple levels of swarm autonomy – on a spectrum from a unit or formation of individual robots, operating simultaneously but remotely controlled and piloted by a human operator each to a self-organized collective of ‘intelligent’ robots, operating in a coordinated manner and as a coherent entity – the term ‘swarm’ is used (unless otherwise indicated) exclusively for the latter case.

over their adversaries.’³ In military imaginaries, swarming will constitute the ‘leading edge of the battlefield’ and thereby holds the potential for ‘rendering previous methods of warfare obsolete.’⁴

At the same time, there is widespread scepticism that these weapon systems can be developed and deployed in a way that is compliant with key principles of International Humanitarian Law (IHL) – distinction, necessity, and proportionality – as well as human accountability and responsibility.⁵ Accordingly, robot swarms have been discussed as a case of Lethal Autonomous Weapons Systems (LAWS) that would undermine a ‘Meaningful Human Control’⁶ over the use of force.⁷ It is also pointed out that the interactions between the robotic elements of a swarm or between several swarms increase the risk of unpredictable events and thus of escalating armed conflicts.⁸

A crucial – yet neglected – question is how both the technoscientific promises and the problematizations of military robotic swarming relate to transformations in the way wars are cognized and conducted by liberal societies. Answering this question is essential for engaging with robotic swarming as it sheds light on the power/knowledge that makes it possible to think and create this biomimetic war machine in the first place and, hence, to account for its ‘becoming weapon.’⁹

The ways in which liberal rule problematizes war, peace, and security directly reflect the forms of life that it enacts.¹⁰ Hence, the liberal way of war has to be understood in terms of biopolitics – the form of power/knowledge that is concerned with the administration and production of life, rather than the ‘right to take life or let live.’¹¹ Whereas sovereign power is distinguished by its reliance on instituting the law and threatening punishment, liberal rule operates on populations determined by biological processes that must be nurtured or confined. Consequently, it has to respect the laws of biological life because their ignorance, misunderstanding, or disregard leads to negative consequences. Liberal rule, therefore, aims to promote life by ensuring the working of natural modes of self-regulation and ordering of populations. However, biopolitics not only aims at the promotion of life but also necessitates its eradication as well. By dedicating itself to the protection of life, liberal rule is poised to fight wars in “the name of life necessity”¹² and based on ‘a break into the domain of life that is under power’s control: the break between what must live and what must die.’¹³ Life is (dis)qualified and hierarchized according to its value for the peace and prosperity of life on

³Paul Scharre, ‘Robotics on the Battlefield: Part 2: The Coming Swarm’ (Center for a new American Security, Washington, D.C., October 2014), p. 5, available at: <https://www.cnas.org/publications/reports/robotics-on-the-battlefield-part-ii-the-coming-swarm>, accessed 10 August 2025.

⁴Robert O. Work and Shawn Brimley, ‘20YY: Preparing for War in the Robotic Age’ (Center for a new American Security, Washington, DC, January 2014), p. 29, available at: <https://www.cnas.org/publications/reports/20yy-preparing-for-war-in-the-robotic-age>, accessed 10 August 2025.

⁵Jürgen Altmann, ‘Autonomous Weapon Systems – Dangers and Need for an International Prohibition’, in Christoph Benzmlüller and Heiner Stuckenschmidt (eds), *KI 2019: Advances in Artificial Intelligence: 42nd German Conference on AI, Kassel, Germany, September 23–26, 2019 Proceedings* (Cham: Springer, 2019), pp. 1–17.

⁶Article36, ‘Key elements of meaningful human control’ (Background Paper, Article36, April 2016) available at: <https://www.article36.org/wp-content/uploads/2016/04/MHC-2016-FINAL.pdf>, accessed 11 August 2025.

⁷Merel Ekelhof and Giacomo P. Paoli, ‘Swarm Robotics: Technical and Operational Overview of the Next Generation of Autonomous Systems’ (UNIDIR, Geneva, 2020), p. 1; Chairperson of the Informal Meeting of Experts, ‘Report of the 2016 Informal Meeting of Experts on Lethal Autonomous Weapons Systems (LAWS)’ (United Nations Office for Disarmament Affairs, Geneva, 2016), p. 12, available at: [https://docs-library.unoda.org/Convention_on_Certain_Conventional_Weapons_-_Informal_Meeting_of_Experts_\(2016\)/ReportLAWS_2016_AdvancedVersion.pdf](https://docs-library.unoda.org/Convention_on_Certain_Conventional_Weapons_-_Informal_Meeting_of_Experts_(2016)/ReportLAWS_2016_AdvancedVersion.pdf), accessed 11 August 2025.

⁸James Johnson, ‘Artificial Intelligence, Drone Swarming and Escalation Risks in Future Warfare’, *The RUSI Journal*, 165:2 (2020), pp. 26–36.

⁹Antoine Bousquet, Jairus Grove and Nisha Shah, ‘Becoming weapon: an opening call to arms’, *Critical Studies on Security*, 5:1 (2017), pp. 1–8.

¹⁰Vivienne Jabri, ‘War, Security and the Liberal State’, *Security dialogue*, 37:1 (2006), pp. 47–64; Michael Dillon and Andrew W. Neal (eds), *Foucault on Politics, Security and War* (Basingstoke, Hampshire: Palgrave Macmillan, 2008); Brad Evans, ‘Foucault’s Legacy: Security, War and Violence in the 21st Century’, *Security dialogue*, 41:4 (2010), pp. 413–33.

¹¹Michel Foucault, *Society must be defended: Lectures at the Collège de France, 1975–76* (New York: Picador, 2003), p. 241.

¹²Foucault, *Society Must Be Defended*, p. 249.

¹³Foucault, *Society Must Be Defended*, p. 254.

a global scale. The category of race and biological racism are bound up in these hierarchies and (de)valuations.¹⁴

However, as the life sciences went through a fundamental transformation during the course of the second half of the 20th century,¹⁵ the very conception of life – and thus of the referent object of liberal rule and war – began to be imagined differently. As a result of the information and molecular revolutions, life was understood as informational, which opened up strategically to new biopolitical strategies and interventions both in the civil and the military realm.¹⁶ Pugliese, for instance, shows how algorithmic targeting in the US remote (drone) warfare performs a ‘bioinformationalization of life’ by transforming living bodies into informational ‘patterns of life’ that can be classified as killable or not.¹⁷ In contrast to its purported objectivity, this ‘art of divination’¹⁸ expresses the racial and gender biases inherent to the algorithmic systems.¹⁹

What has been largely ignored in the analysis of this biopolitical shift, however, is that the re-conceptualization of life as informational has consequences not only for the human animal but also for non-human life. In the military realm, the informationalization of life enables an appropriation of the laws of non-human life for the purpose of combating and destroying dehumanised lives²⁰ – an approach that is currently articulated not only in the field of robotic swarming but also by bioinspired concealment and deception technologies,²¹ plant nanobionics,²² and many other examples of military biomimicry.²³ Hence, swarming is more than just a promising way to make military operations faster and more ‘intelligent’. Whether imagined or real, it forms part of a shift in the biopolitical modalities of war. Here, life itself is no longer just the reference point of biopolitical interventions but also the design principle of the weapons by which these interventions are to be realized; a design principle, however, which has an impact on the possibilities and limits of these interventions.

The advent of robotic swarming in the military points to the need for an analysis of the biopolitics of war that incorporates the entanglements of humans and non-humans, thereby ‘taking both fleshy and steely bodies into account’.²⁴ In what follows, robotic swarming, its problematization and its governing will be analysed through the lens of this more-than-human biopolitics. Firstly, the paper traces how the informationalization of life has enabled translations between different forms of life, both natural and artificial, and how these translations have informed military imaginaries and design-principles of swarming. Secondly, the problematization of robotic swarms as potentially running out of human control is reinterpreted in terms of this re-conceptualizing and

¹⁴Holly Randell-Moon and Ryan Tippet, ‘Introduction’, in Holly Randell-Moon and Ryan Tippet (eds), *Security, Race, Biopower: Essays on Technology and Corporeality* (London: Palgrave Macmillan UK, 2016), pp. V–XXV.

¹⁵Lily E. Kay, *Who Wrote the Book of Life? A History of the Genetic Code* (Stanford: Stanford University Press, 2000).

¹⁶Melinda Cooper, *Life as Surplus: Biotechnology and Capitalism in the Neoliberal Era* (Seattle: University of Washington Press, 2008); Michael Dillon and Julian Reid, ‘Global Liberal Governance: Biopolitics, Security and War’, *Millennium: Journal of International Studies*, 30:1 (2001), pp. 41–66; Nikolas Rose, *The Politics of Life Itself: Biomedicine, Power, and Subjectivity in the Twenty-First Century* (Princeton: Princeton University Press, 2009).

¹⁷Joseph Pugliese, *Biopolitics of the More-than-Human: Forensic Ecologies of Violence* (Durham, London: Duke University Press, 2020), p. 168.

¹⁸Pugliese, *Biopolitics of the More-than-Human*, p. 184.

¹⁹Pugliese, *Biopolitics of the More-than-Human*, p. 172; see also Jens Hälterlein, ‘Facial Recognition in Law Enforcement’, in Christian Borch and Juan P. Pardo-Guerra (eds), *The Oxford Handbook of the Sociology of Machine Learning* (New York: Oxford University Press Inc, 2025), pp. 343–60.

²⁰Lauren Wilcox, ‘drones, swarms and becoming-insect: Feminist utopias and posthuman politics’, *Feminist Review*, 116:1 (2017), pp. 25–45.

²¹Ron Matthews and Thomas J. Matthews, ‘Military mimicry: The art of concealment, deception, and imitation’, *Defense & Security Analysis*, 40:3 (2024), pp. 379–404.

²²Henry N. Osman, ‘From leaf to bomb: Plant nanobionics and the operationalization of ecology’, *Digital War*, 4:1–3 (2023), pp. 18–25.

²³For an overview see: Rebecca Northfield, ‘Military by nature’, *Engineering & Technology*, 13:11 (2018), pp. 56–9.

²⁴Caroline Holmqvist, ‘Undoing war: War ontologies and the materiality of drone warfare’, *Millennium: Journal of International Studies*, 41:3 (2013), pp. 535–52.

appropriation of a more-than-human life. The central argument here is that a biomimetic robotic swarm not only inherits the desired properties of a natural swarm but also its inherent riskiness: the continuous and contingent becoming dangerous of life. Thirdly, the paper analyses how military approaches to the government of robotic swarms and their inherent dangerousness move to a less centralized and less direct form of Command and Control (C2). Here, the concern is to navigate between the twin dangers of governing too much and governing too little, that is, to maximize the benefits of emergent behaviours while minimizing their risks, or in other words, to govern at the 'edge of chaos'. The article concludes with a reflection on how the more-than-human biopolitics of swarming points us to the need to re-think legal ordering beyond the dichotomies and the anthropocentrism inherent to IHL.²⁵

Empirically, the analysis focuses on the US military context. Given the existence of swarming programmes in almost all military advanced countries, however, the aim is to analyse a phenomenon and the changes in warfare associated with it that are of global significance. This analysis is based on an in-depth reading of publicly available documents. These include reports and other publications by think tanks, military research institutes and NGOs, statements by arms manufacturers, defence and security news media, tech journalists, military strategy papers, doctrinal publications and directives, as well as journal articles and proceedings from the field of swarm robotics.

Life as information and the new biopolitics of war

The advent of swarming in the military is closely connected to the interdisciplinary field known as 'complexity sciences'. Since its formation in the early 1980s, complexity sciences have developed into a widely disseminated and popular discourse that has come to re-define the very nature of life itself.²⁶ Complexity sciences focus on the behaviour of complex systems – a concept that applies to living organisms as much as to ecosystems, human populations, financial markets, and societies.²⁷ Complex systems are understood as systems composed of many independent parts which are coupled in a non-linear way.²⁸ The structure of a complex system is that of a network. Complexity arises because the independent parts of a network are interacting simultaneously. It is the accumulation of all the individual behaviours that produces the overall behaviour of the system, which can thus be said to be emergent.²⁹ This emergence has to be understood as the effect of processes that critically depend upon the patterns and dynamics of connectivity: non-linear connectivity also produces non-linear forms of system behaviour. Hence, the system's behaviour cannot simply be explained or even predicted from its previous behaviour.³⁰

Complex Adaptive Systems (CASs) are seen as a special case of complex systems, capable of changing and learning from experience a dynamic network of agents (cells, neurons, human individuals, artificial agents, etc.), acting in parallel, constantly reacting to their environment and to what the other agents are doing.³¹ In these processes of combination and recombination, information is the constituent element and prime mover. Based on the processing, distribution, and exchange of information, CASs are seen to be emergent and continuously co-evolving with their

²⁵ Matilda Arvidsson, 'The swarm that we already are: Artificially intelligent (AI) swarming "insect drones", targeting and international humanitarian law in a posthuman ecology', *Journal of Human Rights and the Environment*, 11:1 (2020), pp. 114–37.

²⁶ Michael Dillon and Julian Reid, *The Liberal Way of War: Killing to Make Life Live* (London: Routledge, 2009), p. 77.

²⁷ Antoine Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York: Columbia University Press, 2009), p. 175.

²⁸ James Moffat, *Complexity Theory and Network Centric Warfare* (Washington, D.C.: CCRP Publication Series, 2003), p. 68.

²⁹ M. Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (London: Simon & Schuster, 1992), p. 145.

³⁰ Jeffrey Goldstein, 'Emergence as a Construct: History and Issues', *Emergence*, 1:1 (1999), pp. 49–72 (p. 50).

³¹ Bousquet, *The Scientific Way of Warfare*, p. 175.

changing environments.³² The connectivity of the components of CAS is transformative, that is, they are continuously combined and re-combined in novel ways. Therefore, CAS would be better equipped than other (complex) systems to deal with the limited predictability and contingency of their environments.³³ In comparison with static or closed systems, CAS can operate more effectively and with a greater degree of adaptability based on the local calculations of the networked entities constituting them.³⁴ For complexity thinkers, 'fitness' is measured less in terms of pure 'survival' than in terms of the capacity to achieve a 'poised state' near the boundary between order and chaos: the 'edge of chaos'.³⁵ The notion refers to a state where systemic structure can be retained and the complexity of tasks CAS can perform is optimized while at the same time their flexibility or 'evolvability' is optimized.

From a complexity sciences' point of view, swarms are to be treated as CAS. Acting together as a coherent whole, swarms of insects, birds or fish would be capable of exhibiting complex forms of collective behaviour based on comparatively simple behavioural rules. Through 'the emergent collective intelligence of groups of simple agents',³⁶ swarms may reach the optimal state of fitness in a given environment – an advantage that the individual members of a swarm could never achieve on their own. This 'swarm intelligence' is what is seen to enable social insects to produce effective solutions to new problems despite the limited cognitive abilities of their individual agents. For example, acting together as a colony, it is argued that ants are able to quickly identify the shortest route to a food source among many possible options by interacting with each other through odour trails.

The non-linear ways by which CAS are seen to emerge and change over time pose many analytical challenges and have major practical implications, as CAS would be, in their nature, uncertain, continuously adapting to changing environments and therefore exhibit an unpredictable, seemingly chaotic behaviour.³⁷ However, as Stuart Kauffman, one of the leading figures of complexity sciences, maintains, there is latent order underlying what appears on the surface to be chaotic.³⁸ The answer to the distortion that complexity sciences have brought upon (the theorizing of) nature is the existence of principles, unfolding from the bottom up and 'akin to the growth of a plant from a tiny seed or the unfolding of a computer programme from a few lines of code, or the self-organizing behaviour of a flock of birds'.³⁹ These laws of emergence are different from traditional causal laws of Newtonian physics because they are immanent, probabilistic, and non-linear. But these laws could still be observed, albeit in different ways.

Given the central assumption of the 'biophilosophical discourse' of complexity sciences that the powers of connectivity and re-combination are the means by which CASs emerge, change, and are capable of meeting the demands of rugged fitness landscapes, Dillon and Reid coined the term 'recombinant biopolitics'.⁴⁰ Here, biopolitics is becoming informational. This does not simply mean that power over life operates through computer-mediated and networked Information and Communication Technology (ICT). Since information is regarded as the principle of formation of life itself, the objects of biopolitical interventions are now conceived as different modes of information circulating and operating through networks, themselves understood in informational terms. Thereby, distinctions between biological and artificial, as well as animate and inanimate,

³²Murray Gell-Mann, *The Quark and the Jaguar: Adventures in the Simple and the Complex* (London: Little Brown and Company, 1994), p. 17.

³³Bousquet, *The Scientific Way of Warfare*, p. 182.

³⁴Waldrop, *Complexity*, p. 279.

³⁵Stuart A. Kauffman, *At Home in the Universe: The Search for Laws of Complexity* (London: Penguin, 1995), p. 26; Waldrop, *Complexity*, p. 293.

³⁶Eric Bonabeau, Marco Dorigo, Marco and Guy Theraulaz, *Swarm Intelligence: From Natural to Artificial Systems* (Cary: Oxford University Press Incorporated, 1999), p. xi.

³⁷Bousquet, *The Scientific Way of Warfare*, p. 181.

³⁸Kauffman, *At Home in the Universe*, p. 23.

³⁹Waldrop, *Complexity*, p. 329.

⁴⁰Dillon and Reid, 'Global Liberal Governance: Biopolitics, Security and War', p. 44.

have been problematized, and a continuity of living and life-like entities (including mechanical and electronic) has been construed.⁴¹

These various entities consisting of information or code are not to be understood as pre-formed bodies with fixed attributes, but as 'bodies-in-formation with continuously adaptive, emergent, and changing properties'.⁴² Hence, if there is one defining feature of all living or life-like CAS, it is that they are contingent. Accordingly, as the essential constituent components of the 'bios' began to be conceived as informational and contingent, biopolitics has become concerned with the generative principles of formation and the ways in which self-organizing informationally ordered forms of life emerge and behave. And to observe and know these laws of emergence is the key to not only understanding the processes of formation and change of CAS but to their re-structuring re-formation, re-coding, re-modelling, and manipulation to provide preferable CAS rather than unpreferable.⁴³ In principle, any form of life, both biological and artificial, as well as organic and non-organic, can be constructed in laboratories – either microbiologically, computationally, or mechanically. Moreover, based on the informational 'nature' of all living and life-like systems, it becomes possible to translate the principles of formation/laws of emergence from one entity to another and to even create hybrid assemblages of the biological and the mechanical. Technoscience now seeks ways of creating 'new life-forms: biological and cyborg; human, hybrid, and machine'.⁴⁴

In this regard, contemporary biopolitics is not only recombinant, but also more-than-human. It represents a power/knowledge, which, in both its epistemic and its technoscientific practices, crosses the boundary between the human and the non-human. This results in new forms and modalities of intervention in life. While human populations and their reproduction as well as human species life as such were the referent objects of government within early modern liberal biopolitics, contemporary biopolitics aim to govern CAS in all their diversity that is, beyond (the) human(ity) as well, and to create new populations of hybrid species. However, in as much as contemporary biopolitics is (still) concerned with life, with the question of how to make life live (in all its diverse forms), it is (still) concerned with the question of how to make life end. Accordingly, the digital and molecular revolutions and the thus promoted understanding of life as information did not only affect the government of private, social, and economic life but also the 'very ways in which war was cognized and waged'.⁴⁵ Ultimately, complexity sciences have been translated into a new understanding of the nature of war. According to complexity scientist Yaneer Bar-Yam,

*it has become widely recognised in the military that war is a complex encounter between complex systems in complex environments. Complex systems are formed of multiple interacting elements whose collective actions are difficult to infer from those of the individual parts, predictability is severely limited, and response to external forces does not scale linearly with the applied force. It is reasonable to postulate that warfare can be better executed by those who understand complex systems than those who focus on simple linear, transparent, classically logical, Newtonian constructs.*⁴⁶

On the level of doctrine, this new understanding of militaries as CAS was reflected in Navy Vice Admiral Arthur K. Cebrowski's and John Garstka's seminal article *Network-Centric Warfare: Its Origin and Future*⁴⁷ in which they advocated the new doctrine of 'Network-Centric Warfare'

⁴¹Dillon and Reid, *The Liberal Way of War*, p. 22.

⁴²Dillon and Reid, *The Liberal Way of War*, p. 59.

⁴³Dillon and Reid, *The Liberal Way of War*, p. 106.

⁴⁴Dillon and Reid, *The Liberal Way of War*, p. 22.

⁴⁵Dillon and Reid, *The Liberal Way of War*, p. 106.

⁴⁶Yaneer Bar-Yam, 'Complexity of military conflict: Multiscale Complex Systems Analysis of Littoral Warfare' (New England Complex Systems Institute, 21 April 2003), p. 1, available at: <https://necsi.edu/complexity-of-military-conflict>, accessed 9 August 2025.

⁴⁷Arthur K. Cebrowski and John J. Garstka, 'Network-Centric Warfare: Its Origin and Future', *Proceedings of the US Naval Institute*, 124:1 (1998), pp. 28–35.

(NCW) that 'looks at war as a complex, adaptive system where non-linear variables continuously interact'.⁴⁸ The doctrine aimed not only to adopt new ICT more thoroughly but also to acknowledge information as the generative principle of formation for military organization and prime mover of all activities, weapons, agents, and military organizations. From the very introduction of the NCW doctrine, military thinking and complexity sciences were being explicitly linked.⁴⁹

On the level of strategy and tactics, the uptake of complexity sciences in the military led to a focus on swarming. Here, the study *Swarming and the Future of Conflict* by John Arquilla and David Ronfeldt from the RAND Corporation was particularly influential.⁵⁰ Drawing from complexity sciences as well as from entomologists and animal behaviourists, the two authors appeal to swarming as seemingly amorphous, but deliberately structured and coordinated 'instances of omnidirectional yet well-timed assaults' from ants and bees and wolf packs.⁵¹ To Arquilla and Ronfeldt, however, swarming is not just a natural phenomenon. They apply the concept to operations ranging throughout military history from ancient wars to insurgents in Afghanistan and Iraq employing swarming as a form of asymmetric warfare against superior conventional armies. But only now, due to the information revolution, could the swarming 'of myriad, small, dispersed, networked manoeuvre units' become 'a doctrine in its own right'.⁵² Besides the high adaptability of swarms, their resilience is of particular interest to military thinking. Resilience, in this case, means that no single individual member is critical to the successful operation of the collective and that swarms can operate under low communication bandwidth. Beyond these capabilities that make military swarms best suited to survive in the increasingly lethal battlefields of contemporary wars,⁵³ they enable extended vigour by attacking a target from multiple directions. The full effect of military swarming is achieved when the small forces of a dispersed network converge on a target, thereby overwhelming its defensive measures through the 'systematic pulsing of force and/or fire, by dispersed internetted units'.⁵⁴ In the imagination of the two authors, the perfect swarm would 'coalesce rapidly and stealthily on a target, then disperse and redisperse, immediately ready to recombine for a new pulse'.⁵⁵ Given these capabilities, swarming should become a central element of future US military campaigns: flexible, self-organized, and powerful operations, based on decentralization and information-sharing. To bolster this claim, Arquilla and Ronfeldt propose the new doctrine of 'BattleSwarm' that the US Army should adopt alongside its Air-Land Battle doctrine of 1982.

A biomimetic approach to swarming

While the 'BattleSwarm' doctrine exclusively referred to soldiers of flesh and blood, other early proponents of military swarming envisioned networks of robotic combat units and explored robotic

⁴⁸ Colin S. Gray, *Strategy for Chaos: Revolutions in Military Affairs and the Evidence of History* (London: Cass, 2003), p. 105.

⁴⁹ Bousquet, *The Scientific Way of Warfare*. Sean Lawson explains the fact that corresponding metaphors and the associated ontological shifts were gaining acceptance at the level of US military thinking with the *appropriation* of complexity science by military and civil defence experts in the 1990s, whose influence reached into high government offices from the turn of the millennium. Sean Lawson, 'Surfing on the edge of chaos: Nonlinear science and the emergence of a doctrine of preventive war in the US', *Social Studies of Science*, 41:4 (2011), pp. 563–84.

⁵⁰ John Arquilla and David Ronfeldt, *Swarming and the Future of Conflict* (Santa Monica, CA: RAND Corporation, 2000), p. 1.

⁵¹ Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, pp. vii–viii.

⁵² Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, p. vii.

⁵³ This is due to the increasing lethality of weapons, in particular weapons of mass destruction and precision-guided munitions, which render concentrations of mass on the battlefield vulnerable. Sean J. A. Edwards, 'Swarming and the Future of Warfare' (RAND Corporation, Santa Monica, CA, 2004), p. 1, available at: https://www.rand.org/pubs/rgs_dissertations/RGSD189.html, accessed 11 August 2025.

⁵⁴ Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, pp. 8–9.

⁵⁵ John Arquilla and David Ronfeldt, 'Looking Ahead: Preparing for Information-Age Conflict', in John Arquilla and David Ronfeldt (eds), *In Athena's camp: Preparing for conflict in the information age* (Santa Monica, CA: RAND Corporation, 1997), pp. 439–502 (p. 465).

swarming capabilities across the domains. Already in 1998, the US Air Force announced plans for the R&D of a robotic swarm of micro-loitering munition called *Low Cost Autonomous Attack System*. However, the project was terminated after a few years and several test flights. Efforts in this direction have been stepped up since the mid-2010s. In 2014, the US Navy's Office of Naval Research launched its *Low-Cost UAV*⁵⁶ *Swarming Technology* (LOCUST) programme with the aim to research, simulate, and demonstrate a batch of swarming drones that would be fired from a tube-based launcher. At the same time, the US Air Force began testing its *Perdix* micro-drones swarm that would be placed in the flare canisters of fighter jets and dropped at a low altitude.

The military interest in robotic swarming was co-developing with the new technoscientific field of swarm robotics. The field lies at the cusp of several interrelated research domains including AI, artificial life, and complex systems. It also borrows from (and relies heavily on) agent-based modelling techniques to first simulate and understand the behaviours that must ultimately be translated into algorithms.⁵⁷ Above all, however, the history of swarm robotics has its starting point in the concept of 'artificial swarm intelligence'.⁵⁸ This connection was already present in the development of the concept at the end of the 1990s, insofar as swarm behaviours can be 'used as a metaphor to design an algorithm, a multiagent system, or a group of robots'.⁵⁹ Moreover, it can guide the engineering of CAS as 'swarm intelligence offers an alternative way of designing "intelligent" systems, in which autonomy, emergence, and distributed functioning replace control, pre-programming, and centralization'.⁶⁰ 'Swarm intelligence' quickly became a catch-all phrase that refers to a large (and still growing) class of bio-inspired algorithms designed to artificially reproduce the decentralized cooperative behaviours of natural swarms.⁶¹ By mimicking the same simple rules of interaction that can be observed in natural swarms (or modelled and simulated by computers), it would be possible to develop robotic swarms that cooperate without central control and rely solely on the principles of swarm intelligence. Based on this research paradigm, the question arose as to how knowledge about swarm intelligence and swarm behaviour can be practically applied in robotics.⁶²

While there are numerous methods for creating a robot swarm,⁶³ there is a common understanding that robot swarms 'operate without centralized control and instead rely on simple local behaviours to cooperate'.⁶⁴ Brambilla et al. suggest that swarm robotics is based on the following principles: robots are (a) autonomous, (b) situated in the environment and can adapt their behaviour to modify it, (c) have local sensing and communication capabilities, (d) do not have access to centralized control or global knowledge, and (e) can cooperate to fulfil a mission.⁶⁵ Since its inception, swarm robotics has thus embraced the paradigm of self-organization, 'where the

⁵⁶ Unmanned Aerial Vehicle.

⁵⁷ Sebastian Vehlken, 'Pervasive Intelligence', *Digital Culture & Society*, 4:1 (2018), pp. 107–32.

⁵⁸ Bonabeau et al., *Swarm Intelligence*.

⁵⁹ Bonabeau et al., *Swarm Intelligence*, p. xii.

⁶⁰ Bonabeau et al., *Swarm Intelligence*, p. xi.

⁶¹ Andrew Ilachinski, 'AI, Robots, and Swarms: Issues, Questions, and Recommended Studies' (Center for Naval Analyses, Arlington, January 2017), p. 110, available at: <https://www.cna.org/reports/2017/ai-robots-and-swarms>, accessed 23 October 2024.

⁶² Gerardo Beni, 'From Swarm Intelligence to Swarm Robotics', in Erol Şahin (ed.), *Swarm robotics: Swarm Robotics Workshop held after the SAB 2004 International Workshop, Santa Monica, CA, USA, 17 July 2004; revised selected papers* (Berlin, Heidelberg: Springer, 2005), pp. 1–9.

⁶³ Manuele Brambilla, Eliseo Ferrante, Mauro Birattari and Marco Dorigo, 'Swarm robotics: a review from the swarm engineering perspective', *Swarm Intelligence*, 7:1 (2013), pp. 1–41; Adam J. Hepworth, Kate J. Yaxley, Daniel P. Baxter and Joshua C. Keene, 'Report on Applied Research Directions and Future Opportunities for Swarm Systems in Defence' (Australian Army Occasional Paper No. 11, Australian Army Research Centre, 2022), available at: https://researchcentre.army.gov.au/sites/default/files/op_11_-_swarming_and_counterswarming.pdf, accessed 11 August 2025.

⁶⁴ Muhammad M. Shahzad, Zubair Saeed, Asima Akhtar, Hammad Munawar, Muhammad H. Yousaf, Naveed K. Baloach and Fawad Hussain, 'A Review of Swarm Robotics in a NutShell', in Xiwang Dong, Mou Chen, Xiangke Wang and Fei Gao (eds), *Intelligent Coordination of UAV Swarm Systems* (Basel: MDPI, 2023), p.69–96 (p. 69).

⁶⁵ Brambilla et al., 'Swarm robotics: a review from the swarm engineering perspective', p. 39; see also Hepworth et al., 'Report on Applied Research Directions and Future Opportunities for Swarm Systems in Defence'.

swarm control is obtained via simple (stochastic) rules that define the way the robots interact with each other and with the environment without exploiting any form of centralized control or of global knowledge.⁶⁶ Centralized control approaches, on the contrary, would require the introduction of specific technologies that would make the system more vulnerable (by implementing a single point of failure) and also difficult to scale. In general, input by human operators should be minimized.⁶⁷

The military research and development of robotic swarms is no exception to these technoscientific imaginaries and guiding principles. According to the US Department of Defense (DoD), the *Perdix* swarm does not consist of pre-programmed, synchronized individual drones. Instead, the drones would 'share a distributed brain for decision-making and adapt to each other, and the environment, much like swarms in nature'.⁶⁸ Accordingly, communication by human commanders addresses the swarm and not the individual drone. In 2016, the DoD deployed 103 *Perdix* drones in a test. The DoD's Strategic Capabilities Office noted that this demonstration '[s]howed off Perdix's collective decision-making, adaptive formation flying, and self-healing abilities. The drones collectively decide that a mission has been accomplished, fly on to the next mission and carry out that one. The benefit of the swarm is that if one drone drops out – and a few appear[ed] to crash – the group can rearrange itself to maintain coverage'. The near-term goal, according to the Strategic Capabilities Office, is to scale the swarm to 1,000 drones to enable even more considerable swarm capabilities.⁶⁹ The Defense Advanced Research Projects Agency (DARPA) project 'Autonomous Multi-Domain Adaptive Swarms-of-Swarms' (AMASS) and the US Navy's Office of Naval Research project 'Advanced Autonomous Systems – Super Swarm' even aim to develop the capability to launch and command thousands of heterogeneous, autonomous uncrewed systems across aerial, surface, underwater, and ground domains – consistent with the Multi-Domain Operations doctrine of the US Army.⁷⁰ In 2023, the US DoD announced its 'Replicator Initiative' and set the task to quickly scale and field thousands of 'all-domain attritable autonomous' (AD2A) systems.⁷¹ While AD2A systems could operate as single agents, contracts have been awarded to companies that will develop 'Autonomous Collaborative Teaming' (ACT) software for the 'automated coordination of swarms of hundreds or thousands of uncrewed assets across multiple domains in order to improve their lethality and efficiency'.⁷² Research into the development of autonomous swarms for military purposes is also being carried out in numerous other countries such as China,⁷³ Russia,⁷⁴ Great

⁶⁶Marco Dorigo, Guy Theraulaz and Vito Trianni, 'Swarm Robotics: Past, Present, and Future [Point of View]', *Proceedings of the IEEE*, 109:7 (2021), pp. 1152–65 (p. 1158).

⁶⁷Ross Arnold, Kevin Carey, Benjamin Abruzzo and Christopher Korpela, 'What is A Robot Swarm: A Definition for Swarming Robotics', in Satyajit Chakrabarti and Himadri N. Saha (eds), *2019 10th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON): 10–12 October 2019, Columbia University, New York, USA* (Piscataway, NJ: IEEE, 2019), pp. 74–81 (p. 74).

⁶⁸Amy Hudson, 'The looming swarm', *Air and Space Forces Magazine* (22 March 2019), available at: <https://www.airandspaceforces.com/article/the-looming-swarm/> accessed 11 August 2025.

⁶⁹Hepworth et al., 'Report on Applied Research Directions and Future Opportunities for Swarm Systems in Defence', p. 38.

⁷⁰David Hambling, 'The US Navy wants swarms of thousands of small drones', *MIT Technology Review* (24 October 2022), available at: <https://www.technologyreview.com/2022/10/24/1062039/us-navy-swarms-of-thousands-of-small-drones/> accessed 11 August 2025.

⁷¹Kathleen Hicks, 'Keynote Address: The Urgency to Innovate', Washington, D.C., 28 August 2023, available at: <https://www.defense.gov/News/Speeches/Speech/Article/3507156/deputy-secretary-of-defense-kathleen-hicks-keynote-address-the-urgency-to-innov/> accessed 11 August 2025.

⁷²Defense Innovation Unit Announces Software Vendors to Support, *Defense Innovation Unit* (20 November 2024), available at: <https://www.diu.mil/latest/defense-innovation-unit-announces-software-vendors-to-support-replicator> accessed 11 August 2025.

⁷³Elsa Kania, 'Swarms at War: Chinese Advances in Swarm Intelligence', *China Brief*, 17:9 (2017), available at: <https://jamestown.org/program/swarms-war-chinese-advances-swarm-intelligence/>, accessed 11 August 2025.

⁷⁴Samuel Bendett, 'Strength in Numbers: Russia and the Future of Drone Swarms', *Modern War Institute at West Point* (20 April 2021), available at: <https://mwi.westpoint.edu/strength-in-numbers-russia-and-the-future-of-drone-swarms/> accessed 11 August 2025.

Britain,⁷⁵ India,⁷⁶ Turkey,⁷⁷ Israel, South Korea,⁷⁸ Australia,⁷⁹ and Ukraine. Within the EU, national swarm R&D programmes exist in Germany, France, Finland, the Netherlands, and Italy⁸⁰ as well as in the context of the multi-national projects Swarm-C-3⁸¹ and AI-WASP,⁸² funded by the European Defence Fund.

Until recently, developments in this area were mostly experimental and operationalization typically came in the form of computer simulations⁸³ or physical tries in laboratories or other structured and controlled testing sights. In 2020, a policy report stated that robotic swarming is 'not yet operational, and the technology is rather brittle, but the prospect of swarms is very real'.⁸⁴ However, the wars in Middle East and Ukraine serve as an accelerator of innovation as they provide 'living labs' for the experimental development, 'prototyping'⁸⁵ and deployment of swarm technologies.⁸⁶ Already in May 2021, the Israeli Defence Forces used Elbit Systems' Legion-X drone swarm in combat against Hamas to search for targets and relay information. According to the company, the swarm has 'adaptive, complex, collective behaviours for intelligent movement, decisions, and interactions with the environment'.⁸⁷ In November 2024, Germany announced that it will deliver 4.000 HX-2 Karma drones to Ukraine, produced by the German defence technology company Helsing.⁸⁸ The company claims that 'multiple HX-2s can assemble into swarms', that the

⁷⁵Defence Science and Technology Laboratory and Defence and Security Accelerator, 'Swarming drones concept flies closer to reality', *Government of the UK Press Release* (28 January 2021), available at: {<https://www.gov.uk/government/news/swarming-drones-concept-flies-closer-to-reality>} accessed 11 August 2025.

⁷⁶Joe Sabala, 'Indian Army Inducts New Swarm Drone Systems', *The Defense Post* (30 August 2022), available at: {<https://www.thedefensepost.com/2022/08/30/indian-army-swarm-drone/>} accessed 11 August 2025.

⁷⁷David Hambling, 'Turkish Military To Receive 500 Swarming Kamikaze Drones', *Forbes* (17 June 2020), available at: {<https://www.forbes.com/sites/davidhambling/2020/06/17/turkish-military-to-receive-500-swarming-kamikaze-drones/?sh=1fe1f730251a>} accessed 11 August 2025.

⁷⁸Bryan Harris, 'South Korea to create "drone-bot combat unit" to swarm North', *Financial Times* (6 December 2017), available at: {<https://www.ft.com/content/6878ba90-da1a-11e7-a039-c64b1c09b482>} accessed 11 August 2025.

⁷⁹A swarm of technological advances', *Australian Government Defence* (15 August 2023), available at: {<https://www.defence.gov.au/news-events/news/2023-08-15/swarm-technological-advances>} accessed 11 August 2025.

⁸⁰Heiko Borchert, Torben Schütz and Joseph Verbovsky (eds), *The Very Long Game: 25 Case Studies on the Global State of Defense AI* (Cham: Springer Nature, 2024).

⁸¹'Insta takes part in SWARM-C3 project funded by European Defence Fund' (20 May 20224), available at: {<https://www.insta.fi/en/defence-and-aviation/news/news/insta-takes-part-in-swarm-c3-project-funded-by-european-defence-fund/>} accessed 11 August 2025.

⁸²'Patria-led Artificial Intelligence Warfare Adaptive Swarm Platform to receive €45 M in EU funding to reinforce Europe's defence capabilities', *Army Technology* (13 May 2025), available at: {<https://www.army-technology.com/news/patria-ai-wasp-e45m-eu/>} accessed 12 August 2025.

⁸³Theresa Hitchens, 'AFRL's Golden Horde to Test Swarming Munitions in Digital 'Colosseum'', *Breaking Defense* (5 March 2021), available at: {<https://breakingdefense.com/2021/03/afrls-golden-horde-to-test-swarming-munitions-in-digital-colosseum/>} accessed 11 August 2025.

⁸⁴Ekelhof and Paoli, *Swarm Robotics*, p. 1.

⁸⁵Marijn Hoijsink, 'Prototype warfare': Innovation, optimisation, and the experimental way of warfare', *European Journal of International Security*, 7:3 (2022), pp. 322–36.

⁸⁶Gian Volpicelli, Veronika Melkozerova and Laura Kayali, "Our Oppenheimer moment" – In Ukraine, the robot wars have already begun', *Politico* (16 May 2024), available at: {<https://www.politico.eu/article/robots-coming-ukraine-testing-ground-ai-artificial-intelligence-powered-combat-war-russia/>} accessed 12 August 2025; Anis Raiss, 'Digital kill chains': The dark side of tech in warfare', *The Cradle* (6 June 2024), available at: {<https://thecradle.co/articles-id/25311>} accessed 11 August 2025.

⁸⁷David Hambling, 'Israel used world's first AI-guided combat drone swarm in Gaza attacks', *New Scientist* (30 June 2021), available at: {<https://www.newscientist.com/article/2282656-israel-used-worlds-first-ai-guided-combat-drone-swarm-in-gaza-attacks/>} accessed 11 August 2025; David Hamblin, 'Israel's Combat-Proven Drone Swarm May Be Start of a New Kind of Warfare', *Forbes* (21 June 2021), available at: {<https://www.forbes.com/sites/davidhambling/2021/07/21/israels-combat-proven-drone-swarm-is-more-than-just-a-drone-swarm/>} accessed 11 August 2025; David Hambling, 'Israel Rolls Out Legion-X Drone Swarm For The Urban Battlefield', *Forbes* (24 October 2022), available at: {<https://www.forbes.com/sites/davidhambling/2022/10/24/israel-rolls-out-legion-x-drone-swarm-for-the-urban-battlefield/>} accessed 11 August 2025.

⁸⁸'Germany Confirms Delivery of 4,000 HX-2 Karma Loitering Munitions to Ukraine', *Global Defense News* (18 November 2024), available at: {<https://www.armyrecognition.com/news/army-news/army-news-2024/breaking-news-germany-confirms-delivery-of-4-000-hx-2-karma-loitering-munitions-to-ukraine?highlight=WYJoZWxzaW5nIl0>} accessed 11 August 2025.

drone is resilient to hostile electronic warfare and jamming ‘through its ability to search for, re-identify and engage targets even without a signal or a continuous data connection’, and that these capabilities have been ‘developed and tested through Helsing’s extensive experience in Ukraine.’⁸⁹ While we should not take military and developer claims at face value, they nonetheless display the technoscientific promise of these endeavours: a robotic swarming mimicking the behaviour of natural swarms, enabling a higher level of autonomy, adaptability and, ultimately, effectiveness. Echoing Arquilla’s and Ronfeldt’s analysis of the advantages of military swarming, robotic swarms are intended to ‘autonomously overwhelm an adversary in offensive and defensive operations with a large variety of mission profiles’⁹⁰, such as intelligence, surveillance, and reconnaissance, working together to destroy an enemy’s defences (particularly Anti-Access and Area-Denial systems employed by peer-state adversaries), coordinated attacks or manoeuvres to deceive the enemy, overwhelming enemy forces with large numbers of vehicles and assisting in the delivery of conventional and nuclear weapons.⁹¹ In light of the expectation that swarms are more versatile, efficient, and resilient, the use of individual platforms, both teleoperated and (semi-)autonomous, appears ineffective, costly, and time-consuming.⁹² This disadvantage would also apply to groups or teams of pre-programmed robots that are not networked and therefore cannot make decisions in real-time or react to external stimuli.⁹³ Autonomy and self-organization, hence, should be seen as prerequisites for swarm-enabled superiority on the battlefields of the future.

Complexity sciences not only provided the blueprint for making the military ‘intelligently life-like’ but also offered a design script for weapons ‘to have properties of living systems.’⁹⁴ This goes, however, beyond the informationalization of weapons – that is, the creation of so-called smart weapons. Based on the new understanding of life as informational and the expansion of the realm of life from the biological to the mechanical and electronic, it has become possible to think and create entanglements and translations between different forms of life, both natural and artificial. Robotic swarming precisely takes advantage of this transversality. Here, swarming is ‘not solely metaphoric but made intelligible through specific understandings of animals that are then used to make possible new assemblages of people and animals, new forms of social relations, and new technologies.’⁹⁵ Already the concept ‘swarm intelligence’, while initially referring to CAS as natural phenomena, was meant to inform the programming of algorithms that would enable the translation of the laws of living emergent collectives to the design-principles of self-organizing multiagent systems. From here, it was only a small step to capitalize on the new technoscientific field of swarm robotics to enhance capabilities in the military realm. Today, swarming forms part of the more-than-human biopolitics of war. In a contradictory connection, military swarming implies a symbiosis of previously separate worlds, which in turn becomes an instrument for the fundamental biopolitical caesura between the life that must be protected and the life that must be destroyed for this purpose. However, by applying the principles of life to its destruction, biomimetic swarms not only inherit the desired properties of natural swarms but also their inherent riskiness: the continuous and contingent becoming dangerous of life understood in terms of information.

⁸⁹‘Helsing unveils intelligent strike drone for mass and precision’, *Helsing* (Press Release, 2 December 2024), available at: <https://helsing.ai/newsroom/helsing-unveils-intelligent-strike-drone-for-mass-and-precision> accessed 11 August 2025.

⁹⁰Hepworth et al., *Report on Applied Research Directions and Future Opportunities for Swarm Systems in Defence*, p. 39.

⁹¹Johnson, ‘Artificial Intelligence, Drone Swarming and Escalation Risks in Future Warfare’.

⁹²Irving Lachow, ‘The upside and downside of swarming drones’, *Bulletin of the Atomic Scientists*, 73:2 (2017), pp. 96–101.

⁹³Daniel M. Gerstein and Erin N. Leidy, ‘Emerging Technology and Risk Analysis: Unmanned Aerial Systems Intelligent Swarm Technology’ (Santa Monica, CA, RAND Corporation, 2024), p. 4, available at: https://www.rand.org/pubs/research_reports/RRA2380-1.html, accessed 9 August 2025.

⁹⁴Dillon and Reid, *The Liberal Way of War*, pp. 110–11.

⁹⁵Jake Kosek, ‘Ecologies of Empire: On the New Uses of the Honeybee’, *Cultural Anthropology*, 25:4 (2010), pp. 650–78 (p. 665).

The emergency of emergent swarm behaviours

One of the central features of robotic swarming is emergent behaviour that may or may not have been intended by human operators. Oftentimes, emergent behaviours are desired but difficult to control.⁹⁶ In other cases, they may even act counter to the operator's intent and 'fail' the mission objectives. Emergence of swarm behaviour results from the non-linearity of connections within the swarm: systems with a large number of parts that are linearly coupled are less prone to 'failure' than systems with the same (or even fewer) number of parts that are non-linearly coupled and in which small local changes can induce disproportionately large global effects.⁹⁷ CASs are particularly prone to display surprising or even unwanted behaviour because of the inherent unknowability of the complete set of global behaviours that can arise from this non-linear coupling. Failures can result via interactions within the swarm (e.g., the logic that defines how a robotic swarm ought to behave), interactions with a human operator (which may have unanticipated effects on the swarm's behaviour), or via a dynamic coupling with the environment (in which a swarm may encounter contexts that were not anticipated by its designers).⁹⁸ Even in computer simulations, the same scenario might produce drastically different results depending on the swarm's initial state.⁹⁹ When moving to real-world scenarios, environmental conditions, hardware, and software peculiarities and a myriad of other issues will present themselves, making results even less predictable.

Therefore, emergent behaviour is said to be both a blessing and a curse.¹⁰⁰ On the one hand, the emergent behaviour of a robotic swarm enables a higher level of autonomy, adaptability, and, ultimately, effectiveness in achieving complex operational tasks. On the other hand, emergence challenges the predictability of swarm behaviours. As a study of the US Defense Science Board states, 'predicting collective behaviours from the rules followed by individual entities is difficult, and today it would be difficult to know *a priori* if the collective's adaptive responses would be beneficial or detrimental to a military mission'.¹⁰¹ In a worst-case scenario, swarms would kill (too many) civilians or friendly fire.

It is precisely this problematizing of emergence that already prompted Arquilla and Ronfeldt to stress the difference between swarming as a military tactic and swarming as it occurs in nature. Even though they draw inspiration from complexity sciences, they are advocating a military swarming concept that is less built on basic individual rules of behaviour and, hence, on emergent self-organization and coordination. What would be lacking in the models that can be derived from observing swarming in the natural world is 'topsight', a superior situational awareness. In military operations, a lack of topsight may result in ineffective or inefficient behaviour or simply indecision.¹⁰² Therefore, 'it is not at all clear that real military swarm forces will be – or should be – fully autonomous or lacking in central strategic control. [...] Someone must – it seems in the military case – retain topsight'.¹⁰³

Ultimately, then, swarming becomes an issue under IHL. Since robot swarms are to be regarded as unpredictable, there is a risk of losing (meaningful) human control over central acts of war, e.g. decisions to attack a target. Consequently, emergent swarm behaviour challenges the possibility of ascribing responsibility to a human operator 'on the loop'. This 'human on the loop' is central to many state positions at discussions within the UN's Convention on Certain Conventional Weapons

⁹⁶ Zsolt Kira and Mitchell A. Potter, 'Exerting human control over decentralized robot swarms', in Gourab Sen Gupta (ed.), *Proceedings of the Fourth International Conference on Autonomous Robots and Agents: James Cook Hotel Grand Chancellor, Wellington, New Zealand, February 10–12, 2009* (Piscataway, NJ: IEEE, 2009), pp. 566–71.

⁹⁷ Ilachinski, *AI, Robots and Swarms*, p. 101.

⁹⁸ Ilachinski, *AI, Robots and Swarms*, p. 102.

⁹⁹ Jens Hälterlein, 'Conflicting Values in Epidemiological Modelling, Simulation, and Dashboard-Design', *Digital Culture & Society*, 9:2 (2023), pp. 161–80.

¹⁰⁰ Ekelhof and Paoli, *Swarm Robotics*, p. 55.

¹⁰¹ US Defense Science Board, 'Report of the Defence Science Board Summer Study on Autonomy' (Washington, DC, June 2016), p. 84, available at: <https://www.hsdl.org/?abstract&did=794641>, accessed 11 August 2025.

¹⁰² Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, p. 64.

¹⁰³ Arquilla and Ronfeldt, *Swarming and the Future of Conflict*, p. 49.

(CCW) – including the US – with regard to the question of how the use of LAWS can be legitimized ethically and, most importantly, under IHL.¹⁰⁴ In this context ‘human-on-the-loop’ means that human operators determine the mission purpose of LAWS and would have the option to abort the mission at any given moment. On the side of the human operators, there is no need for control over the implementation of a mission by means of tactical decisions (human-in-the-loop), but they should be in the position ‘to exercise appropriate levels of human judgment over the use of force’.¹⁰⁵ Moreover, as some proponents of LAWS argue (including state representatives at the CCW level), even if the human is ‘out of the loop’, it would still be possible to use LAWS in a responsible, legal, and safe way insofar the ‘types of combated objects have been previously defined by a human according to the specific criteria. In other words, a man [sic!] decides earlier in what manner the autonomous combat system will carry out its tasks’.¹⁰⁶

However, in the case of autonomous robotic swarms, given the unpredictability of emergent swarm behaviours, neither a ‘human on the loop’ nor pre-programming can eliminate the risk of failures leading to ‘unintended engagements’¹⁰⁷ since ‘there is an irreducible uncertainty in the effect any change – however small – will have on the swarm’s overall behavior’.¹⁰⁸ What the transition from individual (semi-)autonomous weapon systems to autonomous swarms changes, is that the execution of a mission according to predefined parameters (however flawed this execution may be) is transformed into an ‘emergent rule-set’.¹⁰⁹ The threat scenario resulting from this is ‘a fully autonomous(s)war(m) machine whose control would be totally immanent to itself – in other words, for which there would be no outside from which to exert control over it’.¹¹⁰ This problematization of emergence, however, is as much an issue of controlling robotic swarms as it is a central characteristic of contemporary biopolitics. Life understood as contingent, emergent, continuously adapting and unfolding its potential, is a life ‘that is continuously becoming dangerous to itself, and to other life forms’¹¹¹ – especially from the perspective of security and war. The problematization of life and the politics of life itself, thus, shift from the actual to the potential. If life takes the form of CAS, then life exists in the permanent ‘emergency of its own emergence’.¹¹² As Brian Massumi states, ‘the futurity of unspecified threat is affectively held in the present in a perpetual state of potential emergence(y)’.¹¹³ Consequently, the biopolitics of security and war now revolve around this permanent state of emergency, uncertainty, and unpredictability,¹¹⁴ which has drawn many security agencies’ attention to ‘unknown unknowns’¹¹⁵ and abstract threats ‘that are

¹⁰⁴ Automated Decision Research, ‘Convergences in state positions on human control’ (May 2023) available at: <https://automatedresearch.org/news/report/convergences-in-state-positions-on-human-control/>, accessed 11 August 2025.

¹⁰⁵ U.S. Department of Defense, ‘Directive Number 3000.09: Autonomy in Weapon Systems’ (25 January 2023), p. 3, available at: <https://media.defense.gov/2023/Jan/25/2003149928/-1/-1/0/DOD-DIRECTIVE-3000.09-AUTONOMY-IN-WEAPON-SYSTEMS.PDF>, accessed 9 August 2025.

¹⁰⁶ Tadeusz Zieliński, ‘Factors Determining a Drone Swarm Employment in Military Operations’, *Safety & Defense*, 7:1 (2021), pp. 59–71 (p. 68).

¹⁰⁷ US Department of Defense, *Directive Number 3000.09*, p. 1.

¹⁰⁸ Ilachinski, ‘AI, Robots and Swarms’, p. 133.

¹⁰⁹ Ian G. Shaw, ‘Robot Wars: US Empire and geopolitics in the robotic age’, *Security Dialogue*, 48:5 (2017), pp. 451–70 (p. 460).

¹¹⁰ Antoine Bousquet, ‘The Persistent Appeal of Chaoplex Warfare: Towards an Autonomous S(War)M Machine?’, in Artur Gruszczak and Sebastian Kaempf (eds), *Routledge Handbook of the Future of Warfare* (London, New York: Routledge Taylor & Francis Group, 2024), pp. 227–37 (p. 236).

¹¹¹ Dillon and Reid, *The Liberal Way of War*, p. 85.

¹¹² Dillon and Reid, *The Liberal Way of War*, p. 86.

¹¹³ Brian Massumi, *Ontopower: War, Powers, and the State of Perception* (Durham, London: Duke University Press, 2015), p. 15.

¹¹⁴ Cooper, *Life as Surplus*, p. 89.

¹¹⁵ Christopher Daase and Oliver Kessler, ‘Knowns and Unknowns in the ‘War on Terror’: Uncertainty and the Political Construction of Danger’, *Security Dialogue*, 38:4 (2007), pp. 411–34.

more diverse, less visible and less predictable.¹¹⁶ Henceforth, the anticipation of possibilistic risks¹¹⁷ based on the imagination of worst-case scenarios¹¹⁸ should complement probabilistic risk calculations. According to this new excessive culture of insecurity, Western societies and their populations are no longer threatened by a clearly identifiable enemy but rather by a heterogeneous spectrum of threats, ranging from terrorism to large-scale disasters and the spread of viruses throughout physical and virtual space. Contemporary biopolitics of security and war are not only concerned with fighting the opponent's strengths but also with reducing Western societies' perceived weaknesses and vulnerabilities. It addresses the ambiguity of the technological constitution of a physical and virtual network society.¹¹⁹ Digital infrastructures and information and ICTs are considered to be the lifelines of these societies and a source of their susceptibility to global terror networks, cyberattacks, natural disasters, major accidents, and highly contagious diseases. As 'vital systems',¹²⁰ they simultaneously foster new forms of vulnerability.

Of course, this also applies to the modalities of biopolitics: if the technological means to wage wars are reframed in complex adaptive emergent terms and built according to these terms, 'then the epicentre of enmity, fear and danger moves from the external other to the very internal [...], namely its own complex adaptive and emergent properties'.¹²¹ Robotic swarms are hence not only an imitation of life as information and its self-organizing, adaptive properties but also a reproduction of its inherent dangerousness of its emergency of emergence.

Towards a new command and control paradigm

While the uncertainty and risks associated with emergent swarm behaviour cannot be eradicated since non-linear connectivity is both, the very condition of its possibility and the cause of its inherent dangerousness, there is a widespread belief among the proponents of robotic swarming that it is nonetheless possible to maintain a specific form of control and to manage the risks accordingly. From a swarm engineering perspective, new design and modelling approaches are needed. Given the 'inherent absence of centralized/higher-level control', the control of swarm behaviour must be achieved 'indirectly', through the modification of the basic rules that govern individual agent behaviour or of the parameters that 'tune' these rules.¹²² However, according to Scharre and others, maintaining human control over emergent swarm behaviour would not only require technological solutions but also a new, less hierarchical and less centralized C2 paradigm. This would mean moving beyond paradigms where commanders directly control the actions of attached forces to one where the former supervise the mission at the command level and the latter operate independently.¹²³ According to this C2 paradigm of 'mission command',¹²⁴ a human operator should

¹¹⁶European Council, 'The Stockholm Programme: An Open and Secure Europe Serving and Protecting Citizens', (Brussels, 2009), p. 30, available at: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2010:115:0001:0038:EN:PDF>, accessed 9 August 2025.

¹¹⁷Louise Amoore, *The Politics of Possibility: Risk and Security Beyond Probability* (Durham, London: Duke University Press, 2013).

¹¹⁸Claudia Aradau, 'Security That Matters: Critical Infrastructure and Objects of Protection', *Security dialogue*, 41:5 (2010), pp. 491–514.

¹¹⁹M. S. Dillon, 'Network Society, Network-Centric Warfare and the State of Emergency', *Theory, Culture & Society*, 19:4 (2002), pp. 71–9.

¹²⁰Andrew Lakoff and Stephen Collier, 'Infrastructure and Event: The Political Technology of Preparedness', in Bruce Braun (ed.), *Political Matter: Technoscience, Democracy, and Public life* (Minneapolis, Minn.: University of Minnesota Press, 2010), pp. 243–66.

¹²¹Dillon and Reid, *The Liberal Way of War*, p. 107.

¹²²John Harvey, 'The Blessing and Curse of Emergence in Swarm Intelligence Systems', in Hussein A. Abbass Amein, Jason Scholz and Darryn J. Reid (eds), *Foundations of trusted autonomy* (Cham: Springer, 2018), pp. 117–24 (p. 121).

¹²³Scharre, 'Robotics on the Battlefield', p. 6.

¹²⁴US Army, 'Mission Command: Command and Control of Army Forces, Field Manual 6–0', Headquarters, United States Department of the Army, Washington, DC, 2003.

execute mission-level control by providing higher-level instructions but decentralize the execution of the mission to the swarm and delegate lower-level decision-making accordingly.¹²⁵ The ultimate goal, then, is to have an adaptive swarm that reacts to its surroundings in accordance with a commander's intent.¹²⁶

A significant part of R&D in the field of swarm robotics therefore focuses on Human–Swarm Interaction, a variation of Human–Machine Interaction.¹²⁷ DARPA's Collaborative Operations in Denied Environment (CODE) programme, for instance, aimed at 'developing and demonstrating improvements in collaborative autonomy – the capability of groups of UAS to work together under a single person's supervisory control. The unmanned vehicles would continuously evaluate their own states and environments and present recommendations for coordinated UAS actions to a mission supervisor, who would approve or disapprove such team actions and direct any mission changes'.¹²⁸ Another concept that is closely related to HSI is human–swarm Teaming (HST). HST is based on the broader concept 'human–machine teaming' that is highlighted as a key requirement of future military operations both by the US DoD's *Unmanned Systems Integrated Roadmap 2017–2042*¹²⁹ and the *US Army Unmanned Aircraft Systems Roadmap 2010–2035*.¹³⁰ The DARPA project, *OFFensive Swarm-Enabled Tactics* (OFFSET), for instance, pursued the goal of creating swarms of up to 250 robots that can be employed by small infantry units in HST mode to carry out missions in complex urban environments.¹³¹ HST should provide the ability to 'interact with such swarms'.¹³² The intentions of the swarm commander should be translated into machine-readable swarm tactics which should thus enable complex HST. They are the core of what the project calls 'swarm interaction grammar' and would enable the swarm to 'understand' what the commander wants it to do and the commander to understand what the swarm is actually doing. Tactics are recorded in a playbook and are composed of primitives – individual behaviours that can be translated into algorithms. In HST (as in HIS and HMI), information flow is bi-directional and influencing of behaviour is recursive – which is precisely why the term 'teaming' is used instead of 'control'.

However, this understanding of the possibilities (and limits) of controlling a swarm has to be understood against the background of a general shift in the conception of C2 brought about by the NCW doctrine. According to Arquilla and Ronfeldt – who not only authored the aforementioned seminal work on swarming in the military but were also arguably one of the most influential exponents of complexity theory in military affairs in general – to fully acknowledge information 'as a basic and overarching dynamic of all theory and practice about warfare in the information age'¹³³ would require a wholesale 'rethinking of the very basis of military organization, doctrine

¹²⁵Ekelhof and Paoli, *Swarm Robotics*, p. 32.

¹²⁶Paul Scharre, 'How swarming will change warfare', *Bulletin of the Atomic Scientists*, 74:6 (2018), pp. 385–9.

¹²⁷Hepworth et al., 'Report on Applied Research Directions and Future Opportunities for Swarm Systems in Defence', p. 26; for an overview see: Victoria Steane, Jemma Oakes, Samson Palmer and Mark Chattington, 'Human-Swarm Partnerships: A Systematic Review of Human Factors Literature', *Human Factors in Robots, Drones and Unmanned Systems*, Vol. 93 (2023), p. 121–131.

¹²⁸'CODE: Collaborative Operations in Denied Environment', DARPA, available at: {<https://www.darpa.mil/research/programs/collaborative-operations-in-denied-environment>} accessed 12 August 2025.

¹²⁹Office of the Assistant Secretary of Defense, 'Unmanned Systems Integrated Roadmap 2017–2042' (Washington, D.C.: 2018), available at: {<https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/AD1059546.xhtml>} accessed 12 August 2025.

¹³⁰US Army. Unmanned Aircraft Systems. Center of Excellence, 'Eyes of the Army. US Army roadmap for unmanned aircraft systems' (Fort Rucker, Alabama: 2010), available at: {<https://rosap.ntl.bts.gov/view/dot/18249>} accessed 12 August 2025.

¹³¹OFFSET: OFFensive Swarm-Enabled Tactics, DARPA, available at: {<https://www.darpa.mil/program/offensive-swarm-enabled-tactics>} accessed 12 August 2025.

¹³²OFFSET Envisions Swarm Capabilities for Small Urban Ground Units, DARPA, available at: {<https://www.darpa.mil/news-events/2016-12-07>} accessed 12 August 2025.

¹³³John Arquilla and David Ronfeldt, 'Information, Power, and Grand Strategy: In Athena's Camp', in John Arquilla and David Ronfeldt (eds), *In Athena's Camp: Preparing for Conflict in the Information Age* (Santa Monica, CA.: RAND Corporation, 1997), pp. 141–72 (p. 154).

and strategy'.¹³⁴ These 'major innovations', Arquilla and Ronfeldt argue, need to effect 'a shift from hierarchies to networks. The traditional reliance on hierarchical design may have to be adapted to network-oriented models to allow greater flexibility, lateral connectivity and teamwork across institutional boundaries. The traditional emphasis on C2, a key strength of hierarchy, may have to give way to an emphasis on consultation and coordination, the crucial blocks of network designs'.¹³⁵ This orientation towards the network resulted in a limitation of control as such. As noted in a publication of the DoD's *Command and Control Research Program* that had a major influence on the NCW doctrine, it would be crucial to accept that '[c]ontrol is not something that can be imposed on a complex adaptive system, particularly when there are many independent actors. Control, that is, ensuring that behaviour stays within or moving to within acceptable bounds, can only be achieved indirectly'.¹³⁶ This orientation towards changing environmental conditions in turn resulted in the need to dissolve rigid forms of military conduct. In 1996, the revised version of the US Marine Corps's C2 doctrine postulated that '[a]n effective command and control system provides the means to adapt to changing conditions. We can thus look at command and control as a process of continuous adaptation'.¹³⁷ During a conference sponsored by the National Defense University and the RAND Corporation, Major John Schmitt (who led the effort to revise the Marine Corps manual) made the claim that the main lesson to learn from complexity sciences was 'that the object of command and control is not to achieve control but to keep the entire organization surfing on the edge of being "out of control", because that is where the system is most adaptive, creative, flexible, and energized'.¹³⁸

Such a non-hierarchical process of coordination within networks, continuous adaptation to changing environmental conditions (both the environment of the battlespace and the environment within a human-machine interaction), and orientation towards the 'edge of chaos' now represents the core of the new approach to C2 of swarming. Here, the 'emergency of emergence' is governed by a liberal 'apparatus of security'.¹³⁹ swarming is problematized as an autonomous domain of existence with its own laws and dynamics that liberal rule itself has to acknowledge and to treat as limits of government in order to govern effectively. Analogous to the biopolitical government of human populations, liberal rule has to govern biomimetic swarms by encouraging the autonomous existence and the self-regulation of the subject(s) of government as well as to operate between the twin dangers of governing too little and governing too much¹⁴⁰ in relation to the continuous becoming dangerous of this autonomy and self-government. Governing too little would mean to not deal with the risk of emergent swarm behaviours that fail or run contrary to mission objectives. Governing too much would mean interfering with emergent swarm behaviours in a way that diminishes the self-organizing and adaptive capabilities of swarming or even producing precisely the unwanted behaviours that it meant to prevent from happening. Against the background of this liberal problematization of emergence, the governing of swarming follows the model of an economic calculation: it offsets the benefits of emergence with the costs of emergence. Consequently, it seeks to maximize the positive elements of emergent swarm behaviours while minimizing what

¹³⁴ Arquilla and Ronfeldt, *Information, Power, and Grand Strategy*, p. 156.

¹³⁵ John Arquilla and David Ronfeldt, 'Cyberwar is Coming!', in John Arquilla and David Ronfeldt (eds), *In Athena's Camp: Preparing for Conflict in the Information Age* (Santa Monica, CA: RAND Corporation, 1997), pp. 23–60 (p. 45).

¹³⁶ David S. Alberts and Richard E. Hayes, *Power to the Edge Command, Control in the Information Age* (Washington, DC: CCRP Publication Series, 2003), p. 208.

¹³⁷ US Marine Corps, 'Command and Control' (Marine Corps Doctrinal Publications No. 6, Washington, DC, October 1996), p. 46.

¹³⁸ John F. Schmitt, 'Command and (Out of) Control: The Military Implications of Complexity Theory', in David S. Alberts and Thomas J. Czerwinski (eds), *Complexity, Global Politics, and National Security* (Washington, DC, 1997), pp. 99–111 (p. 108).

¹³⁹ Michel Foucault, *Security, Territory, Population: Lectures at the Collège de France, 1977–78* (Basingstoke, Hampshire, New York, NY: Palgrave Macmillan, 2007), p. 21.

¹⁴⁰ Mitchell Dean, 'Power at the heart of the present: Exception, risk and sovereignty', *European Journal of Cultural Studies*, 13:4 (2010), pp. 459–75 (p. 463).

is risky about it. In this modality of risk management, emergence is viewed as unproblematic as long as it stays in an appropriate range. It turns out that emergence is not only a necessity of the operation but a carefully specified and policed parameter of robotic swarming. The questions arise of how much emergence is enough and what kinds of emergence are allowable.¹⁴¹ More precisely, if the optimal state of a CAS is on the 'edge of chaos', it must be prevented from crossing this edge without staying too far away from it. By navigating between these twin dangers of governing too much and governing too little, the C2 of swarming is becoming a CAS f: to govern (a swarm) means to continuously adapt to the changing environmental conditions of government.

However, in the vision of C2 articulated by HST approaches, this CAS is different from the CAS that a robotic swarm already constitutes itself. Here, the 'teaming' of a non-human CAS (the swarm) with a human CAS (the corresponding C2 node) creates a new hybrid CAS that is essentially based on information flows and whose structure (the networking and connectivity of the individual, human and non-human elements) adaptively adjusts to changing environmental conditions. In this re-conceptualization of C2 according to informational terms, the human operator or commander is 'reduced' to a node in the 'network of ordering without orderers, facilitating and empowering the network of order rather than ruling it sovereignly from above'¹⁴² and control, if this is still the appropriate term at all, becomes more-than-human.

Conclusion

While critical security studies have long criticized a naïve-realist understanding that renders the non-human neutral, passive and separate from human agency and thus insignificant for the constitution and transformation of (international) political order,¹⁴³ securitization practices¹⁴⁴ and the conduct of war,¹⁴⁵ robotic swarms resist a reading that sees them merely as 'slavish instruments of human minds'.¹⁴⁶ Hence, the advent of military swarming points to the need for more-than-human ontologies of war that incorporate the entanglements of humans and non-humans.

In order to critically reflect the re-ordering of the human and the non-human within contemporary biopolitics, I show how general transformations in the very conception of life (and thus of the referent objects of liberal rule and war) made it possible to cognize and create these more-than-human assemblages in the first place. Just as much as NCW, military swarming is the result of the adoption of the new understanding of life established by complexity science and reflected by a new politics of life itself. Based on the new understanding of life as informational and the expansion of the realm of life, entanglements and translations between different forms of life, both natural and artificial, have become possible. Robotic swarming, hence, forms part of a shift in the biopolitical modalities of war insofar as life itself becomes the design principle of the weapons by which wars are waged. Thereby, the biopolitics of war is becoming more-than-human.

However, contemporary biopolitics not only manifests in more-than-human assemblages. It also manifests in a potential loss of human control over these assemblages as the biomimetic approach to robotic swarming capitalizes on the laws of emergence 'observed' in nature while simultaneously releasing what is risky about these laws: the uncertainty, unpredictability, and uncontrollability that form part of any CAS. Consequently, military swarming now revolves around the permanent state of emergency triggered by the imitation of life as information and its self-organizing, adaptive properties. The analysis of robotic swarming through the lens of a more-than-human biopolitics has enabled us to reinterpret its problematization as potentially running

¹⁴¹Dillon and Reid, *Global Liberal Governance: Biopolitics, Security and War*, p. 97.

¹⁴²Dillon and Reid, *Global Liberal Governance: Biopolitics, Security and War*, p. 92.

¹⁴³Peer Schouten, 'The materiality of state failure: Social contract theory, infrastructure and governmental power in Congo', *Millennium – Journal of International Studies* 41:3 (2013), pp. 553–574 (p. 563).

¹⁴⁴Aradau, *Security That Matters: Critical Infrastructure and Objects of Protection*, p. 493.

¹⁴⁵Erika Cudworth and Steve Hobden, 'The posthuman way of war', *Security Dialogue*, 46:6 (2015), pp. 513–29.

¹⁴⁶Shaw, *Robot Wars: US Empire and Geopolitics in the Robotic Age*, p. 45.

out of human control in terms of this re-conceptualization and appropriation of a more-than-human life. While the war machine, as Deleuze and Guattari put it, 'is of another species, another nature, another origin'¹⁴⁷ than the state but can be appropriated and tamed by the state to become part of its 'professional army'¹⁴⁸ and fulfil its sovereign purposes, it nonetheless remains exterior to the state and this purpose.

The more-than-human war machine, however, does not evade any form of government. It may elude forms of C2 that are based on the subordination of the non-human to the human, but it can be made governable through the 'teaming' of the non-human with the human and enabling non-hierarchical processes of bi-directional information flow between the two – at least according to proponents of HST. Here, the C2 of swarming becomes a CAS itself and to govern means to continuously adapt to the changing environmental conditions of government at the 'edge of chaos'.

From an IHL or ethics of war perspective, the question arises of how to account for this governing beyond sovereignty. Surely, there is no easy answer to this question. In any case, we must not fall back into old dichotomies. Just as much as human operators and robotic swarms should not be studied as separate objects – or rather: as subjects on the one side and objects on the other – but as more-than-human assemblages, so is the agency of these assemblages not to be studied and evaluated as either enabling human operators to assert their autonomy when making life-or-death decisions or displaying machine autonomy and hence disabling a meaningful human control over such crucial acts of war. The military concept of a more-than-human control does not align with the modern normative idea of autonomy as an attribute of (white male adult abled) human entities¹⁴⁹ as well as ethico-legal concepts linked to it, such as individual responsibility and accountability. Instead, we need to deal with and find new ways to govern the 'distributed, collective, and emergent'¹⁵⁰ agency of these more-than-human assemblages. To be clear, the point I want to make is not that we should simply abandon any legal or normative stance towards robotic swarming in the military nor that we should simply accept that emergent swarm behaviours may or may not comply with IHL. On the contrary, I want to stress that the dangers of swarming in fact multiply if we stick to a politico-epistemological practice of purifying the materializations of the epistemo-technoscientific practice of constructing these more-than-human assemblages. They multiply if we either focus on humans and their capacity to execute meaningful control or on weapon systems and their capacity to operate 'autonomously'. In the undefined space between the two, a new hybrid form of control is developing that needs to be scrutinized. All the more, as this more-than-human control turns the more-than-human war machines operational in the first place. From the perspective of a military thinking informed by complexity sciences, a governing at the 'edge of chaos' is the appropriate form of controlling swarms with self-organizing, adaptive properties. The question that needs to be addressed is, hence, how to govern what is already governed – albeit not in terms familiar to IHL. A more-than-human control challenges us to think legal ordering differently and to problematize our current dualistic and anthropocentric regimes of governance of emerging/emergent technologies of warfare.

¹⁴⁷ Gilles Deleuze and Félix Guattari, *Nomadology: The War Machine* (Seattle: Wormwood Distribution, 2010), p. 4.

¹⁴⁸ Deleuze and Guattari, *Nomadology*, p. 97.

¹⁴⁹ Jutta Weber and Lucy Suchman, 'Human-Machine Autonomies', in Nehal Bhuta, Susanne Beck, Robin Geis, Hin-Yan Liu and Claus Kreis (eds), *Autonomous Weapons Systems* (Cambridge, UK: Cambridge University Press, 2016), pp. 75–102.

¹⁵⁰ Mark Coeckelbergh, 'From Killer Machines to Doctrines and Swarms, or Why Ethics of Military Robotics Is not (Necessarily) About Robots', *Philosophy & Technology*, 24:3 (2011), pp. 269–78 (p. 273).